INDUSTRIAL TOXIC WASTE AND HEALTH: A PRACTICAL CASE STUDY

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To my father, in memoriam.

ABSTRACT:

Objective - The objective of this thesis is to develop a standard, simple methodology for the assessment of health in areas near sources of pollution. This methodology should make use of readily available data and computing facilities.

Development of the methodology - A literature review on previous studies on the subject was carried out in order to draw from existing experience. A total of twenty-five studies on health near sources of pollution were reviewed. These studies were carried out between 1982 and 1997, most of them in Britain, two in France. The types of pollution sources studied ranged from waste dumps to incinerators, to nuclear power stations. Each study was described, stressing on their respective backgrounds, building of geographical (study) areas, data, analysis and results. Brief synopses of the studies were next grouped, according to those using conventional epidemiological methods and more innovative ones. Finally, it was concluded from the review that the methodology intended should be descriptive, making use of routinely collected data, with a study area based on small geographical divisions (small areas) and taking into account socio-economic differences over its study area. In the absence of accurate data on pollution levels, and from the previous experience of one of the studies reviewed, circular study areas centred on the source of pollution and subdivided into rings were used, with distance of each ring to the centre as a proxy indicator of levels of pollution.

Case study - In order to try out the methodology, a case study was selected: soil pollution by chromium waste in Southern Glasgow. A human risk assessment was carried out in three steps: a) a literature review (mostly occupational) of the health effects of the different types and levels (doses) of chromium and its routes of exposure; b) an assessment of quantities of the pollutant in Glasgow and of its likely levels of exposure; c) a quantification of the risk to health posed by the pollutant in the areas surrounding it. Three separate areas were found to have relatively high levels of chromium in soil. One of them, containing the highest levels, was chosen as centre of the study area.

Data and methods - From the risk assessment, ten diseases were selected for study as likely to be caused by chromium. These were: Lung, Pharyngeal and Nasal cancers, Upper respiratory and Upper digestive irritations and Skin and Eye irritations, Kidney dysfunction, Asthma and Chronic Obstructive Pulmonary Disease. A further three,

Leukaemia, Skin cancer and Congenital Abnormalities were also selected to allay local residents' concerns about them, although no connection between these and chromium were found in the medical literature. Routinely collected data on cases were used, coming from two sources: Registries and hospital discharge records (SMR1). Data on population and on their levels of deprivation were also obtained. All data were at the Enumeration District level. The methodology was that of a Geographical (Ecological) descriptive study, since it assumed that levels of disease in a population depended on their distance to a centre of pollution (a point in the chromium main polluted area in this case). The name chosen for the methodology was that of Small Areas and Rings. The study area was formed by all Enumeration Districts (Eds) whose centroids lay within 10 kilometres from the centre of pollution and it was divided into ten rings, each 1 km. wide, made up by those EDs whose centroids lay inside the ring. Rings were considered as separate areas. Levels of pollution were assumed to diminish with growing distance from the centre and to be constant within a given ring. The objective of the case study was to assess whether distance to the centre of pollution (and of the study area) had any effect on the incidence of each of the diseases, with the prior suspicion that inner rings would have higher incidences (perhaps due to occupational reasons). The null hypothesis was that proximity to the pollutant did not have any effect on health and that levels of disease remained constant with distance from the centre. Estimates of detection levels were calculated for the innermost rings and for different combinations of areas. Levels of disease inside each ring were expressed as Standardized Registration Ratios, with corresponding confidence intervals and levels of significance (0.05, two-sided). Standardization was indirect, by age. Study periods were 1975-89 for cancers and 1981-91 for most other diseases. Total population, males, females and chosen age groups for some diseases were analysed separately. Hypothetical occupational periods of 20 and 30 years in the former factory at the origin of the pollution were considered. The river Clyde divided the area into almost identical halves and, since it might represent a barrier to exposure to the pollutant, some analyses were carried out separately for each half. Standard rates were those for the overall study area. Standardization by deprivation category was carried out by editing population data using routine commands in a statistical package. As indicators of overall trends of disease with distance, simple linear regression and a statistic (Stone's) were used in combination. Analyses were carried out on Personal Computers. Programmes were either commercially available or short ones made at a local hospital. Sensitivity of the method was tested by repeating some analyses with different centres for the study area and comparing their results with those for the actual centre. An alternative regression method (Logistic regression) for trends with distance was also tested.

Results and conclusions of the case study - Lung cancer appeared generally higher in the inner rings, with overall trends to diminish with distance from the centre. It was also higher for males and higher North of the Clyde (the centre of pollution is in the Southern side) and since it was also high for females North of the river (although less so than for males) an unaccounted environmental factor was suspected in the area. Surprisingly, Chronic Obstructive Pulmonary Disease followed in general trends different to those for Lung cancer, but not so for females and for older males South of the river. Levels of Skin irritation also appeared to increase with distance for unknown reasons. Nasal cancer appeared high near the centre of pollution, possibly due to former occupational factors. Analyses of Leukaemia for those under 15 years of age confirmed an already suspected excess in a particular area, too far away from the pollutant for a likely connection with it. Results for other diseases were generally unremarkable, besides some small excesses. Analyses with displaced centres of pollution showed equivalent displacements of already known levels of disease, therefore confirming the sensitivity of the method. Logistic regression did not reveal anything new, although the comparison was very limited. The null hypothesis could not be rejected, and a case-control on Lung cancer recommended on the basis of the findings.

Validity of the method - The new methodology was found valid and the objective of the study was met. It compared favourably with previously reviewed methodologies. The methodology is intended to be used as a descriptive, exploratory tool, whose findings may warrant further analytic studies, which the method is not designed to, and can not, replace. The use of routinely collected data greatly facilitated the study, although caveats for future studies exist on them. Distance as a surrogate for exposure is seen as a simplistic approach, but in the absence of reliable exposure data it is a useful one. Standardization by Deprivation category has also been found useful to account for factors for which little data exist. The method is appropriate for the assessment of the health effects of pollution sources on general populations, particularly in those cases where a rapid study with easily interpretable results is needed. These assessments can be carried out locally, using readily available Personal Computers and programmes.

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LIST OF ABBREVIATIONS USED THROUGHOUT THE THESIS.

ALL - Acute Lymphoblastic Leukaemia.
BNF - British Nuclear Fuels.
CEE - Communauté Economique Européene.
CENDEP10.SYS - Population (Census) and Deprivation Category by Enumeration District inside a 10 km. Circle (SPSS-PC+ system file).
CI - Carstair's Index.
CM.PAD - Congenital Malformations Analysis SPSS-PC+ command file.
CMR - Cancer Malformations Register.
CMS.PAD-Congenital Malformations (Standardized) Analysis, SPSS-PC+ command file.
COMARE - Committee on Medical Aspects of Radiation in the Environment.
COPD - Chronic Obstructive Pulmonary Disease.
CPD - Central Postcode Directory.
CRR - Cancer Registration Ratio.
DEPCAT - Deprivation Category (Carstairs).
DHA - District Health Authority.
ED - Enumeration District.
EHD - Environmental Health Department.
EUROCAT - European Register Of Congenital Abnormalities And Twins.
GAM - Geographical Analysis Machine.
GGHB - Greater Glasgow Health Board.
HD - Hard Disk.
HWI - Hazardous Waste Inspectorate.
ICD - International Classification of Diseases.
ICRCL - Interdepartmental Committee on the Redevelopment of Contaminated Land.
ISD - Information and Statistics Division.
OPCS - Office of Population Censuses and Surveys.
OS - Ordnance Survey.
PAHs - Polycyclic Aromatic Hydrocarbons.
PCBs - Polychlorinated Byphenils.
PCHs - Polychlorinated Hydrocarbons.
PCS - Post Code Sector.
PCU - Post Code Unit.
PSSNPRB.FOR - Poisson Probability (Fortran Programme).

RHA - Regional Health Authority.

RD - Rural District.

SAHSU - Small Area Health Statistics Unit.

SHS - Scottish Health Service.

SMR - Standardized Mortality Ratio.

SMR (digit) - Scottish Morbidity Record (digit).

SRR - Standardized Registration Ratio.

SRRPRG.FOR - Standardized Registration Ratios Programme (Fortran Programme).

UKAEA - United Kingdom Atomic Energy Authority.

USEPA - United States Environmental Protection Agency.

WoS - West of Scotland.

WHO - World Health Organization.

1 - INTRODUCTION.

Toxic waste: a conspicuous presence:

Although there is nothing new about byproducts of human activities, particularly industrial activities, which can pose a hazard to health, their presence, if only in terms of sheer quantities, has become only too obvious over the past few decades. Although the definition of Toxic Waste is still somewhat hazy, there is already a corpus of legislation listing those substances which can be considered as such, in the United Kingdom (Department of the Environment, 1980) as well as in European Union (Conseil des Communautes Europeenes, 1978). In Britain, these substances have been grouped under the common denomination of Special Waste.

As pointed out, one of the main reasons why Special Wastes have become a focus of attention is their volume. Even though this is admittedly high, the precise amount is still undetermined. One of the bodies responsible in the recent past in Britain for their estimation, the Hazardous Waste Inspectorate complained in its Reports of the difficulties for doing so, mostly due to the mixing at source or at disposal of wastes posing different levels of danger to human health (Hazardous Waste Inspectorate, 1985). Nevertheless, later estimates carried out by the Inspectorate revealed approximate amounts in the order of 1.6 million tonnes per annum of Special Waste in England and Wales and 30,000 tpa. in Scotland (Hazardous Waste Inspectorate, 1988). The successor of the HWI, Her Majesty's Inspectorate of Pollution, estimated the amount of Special Waste in England and Wales in 1989-90 at 2.2 million tonnes, perhaps due to improvements in the collection of information (Her Majesty's Inspectorate of Pollution, 1990). To these figures, the legacy of uncontrolled disposal from the past must be added, in quantities still unknown. The subject of the present study is a situation arising from this legacy.

Public awareness of toxic waste.

Perhaps due to a redefinition of priorities in the public's appreciation of quality of life, an awareness of environmental problems, Toxic Waste among them, has appeared, at least in the West. The expression of this awareness in Britain (and to some extent its reason) may range from the sensationalism of the popular Press at a newly discovered deposit of Toxic Waste (Sunday Mail, 1991) or the more informed report on the situation of waste disposal (The Observer, 1990 ; Which?, 1990), to reports on the subject in the specialized medical Press (Walker, 1991) or publications (British Medical Association, 1991). Similar expressions can be found in countries as different as the USA (Boraiko, 1985) or Spain (El Correo Español, 1989). This awareness has partially materialised in Britain since the mid-1980s in concern about the safety of Toxic Waste disposal plants, such as the incinerators of Bonnybridge/Denny, in Scotland, and Pontypool, in Wales. Earlier than those, the possible risks of former or current land disposal of Toxic Waste had reached a high profile in the USA, such as in the cases of Love Canal (New York) and Drake (Pennsylvania).

An answer to this awareness.

Since the early 1980's, as an answer to this public concern, studies have been carried out on the possible incidence on human health of Toxic Waste disposal, of which the pioneer was a review of routine cancer data in the vicinity of the Love Canal dump (Janerich et al., 1981), followed by other studies on similar cases in the USA (Budnick et al., 1984 ; Najem et al., 1985). The studies have ranged from the assessment of general health in the communities near the sites, to more specific studies on cancer and congenital malformations, making use of classical descriptive and analytic methodologies. The forerunner of British studies on the subject was the assessment of health in the area near the Toxic Waste incinerator at Bonnybridge (Scotland), carried out by a team under the direction of Professor Lenihan (Lenihan, 1985), and most studies since have focused on incinerators, mostly carried out by Universities or by local Health Authorities. Since its creation in 1987 at the London School of Hygiene, a new specialized facility, The Small Area Health Statistics Unit, has carried out some interesting work in the epidemiology of Toxic Waste Disposal (Elliott et al., 1992 *c* and 1992*d*). Nevertheless, after a decade of such studies in the United Kingdom, the situation has not substantially improved since the British Medical Association concluded in 1991 that:

> 'It is noticeable that most research on human health and hazardous waste has originated from the US. There is little epidemiological information from the UK, either on those working in the waste management industry, or on populations who may be otherwise exposed to hazardous wastes. There is a need for more well-designed epidemiological studies in this area.' (British Medical Association, 1991, p.172).

The reason for this study.

Medical professionals and the public are demanding answers concerning health and Toxic Waste, particularly in connection with former industrial, contaminated land and with the more conspicuous facilities for disposal, i.e., incinerators, treatment plants and landfills. And, along with Toxic Waste, there is similar concern about industrial emissions, not to say nuclear plants. More studies are needed on all these types of pollution sources, and an easy to apply, yet reliable methodology is necessary. Perhaps one of the reasons why relatively little has been done in this field in Britain has been the lack of a methodology adapted, or specific to, environmental studies. Another is the relative lack of contact between the health professionals, the first to perceive a public concern on a possible problem, and those more able to give an answer to this concern, University researchers. Again, the lack of a simple methodology seems to prevent a closer contact between both groups of professionals. The work of University researchers, of statisticians and of computing experts appears somewhat remote from public concerns and from the work of many GPs and clinicians.

The present study has been conceived as an attempt to provide this simple methodology. To that effect, it has firstly drawn from the experience of previous environmental studies, not just on Toxic Waste disposal, but also on industrial pollution and nuclear plants, in order to bring together some of their best methodological characteristics. There has been an stress on simplicity of means (use of personal computers) and of data (routinely collected data) to make it accessible to those most likely to use the resulting methodology, the health professionals. Whether the attempt has succeeded, and a new tool exists to answer the growing public demand for environmental health studies, can be seen in the following chapters.

2 - AIM AND OBJECTIVE

2.1- Aim:

To carry out a health assessment of an area near a source of pollution, drawing from previous expertise in the field, based on readily available data, computing facilities and programmes.

2.2 - Objective:

To develop a standard, simple methodology for such health assessments.

3 - LITERATURE REVIEW

Summary: **This chapter reviews twenty-five studies on the health effects of localized sources of pollution, all conducted between 1982 and 1997, most of them in the United Kingdom. The review starts with 4 studies on industrial compounds, follows with 7 studies on incinerators, and closes with 12 studies on nuclear sites, plus 2 studies on non-nuclear sites, one on a group of incinerators, since these studies are connected to the preceding ones. Each study is reviewed separately, detailing their geographical areas, methods, data and other factors and results. A critique of the different methodologies follows, grouping them into those which follow standard epidemiological techniques and those attempting to create innovative ones, better suited to environmental studies. From this critique and its conclusions, recommendations are made on the characteristics of a new methodology. This methodology takes some elements from the studies reviewed and it is intended to be specifically used in the assessment of health near localized sources of pollution.**

3.1 - Studies on industrial pollution.

3.1.1 - Mortality in a Small Industrial Town: Problems of Analysis and Interpretation (Lloyd, 1982).

Background: Starting in the late 1960s, the small town of Armadale in central Scotland experienced a notable increase in the incidence of deaths from respiratory cancer. Data from different sources (Registrar General for Scotland, local cancer registry, hospital records) confirmed that, whereas the annual numbers of deaths from respiratory cancer averaged around 2 until 1967, thereafter the numbers were never less than 6. This caught the attention of a group of researchers at Dundee's Ninewells Medical School, who, under the direction of Dr. Owen Lloyd, conducted a detailed, and in some aspects innovative, study. It should be noted that the town was known in earlier papers on the study as 'Town V'.

Assessment of the excess mortality: Using rates for the whole of Scotland as standard, Standardized Mortality Ratios (SMRs) for respiratory cancer in Armadale were calculated for the years 1958-77. A 'Cum-Sum' (cumulative sum) of differences between each of these yearly SMRs and the Scottish norm (i.e., 100) was then carried out. The graphic of this Cum-Sum showed a nearly sustained decline into negative figures until 1967 (i.e., deficit mortality in Armadale compared to Scotland), after which, a steep increase up to well above the zero level is apparent (i.e., excess mortality) (Lloyd et al., 1982). Since the change in trend was so sudden, the authors concluded that, whatever the cause for this increase in respiratory cancer, the latency period had to be short, perhaps shorter than two years (Lloyd, 1979 and 1982). Numbers of deaths and populations before 1974 were for the burgh of Armadale. After burghs disappeared as geographical subdivisions that year, these corresponded to the slightly larger town of Armadale, but this did not seem to have much impact on the already established trend.

Age-standardized general mortality in Armadale was found to be outstandingly bad when compared to other Scottish towns. Nevertheless, this appeared to be a relatively recent phenomenon, which the authors thought might be related to a hypothetical environmental agent also related to the recent increase in respiratory cancer, since social class distribution and population habits (smoking) appeared unremarkable. Trends of SMRs for non-malignant chest disease (pneumonia, bronchitis, etc.) were found to be similar to those for lung cancer.

The fact that workers in heavy industry (foundry, brickworks) did not appear to be more affected than the general population, and an SMR of 174 for female respiratory cancer in 1968-74, would point towards an environmental, rather than occupational, factor. Nevertheless, at least among males, only the age groups usually most at risk from respiratory disease (i.e., over 55 years of age) were found to have a higher incidence of deaths from respiratory cancer, incidence higher than elsewhere (Lloyd, 1982).

Environmental assessment: Investigation of air pollution in Armadale showed that monthly values for suspended particulates were higher than those for larger, more industrial towns. Closer investigation revealed that peaks of pollution were brought about by light easterly winds, coinciding with the fact that most of Armadale's industries were in its eastern side. Of those, the most noticeable source of pollution was a steel foundry. Wind-tunnel modelling was also utilised to corroborate the flow of air pollution (Lloyd et al., 1987).

A highly original trait in the study was the use bags of dried moss to monitor possible pollution from the foundry (*Sphagnum* and *Hypnum* species). Airborne metals adsorb to the surface of moss, and later spectrophotometric analyses can determine the types and quantities of these metals. Convenient distribution of the bags within the town proved the foundry as a major source of airborne iron, manganese, zinc and nickel, with concentrations generally decreasing with distance from the factory, and revealing a 'hot spot' of pollution in the area around the factory (Lloyd, 1982). This efficient, cheap and unobtrusive method was eventually joined by studies of lichen distribution, since lichens are sensitive to air pollution, and metal contents in some species of grass (Yule and Lloyd, 1984) (Gailey -née Yule- and Lloyd, 1985 and 1986).

Distribution of cases: geographical areas: Once a focus of air pollution had been demonstrated, the next step in the study was to check the distribution of respiratory cancer deaths respect to it. The smallest geographical divisions for which population statistics were available were Enumeration Districts (Eds), small enough to be the building units for geographical areas of size and shape appropriates to cover the zones of interest. By grouping Eds, an 'at risk' area was drawn on either side of the foundry, along the direction of prevailing winds, and a control area of similar size and housing characteristics but not downwind from the factory. Deaths from respiratory cancer and from other common causes were counted (and plotted) for both areas. Rates per 1,000 population aged 60 and over at the 1971 Census were calculated for these causes of death for the period 1968-74. The 'at risk' area had an incidence rate of respiratory cancer substantially higher than the 'control area', but not so for the other causes of death. The highest incidence was found in the part of the 'at risk' area downwind from the pollution-associated easterly winds: 15 male deaths from respiratory cancer, while the expected number, derived from town-wide rates, was 6.

Next, the radial distribution of (male) respiratory cancer respect to the foundry was assessed, i.e., the distribution of cancer within circles with the factory at their centre. On a map of the town, seventeen concentric circles were drawn, the outermost one representing about 1 kilometre in radius, the innermost some 200 metres, with approximately 50 metres of width for each ring in between (the scale was in inches, the divisions metric). Inside each of the rings, usual residential addresses (after checking for mobility) of registered male deaths from respiratory cancer were plotted. Logically, population statistics were not available for circular areas, and Enumeration Districts were too large to build with them approximations to these areas. Deaths from ischaemic heart disease were taken as 'control', and marker of the demographic characteristics of the population: the disease is common, evenly distributed and shares risk factors with respiratory cancer, air pollution possibly not one of them.

For each disease, numbers of cases in each ring were expressed as percentage of the total in all rings. Starting at the outermost ring, these percentages were then summed cumulatively, so that the innermost one had a figure of 100 (excluding the central ring, open ground). Graphs for these sums showed a more even distribution of heart disease than respiratory cancer, since cumulative percentages for the latter appeared to increase faster near the factory. A test can be used to evaluate statistically cumulative percentage differences between the two diseases (for this test, see: Lloyd, 1982).

Another series of circles were drawn around the foundry and other hypothetical sources of pollution (gas-works, mine-works, crossroads). Cumulative sums of numbers of deaths from respiratory cancer (instead of percentages) were calculated as before, and plotted against the squares of the consecutive radii (actually, squares of radii lengths on the map). Near-linear slopes around most of the sources indicated random distribution of cases (since numbers of cases would be proportional to squares of distances, i.e., areas). The only plot to deviate from this was the one for the foundry, showing again a grouping of cases towards the inner circles. When plots were repeated for male heart disease, the one for the foundry did not stand out from the others (Lloyd, 1982).

<u>Conclusions</u>: Deaths from respiratory cancer in Armadale had been shown to concentrate in or towards an area polluted by airborne metals. Nevertheless, an interpretation of this finding should wait for more detailed research on the working life of the cases, as well as on other risk factors, such as smoking. Occupational studies support a connection between airborne metals and respiratory cancer, but it remains to see whether metallic compounds have the same effect after being expelled from fume-stacks and undergoing physico-chemical changes. Future similar studies were seen as necessary to increase the 'burden of proof' against pollution (Lloyd, 1982).

3.1.2 - Landfill waste disposal - an environmental cause of childhood cancer? (Muir et al., 1990)

Case background: A complex for toxic waste processing at Stubber's Green, Walsall, West Midlands, consisted of acid reclamation facilities and a plant for waste treatment through solidification by mixing it with concrete. Council commissioned investigations found that the material resulting from the solidification process, which was dumped into disused mineshafts, had not universally solidified, which might have led to leakings and pollution of the surrounding area. The waste treated was known to include arsenic, cyanide, mercury and antimony (Muir et al., 1990). There was also concern about airborne pollution resulting from the vaporisation of the semi-solid material, fires and clouds of nitrogen oxides from the acid plant. This led to widespread protests by local residents (Holderness, 1992; Walsall Health and Safety Group, 1989). Complaints ranged from sore throats and asthma to high rates of childhood cancer and leukaemia in the surrounding communities (Muir et al., 1990 ; Singal, 1990). An investigation of the potential carcinogenic effects on children of the alleged pollution was undertaken by researchers at the West Midlands Regional Children's Tumour Registry

Geographical area: To assess possible effects from seepage into water and from airborne pollution, reported cases were examined in three areas: (a) the ward containing the site, Hatherton Rushall, with 4 cases; (b) wards in the radial vicinity of the site, including Hatherton Rushall, with 19 cases; and (c) wards in an area defined as an equilateral triangle, with apex centred on the site and downwind to the prevailing NE wind, with 3 cases.

Data: The West Midlands Regional Children's Tumour Registry collects reports on cancer cases in patients less than fifteen years of age in the West Midlands Health Authority Region, including the Walsall District. Ascertainment, after pathology review, is believed to exceed 95%.

Analysis: Registration data on childhood cancer for the period 1980-88 were standardized using the local children's population and the average regional rate. Observed and expected numbers were compared to assess any significantly high incidence. 1980 was chosen as the start of the study period since it was then that regular treatment of waste commenced.

Results: No statistically significant differences were found in any of the three areas between observed and expected numbers. The authors concluded that they could no demonstrate any adverse health effect, at least as far as childhood cancer was concerned, associated with the Walsall waste disposal site.

3.1.3 - Respiratory symptoms in children at schools near a foundry (Symington et al., 1991)

Case background: The Medical Research Council (MRC) maintains an Environmental Epidemiology Unit at the University of Southampton (Southampton General Hospital). The Unit carried out a study on respiratory symptoms in children attending schools near a foundry in Walsall (West Midlands) following complaints about the effects of its airborne emissions on pupils. Walsall's toxic waste disposal plant, already the object of the health study mentioned in (Muir et al., 1990), was also taken into account and some of its respiratory effects assessed.

Geographical Area and Data: The study sample consisted of all children in the top infant year at 39 Walsall schools. These comprised all schools within one mile of the foundry (four in an incomplete circle, the foundry being near the borough's boundary) or the waste disposal site (nine, in a full circle) plus one school from each ward of the borough (twenty-six). The one-mile radius was chosen so that the circles did not overlap. The ages of the children studied ranged from 6.8 to 7.8 years.

Analysis: Self-administered questionnaires (1631) were distributed to parents through the schools in June 1989, requesting information about children's respiratory symptoms and possible risk factors. The symptoms were: wheeze, breathlessness, cough, chest discomfort, and chestiness at night. The risk factors (potential confounders): sex of child, social class, housing tenure, passive smoking, and parental history of asthma. Symptom prevalences were calculated according to whether children attended school (a) within one mile of the foundry, (b) within one mile of the waste disposal plant, (c) more than two miles from the waste disposal plant and from any foundry, (d) elsewhere in the borough. Prevalences for each area were adjusted for potential confounders by logistic regression and compared. Percentages of one year period prevalences of symptoms in Walsall and in Southampton schools were compared. The characteristics and size of both samples were almost identical and the questionnaire the same.

Results: No excess reporting of symptoms existed near the foundry or the toxic waste site. The reported prevalences in Walsall were in general lower than in Southampton. Schools in Southampton, acting as control, were chosen as representative of the whole town and were not situated near any known source of pollution. Comparison between the two towns gave no indication of excess respiratory disease in Walsall.

3.1.4 - The Monkton Coking Works Study (Bhopal et al., 1992 and 1994).

Background and objective: In 1937, the Monktown coking works was built in an open field to the East of Newcastle Upon Tyne. The capacity of the plant varied from 33 ovens (1937) to 66 (1980). Between the 1940s and 60s, housing states were built to the North, East and South-East of the works. Production ceased in 1990 (Bhopal et al., 1994). Residents in the area complained for a long time about the nuisances and possible health effects of the dirt, odours and fumes emitted. Answering these complains, the Metropolitan Borough of South Tyneside funded this study, proposed by researchers of the University of Newcastle Upon Tyne. Its objective was to determine whether there was excess in ill health (respiratory conditions in particular) in people living near the Works, and if so, whether it was related to exposure to emissions from it.

Geographical areas: The range of areas utilised was quite complicated. Seventy-eight Enumeration Districts (EDs) in South Tyneside within a two miles radius of the coking works were included as containing populations potentially at risk. Each ED comprised on average around 150 households. The plant itself was only about 1/3 of a mile from the border of the Metropolitan Borough. The whole of this area was later subdivided into two sub-areas according to perceived (by the researchers) exposure to pollution.

These were: Perceived higher (including the Monkton Works), with 42 EDs divided between 9 housing estates, and Perceived lower (to the North), with 36 Eds in 7 estates.

From data gathered by the Borough's air quality monitoring stations and other on emissions facilitated by the factory, two modellings of atmospheric dispersion of pollution (SO2) were carried out using software from the United States' Environmental Protection Agency (USEPA). From this resulted two new areas (always inside the Borough's boundaries): one of Modelled higher exposure (29 EDs), and another of Modelled lower exposure (38 Eds).

As targets for a health questionnaire, two more areas were defined: Inner, consisting of the 12 EDs up to approximately 1.3 km. from the Monktown Coking Works, and Outer, the 16 EDs up to approximately 3 km. from the factory.

Finally, as a baseline against which to compare health in the areas defined above, a control area was selected 6-10 kms from the Coking Works (and so, presumed unaffected by it). The control area was of similar demographic, social and economic characteristics as the study areas (according to the Townsend index of deprivation), and contained 37 EDs divided between 5 housing estates.

Data and Analysis: Routinely collected data were obtained from the Northern Regional Health Authority. These were: mortality data (1981-89) cancer registrations (1986-89) and births (1982-89). Personal data and perceptions were collected from 4,601 questionnaires sent to systematic samples in the Inner, Outer and control areas (response rate 65-69%). Further health data came from samples of case notes from 4 general practices (2 in the control area).

Deaths and cancer cases were aggregated for each of the areas (and estates). EDs' populations (1981 Census, 1984 and 1987 estimates) were also aggregated. Using South Tyneside's rates as standard, age and sex Standardized Ratios were calculated. Birthweights, stillbirths and birth sex ratios were compared between areas. For questionnaire data, the Chi-square statistic was used to compare trends between the Inner, Outer and control areas. Daily numbers of respiratory consultations from case notes were related to pollution data through a log-linear modelling. Other statistics on lung function and environmental data were carried out. The University mainframe and microcomputers were used as convenient.

Results and conclusion: Mortality and cancer incidences were comparable for areas near or further away from the Coking Works, as were birth-related statistics. There was a positive gradient with proximity to the factory for some self-reported respiratory symptoms, but not for asthma and chronic bronchitis. GP consultations for respiratory disorders increased with levels of pollution. Routinely collected data failed to provide evidence of increased ill health due to the Monktown Coking Works. On the other hand, self-reported and case notes data seemed to indicate that respiratory health in those living close to the Works was worse than expected, and that some of this excess could be due to pollution from the factory.

3.2 - Bonnybridge and other studies on incinerators.

3.2.1 - Bonnybridge/Denny Morbidity Review (Lenihan, 1985).

Case background: During the early 1980s allegations rose that emissions from a toxic waste incinerator at Bonnybridge, Central Scotland, were having a negative effect on the health of local residents. It had become generally known that polychlorinated biphenyls (PCBs) were incinerated at the facility and that these could give off emissions of potentially toxic, and supposedly carcinogenic, polychlorinated dibenzo dioxins (PCDDs) and dibenzo furans (PCDFs). Also, rare congenital eye defects were reported among children born in the area. The above concerns led, in June 1984, to the set-up by the Secretary of State for Scotland of an independent Review Group, to be chaired by Professor John Lenihan, whose terms of reference were: 'To review any unusual features of morbidity recorded in the Bonnybridge/Denny area and in the surrounding district; to take full account of other available studies of statistical variations of morbidity in areas of comparable size; to report on the significance of any abnormal findings and on any other relevant information that is available; and to advise whether further studies are required' (Lenihan, 1985).

Geographical area: In defining the geographical area of study, and therefore its population and associated morbidity figures, the study of Post Code Sectors (PCSs) covering Bonnybridge/Denny was rejected. This was because the irregular shape of these PCSs would have extended the study area far away from that of specific interest. Instead, Enumeration Districts were chosen as the building block to define the area of study. The selected Enumeration Districts were those whose geographical centroid lay on or inside a circumference, five kilometres in radius, centred on a point halfway between Bonnybridge and Denny. Since an ED is some ten to twenty times smaller than the PCS containing it, the perimeter of the resulting area did not extend far either side of the circumference, enclosing what the Review Group considered to be the Bonnybridge/Denny area and its surrounding district.

To compare health data, eighteen localities, or combinations of these, were selected from the Census as control areas. As defined in the Census, each locality was a grouping of urban EDs surrounded by rural ones; in this and in population size (range 31,311 to 58,437), these were similar to the study area.

Data: To ensure a valid comparison between the study and control areas, data uniformly collected through Scotland were chosen; as mortality, eighteen causes of death, including all deaths; as morbidity, nine categories of cancer, corresponding to those included in mortality, including all cancers. Mortality data were provided by the Registrar General for Scotland from mortality records aggregated over the period 1980-82. Morbidity data came from the Information and Statistics Division (ISD) of the Common Services Agency (Scottish Health Department), Edinburgh, which keeps a Cancer Registration scheme, aggregated over the then latest available three year period, 1979-81. Data from the Cancer Registration scheme were considered to be less reliable than mortality records, since the former have no statutory backing and some cases may be missing.

Analysis of causes of death and cancer categories: The ISD was asked to carry out the statistical analyses. These consisted of:

- Indirect standardization by age and sex of cases (cancers and deaths) for each cause or category and area, taking as standard the average rates for all the areas put together.

- Calculation of standardized mortality ratios (SMRs) and cancer registration ratios (CRRs).

- Two-tailed significance tests at the 5% level for each SMR and CRR. When the expected number of cases exceeded 15, the Normal Test (Normal approximation to a Poisson distribution) was used, and the exact Poisson test if the number was less or equal to 15.

Other data and their analysis: Echoing concern about congenital malformations, neonatal discharge records for 1980-82 were reviewed. These had a 100% coverage for the study area, but this was not the case for all the control areas. In consequence, all-Scotland figures were used for comparison, although only 79% of all hospital births were recorded for the period. Assessment of coverage required that '... ISD carried out a special exercise ...' (not specified in the Report) '... since this information is not routinely held on a postcoded basis...' (Lenihan, 1985). Local and nationwide percentages of abnormalities were then compared.

As an extension of the above, hospital admission rates for spontaneous abortions for 1980-82, together with stillbirths, were also compiled for the study and control areas. These are routinely postcoded, but data for five of the control areas were incomplete. Numbers per 1,000 conceptions were compared.

Also, in view of the recent suggestion that abnormal sex ratios could be an indicator of unusual morbidity associated with environmental pollution, the ratio of male/female births in the study and control areas (1980-82) were examined .

Two further sets of 'informal' data were assembled. Through the Forth Valley Health Board (in whose geographical area Bonnybridge/Denny lies), general practitioners and specialists working in the study area were asked to report on individual cases which could be of assistance in supplementing or interpreting the statistical data. Finally, a general invitation was made for submission of written evidence.

Results: One cause of death was found to be significantly high: that of respiratory disease, but this increase seemed to be limited to elderly men. The Review Group concluded that there was nothing unusual about the general health of the local people, with the exception of the incidence of the congenital anomaly microphthalmos, which warranted further investigation. The final report is known as the Lenihan Report.

3.2.2 - 'Report of a working party on microphthalmos in the Forth Valley Health Board area, 1988'. (Strong, 1988)

Case background: Following a recommendation in the Lenihan Report, the occurrence and case ascertainment of microphthalmos, congenital cataract and coloboma in the Forth Valley area of Central Scotland were investigated. These congenital malformations were allegedly linked to air pollution from the Bonnybridge/Denny chemical incinerator, disposing of polychlorinated byphenils. Funded by the Health Services Research Committee of the Scottish Home and Health Department, a working party under the chairmanship of Professor J. Strong was set up in September 1985. Dr. Barbara Russell, of the Department of Community Medicine, University of Edinburgh agreed to undertake the investigation, whose remit was:

- To make a detailed assessment of the occurrence of certain types of congenital eye anomalies in the Forth Valley Health Board area.
- To establish whether there was any obvious associations of time, person or place linking these causes.
- To establish whether case ascertainment was complete for cases of microphthalmos, coloboma and congenital cataract in this area and other areas of Scotland. (Strong, 1988)

Health data and area of study: At first it was decided to obtain prevalence data for the whole of Scotland by collecting information from consultant ophthalmologists. This was later ruled out, since only two Scottish eye departments consistently maintained an out-patient diagnostic index. Although all consultant ophthalmologists with a paediatric practice were approached, data were sought mainly from other sources, twenty-four in all (Russell, 1993), such as centrally recorded data, data from Handicap Registers, of which Greater Glasgow Health Board's Congenital Malformations Register (CMR) was considered to be the most complete, as it recorded defects apparent at birth and also those newly detected by a health visitor on three visits before four years of age (Strong, 1988). The Glasgow CMR started to collect data on the 1st of January 1972 and began to contribute to the Eurocat Register of congenital anomalies in 1979 (Eurocat brings together data from registers of congenital malformations in the European Community countries) (Stone, 1989). Other sources were records from medical officers at schools, as well as manual examination of other records (Blind Welfare Societies, schools for the visually handicapped, among others). Not all sources were available or appropriate in every area.

The centrally recorded data were those from the Scottish Neonatal Discharge Record (SMR11), Scottish Hospital In-Patient Statistics (SMR1) and the School Health Service Medical Record Card (SMR10). The neonatal morbidity recording system SMR11 was available for some areas in 1977 and for all areas by 1979, SMR10 data applies only to children reaching school age during the study period, and only those in the State Educational System. These three sources contributed 50% of the cases (Russell, 1993).

There are no diagnostic criteria for microphthalmos in Scotland (Strong, 1988). In the data consequently analysed, diagnosis was based on clinical diagnoses made by individual ophthalmologists. The working party was aware that this could lead to some inaccuracy, particularly in the diagnosis of borderline cases. Diagnostic confirmation was performed for all children with microphthalmos from their case notes, except those notified from the Greater Glasgow CMR from 1979 onwards for which a diagnostic confirmation was made for a random sample of cases.

Only liveborn infants were identified (Russell, 1993). Data on eye malformations in the stillborn were not sought, since they were recognised to be very variable.

The area of study was redefined as that covered by six Health Boards. These were Forth Valley (the area containing the incinerator), Lothian, Fife, Lanark and Greater Glasgow, chosen because of their close geographical relationship to Forth Valley and also to take account of the prevailing wind directions in the region. The sixth area, Grampian Health Board was selected because it was geographically distanced from the others, had a sufficiently large population, less industrial environmental pollution and a reputation for good recording of Health Service information.

Exact information on the place of residence at the time of conception and during early weeks of pregnancy, when eye malformations are most likely to originate, was not obtained, since it was thought inadmissible to interview the parents of afflicted children. Place of usual residence at the time of birth was used as the best available proxy, but this could be done only for microphthalmos. Children with microphthalmos born outside the six Health Board areas were excluded from the study.

Since the chemical incineration plant opened in 1974 and ceased operating in October 1984, it was decided to identify children born in the 15-year period 1971 to 1985.

Analysis: The study was purely descriptive. For comparative purposes, tables for each Health Board area were drawn from the data, showing numbers of children found to have microphthalmos or, separately, congenital cataract-coloboma, for the whole period 1971-85 and for subdivisions of it. Prevalence rates were also worked out and cases were mapped.

Results: The quality of the study was dependent on the completeness of case identification in different Health Boards. Unfortunately there were no means of assessing this completeness or its variation between areas.

A comparatively higher prevalence rate of microphthalmos in Greater Glasgow Health Board became much closer to the total rate once cases registered solely by its Congenital Malformations Register (CMR) were discounted (40% reduction). It seems reasonable to assume that, in the absence of a Register an unknown proportion of cases went unnoticed in other Health Boards. An overall increase in the number of cases, particularly after 1980 could be real or due to problems of identification, with children born more recently being more likely to be notified.

Even with a dramatic increase in Forth Valley (one case prior to 1980, five in 1980-85) its prevalence rate remained lower than that for Glasgow and only slightly higher than that for Lothian. Since all five cases happened between 1983 and 1985 a cluster could be suspected, but reliable data to calculate its significance do not exist. Also relatively rare abnormalities can occur in clusters and no cause be established. As surprising as this hypothetical cluster was the occurrence of a single case in 1971-82.

The rates for congenital cataract and coloboma in Forth Valley were unremarkable, except perhaps for relatively high rates (along with Fife) in 1976-80. Bearing in mind the suspected shortcomings in registration, there was no evidence of a clustering in time for either abnormality in Forth Valley.

Based on the available data, it was concluded that the verdict on whether or not microphthalmos presented a special problem in Forth Valley had to be the (according to the working party) unsatisfactory one of 'not proven', and that if a problem did exist it was a very small one.

3.2.3 - Animal and Human Disease around a site with two incinerators: A Review. (Williams et al. ,1987).

Case background: Following the publication of the already mentioned Lenihan Report (Lenihan, 1985), the Department of Community Medicine of Dundee University undertook its own research on the possible effects on health of emissions from the Bonnybridge/Denny industrial incinerator, along with which a second incinerator for municipal waste, situated within one hundred metres of the first, was also included. The research was carried out by Drs. Fiona Williams, Owen Lloyd and M. Lloyd.

Geographical area: The area under review included all Post Code Sectors within the Local Government District of Falkirk, which was divided for the study into six zones alphabetically coded A to F and made of groups of Post Code Districts (although, according to the paper, Post Code Sectors were grouped). These zones were in turn grouped into three wider areas, as follows.

1- 'Most at risk area' (A), chosen by its proximity to the incinerators and taking into account the effects of wind direction and topography on the dispersal of fumes.

2- 'Secondary at risk area' (B, C and D), to the North and NE of the zone A.

3- 'Comparison area' (E, F), to the North of the other two areas.

Data: Data on cancer covering the period 1976-84 were obtained from the West of Scotland Cancer Surveillance Centre, at Ruchill Hospital, Glasgow. These were on Non Hodgkin's Lymphoma (ICD 9th, 200 and 202), Hodgkin's Disease (201) and on Leukaemia (203 to 208). These three types of cancer of the haematopoietic and lymphatic tissue were chosen because of their alleged association with occupational exposure to the kind of chemicals emitted by the incinerators (Alderson, 1984).

Analysis: The data were grouped for two periods, 1976-79 and 1980-84, and Standardized Registration Ratios (SRRs) of each type of cancer were calculated for each of the six zones. Age-specific ratios were also calculated for leukaemia. Expected figures were derived from the (whole) Scottish cancer registration rates (Williams et al. , 1987) and the population data corresponded to the 1981 census. Percentage changes in the SRRs between the two periods were calculated.

Results: The relatively small number of cases under study made interpretation of results difficult. Nevertheless, that the 'most at risk' zone showed the greatest (positive) percentage changes in SRR for Hodgkin's Disease and leukaemia was, in the authors' opinion, consistent with environmental contamination, but did not prove causality. Also, the shift in leukaemia towards the younger ages in that zone and in the adjacent, while this did not happen for the whole of Scotland, was interpreted as an indication of environmental pollution (Williams et al. , 1987).

3.2.4 - Twinning in human populations and in cattle exposed to air pollution from incinerators. (Lloyd et al. , 1988).

Case background: Evidence existed that Polychlorinated Byphenils (PCBs) had been disposed of at the Bonnybridge incinerator, which could have led to the release of polychlorinated hydrocarbons (PCHs) as byproducts of combustion in the surrounding area (Lenihan, 1985). Some PCHs (dioxins and furans) are known to have oestrogenic properties, and these exogenous oestrogens may increase the frequency of twinning (Lloyd et al. , 1988). Since increased numbers of twins had been reported anecdotally in cattle at risk from plumes from the incinerator, the Environmental Epidemiology and Cancer Centre at the Department of Community Medicine of the University of Dundee, and the Department of Mathematics and Computer Studies of the Dundee College of Technology, decided to explore the possibility that an increased frequency of twinning might provide a sensitive and early indicator of environmental toxicity from PCHs.

Geographical area: It included seventeen Post Code Districts. There are 400 such Districts in Scotland (e.g., FK4, in the Falkirk area), with a mean population of around 13,000, fewer in rural districts such as these (Carstairs and Lowe, 1986). Two of these

Districts were named as Areas of Primary Risk, since fumes from the incinerators would be carried to them by easterly winds, which cause in Central Scotland the maximal accumulation of air pollution due to their association with sluggish airflow and temperature inversions (Lloyd, 1982). The Areas of primary Risk included Bonnybridge and Denny, the incinerators lying just outside their eastern boundary. Two other Districts (where the incinerators were located) constituted the Sectors of Secondary Risk, where air pollution could be carried by the more vigorous southwesterly winds, which are most prevalent in Scotland.

The remaining 13 Post Code Districts provided background values of twinning. Districts with fewer than 200 births during either of the periods analysed (see Data) were included in adjacent ones. This resulted in a final number of 10 background areas. The total number of areas under study was, then, 14.

Data: Data on the number of single and multiple births were obtained from the Information and Statistics Division of the Common Services Agency. These were for the relevant area and for the period 1975-83 by year of registration. An isolated case of triplets was computed as twins.

Analysis: The twinning rates per thousand total births were calculated and compared for the 14 areas for the two four-year periods 1976-79 and 1980-83. The pattern of twinning in the 14 areas between 1975 and 1983 was studied on an annual basis by two methods. Firstly, the annual twinning rates in those areas were calculated and ranked (Gilmour, 1990). Secondly, Moran's I coefficient for detecting spatial autocorrelation was used to detect spatial clustering or regularity in the mapped pattern (Cliff and Ord, 1981).

The statistic may be tested as a standard normal variable. If large negative values of Z are found the map displays regularity; large positive values denoting clustering. Both types of value suggest non-randomness in the pattern. Values of Z close to zero denote random map patterns. Both rank order and Moran's I statistic-Z score were based on the 14 areas.

Since incidence of twinning increases for mothers over the age of 35, the ages of mothers of twins in the at risk areas were compared with the ages of mothers of twins in whole of the study area.

Results: The analysis of the human twinning rates in the Post Code Districts, by ranking and spatial autocorrelation indicated the late 1970s and early 1980s as the period when clustering became evident. This was found to be consistent with the hypothesis that PCHs or other chemicals with biological actions similar to those of PCHs were introduced into the local environment in the late 1970s and had been distributed by the easterly winds (Lloyd et al., 1988).

Nevertheless, the authors found it premature to attribute causality to the association between this pollution and twinning since: a) the genetic component of the twinning phenomena in these populations had not been investigated, b) although the mean ages of mothers of twins were similar in the risk and in the whole study areas, other social factors affecting twinning had not been investigated (Hemon et al. , 1981) and, c) statistical coincidence could not be ruled out.

3.2.5 - 'The incidence of congenital malformations in Wales, with particular reference to the district of Torfaen, Gwent. (Welsh Office, 1985)

Case background : An industrial waste incinerator began operating in Pontypool (district of Torfaen, Gwent, SE Wales) in 1974 (Communicable Diseases, 1990). PCBs were first handled at the site in 1979, although no details of subsequent PCBs disposal were known as of early 1993 (ENDS, 1993). Immediately after the appointment, in June 1984, by the Secretary of State for Scotland of an enquiry group to look into the possible effects on health of the Bonnybridge incinerator (Lenihan, 1985), the Secretary of State for Wales instructed Welsh Office officials to examine health data for the Torfaen area. As with the Scottish case at Bonnybridge, PCBs and their combustion derivatives, dioxins, were a main source of concern as a possible cause of congenital malformations of the eye, spontaneous abortions and changes in the ratio of male to female at birth (Lenihan, 1985; Welsh Office, 1985).

Data: Specifically commissioned to review in detail the incidence of congenital abnormalities, this is the study eventually published in March 1985 under the title 'The incidence of congenital malformations in Wales, with particular reference to the district of Torfaen, Gwent. A Welsh Office review of notifications made to the Office of

Population Censuses and Surveys' (Welsh Office, 1985). Fourteen kinds of abnormalities were reviewed.

Anophthalmos and microphthalmos were particular causes for public concern, especially after reports of cases of these malformations in the Bonnybridge area of Scotland, but besides eye abnormalities the report does not explain why the other specific malformations were chosen for analysis. The data were drawn from returns by District Health Authorities to the Congenital Malformations Section of the Office of Population Censuses and Surveys (OPCS), following the voluntary scheme introduced in England and Wales in 1964. The Welsh Office was aware at the time of the review that the data were subject an unknown degree of inaccuracy, as a consequence of possible incomplete returns (Knox et al., 1984).

Geographical Area and Analysis: The OPCS was asked to provide data at District Council level for the whole of Wales, covering the ten-year period 1974-83. Data prior to 1974 are not directly available due to administrative boundary changes carried out that year. For each of the fourteen abnormalities reviewed and for each Welsh District and County, yearly numbers of reported cases were listed and crude rates per 10,000 births for the whole period 1974-83 worked out. Rates for the District of Torfaen were compared for significant differences with overall Welsh rates and with Gwent County's rates.

Results: Only two kinds of congenital malformations were significantly raised in Torfaen District, anencephalus (higher than Wales as a whole) and polydactyly (higher than both Wales and Gwent County). Anencephalus incidence had previously been noticed to be higher than average in South Wales (Lowe et al., 1971), for which there is no generally accepted evidence. On the other hand, the report under review was the first study to bring to attention a raised incidence of polydactyly in Torfaen.

3.2.6 - 'Health of the population in the vicinity of the refuse incinerator, Sinderland Road, Altrincham' (Hill, 1989)

Case background: Early in 1989, the local press reported a general increase of cancer in the Lingfield Avenue area of Trafford (Greater Manchester). It was also reported that children in the area suffered from recurrent respiratory diseases and general ill health. Although local doctors had not seen an increase in consultations due to the alleged situation, the Director of Public Health at the local District Health Authority (Trafford) decided to review health figures for the area, as well as investigate possible environmental problems. Besides social conditions, personal behaviour or hitherto unknown pollution of soil or water, the Sinderland Road refuse incinerator was taken into account.

Geographical Area, Data and Methods: Health data for the residents of three wards were compared to that for Trafford District and for Greater Manchester (216 Wards). Socio-economic differences according to the Townsend score (Townsend et al., 1988) and differences in the index of need for Local Authority services between the Wards were considered.

Standardized , by age and sex, Mortality Ratios (SMRs) for all causes combined were available for each Ward. SMRs for the three study Wards followed a ranking close to that for their deprivation scores among Greater Manchester Wards, Z score(*) (1981) rankings: 10th, 28th and 142nd ; SMR rankings: 12th, 33rd and 133rd. In Trafford, the most disadvantaged study ward was fourth highest for Z score and sixth for SMR. Also available were SMRs for Coronary Heart Disease mortality between 1980-86, showing a similar pattern, with two of the study wards having low SMRs and the most disadvantaged being fourth highest for both deprivation score and SMR.

An analysis of cancer registration was carried out by statisticians at the North West Regional Cancer Registry, at the Department of Epidemiology and Social Oncology, Christie Hospital (Manchester), to which all cancer cases are reported. Using the latest complete information available (years 1979-1984) and taking the North Western Region rates as standard, Standardized Registration Ratios (SRRs) were calculated for fourteen classes of cancer, all other cancers and the total for all cancers in males and females in each of the three Wards and in all three combined. Three SRRs were found to be significantly higher than the regional average, for carcinoma of the pancreas in males in one of the less deprived Wards and for carcinoma of the ovary and for all cancers combined for females in the most deprived of the three Wards. In this Ward, SRR for all cancers in females was 121, comparable to its overall SMR of 129 and to its SMR for Coronary Heart Disease of 125. In two other cases SRRs were significantly smaller.

Results: Mortality indices for the three Wards followed closely their respective deprivation scores in their rankings among all Greater Manchester or Trafford Wards, pointing towards general social and environmental factors as reasons for differences in health, rather than to one isolated source of environmental pollution. As for cancer registrations, five out of 128 SMRs were significantly different from the Regional average, three above and two below it, inside the expected variation due solely to chance at the 5% level. The conclusion of the study was that, rather than demonstrating that the incinerator had no adverse effect on the health of the local population, it could not be proved, using the available health statistics, that it had any such adverse effect.

3.2.7 - Laryngeal cancer in the vicinity of an incinerator in Lancashire.
(Gatrell and Lovett, 1991)

Case background: Between 1972 and 1980, an industrial waste incinerator burning solid and liquid waste, mostly solvents and oils, was in operation at Charnock Richard, two kilometres to the Southwest of Coppull, Lancashire. Its opening preceded the setting up of pollution regulations under the Control of Pollution Act (1974). No environmental monitoring was conducted and, therefore, there is no evidence as to what was emitted by the plant (Gatrell, 1991), but allegedly irritant gases gave rise to public protests by the residents about noxious smells and respiratory problems and to demands to study long-term health effects after the incinerator closed.

Geographical area: The study was carried out jointly by the Department of Geography of Lancaster University and the School of Environmental Sciences of East Anglia University (Gatrell and Lovett, 1991). The statistical model on which the analysis was based had been developed at the Department of Mathematics of Lancaster University (Diggle, 1990) and first tested in this study. It is called Spatial Point Process Model and states that the 'intensity' (number of cases per unit area) of a cancer is proportional to the product of a 'background intensity' (population at risk per unit area, taking into account age and sex) and a function of distance from the alleged source of pollution. Using the CPD, cases are defined by point coordinates. Cases are mapped by plotting the Postcode Unit of each case as Ordnance Survey grid references (accurate to 100 metres), using the computerised Central Postcode Directory (CPD) (Gatrell, 1989 ; Gatrell et al., 1992)., spreading over a continuous space around the source of pollution and thus avoiding a system of arbitrary area units. In the absence of any environmental factor the spatial distribution of cases would depend solely on the spatial distribution of the population at risk.

Data: Through literature review the authors found studies, mostly occupational, on possible links between incineration and laryngeal cancer. Emissions of polycyclic aromatic hydrocarbons (PAHs), asbestos, formaldehyde and chromate dust, among others, were mentioned as possible causative factors. Intensity and length of exposure were also taken into account (Diggle et al., 1990).

There were fifty-eight cases of laryngeal cancer in Chorley and South Ribble DHA during the study period, 1974-83, following an age-sex distribution roughly in line with that drawn from much larger samples (Diggle et al. 1990). The North West Regional Cancer Registry provided data on all the types of cancer reviewed in the study.

While distribution of individual cases of laryngeal cancer could be defined by the point coordinates of their Postcodes Units, obviously this was not the case with population (background intensity) for which data were available as aggregates for arbitrary spatial units such as Wards or Enumeration Districts. As a proxy, reflecting both density and distribution of population, point data on the distribution of lung cancer were used. This much more common type of cancer seems to reflect quite well the distribution of population clusters in towns and villages (Gatrell and Lovett, 1991), with the additional advantages that its age-sex distribution is broadly comparable to that for laryngeal cancer and that smoking is a risk factor common to both diseases. A disadvantage would be that lung cancer could be associated with proximity to the incinerator, an overmatching reducing the possibility of finding a significant association between distance and laryngeal cancer. In an exploratory study such as this the authors preferred risking an overmatching between readily available cancer data rather than resorting to a laborious search of individuals from census data for appropriate age-sex controls, a reduction in likelihood being of concern only in case the hypothesis under consideration was rejected (Diggle et al., 1990). There were 978 cases of lung cancer in the DHA between 1974-83.

As well as lung cancer, other common types of cancer could be, and were, used as a proxy for 'background intensity' of population.

Analysis and Results: The analysis tested the hypothesis that proximity to the incinerator had a significant influence on the incidence of laryngeal cancer. The Spatial Point Process Model follows the method of maximum likelihood. Firstly, a null model assumes that distance to the incinerator has no effect and that laryngeal cancer follows the same spatial distribution as the population (lung cancer, as proxy, in this case). Secondly, a maximum likelihood estimate incorporates the parameters of a distance function. Thirdly, the difference between the null and maximum likelihood values tests the null hypothesis of no link between distance and effect. At the 5% confidence level, a statistically significant association with proximity to the incinerator was found, this in spite of a possible overmatching between lung and laryngeal cancer cases (see above) (Gatrell and Lovett, 1991 ; Gatrell, 1992).

The analysis was repeated using cancer of the stomach as a measure of 'background intensity' (398 cases) also with a positive result. Another reasonable measure of 'background intensity', independent of cancer incidence but based on arbitrary (the smallest available) space units, was the distribution of the 4389 Postcode Units within the DHA, each with 16 households on average. As with cancer cases, this point distribution was obtained using the CPD, and the analysis based on it found also a significant association (Gatrell and Lovett, 1991; Gatrell, 1992).

Looking for other points in the DHA to which laryngeal cancer could be associated, 'dummy' sources of pollution were distributed following a lattice of one kilometre resolution. After repeating the analysis for each of the imaginary locations, the only point to which laryngeal cancer was significantly associated was that for the real incinerator (Gatrell and Lovett, 1991).

The incinerator lay near the southern boundary of the DHA under study. To assess the impact on the results of cases in neighbouring Districts, the study area was redefined as an square of 30 by 30 kilometres centred on the incinerator site. The North West Regional Cancer Registry provided point data on cancers of the larynx (261 cases) and cancers of the lung (5029 cases) inside this area for the study period. Repeating the analysis for this new area confirmed the previous findings (Gatrell, 1992).

The study concludes that: 'the incidence of cancer of the larynx in part of Lancashire is associated with proximity to the site of a former industrial waste incinerator' (Gatrell, 1992). Nevertheless, and also in the words of the authors: 'in the absence of additional information it is foolish to claim that living near the incinerator has caused cancer of the larynx' (Gatrell and Lovett, 1991). This information was unavailable as routine data, and would have dealt with residential and occupational histories of cases for both the cancer under study or those acting as indicator for population distribution, as well as information on other risk factors such as smoking and alcohol consumption. Two other important points were missing, quantity and composition of emissions, for which there had not been any monitoring during the operative life of the incinerator, and reliable estimates of latent period(s) for cancer of the larynx, ranging in occupational studies between four or five years to thirty years or more (Diggle et al., 1990).

3.3 - The Black report.

3.3.1 - Investigation of the Possible Increased Incidence of Cancer in West Cumbria (Black, 1984).

Case background: In 1952, two nuclear reactors for the production of military-grade plutonium, and a spent-fuel reprocessing plant started operating at Windscale, near the Irish Sea, in the former county of Cumberland (in Cumbria since 1974), NW England. Over the next thirty years, the site saw the addition and decommission of different nuclear facilities. By the early Eighties the site had long expanded into a complex, now known as Sellafield (Gardner and Winter, 1984), producing plutonium as nuclear fuel, with four nuclear power reactors in operation at Calder Hall. It was also (and still is in 1997) the main UK facility for the reprocessing of spent nuclear fuel from British (and some foreign) nuclear power plants, at Windscale, with storage sites for the different products treated or produced, and with a disposal site for low-level radioactive waste at the coastal site of Driggs, four miles South from the main compounds. Three pipelines discharged radioactive waste liquid from the complex into the Irish Sea.

On November 1st. 1983, a Yorkshire Television programme: *Windscale, the Nuclear Laundry*, suggested that there was an excess of leukaemia in the coastal village of Seascale, near the Sellafield complex (Anon.- Lancet, 1984). Following this programme, Sir Douglas Black was asked by the Minister for Health if he would head an independent enquiry into examining the evidence concerning the alleged cluster of leukaemia in Seascale, which he did, with the cooperation of a group of six experts in relevant fields. Their report (known as The Black Report), was published in the summer of 1984 (Black, 1984).

Geographical area: The Advisory Group decided to investigate the incidence of cancer (particularly leukaemia) in the area adjacent to the Sellafield complex and to compare it with the incidence of similar cancers in other areas of the United Kingdom and Cumbria. As expressed in their report, the Advisory Group was aware that the selection of specific geographical areas (i.e., subdivisions) for study had a direct influence on the results, or, in the report's words: 'if (they) are selected for study because cases of cancer are known to have occurred there, it is not surprising if the incidence of cancer (in those areas) is found to be unusually high ' (Black, 1984, Ch. 2).

Radiation exposure: At the same time, the Advisory Group also decided to carry out a risk assessment which, combining evidence relating radiation exposure to cancer with available data on such exposure in the study area, assessed the likelihood of any local increase in cancer to be due to radiation.

Case review: The Advisory Group started by examining one by one the vital records of leukaemia cases registered since 1955 among the under 25 year old resident in the Millom Rural District (32 cases), in whose northern tip Seascale is located. At the time of the review, Millom Rural District (RD) did not exist as such any longer, having been incorporated into the newly created Copeland District after the nationwide administrative reorganisation of 1974. The former Millom RD can be described very approximately as the southern half of Copeland, now one of four Districts making up the County of Cumbria. This exam was based on death certificates and West Cumbria Health Authorities' hospital records. Cases in Seascale (7 cases) were also examined on their own, but without the report specifying the area considered as being Seascale, presumably based on census tracts. The exam considered the levels of radiation that each of the cases would have been exposed to since conception.

Review of previous studies: The Advisory Group also reviewed previous studies (published or not) having investigated cancer incidence and/or death rates among the under 25 or under 15 year old in an area including Seascale. Some of them did not consider geographical units smaller than Copeland District and were, in the Group's opinion, open to the criticism that the geographical spread of the study was large and might conceal a local raised incidence of childhood leukaemia near the Sellafield complex.

Other studies included smaller areas, such as parishes, alongside larger ones, such as Districts or the old Rural Districts (there are 10,250 parishes in England, as against 366 Districts, like Copeland) (Carstairs and Lowe, 1986). Using Cumbria or England overall rates as standard, these studies found significantly high rates of cancer and/or leukaemia in several of the geographical subdivisions studied, including Seascale. The lack of homogeneity in geographical areas, as well as some choices, like parishes South of Sellafield, but not North of it, were criticised by the Advisory Group. In their opinion, where large areas were looked at, possible local excesses would disappear, as already indicated. Conversely, using smaller areas excesses of childhood cancers would be found in certain areas, but this approach would increase the possibility of statistically significant excesses being found by chance as more areas were examined. Also, when small numbers of cases are involved high rates could occur also purely by chance, and have no particular local interpretation. It was thus considered important to compare the rates in Seascale and its surrounding Millom Rural District with levels in similar communities through the region and country to enable the Advisory Group to assess how unusual increased rates might be.

This was done by two further studies reviewed. The first of these did compare Seascale with areas of similar size (Craft and Openshaw: personal communication to the Advisory Group, in Black, 1984). It took into consideration a large geographical area, but subdivided it in turn into much smaller ones. Craft and Openshaw used the Northern Children's Cancer Registry to calculate cancer and leukaemia incidence rates in each of the 765 electoral wards in the region covered by the Registry, for the period 1968-82 among under 15 years-olds (there are 8,485 such wards in England) (Carstairs and Lowe, 1986). The authors estimated that the Registry contained more than 98% of the 0-14 year old cases of childhood cancer occurring in the catchment area. In this study, Seascale ranked sixth highest in incidence rates for all childhood cancers (five times the regional incidence, although based on only four cases). Seascale had also the third highest incidence rate of childhood 'lymphoid malignancy' among the 765 electoral wards (16 times the regional incidence, the same four cases).

A second study, published while the review was in progress (Gardner and Winter, 1984), examined leukaemia death rates in people under 25 year-old during 1968-78 in the 469 Rural Districts in England and Wales. Millom Rural District had the second highest rate out of the 152 similarly sized Rural Districts, i.e., those with between 1 and 2 expected deaths (it had 6).

Conclusions: Even though they were based on small numbers, the last two studies reviewed were consistent in demonstrating a higher incidence of leukaemia in young people resident in the Seascale - Millom area. The Advisory Group concluded that they represented epidemiological evidence indicating that the incidence of leukaemia was above average both in the village of Seascale and in the Rural District in which it lies.

As to the radiation risk assessment, the Advisory Group concluded that the estimated levels of radiation received by the population were insufficient to account for the additional cases of leukaemia in the area. Levels of radiation were within the maximum recommended by the International Committee on Radiation Protection, and the risk assessment carried by the Group's experts estimated that these could be responsible for only 0.1 additional death by leukaemia in the Seascale parish, compared to the known excess of 4 to 5.

Recommendations: Among the final recommendations in the report, the review Group saw the convenience of further epidemiological studies, such as a case-control study of the leukaemia cases, a record-based study of cancer and mortality among those born in the area since 1950 and another of those having attended schools in the area (Recommendation 1 to 3), and further work in the direction of a ward-based study of leukaemia (Recommendation 4). It was also recommended that encouragement should be given to an organisation such as OPCS or the Medical Research Council to co-ordinate centrally the monitoring of small area statistics around major installations producing discharges that might present a carcinogenic hazard to the public, as a way to obtaining early warning of any untoward health effect (Recommendation 5). Finally, a designated body with significant health representation should be created, to act as adviser in matters concerning the control of radioactive discharges (Recommendation 10).

Recommendations 1 and 3 were eventually answered with studies taking them as the basis for their remits (Gardner et al., 1990*a* for Recommendation 1; Gardner et al., 1987*a* and *b*, for 3). Related studies were those by (Kinlen, 1993*b*) and (Parker et al., 1993). Recommendation 4 led to the development of the novel method known as the Geographical Analysis Machine (Openshaw and Craft, 1988). Finally, following Recommendation 5, the Small Area Health Statistics Unit was set up in 1987 at the London School of Hygiene, which to date has produced an study on incinerators (Elliott et al., 1992*b*).

It should be mentioned that a later study investigated whether the observed excess incidence in Seascale had continued in the years after the Black report. It made use of England and Wales rates to calculate expected numbers of cases among those aged under 25 in the County of Cumbria, the District of Copeland and Seascale ward, and concluded that in 1984-90 the incidence of leukaemia and non-Hodgkin lymphomas in Seascale was higher than would be expected, excess unlikely to be due to chance (Draper et al., 1993).

3.4 - Studies following recommendations in the Black Report. Other studies on Sellafield.

3.4.1 - Follow up study of children born elsewhere but attending schools in Seascale, West Cumbria (schools cohort) (Gardner et al., 1987*a*), and:

3.4.2 - Follow up study of children born to mothers resident in Seascale, West Cumbria (birth cohort) (Gardner et al., 1987*b*).

Background, Geographical area: This double study was carried out as an answer to Recommendation 3 in the Black report. Its geographical unit the Seascale parish, both as birthplace of those in the births follow-up, and as location for the four schools which pupils born elsewhere had attended (schools follow-up).

Analysis and results: Although also referred to as cohorts, the proper denomination of the double study was that of record-based follow-ups. Schools records and birth, cancer (since 1971) and death registrations were reviewed to work out numbers of pupils, of births (both used as population in the corresponding group) and cases. The person-years method of analysis was used, with confidence intervals calculated using standard methods based on the Poisson distribution. The schools follow-up reviewed records on 1546 children identified as having attended schools in the Seascale parish up to November 1984, and born since 1950 but not in the parish. Data (for both groups) came from the National Health Service Central Register. Overall mortality for this group (to mid-1986) was found to be comparable to that expected at national rates, even slightly lower: 10 observed deaths, 12.69 expected. The same was true for cancer deaths: 1 (no leukaemia or lymphoma) against 0.83 expected) and non-fatal cancer incidence: 5 cases since 1971 (when registrations started) compared to 3.83 expected. The only known case of leukaemia in this group took place in 1968, before reliable national rates became available.

The births follow-up reviewed records of 1068 children born to mothers resident in Seascale parish between 1950-83. Many children left the area before school age (about half of them did not attend schools in Seascale parish), but their records in the National Health Service Central Register could be followed up irrespective of place of residence. The number of deaths for all causes were below that expected: 27 against 32.06 expected at national rates. This could be due, in the view of the authors, because of the very high prevalence of social class I in Seascale (28% against 6% in England and Wales), although no standardization by social class was carried out.

Nevertheless, deaths due to cancer were much higher than expected: 9 for all cancers against 1.60 expected (1 during residence in Seascale). Most of these cancer deaths were due to leukaemia: 5 against 0.53 (4 during residence in Seascale). Social class, although slightly higher in social class I, could not possibly explain this excess of leukaemia. A further 3 non-fatal cases of cancer were reported, against 1.19 expected.

Conclusion : If not in mortality, there was an evident excess of cancer cases in the births group which was not apparent in the schools one. This excess applied particularly to leukaemia. This raised the question of whether risk factors for cancer, having an effect before birth or early in life, were present in Seascale.

3.4.3 - Results of case-control study of leukaemia and lymphoma among young people near Sellafield nuclear plant in West Cumbria (Gardner et al., 1990*a*)

Objective, cases and controls: This study is an answer to Recommendation 1 in the Black report (Black, 1984). It was also a logical continuation to the study reviewed above (Gardner et al., 1987*a* and *b*), taking into consideration risk factors which could act before birth or early in life. Its objective was to investigate whether the previously observed excess of childhood leukaemia near the Sellafield complex was associated with known risk factors for leukaemia, and independent of the existence of a nuclear complex in the vicinity: antenatal x-rays examinations and viral infections, or with factors related to the complex: habit factors such as using the beaches near the complex, proximity to and employment characteristics of parents at Sellafield (radiation doses). Cases consisted of those born in West Cumbria, diagnosed between 1950 and 1985 (52 of leukaemia and 45 of lymphoma). Controls (1001) were also born in West Cumbria. Both were matched for sex and date of birth (Gardner et al., 1990*b*).

Geographical area: It was the West Cumbria Health District. The most outstanding feature of the study was the use of Ordnance Survey (OS) grid references of the addresses of cases and controls in order to group them by distance to the Sellafield plant (accurate to 100 metres) for some of the analyses. This was done too with a subgroup of controls matched also by area of residence of mothers (same parish as cases). These cases and controls were grouped into seven concentric rings 5 kilometres wide (in fact the fifth ring was open and covered the remainder of West Cumbria), whose centre was the OS grid reference of the plant as used by the National Radiological Protection Board in its analysis of atmospheric discharges, i.e., a point taken as the centre of polluting emissions in the extensive complex. Otherwise, the study consisted of a conventional case-control, making use of routine and questionnaire data.

Results: Estimates of relative risk (odds ratio) were calculated for cases and controls, subject or not to the relevant factor. The high incidence of lymphoid malignancies, particularly leukaemia, near Sellafield was found to be statistically associated with fathers' occupation at the plant and to the total radiation doses received by these before conception of their children. The next two papers reviewed (Kinlen, 1993*b*, and Parker et al., 1993) were a direct consequence of this finding, both looking further into the subject.

In the eventuality of the factor being distance to Sellafield, odds ratios were calculated separately for each of the rings. There was a large fall in the odds ratio figures as they moved away from the centre, to levels of about one-third that in the inner circle, thus suggesting a decrease in risk with distance from the source of pollution.

3.4.4 - Can paternal preconceptional radiation account for the increase of leukaemia and non-Hodgkin's lymphoma in Seascale? (Kinlen, 1993*b*).

Background and objective: A direct consequence of the findings in the studies previously reviewed (Gardner et al., 1987*a* and *b*) (Gardner et al., 1990*a*), the objective of this study was to determine if the excess of malignant lymphoma (particularly leukaemia) in Seascale was restricted to those born in the parish, and whether it might be explained by a possible relation with paternal preconceptional radiation (Gardner et al., 1990*a*).

Geographical area and population: The geographical area was the civil parish of Seascale, one of 10,250 in England in 1981 (Carstairs and Lowe, 1986). Population was that of residents (1951-91) under 25 years old. Five-year age groups by quinquennial calendar periods were calculated from the decenial censuses 1951 to 1991 by linear interpolation between censuses. Totals were divided into residents born in the parish and those born elsewhere by estimating numbers of births to residents and movement out of the parish from data utilised in a previous study (Gardner et al., 1987*b*, other data came from OPCS), and deducting these from totals to estimate those born outside. Underestimated and overestimated figures of both natives and immigrants were calculated.

Analysis: Quinquennial incidence rates of leukaemia and non-Hodgkin lymphoma for England and Wales were utilised to obtain standardized, expected numbers of cases among both natives and immigrants. Ratios of observed / expected cases and their p-values were calculated. Also, cases were stratified by recorded (or estimated) radiation levels received by fathers during the 28 weeks prior to conception (data from British Nuclear Fuel and Atomic Energy Authority), for each of the two groups.

Results and conclusion : Contrary to expectations, both those born in Seascale and those born outside the parish had highly significant incidence rates for leukaemia and for non-Hodgkin lymphoma. Also contrary to prior hypotheses, low proportions of these cases were associated with high levels of radiation. For the authors, neither to be born in Seascale nor father's preconceptional radiation could explain the excess incidence in Seascale, although perhaps these were indirectly related to the true, unknown, cause.

3.4.5 - Geographical distribution of preconceptional radiation doses to fathers employed at the Sellafield nuclear installation, West Cumbria (Parker et al., 1993).

Background and objective: Another study looking further into previous suggestions (Gardner et al., 1990*a*), its objective was to examine the geographical distribution of births of those children whose fathers were known to have received radiation doses at the Sellafield nuclear complex, and to explore a possible relationship between this distribution, these doses and the incidence of childhood lymphoid malignancy in the village of Seascale. This study can also be seen as a partial answer to recommendation 2 in the Black Report (Black, 1984).

Geographical area and study population: The former consisted of three areas of increasing size: Seascale civil parish, West Cumbria health district (minus the Seascale civil parish) and the remainder of the county of Cumbria. Study population consisted of the 10,363 children born in Cumbria during 1950-89 to fathers employed at Sellafield.

Analysis: The study was defined as a retrospective birth cohort (Parker et al., 1993), although its design was that of a descriptive, geographical distribution study. Data on births in Cumbria between 1950 and 1989 (267,426), provided by OPCS, were entered on a 4th. Dimension database package in a Macintosh computer. The mother's residential address at birth was assigned a postcode manually from postcode directories, and then allocated a grid reference accurate to 100 metres by means of the Royal Mail's Postzon database. British Nuclear Fuels (BNF) and the United Kingdom Atomic Energy Authority (UKAEA) provided a database of their employees at Sellafield between 1950 and 1989, which was matched (manually) to that of Cumbrian born children, resulting in

10,363 matches to 5776 fathers. Finally, radiation doses received by each father prior to conception of the child were calculated from the BNF-UKAEA database. Stratified by dose levels, each birth was allocated by coordinates, through an ARC/INFO geographical information system, to one of the three subdivisions of the study area. Due to poor resolution of the system, numbers of births within the same 1 km. square had to be added, as were doses, which were then divided by the number of children.

Results and conclusions: Mean individual preconceptional doses, both total and for the six months prior to conception, were consistently lower for children born in Seascale than for those born in the remainder of West Cumbria. Mean doses in the remainder of Cumbria were the lowest. Therefore, as there is no evidence of an excess of childhood leukaemia or lymphoma in West Cumbria comparable to that in Seascale, the geographical distribution of births to men with higher doses was found not to follow that of lymphoid malignancies. The cluster of cases in Seascale remains an enigma (Parker et al., 1993).

3.4.6 - Acute lymphoblastic leukaemia in children in Gateshead (Tyneside). (Openshaw et al., 1988)

Case background: The authors of this study had already contributed to the Black enquiry on Sellafield with an analysis of childhood leukaemia in the 765 electoral wards in the Northern Region (Black, 1984). Following this, the enquiry's Report had recommended that further work should be conducted in the direction of a ward-based study of leukaemia (Recommendation 4), and, in general, of studies based on divisions into small areas. The reason for these recommendations were the somehow uncertain results of the review of studies based on larger areas. The authors decided that, to avoid as much as possible these uncertainties, a new method should: a) be able to analyse data independently of any preconceived hypothesis regarding causation and, b) be independent of any arbitrary geographical boundary (Openshaw et al., 1988). By 1987, the team were ready to test a first model of such a methodology, based on automated computer analysis and known as the Geographical Analysis Machine (GAM) (Openshaw et al., 1987).

Geographical Area and Data: The first application of GAM consisted of a study of acute lymphoblastic leukaemia (ALL) in children in Northern England. Between 1968 and 1985, a total of 853 children aged 0-14 years were diagnosed as having ALL in the Northern and Northwestern Health Regions and in the Southport and South Sefton districts of the Mersey Region. Data on leukaemia registration were provided by the Children's Malignant Disease Registry (Northern Region), the Children's Tumour Registry (Northwestern), both considered to have an overall 98% ascertainment, and the Mersey Cancer Registry (Southport and South Sefton districts) (Openshaw et al., 1988). GAM's method is based on both point (cases) and area (population) information (de Lepper and Scholten, 1991). Using its post code address at time of diagnosis, each case was converted to a grid reference point with 100 m resolution. For each Enumeration District (ED) in the study area, the population at risk figure for those under 15 years of age (1981 Census: 1,544,963) was allocated to the District's Ordnance Survey centroid coordinates, also with a 100m. resolution (Openshaw et al., 1988).

Analysis: Using a computer (Amdahl 5860), 812,993 circles covering the whole of the regions under study were generated. Centres were 'regularly spaced' (Openshaw et al., 1988) and circles with radii ranging from 1 to 25 km were drawn from each one. Each circle overlapped their neighbour circles in all directions by 0.8 of its radius. The observed number of leukaemia cases inside each circle was tested for significance using the Monte Carlo significance test (Hope, 1968). Based on the EDs centroids' distribution and their under 15 population figures, a total of 499 sets of artificial data were generated, each allocating randomly through the area a number of leukaemia cases identical to those actually observed (853). Of the 812,993 circles, those with at least 2 observed cases were selected and these numbers of cases were then tested for deviation from Poisson distribution. Each circle ranking more extremely than its 499 simulated equivalents was considered significant (p=0.002) and drawn in a print-out. The analysis, carried out at Newcastle University took about seven hours of central proccssing unit time.

The sensitivity of the Geographical Analysis Machine depended on the number of sets of artificial data generated (simulations), and this number depended, in turn, on computing power. In 1988, the GAM technique was highly demanding of computer time. Further similar studies at Newcastle were to utilise a Cray XPM 'supercomputer'.

Results: A total of 1792 circles were found to be significant. Most of these were grouped in five clusters, one around Seascale-Seafield, a much larger one around

Gateshead (Tyneside) and three other minor clusters (Openshaw et al., 1987 and 1988). If leukaemia had followed a Poisson distribution, 173 circles scattered over the study area would have been significant. Results showed more than ten times that number, grouped into two major and three minor clusters. Thc authors concluded that the pattern of leukaemia did not follow a Poisson distribution and that true clusters did exist (Openshaw et al., 1988).

The Tyneside cluster had been suspected in the late 1970s, but it had not been properly investigated since the cases were scattered over contiguous administrative areas, on both sides of a major river (Openshaw et al., 1988; Craft et al., 1985). The Geographical Analysis Machine provided a boundary-free method of analysis. The cluster in the Sellafield-Seascale area had been predicted by previous research (Black, 1984). The Newcastle study showed that increased leukaemia was not necessarily associated with nuclear facilities, since none existed within 35 miles of Tyneside. For the first time there would appear to be a possible link between leukaemia and some other form of environmental pollution (Openshaw et al., 1987 and 1988).

3.4.7 - Incidence of cancers of the larynx and lung near incinerators of waste solvents and oils in Great Britain. (Elliott et al. , 1992*b*)

Case background: Recommendation 5 in the Black Report encouraged the creation of an organisation to centrally coordinate the monitoring of small-area statistics around major installations producing discharges (Black, 1984). This study became the first substantive inquiry by that organization, set up in 1988, the Small Area Health Statistics Unit (SAHSU), at the London School of Hygiene and Tropical Medicine's Department of Public Health and Policy, Environmental Epidemiology Unit.

In England and Wales cancer of the larynx is much rarer (1% of all cancers) than lung cancer. Nevertheless, the literature review carried out by the SAHSU showed that both cancers share some epidemiological features, such as social-class gradient (higher incidence in lower classes), similar occupational risks and relation to cigarette smoking. Lung cancer risk may also be increased by exposure to polycyclic aromatic hydrocarbons (PAHs) secondary to combustion processes. According to the Department of the Environment, plants like that at Charnock Richard could emit PAHs, along with black smoke, aldehides, benzene and, if chlorinated waste was burnt, dioxins and furans

(Elliott et al., 1992*b*). In consequence, the SHASU team decided to study both cancer of the larynx and cancer of the lung around British incinerators of this type.

Geographical area: Licensed plants identified by the Department of the Environment as burning mainly waste solvents and oils were identified. Those similar in type and mode of operation to the Charnock Richard incinerator were further selected. Finally, ten plants licensed prior to 1979, including Charnock Richard, were taken into account for study and their Ordnance Survey grid references obtained.

Following the methodology adopted by SAHSU, the areas around the sites were divided into circles and concentric bands with the incinerators at their centre (Elliott et al., 1992*c*). First, a circle 3 kms. in radius and an outer band between 3 and 10 kms away. Then, ten bands of radius 0.5, 1.0, 2.0, 3.0 kms. (the first band being actually a circle), and 4.9, 6.3, 7.4, 8.3, 9.2, 10.0 kms. (the last six bands enclosing approximately equal areas). Data in the circles and bands up to 3 kms from the incinerators were analysed to assess possible health effects in the areas near the plants, data in the outer bands to assess them up to a further distance. The 10 kms. limit was considered to enclose the area of any hypothesized health effect (Elliott et al., 1992*a*).

Data: Following the International Classification of Disease (ICD), 8th and 9th Revisions, registered cases of larynx cancer (ICD-161) and lung cancer (ICD-162) for 1974-84 (England and Wales) and 1975-87 (Scotland) were selected from the SAHSU-OPCS database (World Health Organization, 1977; Elliott et al., 1992*d*). Only those cases of lung cancer with complete residence postcode at registration were taken into account. An extra effort was made by the OPCS and the Scottish Health Service-ISD, managing to correctly postcode 90% of the 765 larynx cancer cases with incomplete postcode that could have been included in any of the study circles. A check on data quality was done for larynx cancer (confirmation of a 10% of thc finally analysed cases). Only incinerators having started operations before 1979 were taken into account to allow the analysis of cancer cases collected at least five years after waste burning began. For four of the ten incinerators (including Charnock Richard) there were cases collected at least ten years after their entry into service. These time-lags of five or ten years represented two likely latent periods for cancers to develop since first exposure to their putative agents, incineration byproducts.

Analysis: For the calculation of rates, numbers of cases (numerators) are available at Post Code Unit level. Population numbers (1981 census) are the denominators, available at Enumeration District level. The two can be connected through the computerised Central Postcode Directory (CPD), kept by OPCS and the Registrar General for Scotland (Carstairs and Lowe, 1986). Making use of CPD, the SAHSU supplements it with a computer program of its own relating cases to populations inside geographically defined circles and bands as, for example, those defined above. Cases are allocated to a particular band according to their Post Code Units' Ordnance Survey coordinates and the distance between these coordinates and those for the incinerator. To calculate populations, Enumeration Districts are allocated to each circle or band according to their centroids' Ordnance Survey coordinates. Enumeration Districts straddling two bands are allocated to the one containing most of its Postcode units (Elliott et al., 1992*d*;).

Registration rates of cancers of the lung and larynx for the whole of Britain were worked out by sex and 5-year age groups (1981 census) using the SAHSU-OPCS database. To take into account differences in incidence and registration, and using these all-Britain rates, standardized observed/expected ratios were calculated for each of the Regional Health Authorities (RHAs, corresponding to cancer registries) in which the incinerators were. When the circles straddled RHAs, weighted averages of the observed/expected ratios were calculated according to the number of Postcode Units in each RHA. Each regionally standardized ratio was then multiplied by the number of expected cases in each circle or band around the local incinerator(s), worked out using the all-Britain rates, to obtain locally standardized numbers of expected cases. Since postcode ascertainment and repostcoding of cases of interest had been carried out, all registered cases of larynx cancer for the period 1975-84, for which data for the whole of Britain were available, were used for the calculation of standard rates. For lung cancer rates only fully postcoded cases were used and, to allow for time trends in completeness of postcoding and incidence, standardized expected numbers for each site were calculated using rates for the period each incinerator was studied, defined by the year it began operation and the time-lags (Elliott et al., 1992*a*). For the years when data were not available either for Scotland (1974) or for England and Wales (1985-87), averages of the two next or last years were used (Elliott et al., 1992*b*).

Since socio-economic differences could be a confounding factor in health studies (Jolley et al., 1992), a second set of expected numbers of cases for each site were calculated using the Carstairs' deprivation index, or CI (Carstairs and Morris, 1991). All Enumeration Districts (EDs) in Britain were grouped into quintiles according to their Carstairs' index (a sixth group consisted of EDs with undefined CIs) and British age-sex specific rates were calculated for each group, for each cancer. ED populations in each circle or band were in turn grouped by CI and expected numbers of cases for each group were worked out using the British rates. The numbers for each group were then summed to calculate the total expected number standardized by socio-economic category in that band or circle.

For each of the 3 km. circles and their outer 3-10 km bands and for each of the ten concentric bands, numbers of observed cases of lung cancer and of larynx cancer were worked out. Expected cases were also calculated, based on the regionally standardized rates, with and without standardization by socio-economic deprivation. These numbers were calculated for two time lags of 5 and 10 years since each incinerator started operations. Figures for each individual band were added over all sites to increase the power of the study (Hills, 1992). Figures for the Charnock Richard's incinerator, the one at the origin of the study, were added to those for the other nine, but the site was also individually analysed.

Once the above figures had been obtained, for the 3 km circle (possible effects near the source) and for the 3 to 10 km band (theoretical distance limit for possible effects) observed/expected ratios and their 95% confidence intervals were calculated with the Poisson distribution (Bland, 1987).

Based on the assumption that the observed number of cases inside each of the ten concentric bands had a Poisson distribution, these were analysed following Stone's method (Stone, 1988). The method tests the null hypothesis that the ratio observed/expected (relative risk) equals 1 for each band, against the alternative that this ratio is either a constant different from unity or that it decreases with distance from the centre. This is done with an overall likelihood test. To assess a possible decreasing trend with distance a further likelihood test is carried out (Stone, 1988; Elliott et al., 1992*b* and *c*; Hills, 1991 and 1992).

Analyses were carried out for both sexes separately and for ages 0-65 and 65+. Nevertheless, results were similar for males and females and for younger and older age groups. In consequence, published results refer to total figures for all ages of both sexes combined (Elliott et al., 1992b).

Results: The authors found no evidence to suggest excess risk of cancers of the larynx and lung among residents living near waste solvent incinerators of the Charnock Richard type, concluding that the apparent cluster of cancer of the larynx previously observed at Charnock Richard was unlikely to have been caused by the incinerator.

Stone's method did not confirm the previously found association between cancer of the larynx and proximity to the Charnock Richard incinerator using Diggle's Spatial Point Process Model (Gatrell and Lovett, 1991). In the SAHSU analysis, ratios of observed/expected cases of larynx cancer in the 0-3 km. band, were consistently higher than the corresponding ratios for lung cancer (Elliott et al., 1992*a* and *b*). This relative deficit of lung cancer, used as proxy for population density (Gatrell and Lovett, 1991), could have exaggerated the findings for larynx cancer in the previous study (Elliott et al., 1992*a* and *b*).

3.5 - Other studies on nuclear plants: Dounreay and La Hague.

3.5.1 - Incidence of leukaemia in young persons in West of Scotland (Heasman et al., 1984).

Background: In 1983, in connection with the Advisory Group's investigation on Sellafield, a study of the incidence of leukaemia on the West Coast of Scotland for the period 1968-81 was undertaken by the Information and Statistics Division (ISD) of the Scottish Health Service. This study investigated possible effects of radioactive sea discharges from Sellafield carried into Scottish coastal waters (Bobrow, 1988). Along with this primary objective, ISD decided also to examine the incidence of leukaemia near the three nuclear power stations in Scotland: Chapel Cross, Hunterston and Dounreay (Heasman et al., 1984).

Geographical area: Around nuclear power stations, cases and populations studied were those in Post Code Sectors falling totally or partly within a 10 mile (16 kilometrės) radius of the station (there are 1,211 such Sectors in Scotland).

Analysis and Results: The period 1968-81 was subdivided into two seven-year periods and incidence of myeloid, lymphoid and all leukaemia (both together) cases were analysed, following a Poisson distribution, for residents under 25 years of age. The only (just) significant result was that for all leukaemia for Hunterston in 1975-81.

3.5.2 - Investigation of the possible increased incidence of leukaemia in young people near the Dounreay Nuclear Establishment, Caithness, Scotland . (Bobrow, 1988).

Background: The Dounreay Nuclear Establishment (henceforth mentioned as Dounreay), in the district of Caithness, Northern Scotland, started operating in 1958. Up to 1983, a total of three nuclear power reactors had been operative at the site, with a minimum of one and a maximum of two in service at any time ever since. Associated with the reactors, facilities for the reprocessing of nuclear fuel also existed in the complex (Bobrow, 1988). In 1986, a planning application was put forward for a new nuclear reprocessing plant at Dounreay. In preparation to the Public Inquiry for the mentioned planning application, the Highland Regional Council asked the Scottish Health Service's Information and Statistics Division (ISD) to analyse the incidence of leukaemia among young people in the area (Bobrow, 1988). The study revealed a significantly raised incidence of leukaemia around Dounreay (Heasman et al, 1987).

Following Recommendation 10 in the Black report, a Committee on Medical Aspects of Radiation in the Environment (COMARE) was established in November 1985 by the Minister for Health to assess and advise government on the health effects of radiation in the environment (Black, 1984; Bobrow, 1988). In view of the results of ISD's study, and with the Sellafield inquiry as a precedent, COMARE was asked by the Secretary of State for Scotland to consider and advise on the incidence of childhood leukaemia around Dounreay. COMARE based their inquiry on analyses carried out by ISD, as well as conducting a risk assessment of radiation in the Dounreay area.

Data and analysis: Cases were all forms of leukaemia registered between 1968 and 1984 (or subdivisions of this period) among residents aged under 25 years, resident in the corresponding study areas. These data were provided by the Scottish National

Cancer Registry (SNCR). Area population consisted of those in the same age group as the cases, from the 1971 or 1981 censuses as appropriate.

Analyses consisted on one-sided Poisson distribution significance tests of the differences observed-expected (significant at the p=0.05 level). Standard rates for each period were those for the whole of Scotland.

Geographical areas and their results: By taking as study area the Post Code Sector containing Dounreay (KW 14.7), the ratio Observed/Expected, 1968-84, was significant (p=0.0061, 6 observed, 1.60 expected). With an area made up by those Post Code Sectors totally or partially inside 16 km. from Dounreay (four Sectors), the ratio O/E was again significant (0.035, O=7, E=3.03) (Bobrow, 1988), which the same area had not been for 1968-91 (Heasman et al., 1984). Nevertheless, areas built of Post Code Sectors are very irregular in shape, with boundaries wildly varying in distance from Dounreay, particularly the single-Sector area, which consists of a long and narrow coastal strip, with a relatively small population (3,295), and including a leukaemia case quite far away from Dounreay (Bobrow, 1988).

As an alternative to the irregular shapes of Post Code Sectors' boundaries, nearly-circular areas were built around Dounreay by grouping those Enumeration Districts (their populations and cases) whose centroids, defined by Ordnance Survey (OS) coordinates, lay within a given distance from a point in the nuclear plant, taken as the source of radioactive emissions and also defined by OS coordinates (Heasman et al., 1987). Two main circular areas were built, one within 12.5 km. of Dounreay and another within 25 km.. These radii were derived by ISD by successive halving of an arbitrarily chosen basic unit of 100 km. In studies such as this there is no clear rationale for selecting any particular zone and the choice of boundaries must therefore be arbitrary. ISD selected 100 km. as the basic unit in order to be objective (Bobrow, 1988).

The 12.5 km. circle contained a population of 3,127, almost equal to the Post Code Sector including Dounreay. It was also significant for 1968-84, albeit with a higher p value than the Sector (p=0.020, 5 observed leukaemia cases, 1.53 expected), because it did not include the one case in the Sector further away than 12.5 km. from the nuclear complex. The 25 km. Circle had a non-significant ratio (0.079, O=6, E=2.95), unlike its near equivalent four-Sector area (and, again, with a similar population: 6,069 against 6,227). The reason for this was, again, the lonely case away from Dounreay, also outside this second circle, i.e., more than 12.5 km. away from any other case.

The above showed that results from Post Code Sector built areas had to be treated with caution (Bobrow, 1988), since their erratic boundaries could (and had in this case) include isolated cases, far away from any others and from their putative cause (radioactive emissions from Dounreay).

At the request of COMARE, further circle-based studies were carried out by ISD. Instead of just two circles (12.5 and 25 km. in radii), a more gradual widening of the study area was sought (partly because the 12.5 km. radius area divided Thurso, the main town near Dounreay). Eight concentric circular areas were built, the radius of each successive circle increasing by a regular amount, 1/8 of 25 km. Results for the period 1968-84 were similar to the two-circles analyses, with only the 12.5 km. area significant. Inspection of the data proved that all cases less than 25 km. away from Dounreay had been registered in the period 1979-84. Analyses for this period showed six of the eight areas as significant: one of the first three, all with very small populations and 0-1 cases, and all those with a substantial population and number of cases (i.e., partially or totally including Thurso, which had 4 of the 6 cases inside the 25 km circle). The 12.5 circle had a $p=0.00016$, the 25 km. circle had a $p= 0.00039$.

For the same 1979-84 time period, both the Post Code Sector including Dounreay ($p=0.000017$), and the four-Postcode Sectors area ($p=0.000062$) were highly significant, with p values lower than any other area examined for any period. In the researchers' opinion, no one set of area boundaries and time period was clearly correct, and the results should be considered as a whole, yet they were aware of the effect those boundaries could have on the results. The results for the Post Code Sector areas were greatly influenced by the inclusion of a single, isolated case, far away from Dounreay.

Conclusions: The full range of comparisons made by ISD provided clear evidence of a significant excess of leukaemia in young people, and it was remarkable that all cases considered had been registered inside the final six-year period. Conventional dose and risk estimates suggested that neither authorised nor accidental discharges could be responsible for the excess incidence.

Recommendations on further epidemiology: These were similar to those in Sellafield's Black Report: a) a birth cohort study of people born to mothers resident in Thurso and the neighbouring area, b) a school cohort of children attending schools near Dounreay (Recommendation 2) and: c) epidemiological studies considering any possible effects on the health of offsprings of those occupationally exposed to radiation (Recommendation 3). Studies based on these recommendations are reviewed below.

3.5.3 - Case-control study of leukaemia and non-Hodgkin's lymphoma in children in Caithness near the Dounreay nuclear installation (Urquhart et al., 1991).

Background: This study broadly follows Recommendation 3 in the COMARE report: to carry out epidemiological studies on the health of offsprings of those occupationally exposed to radiation at the Dounreay nuclear plant (Bobrow, 1988). Actually, the study is almost identical to that carried out previously in the area of the larger Sellafield plant (Gardner et al., 1990*a* and *b*).

Objective, cases and controls: Its objective, again, is identical to the 1990 Sellafield study: to examine whether the observed excess of childhood leukaemia and non-Hodgkin's lymphoma in the area around the Dounreay nuclear installation was associated with established risk factors, or with factors related to the plant, or with parental occupation in the nuclear industry. The main differences between risk factors considered in both studies were that residential distance at birth to the nuclear plant was greatly simplified in the Dounreay case, and that distance of usual residence from the path of a military microwave beam was considered as a risk factor. Social class of father at child's birth was also a factor. Cases were residents in Caithness, under 15 years of age, diagnosed of leukaemia and non-Hodgkin's lymphoma between 1970 and 1986 (14 cases). These were matched to 55 controls by sex, date of birth and area of residence within Caithness at time of birth.

Geographical area: The Caithness Local Government District. There were 53 such districts in Scotland at the time (Carstairs and Lowe, 1986). This area was further subdivided into two: the area lying less than 25 km. from Dounreay, and the remainder of Caithness. In this way, residential distance to the plant at birth was accounted as a risk factor, and cases and controls were matched accordingly. Residential distances at diagnosis to the path of the military (US Navy) microwave beam were calculated using Ordnance Survey coordinates (Urquhart et al., 1991).

Methods and results: Odds ratios between cases and controls were calculated for each of the risk factors. The only significant association found was that between use of beaches less than 25 km. away from Dounreay, and the development of malignant lymphopaties. No level of paternal exposure to radiation before conception was associated to significant results, and a later case-control study for the whole of Scotland also failed to find a significant association, for any radiation level or conceptional period (Kinlen et al., 1993*a*). Social class as a factor (I, II and III non-manual, versus III manual, IV and V) had non-significant odds ratio.

3.5.4 - Incidence of leukaemia and other cancers in birth and schools cohorts in the Dounreay area (Black et al., 1992).

Background: The study was carried out by the Scottish Health Service's Information and Statistics Division (ISD), also responsible for the analyses on Dounreay reviewed by COMARE, and answers Recommendation 2 in the COMARE report (Bobrow, 1988). It mirrors very closely the double study on birth and schools cohort carried out on Seascale over four years previously (Gardner et al., 1987*a* and *b*).

Geographical area: It was made up of five Civil Parishes: Reay, Halkirk, Thurso, Olrig and Bower. According to the authors, these Districts were chosen because: a) as a whole, these areas approximate to the 25 km. zone around Dounreay analysed by ISD for COMARE; b) birth records in Scotland are organised in Registration Districts which, in the Caithness area, are coterminous with Parishes; and c) the Parishes chosen form the Western District, as defined by Caithness County Council's Education Department in the period up to 1974 (Black et al., 1992).

Data, analysis and results: While the Seascale cohorts (or, rather, follow-ups, which this study is also) had deaths from cancer as cases, the Dounreay cohorts had cancer registrations, regardless of eventual survival. All data, school, birth and cancer, were drawn from routinely held records. In the birth cohort, 4,144 children born in the area between 1969-88 were included. The schools cohort consisted of 1,641 children, born outside the study area and since 1969, having attended at least one of seven selected schools up to the end of 1988. Like its predecessor on Sellafield, the study was a record-based double cohort. Expected numbers of cases were calculated by applying Scottish national rates to person-years at risk, calculated from birth to the end of the study (birth cohort) and from school admission to the end of the study (school cohort). Ratios of observed/expected cases had confidence intervals calculated by standard Poisson-based methods.

Five cancer registrations were found in the birth cohort, compared with 5.8 expected at all-Scotland rates. All five were of leukaemia (2.2 expected). In the schools cohort three cases were found, with 1.4 expected. Again, all three cases were of leukaemia (0.4 expected, only confidence interval significantly high in the study). All eight cases had been diagnosed in the study area.

Conclusions : The main finding was the raised incidence of leukaemia registrations in both birth (relative) and schools (significant) cohorts, unlike leukaemia deaths at Seascale (raised in the birth cohort only), suggesting that place of birth was not a more important factor than place of residence at diagnosis. Given improving prognosis in childhood cancer, incidence data seem more sound than mortality as basis for studies. The most remarkable feature of leukaemia incidence near Dounreay remained the concentration of cases in the relatively short period of time 1978-83 (Black et al., 1992).

3.5.5 - Childhood leukaemia around the La Hague nuclear waste reprocessing plant (Viel and Richardson, 1990).

Background: La Hague, in Normandy (France), along with Sellafield (England) and Dounreay (Scotland) is one of three nuclear reprocessing plants operating in the world on an industrial scale (Pobel and Viel, 1997). It was the last of the three to start operations (1966), and it was also the last one to be the subject of an epidemiological study, prompted by those undertaken earlier on its sister plants.

Geographical area: All electoral wards (around 10,000 inhabitants each) with half or more of their area within specified distances from the plant. Three distances were chosen: 0-10 km., 10-20 km. And 20-35 km., with a total of 10 wards studied. The study area is a rural one.

Data, analysis and results: Deaths from leukaemia among the under 25 years-old, for each of the rings and for the periods 1968-78 and 1979-86, were examined. Cases were separated into three age groups: 0-4, 5-14 and 15-24 years of age. Centrally held routine records were used. Age-specific departmental (county) rates were used to work out numbers of expected cases. Results were analysed by two-tailed tests based on the Poisson distribution. No standardized mortality ratio was significantly high.

Conclusions: The authors concluded that: a) detailed geographical location of cases was needed in further studies, and: b) a cancer Registry, available to researchers, should be established for the region.

3.5.6 - Case-control study of leukaemia among young people near La Hague nuclear reprocessing plant. (Pobel and Viel, 1997).

Background and objective: After the inconclusive study already reviewed (Viel and Richardson, 1990) and the contradictory results of the case-control studies on British nuclear reprocessing plants (Gardner et al., 1990*a* ; Urquhart et al., 1991), French researchers decided to carry out their own case-control study on Normandy's La Hague plant. This was to be the first such study on a French nuclear installation.

Geographical area: Consisted of a circular area within a 35 km. radius from the plant, therefore including the usual places of residence of most of its workforce.

Objective, cases and controls: The objective, as in the mentioned British studies, was to investigate the association between childhood leukaemia and established risk factors (antenatal x-rays and drugs, lifestyle) or other factors related to La Hague nuclear plant (occupational exposure of the parents before conception). Twenty-seven parents of cases (under 25 years of age when diagnosed) and 192 parents of controls were included. Cases were diagnosed between 1978-1993, and were identified from local and regional hospital records. Controls were selected with the help of local general practitioners, and parents of both cases and controls were approached through these same practitioners. Matching was for age, sex, and places of birth and residence. Data on lifestyle were collected through personal interviews, those on occupational exposure levels were obtained from employment records.

Analysis and results: Estimates of relative risks (odds ratios) were calculated with a LogXact statistical computer package. Some lifestyle factors were found to have odds ratios significantly high. These factors were: use of local beaches by mothers and children, consumption of local fish and shellfish, and length of residence in a granite-built house. In all, 172 parameters were analysed. No association was found between leukaemia and occupational radiation exposure in parents.

Conclusions: The study authors concluded that there was some evidence for environmental radiation as a cause for leukaemia.

3.6 - Methodologies of the studies: traditional and innovative

Almost all of the studies reviewed employed in their analyses statistical methods of general use in Epidemiology, but non-specific to environmental studies. This is understandable, since interest in this area of study is quite new and new statistical procedures have seen the light only recently. Nevertheless, some studies, even though making use of conventional methods for their statistical analyses, have been able to take a more imaginative approach to what is possibly the main problem associated with environmental studies: the choice, next to a focus of pollution where an excess of disease may exist, of an appropriate geographical area and its corresponding population. In defining those areas, many of the studies took into account distances to the pollution source, since distances serve as, sometimes unstated, proxies for areas of dispersion of the pollutants and for the different levels of exposure of the population. Since the early Eighties, studies of environmental epidemiology have been able to make use, at least in Britain, of small geographical units as the building blocks for their study areas. These small areas (e.g., Enumeration Districts) allow the building of geographical study areas much closer in size and shape to what is judged as appropriate. Taking into account first the statistical analysis used and then the choice of building blocks for the geographical area, the studies are classified below into those using general, traditional methods and those making use of more innovative ones.

3.6.1 - Simple comparison of rates

The study on microphthalmos in Forth Valley (Strong, 1988) simply compared prevalence rates between the Health Boards making up the study area, which resulted very irregular in shape (there are 15 Health Boards in Scotland: Carstairs and Morris, 1991). Because of this irregularity, and although the area was chosen in function of the most likely axis of pollution dispersion, wide zones possibly affected were left out, while others, away from this axis, were included.

In the second Walsall study (Symington et al., 1991), prevalence percentages were also compared. No real study area existed, just three groups of schools, two of which had to be within a certain distance from pollution sources.

The Welsh Office compared for significant differences crude rates for the District of Torfaen with overall Welsh rates and with Gwent County's rates (there are 37 Districts and 8 Counties in Wales). As with the studies in the Black report, no real study area was built (Welsh Office, 1985).

Finally, of the studies reviewed in the Black report (Black, 1984), two were considered as epidemiological evidence of the disease being above average. The first of these (Craft and Openshaw: personal communication to the Advisory Group, in Black, 1984) subdivided a large geographical area (The Northern Health Region) into 765 much smaller electoral wards, and ranked the incidence rates of the disease in each of them (there are 8,485 wards in England). In the second study (Gardner and Winter, 1984), death rates for the 469 Rural Districts in England and Wales, one of which contained the nuclear installation under study, were also ranked (there are 366 Districts in England). But the main contribution of the report to environmental studies came from its final recommendations. The review group voiced in the report their concern that the use of large, undivided study areas might conceal locally raised incidences of disease. Therefore, it recommended and encouraged the use of small areas, or rather of groups of these, in futures studies. Fruit of these recommendations are some advanced methodologies mentioned in sections **3.6.3** and **4**.

3.6.2 - Conventional epidemiological studies

The first Walsall study looked for significantly raised Standardized Registration Ratios in three areas: the ward containing the site, wards in the radial vicinity of the site and wards in a windward area defined as an equilateral triangle with apex centred on the site and downwind to prevailing winds (Muir et al., 1990).

The Monktown Coking Works study (Bhopal et al., 1992 and 1994) worked out age and sex Standardized Ratios for cancers and for death, for each subdivision of its study and control areas, and compared them. Also, the Chi-square statistic was used to compare trends between three areas, according to their (assumed) pollution levels, and numbers of medical surgery consultations and levels of pollution were linked through a log-linear modelling. The use of Enumeration Districts allowed the building of study areas similar to the areas of interest (there are 105,603 Enumeration Districts in England).

Dundee University's analysis on cancer near the Bonnybridge incinerator (Williams et al., 1987) calculated and compared Standardized Registration Ratios (SRRs) for each type of cancer in each of the six zones into which the study area was divided. Percentage changes in those SRRs between two time periods were also calculated. The study area was the Local Government District of Falkirk, divided into six zones made up of groups of Post Code Districts, of which there are 400 in Scotland.

In Altrincham, (Hill, 1989) Standardized Mortality Ratios-SMRs (all causes) were ranked at the ward level for the whole Greater Manchester area. SMRs rankings for the wards under study were compared to that for their deprivation scores. A similar type of comparison was carried out for SMRs for coronary heart disease. Standardized Registration Ratios (SRRs) were calculated for fourteen classes of cancer, all other cancers and all cancers, in males and females, for each of the wards under study and for all of them combined, and tested for significance respect to the regional average.

A study on the Sellafield nuclear power station (Kinlen, 1993*b*) worked out Standardized Rates of leukaemia and their statistical significance for two groups of residents in the nearby village of Seascale: those born in the study area and those born outside it. Cases were also stratified by levels of radiation received by their parents prior to conception. The geographical area was the civil parish of Seascale, a relatively small area (English civil parishes contain ten Enumeration Districts on average).

A simple, descriptive study was conducted around nuclear power stations in Scotland (Heasman et al., 1984), exploring possibly increased incidences of leukaemia. Study areas consisted of Post Code Sectors (PCSs) total or partially inside a 10-mile radius circle centred on the station (there area 1,211 PCSs in Scotland). Standardized Ratios for each area and their significance were calculated.

A similar study, but with a more complex geographical area, was conducted around the French nuclear power station of La Hague (Viel and Richardson, 1990). Standardized Mortality Registrations for leukaemia were obtained and tested as Poisson distributions for significance. The study area was composed of ten (French) Electoral Wards, totally or partially inside a circle 35 km. from the power station, and further divided into those with half or more of their areas at three variable distances from it, for each of which SRRs were calculated. The resulting areas were very irregular in shape.

The double follow-up on two separate groups, analysing mortality and cancer in both of them near the Sellafield nuclear complex (Gardner et al., 1987*a* and *b*), used the person-years at risk method of analysis as the base to calculate observed and expected figures of cases. Ratios of these figures and their Poisson-based significance were obtained. The geographical area consisted of a single civil parish (there are 10,250 such parishes in England). The Black report (on the same source of pollution), having already pointed out the possibility of overlooking an existent excess of disease by the use of too large areas of study, warned also that the use of small areas in isolation could increase the possibility of statistically significant excesses being found.

A similar double follow-up was conducted for Dounreay (Black et al., 1992). The person-years at risk method was also used for both groups, expected numbers calculated for the whole study area, and the ratios observed/expected tested for Poisson-based significance. The study area was made up of five Civil Parishes, roughly covering 25 km around the nuclear station.

The case-control study on Sellafield (Gardner et al., 1990*a* and *b*) calculated odds ratios for several risk factors, linked or not to the plant, and their statistical significance. But although its analysis was that of a common case-control, it was in the subdivision of the study area into small areas that the study showed some innovative characteristics. This study area was a large one, the West Cumbria Health District. It was divided up for the study into seven rings, each 5 km. wide, all centred on the putative source of pollution, the nuclear plant. The Ordnance Survey grid reference of the plant, and those of residences of cases and controls (all accurate to 100 metres) were used to group these cases and controls by distance from the plant. Then, each distance was used as another risk factor and odds ratios calculated.

As with Sellafield, a case-control study was conducted for the nuclear complex of Dounreay, in Scotland (Urquhart et al., 1991), and both were almost identical in design. Odds ratios for several risk factors, related or not to the complex, were calculated. The study area was the large Caithness Local Government District (there are 53 such Districts in Scotland). Residential distance to the nuclear plant at birth was again one such factor, but much simplified respect to its use with Sellafield: instead of several staged circles, the study area was divided between a (semi)circle 25 km from Dounreay and the remainder of Caithness. Distance to a military microwave beam was also taken into account.

After the case-control studies on the two British nuclear power stations, another one was conducted on the French station of La Hague (Pobel and Viel, 1997). Methods were standard, with odds ratios for several possible risk factors calculated. The area from where all cases and controls were drawn consisted of a circle 35 km. in radius, centred on the nuclear plant.

3.6.3 - Innovative studies.

Armadale: The study on respiratory cancer mortality in a small Scottish town (Lloyd, 1982) had several novel features respect to routine epidemiological research. First, the use of cumulative sums of previously calculated SMRs to ascertain the time when a change in the town's mortality trends happened. The method proved effective, even though, as the study admitted: 'it is rarely mentioned in medical papers'. Once known levels of pollution pointed towards a particular source (and pollution monitoring was also original on its own, as pointed out in **3.1.1** and **3.7.1**), the building of a study area near the source was a very early example of the use of Enumeration Districts in environmental studies.

Since this study area consisted of circular (rings) subareas centred on the source of pollution in order to investigate incidences of the disease with varying distances from the suspected cause, the study had to try to overcome the problem posed by the use of areas newly created for the purpose of a particular study: the lack of population statistics. To that end, a "control" disease was used as population proxy, a disease relatively common (i.e., one whose distribution approached the underlying population's distribution) and not known to have a possible connection with the study pollutants. In this respect, Armadale's study can be seen as a precedent for the later use of "control diseases" in more advanced methodologies (see Gatrell and Lovett's study in **3.6.4**). The use of ring areas centred on the source of pollution also precedes the Small Area Health Statistics Unit use of similar areas (see below), although these would be larger and with a very different approach to the population problem.

Bonnybridge/Denny Morbidity Review: In this study (Lenihan, 1985), the statistical analysis of morbidity near an incinerator in Central Scotland was in itself unremarkable. It consisted, besides some simple comparisons of rates, of the calculation of Standardized Mortality Ratios (SMRs) and Standardized Registration Ratios (SRRs), for diverse causes of death and cancers, for a study area and for several control areas, between which these SMRs and SRRs were compared. Statistical significance of each ratio was also calculated.

The characteristic setting this study out from others was the use of Enumeration Districts (EDs) as the building block for the areas, particularly the study area. One of the aims of the study had been to build a circular geographical area (centred not on the incinerator, but on a point halfway between Bonnybridge and Denny), and a first study area had been formed with Post Code Sectors (PCSs), but the irregular shape and size of these had resulted in it being too large, including zones far away from that of interest. Therefore, smaller units were needed to fit the shape of the area as closely as possible to a circle five kilometres in radius. There are some 10-15 EDs in a PCS and health and population statistics at such small area level had become available with the 1981 Census. Finally, all EDs whose geographical centroids lay on or inside the five-kilometre circumference were included. Control areas needed not be circular, but these too were made up of EDs groupings. All this made the study an early example of the use of small areas.

Twinning near the Bonnybridge incinerator: Beyond the use of common epidemiological methods, the study on twinning (Lloyd et al., 1988) looked for spatial autocorrelation of rates, i.e. systematic spatial variation or indication of clustering of cases. This was achieved through ranking of rates and the use of this ranking to obtain Moran's I coefficient. The statistic, first proposed in 1950, was in this case tested as a standard normal variable, by which large positive values of Z denoted clustering, large negative values regularity in spatial distribution of rates, and values close to zero a random distribution (Cliff and Ord, 1981). Although the results were inconsistent (all three possibilities appeared during the study period), the use of such statistic showed an attempt to explore the spatial distribution of a health outcome and the possible relationship between this distribution and the location of the incinerator. In this respect, the study marks a departure from those enquiries purely comparing amount of disease between allegedly polluted and non-polluted areas, being closer to the works which make use of more elaborate or even novel methodologies, to try to find a relationship between health outcomes and distances to a source of pollution.

A geographical distribution around Sellafield: Although defined by its authors as a retrospective birth cohort (?), the methodology of this study on the nuclear plant at Sellafield (Parker et al., 1993) was that of a descriptive geographical study. The novel aspect of it consisted of the use of a Geographical Information System (GIS) computing programme to represent the geographical location of births to fathers having been employed at the nuclear plant, indicating also the (stratified) dose of radiation each father had received prior to conception. The graphic output was highly representative, but somehow below its full potential, since numbers of births and radiation doses had to be grouped by 1 km. square due to poor resolution of the system. For those squares, doses were averaged.

COMARE-ISD study of leukaemia around Dounreay: This study, conducted by the Scottish Health Service's Information and Statistics Division for COMARE (Committee on Medical Aspects of Radiation in the Environment, see Bobrow, 1988) can be considered as a further development of the Lenihan study on Bonnybridge/Denny. Like its predecessor, a circular first study area made of Post Code Sectors was drawn near the source of pollution (in this case centred on the source, unlike that at Bonnybridge/Denny). Although Standardized Ratios were worked out for this first area, the high irregularity of its boundaries made feel the necessity of smaller building blocks, if distance to the source of pollution as a risk factor was to be considered at all. As at Bonnybridge/Denny, Enumeration Districts were used for further analyses as those building blocks. Nevertheless, in this case, instead of a single circular area (actually, nearly semicircular, since Dounreay is on the seaside), two were used: an inner one 12.5 km. in radius, and an outer ring 12.5 to 25 km. from the plant used as control area, instead of the several discontinuous control areas used at Bonnybridge/Denny.

The study by the Small Area Health Statistics Unit (SAHSU): This study on larynx and lung cancers near ten selected solvent incinerators (Elliott et al. , 1992*b*), while also making use of traditional methods, incorporated innovative procedures. As in more traditional studies, after data for the areas surrounding each of the incinerators were pooled to increase the statistical power of the study, Standardized Registration Ratios (SRRs) and their 95% confidence intervals were worked out for two (pooled) areas, one near the incinerators (0 to 3 km distance), and one more distant (3 to 10 km). Nevertheless, for the first time in a British environmental study, the SRRs were standardized by social deprivation, as well as age and sex. The social deprivation index used was Carstairs' (Carstairs and Morris, 1991). Standardisation by this variable was done by stratification, another possibility being multiple regression (Jolley et al., 1992). Socio-economic indexes had been used in past health studies, but always on a national or regional scale and never in connection with an environmental hazard, with the exception of the study in Altrincham (Hill, 1989) which made use of the Z-score, but not for standardisation.

Another innovation was the use of a test to measure variations in relative risk with distance from the pollution source. As will be seen in **3.6.4**, Lancaster University had used in a similar study an algorithm (Spatial Point Process Model) linking the emplacement of the posited source of pollution with distribution of the disease (Diggle et al., 1990). SAHSU's approach consisted on overall testing of deviation from unity of the relative risk for each of a series of rings, all centred on the posited source of pollution, as well as testing their possible decreasing trend with distance. This area rather than point approach avoided the main problem encountered by the Spatial Point Process Model, the lack of an appropriate surrogate for the population variable.

In the absence of data on intensity and spread of pollution, this analysis of variation of relative risk according to distance tested the hypothesis that intensity of pollution, and therefore its effects, is inversely proportional to distance from its source. The test used was that proposed by Stone (Stone, 1988) and is based on Poisson variability. It assumes that the observed number of cases in each of a series of areas gradually apart from the source of pollution follow a Poisson distribution, being $\mathbf{O_0}$ the number of observed cases and $\mathbf{E_1}$ the number of expected (following regional rates in this study) cases in the area nearest to the source, $\mathbf{O_2}$ and $\mathbf{E_2}$ those for the area next in distance, and $\mathbf{O_K}$ and $\mathbf{E_K}$ those for any area in general. $\mathbf{O_K}$ follows a Poisson distribution with mean $\lambda_K\, \mathbf{E_K}$. In the SAHSU study the areas consisted of ten concentric rings, of radii 0.5, 1.0, 2.0, 3.0, 4.9, 6.3, 7.4, 8.3, 9.2, and 10.0 km (the first four investigated effects close to the source of pollution, the other six represented equal areas). Observed and expected cases inside each of these rings resulted from pooling those from equivalent rings around each of the incinerators. The null hypothesis is that pollution does not increase the risk of disease and, in consequence:

$$\lambda_1 = \lambda_2 = \ldots - \lambda_K = \ldots = \lambda_N = 1$$

The alternative hypothesis is that pollution does increase the risk of disease, distance from the source of pollution being a proxy for distribution and intensity of disease, with an increased risk in areas nearer to this source. Therefore:

$$\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_K \geq \ldots \geq \lambda_N$$

The test of the null hypothesis follows the Maximum Likelihood Ratio statistic (Armitage, 1971). The ratio calculated is that between the likelihood when all values of λ are estimated from the data (with the restriction that estimated values do not increase with distance) and the likelihood when all values of λ are equal to 1. The **p** value for this test is derived through simulation of observations using the Poisson distribution with means $E_1, E_2 \ldots E_N$ and counting how often the simulated likelihood ratio exceeds the actual one. Rejection of the null hypothesis would only prove that $_K \neq 1$, but this can be true because λ is a constant different from 1 or because of a decreasing trend. Therefore, a second test for trend with the Maximum Likelihood Ratio statistic is required, where the null hypothesis is now:

$$\lambda_1 = \lambda_2 = \ldots = \lambda_K = \ldots = \lambda_N$$

and the alternative hypothesis:

$$\lambda_1 > \lambda_2 > \ldots > \lambda_K > \ldots > \lambda_N$$

The common value of λ is estimated from the data. The **p** value is also derived through simulation as before, but under the restriction that the total number of cases is equal to that actually observed (Elliott et al., 1992*c*).

The number of computer simulated observations was 1,000 in both cases. Stone also proposed an alternative statistic, called the Poisson maximum test, for which no simulations were required, its **p** value being calculated using a algorithm based on a random walk with Poisson transition probabilities. Using concentric rings, the test selects the distance at which the ratio of cumulative observed and expected cases is maximum (therefore, inside this distance the health effect would also be maximum), and tests this ratio for significance against the ratio of total observed and expected cases over all areas (Stone, 1988). This Poisson maximum statistic was not utilised by SAHSU, but offers an alternative to the Maximum Likelihood Ratio method, particularly in cases when the computing power available, and therefore the capacity for **p** distribution simulation, is limited.

Another two factors place SAHSU's among the new methodologies. As Newcastle's Geographical Analysis Machine did first and Lancaster's Spatial Point Process Model later (see **3.6.4**), it makes extensive use of data at both Enumeration District and Post Code Unit levels. Also, along with Newcastle's, SAHSU's methodology is based on intensive use of a computer system. Nevertheless, the similarities end here. Besides differences in the use of data, SAHSU's computer system is by far the most powerful of the three and its database the largest, containing data on a national rather than regional basis.

As pointed out already, cases (numerators) were allocated to a particular ring on the basis of the distance from their Post Code Unit's Ordnance Survey coordinates to that of the incinerator near which they occurred. Populations (denominators) for each ring were constructed by adding these for Enumeration Districts whose centroids lay within the inner and outer circles limiting the ring. In the event of an ED straddling a circle, the number of its PCUs inside and outside the circle were calculated, by using their coordinates as with the cases. The ED's population was then partitioned between the two adjacent rings according to these numbers, making the assumption that each PCU has the same population. Since the 1991 Census data have been made available, SAHSU is in a position to use exact population figures at the PCU level, which, nevertheless, means that the population database utilised will be much larger (see below). The use of complete EDs, allocated to the rings where their centroids lie, greatly simplifies the process and gives results differing only very slightly from those obtained by taking PCUs into account. This is particularly the case in studies carried out in densely populated (urban) areas, where EDs are small .

In 1992, total computer storage requirements for the databases utilised by the SAHSU method were 1397 Megabytes (Mb), including indexes. Cases (numerators) and their indexes occupied 1040 Mb. Population (denominators) at Enumeration District level took 73 Mb. Post Code Unit coordinates and other data took 374 Mb. The use of population data at the Post Code Unit level (1991 Census) would multiply the storage requirements by a factor of 10 to 15, nearly doubling the total. Since SAHSU was set up to carry out studies at national level, all databases cover the whole of England, Wales and Scotland. Processing time for a population of 1,000,000, or about 2000 EDs, is in the order of two hours (Elliott et al., 1992*d*).

The general appraisal of SAHSU's methodology has been positive. It continues the tradition of classical epidemiology, with results expressed as Standardized Ratios, while avoiding the problems created by preset, inadequate territorial divisions, by making appropriate use of data for small areas. These data can be grouped to obtain numbers of cases and population of any size over areas (rings in the general case) of any extension. Although the method is still based on arbitrary territorial divisions (Enumeration

Districts and/or Post Code Units) these are small enough to be combined into study areas reasonably similar to those deemed appropriate by the researchers.

Another positive feature is the use of a simple method (Stone's) to test the relationship between distance from the pollution source and incidence of disease. The assumption behind the use of this test is that distance can be used as a proxy for levels of pollution and, therefore, incidence levels of diseases related to it. Although it is generally true that levels of pollution diminish with distance from the emitting source, this radial model of dispersion is a crude one, not taking into account the effects of winds and the terrain's relief. Nevertheless, in the absence of routine monitoring of pollution levels and modelling of its dispersal, which is the usual case in environmental studies, the use of Stone's test provides a practical approach to the problem of detecting a possible relationship between incidence of pollution-induced disease and distance to the source of pollution.

The use of Carstair's index to standardize by social category is also a welcome feature. Since morbidity and mortality are known to increase with social deprivation (Carstairs and Morris, 1991), this standardisation removes the effect due to the existence of sub-areas with different levels of deprivation inside the study area.

At the same time, SAHSU's methodology has some evident shortcomings. Firstly, as with any study based on routine data, the reliability of the results depend to a great extent on the quality of these data. Registers of diseases in the UK, such as the cancer registers utilised for the incinerators' study, are known to have a varying degree of completeness and case ascertainment, although there is a continuous effort to improve both (Muir, 1993). Secondly, centralising health and population data for the whole of the UK is a cumbersome task, particularly considering that both these data have to be kept up to date and that the variety of diseases to study will in all probability grow. A more flexible, decentralised system of storage and process of data should be taken into account. Thirdly, Stone's test is a reasonable approach as long as the study areas consist of circles, but it should be substituted in the long term by more accurate models of spread based on routine monitoring of pollution levels.

3.6.4 - Experimental analyses:

The Geographical Analysis Machine (GAM): The aim behind Newcastle University's GAM was simple: to be able to automatically scan a previously defined (large) area in search of 'clusters', or statistically raised local numbers of a particular disease (Openshaw et al., 1987 and 1988). Thus, the main use of GAM would be as an exploratory tool, leading to more detailed epidemiological studies once local excesses of disease were uncovered. The first practical study focused on the search for such clusters of children's leukaemia in the Northern and North Western Health Regions of England. Briefly, the analysis involved:

1. Locating by geographical coordinates the cases over the study Regions.

2. Testing for significance overlapping sets of circles (1 to 25 km. in diameter) whose centres were distributed following a regular grid over the area.

3. Drawing the significant circles. Two main groupings of circles with excess leukaemia emerged, roughly centred on two points: Seascale, near the Sellafield nuclear plant, and Gateshead, in Tyneside.

Although apparently simple, the GAM represents an ambitious attempt to marry statistical analyses and geographical representations through computers using Geographical Information Systems (GIS). Also, and more importantly, it represents a challenge to the tradition of "a priori" hypotheses for studies (i.e., having a source of pollution, look for levels of possible adverse health effects around it), rather than "a posteriori" or "post hoc" (i.e., having proof of elevated adverse health effects in an area -"clusters" of disease- look for a possible cause, perhaps a source of pollution).

The GAM analyses make extensive and intensive use of computer facilities and power. Computerised population at risk figures, at Enumeration District level, are extracted from the Census and allocated to their respective ED centroid coordinates. Each of the cases is also allocated to its respective Post Code Unit coordinates, using the computerised Central Post Code Directory. Since distributions followed by different diseases are likely to differ, a Monte Carlo significance testing is used to make the methodology more adaptable (Hope, 1968). To determine significance levels the test involves simulations of random distributions of a number of cases equal to the actual number of cases among the at risk population. In the study of children's leukaemia in

Northern England 499 such simulations involving 853 cases each for a population at risk of 1.54 million were carried out. The final analysis consists of comparing simulated to real figures inside each of the 1 to 25 km circles, selecting those with two or more real cases, and plotting the ones ranking more extremely than their respective 499 simulations. In the initial study 812,993 circles were thus tested for deviation from Poisson based on the Monte Carlo simulation.

Such an analysis is a huge undertaking. After obtaining and storing the health and population data, these are retrieved using a GIS installed on the computer carrying out the simulation and testing. Also linked to the GIS, a geographical display produces the maps showing the significant circles. Significance testing for the circles took about seven hours of Central Processing Unit (CPU) on an Amdahl 5860 computer (Openshaw et al., 1988). Simulation time was reduced to 3 hours using a Cray X-MP/48 mainframe and further rationalisation of the data also reduced CPU time on the Amdahl.

The GAM methodology has come under criticism. Although it was conceived as a method to move away from arbitrary geographical divisions, GAM uses a hybrid approach using both point (case) and area (population) information. To assume that populations were concentrated on points (the ED's centroid) inside circles, while they are actually spread over irregularly shaped areas often larger than the circles has been found unacceptable by some critics (Marshall, 1991). It is also true that many of the concentric or overlapping circles indicating a 'cluster' contain the same cases and that the importance of these 'clusters' is judged somewhat subjectively as a function of their number of circles (Hills and Alexander, 1989). A clearing method to select circles should be devised to counteract these objections.

But, perhaps the most controversial aspect of GAM is the very idea on which it was conceived in the first place, to use it as an exploratory tool to identify abnormal concentrations of cases over a geographical area. Once such a concentration is identified, the search for a possible cause, e.g., a source of pollution starts. This is a 'post hoc' or 'a posteriori' approach. The usual environmental studies start with prior ('a priori') knowledge of an alleged source of pollution and try to determine how much, if at all, disease around this source exceeds what statistically would be deemed to be normal, always taking into consideration other factors which could produce the same kind of disease that particular kind of pollution is known (or suspected) to do.

It has been argued that the only clusters of cases worth investigating are those with a prior hypothesis as to their common origin. Otherwise, clusters could be 'fabricated' by not discriminating between cases due to different causes, with the result that the total reflects a high rate. In short, if GAM reveals unsuspected space-temporal groupings (clusters) of disease this means that no clear common cause seems to exist, otherwise it would already have been the candidate for an 'a priori' study, and according to the above the cluster is a dubious one. And if a possible cause has already been suspected GAM is redundant.

The Geographical Analysis Machine has, so far, failed to win acceptance and no further studies using the method have been undertaken, although Professor Openshaw (now at Leeds University) plans to adapt it to a Sun workstation (Openshaw, personal communication in 1995) which would make it more flexible and faster. While the very definition of clusters is still being discussed (Small Area Health Statistics Unit, 1989; American Journal of Epidemiology, 1990), there is an insistence on 'a priori' hypotheses (Knox, 1989), although there are calls for an accepted methodology to deal with 'a posteriori' approaches (Hills and Alexander, 1989).

GAM is a powerful exploratory device, with a fuzzy and controversial output. Until discussions as to the role of clusters in Epidemiology and on the 'a posteriori' approach reach conclusions its possible usefulness will remain undecided.

The Spatial Point Process Model: Conceived by P. Diggle at the Department of Mathematics of Lancaster University, the SPPM was tested some two years after GAM (Gatrell and Lovett, 1991). Its approach to studies of disease distribution was radically different from GAM's. The starting point consisted of a known source of pollution (an industrial incinerator in the only study carried out so far). The 'a priori' hypothesis to be tested was whether there was an association between the point source of pollution and the distribution of a disease, a cancer in this case (Diggle et al., 1990): i.e., whether the number of cancer cases at a point in the vicinity of the incinerator depended only on the population at the point (null hypothesis) or also on the distance from the point to the incinerator. The main characteristic of the model is that it is not so much concerned with detecting clusters or raised incidence of a disease, as with association between an environmental factor and that disease, although care is taken not to claim causation. Its other main aim is to be independent, as far as possible, from data for arbitrary geographical subdivisions, i.e., to use only point data, unlike the hybrid approach of GAM. Thus, the model has the form:

$$\lambda(x) = \rho \, \lambda_0(x) \, f(x; \theta) \qquad \text{(Gatrell, 1992).}$$

where $\lambda(x)$ is the 'intensity' of cases at point x, being dependent on ρ, number of cases per unit area; $\lambda_0(x)$, spatial variation in background population 'intensity'; and $f(x;\theta)$, a function of distance between the source of pollution and x. Population 'intensity' reflects the population figure at the point. Obviously, populations do not pile up on a dimensionless point. This intensity is expressed as a function (usually a Gaussian probability density function) of the weighted sum of distances between the point x and points representing population.

In short, if a set of parameters indicating distance and represented as θ are such that θ=zero, then $f(x;\theta)=1$, which means that the 'intensity' of cases at a point depends only on overall incidence and on the 'intensity' of the underlying population, distance to the pollution source having no effect on the 'intensity' of cases. This is the null hypothesis, by which spatial distribution of cases follows the population distribution, without being affected by the location of the pollution source. The alternative hypothesis is that in which θ differs from zero and distribution of cases follows a function of distance from the source. A log-likelihood function for θ is evaluated under the null hypothesis, as well as a maximised log-likelihood for its alternative. The difference between the two likelihood values decides whether the null hypothesis should be rejected, or not, at the 0.05 significance level (Diggle et al., 1990). In the actual study the null hypothesis was rejected and cancer of the larynx, according to the SPPM, was found to be associated with the presence of the incinerator.

The intensity of cases is calculated from a case by case plotting of cases using the coordinates of their respective Post Code Unit of residence at diagnosis. The whole method hinges on how to calculate population intensity. What kind of data will provide the points representing population?. Surely not individuals, nor will population figures for EDs, conventionally referred to its centroid, but actually spread over a relatively large area.

As a proxy for population distribution, plotting of cases of more common diseases was used, lung cancer first and cancer of the stomach later. Both are relatively common and supposedly reflect population distribution in a given area. But there is no indication that larynx, lung and stomach (or any other cancer for that matter) do not share solvent incineration as a risk factor, in which case their respective case distributions would be affected by the incinerator's location and not just by the population's distribution. The method has been criticised for this reason (Marshall, 1991). The authors of the study were also aware of this problem, but thought of it as a matter of overmatching, only to be reconsidered in case no association with distance was found (Diggle et al., 1990). The use of data on one disease to study another is likely to introduce unknown risk factors, common or not to both. These unaccounted for variables may (as they did in this case) cause criticism of the study and diminish or annulate the credibility of its results. For this reason, the use of disease as proxy for population should be avoided.

More reliable was the use of Post Code Units, by which their respective populations, an average of 38 individuals each, were assumed to be located at their centroids. The availability of data on age groups, sex and socio-economic status at Post Code Unit Level would make the use of PCUs more accurate, as would an improvement in the resolution of centroids (100 metres at the time of the incinerator's study). The former depends on the Census, the latter on the Central Post Code Directory or on commercial agencies (such as Pinpoint Analysis Ltd.). Nevertheless, although based on very small divisions, the method would not be independent from arbitrary geographical divisions. To carry out a real point process analysis an appropriate method to introduce the population variable in the model should be found.

Table 3 -1: Synopsis of studies reviewed.

Site studied. Type (Main reference)	Study design (Methodological remarks)	Main health parameters (Period, collection)	Basis for study area	Findings (Remarks)
Foundry at Armadale (Central Scotland) (Lloyd, 1982)	Descriptive: Comparison between areas. Study of gradients with distance. Lo-tech monitoring.	Respiratory cancer mortality (cases). Isch. heart disease (proxy population). (1968-74) (Routinely)	a) Enumeration Districts. b) None: cases and proxy population inside same-width rings.	Higher rates of respiratory cancer downwind from foundry. Grouping of cases towards inner rings.
Toxic waste processing and disposal plant, Walsall, West Midlands (Muir et al., 1990)	Descriptive (Comparison of observed and expected cases)	Childhood cancer (1980 - 88)	Ward	No adverse health effect demonstrated
As previous one, alongside several local foundries (Symington et al., 1991)	Cross-sectional (Questionnaires to schools, grouped by distance from pollution sources)	Respiratory symptoms in schoolchildren (Current) (Questionnaire)	Arbitrary: one-mile radius circles around sources of pollution	No overeporting of symptoms near toxic waste site
Monktown Coking Works (South Tyneside) (Bhopal et al., 1992 and 1994)	Descriptive: Comparison between areas. Use of routine and questionnaire data. Pollution modelling	Overall mortality (1981-89) Cancer (1986-89) (Routinely) Questionnaire on health perception.	Enumeration Districts.	No difference in cancer or mortality between areas. More self-reported symptoms nearer the Works.
Bonnybridge, Scotland. Toxic waste Incinerator (Lenihan, 1985)	Descriptive (Comparison of SMRs and SRRs by areas)	Several mortality (1980-82) and cancer (1979-81) (Routinely)	Enumeration District	No excess morbi-mortality (Possible exception: microphthalmos)
Bonnybridge, Scotland. TW Incinerator (Strong, 1988)	Descriptive (Comparisons of numbers of cases and rates)	Related congenital eye defects (1971-85) (Routinely)	Health Board	Excess 'not proven' ('if existent, very small')
Bonnybridge, Scotland. TW - refuse incinerators (Williams et al., 1987)	Descriptive (SRRs over two periods and in several areas)	Haematopoietic and lymphatic cancer (1976-84) (Routinely)	Post Code District	Increases in SRRs and their age distribution, 'consistent with pollution'

Table 3 - 1 (Cont.)

Site studied. Type (Main reference)	Study design (Methodological remarks)	Main health parameters (Period, collection)	Basis for study area	Findings (Remarks)
Bonnybridge, Scotland. TW - refuse incinerators (Lloyd et al., 1988)	Descriptive (Ranking and spatial autocorrelation of rates by area)	Twinning in births (1976 - 83) (Routinely)	Post Code District	'Pollution might have affected obstetric parameters'
Torfaen, Wales. Toxic Waste Incinerator (Welsh Office, 1985)	Descriptive (SRRs by County and District)	Fourteen types of congenital malformation (1974-85, with update)	District	Anencephalus and polydactilia significantly raised in incinerator's District
Altrincham, Manchester. Refuse incinerator (Hill, 1989)	Descriptive (SMRs and SRRs by Ward. Comparison with deprivation scores)	Overall and selected mortality (1980-86), id. cancers (1979-84) (Routinely)	Ward	Differences in health pointing towards deprivation, rather than pollution.
Coppull, Lancashire. Industrial Waste Incinerator (Gatrell and Lovett, 1991)	Descriptive (Spatial Point Process model, to investigate relationship incidence-distance)	Laryngeal cancer (1974 - 83) (Routinely)	Post Code Unit coordinates used to plot cases and (proxy) population.	'Incidence of larynx cancer associated with proximity to the incinerator'
Sellafield nuclear plant. (West Cumbria) (Black, 1984)	Review of previous studies. Risk assessment of radiation emission levels	Cancer and/or leukaemia in under 25s or under 15s. (Late 60s to early 80s) (Routinely).	Rural Districts Civil parishes Electoral wards (according to study reviewed)	Leukemia high near plant. Recommendations for further studies using small areas.
Sellafield nuclear plant. (West Cumbria) (Gardner et al., 1987*a*)	Analytic: Record-based follow-up of schoolchildren in study area but born outside it.	Overall mortality (1950-86) Cancer deaths (1971-86) (Routinely)	Civil parish (Seascale)	Excess of cancer, particularly leukaemia.
Sellafield nuclear plant. (West Cumbria) (Gardner et al., 1987*b*)	Analytic: Record based follow-up of children born in study area.	Overall mortality (1950-86) Cancer deaths (1971-86) (Routinely)	Civil parish (Seascale)	No apparent excess found.

Table 3 - 1 (Cont.)

Site studied. Type (Main reference)	Study design (Methodological remarks)	Main health parameters (Period, collection)	Basis for study area	Findings (Remarks)
Sellafield nuclear plant. (West Cumbria) (Gardner et al., 1990*a* and *b*)	Analytic: Case-control. Parental radiation dose as a factor considered.	Leukaemia and lymphoma. (Born in West Cumbria,1950-85) (Routinely)	Health District (West Cumbria)	Statistical association (odds ratio) leukaemia-preconceptional radiation doses.
Sellafield nuclear plant. (West Cumbria) (Kinlen, 1993*b*)	Descriptive: comparison of rates between children born inside and outside study area	Leukaemia and non-Hodgkin lymphoma in residents under 25 (1951-91) (Routinely)	Civil parish (Seascale)	Statistically high incidences in both groups. No association found with parental radiation doses.
Sellafield nuclear plant. (West Cumbria) (Parker et al.,1993)	Descriptive: geographical distribution of preconceptional radiation doses.	Births in Cumbria. Preconceptional radiation doses. (1950-89) (Routinely)	Civil parish (Seascale) Health District (West Cumbria) County (Cumbria)	Mean preconceptional doses lower in Seascale than in remainder of Cumbria
Gateshead, Tyneside. Municipal Incinerator (Openshaw et al., 1987)	Descriptive (Monte Carlo test for significance, inside variable radii circles)	Childhood leukaemia (1968-85) (Routinely)	Post Code Unit (cases) Enumeration District (population)	Large cluster of significant circles around Gateshead. (Incinerator as one of possible causes)
Ten incinerators of waste solvents in England, Scotland and Wales (Elliott et al., 1992*a*)	Descriprive (O/E cases and 95% CI for each of ten concentric circles. Stone test for trend with distance	Larynx cancer and Lung cancer (1974-84, E & W) (1975-87, Sct.)	Post Code Unit (cases) Enumeration District (population)	No evidence to suggest excess incidence risk near incinerators
Scottish nuclear power stations (Dounreay, Chapel Cross, Hunterston) (Heasman et al., 1984)	Descriptive: Observed and expected cases in study area.	Leukaemia in under 25s. (1968-81) (Routinely)	Post Code Sectors	Only significant result for Hunterston

Table 3 - 1 (Cont.)

Site studied. Type (Main reference)	Study design (Methodological remarks)	Main health parameters (Period, collection)	Basis for study area	Findings (Remarks)
Dounreay nuclear plant (Caithness, Scotland) (Bobrow, 1988)	Review of previous studies by (Scotland Health Service's) Information and Statistics Division.	Leukaemia in under 25s. (1968-84) (Routinely)	Post Code Sectors. Enumeration Districts.	Significant excess of leukaemia. All cases between 1979-84. Recommendations for further studies.
Dounreay nuclear plant (Caithness, Scotland) (Urquhart et al., 1991)	Analytic: Case-control. Parental radiation dose and social class considered as factors.	Leukaemia, non-Hodgkin lymphoma in under 15s. (1970-86) (Routinely) (Some data by survey)	Local Government District (Caithness)	Significant association with use of beaches. No association with radiation dose or social class.
Dounreay nuclear plant (Caithness, Scotland) (Black et al., 1992)	Analytic: Record-based birth and school cohorts.	Cancer registrations. (1969-88) (Routinely)	Civil parishes.	Relative high incidence in birth group. Significant in schools group.
La Hague nuclear plant (Normandy, France) (Viel - Richardson, 1990)	Descriptive: Comparison of SMRs at varying distances from plant.	Deaths in under 25s from leukaemia (1968-86) (Routinely)	French Electoral Wards (mean population about twice that of Scottish PCSs)	No Standardized Mortality Ratio was found high.
La Hague nuclear plant (Normandy, France) (Pobel - Viel, 1997)	Analytic: Case-control. Use of routine and questionnaire-collected data.	Leukaemia in under 25s (1978-93) (Routinely). Questionnaire-collected data on behaviour.	None: cases and controls inside circle 35 km. in radius.	Significant odds ratios for some lifestyle factors. No association with parental radiation doses.

3.7 - Review's conclusions and recommendations:

3.7.1 - Conclusions:

Regarding methodologies, the potential of new ones should be explored, while retaining more traditional methods. Of the new methods, Lancaster University's Spatial Point Process Model will be of interest when trying to investigate the possible link between one particular kind of pollution source and one particular disease or series of diseases, particularly if the problem of introducing an adequate population variable in the equation can be solved. Newcastle's Geographical Analysis Machine (GAM) offers possibilities of use in areas near known sources of pollution to be investigated, to show the position in relation to these sources of the circles with significant excess of a disease. This means that, contrary to what the method has been doing so far, a suspected source of pollution should be investigated, instead of looking for one ('a posteriori') to explain previously found excesses of the disease. The output would be highly graphic, but difficult to express in figures for the whole area.

From the point of view of this work, SAHSU's methodology is the more promising. It combines traditional, well tried epidemiological methods with the flexibility in creating adequate study areas offered by small area statistics. Its output is rapidly understandable in terms of showing the amount of disease in an area allegedly affected by pollution, and its statistical significance against a standard, as well as taking into account differences in social class over the study area. It also incorporates a simple test to explore the possible trends with distance from the pollution source of the health outcomes. It has been used so far in a generic way, to investigate the possibility of a raised incidence of certain cancers around a particular kind of pollution source, solvent incinerators, and in that way it can be used to explore links between sources and diseases, much as Lancaster's Spatial Point Process Model, but with the advantage of a simple pooling of populations and cases to increase the power of the studies. But it has also shown its potential for studies around individual sources, the Charnock Richard incinerator in this case. Therefore, the method offers a double function: a) as a tool to test theoretical links between kinds of pollution and kinds of disease, b) in a more utilitarian way, to assess the possible effects that a particular, localised source of pollution may have on the nearby population.

Nevertheless, the current access and use of the method is rather awkward. SAHSU is a centralised facility, maintaining, updating and analysing large databases on health and population for England, Wales and Scotland. Whereas it seems ideal for large studies over extensive or multiple areas, or to report at request to the Departments of the Environment and Health, it is rather too grand for the needs of local Councils and local Health Authorities. These may require an exploratory, quick study of health around a local, proven or alleged, source of pollution. In the same way as British District and Regional Health Authorities carry out health studies without resorting to the central Department of Health, they should also be able to carry out environmental studies without resorting to SAHSU.

3.7.2 - Recommendations:

a). In order to obviate the current lack of knowledge on the possible effects of pollution on the health of populations, more studies should be carried out in the vicinity of pollution sources.

b). Descriptive studies using routinely collected, readily available data should be considered as a first choice for the investigation of health around sources of pollution, mainly in reason of their potential for rapid response to the public, which in the case of pollution-related health issues is often of prime importance. Depending on the outcome of these descriptive studies, further analytical ones can be justified.

c). As sources of data for the studies, the quality of cancer and congenital malformations registers should be regularly assessed and, where necessary, improved. Registers should have a unified system of classification and requiring compulsory notification to assure as much completeness as possible. Case-ascertainment should also be insisted upon in order to prevent as much as possible the inclusion of false cases. Reliable data on other health parameters, such as hospital discharges and GP consultations, should also be made available. While assuring confidentiality, the data should be readily available for analysis.

d). Since Britain, and increasingly other nations, has the capability to conduct environmental studies at the small area level, data for these areas should be used in order to define adequate geographical boundaries for the studies. In Britain, small areas would be Post Code Sectors and, particularly, Enumeration Districts and Post Code Units.

e). Deprivation scores at small area level should be used in studies in order to take into account socio-economic differences over the study areas. These scores should be regularly reassessed to account for changing conditions.

f). A standard methodology for conducting studies at different sites should be available. This methodology should be reliable, affordable and relatively simple, to ensure rapid results. A unified methodology, using standardized routine data would ensure comparability and pooling of results from different studies.

g). The proposed standard methodology for the studies should be based on that developed by SAHSU, adapted for its use on microcomputers, using simple programs and commercially available packages for the analysis of data.

h). This methodology should be considered as the basis for the development of more advanced methods. These should incorporate more accurate models of dispersion and levels of pollution, instead of circles. Accurate modelling will only be possible after routine, continuous monitoring of pollution is implemented.

4 - CASE STUDY: SOIL POLLUTION BY CHROMIUM IN GLASGOW.

Summary: In order to test a general methodology based on the review carried out in Chapter 3, several cases of pollution were considered for study. An appropriate such case came to light in 1991, when certain areas of SE Glasgow appeared to be contaminated by chromium slag. A human risk assessment of the case was carried out following a pre-existing format consisting of four steps: 1) hazard identification, 2) dose-response analysis according to route of exposure (inhalation, skin contact, ingestion), 3) exposure assessment (according to existing levels of the pollutant) and 4) risk characterisation by route of exposure. The assessment revealed that health risks would be higher for those living in or near a localized main polluted area than for those further away, which made the case similar to those in the studies reviewed. Although the literature review (mostly based on occupational studies) suggested that only minor health effects were likely to occur, chromium levels were well in excess of those deemed as safe by different guideline documents. This, along with the need to address the high degree of concern among local residents, suggested the need of further exploring the case by carrying out a health study.

4.1- Description of the problem:

In order to define further and try out the standard methodology outlined at the end of the studies' review, a search for a suitable case study was carried out. Between 1990 and 1991, several possible such cases were considered. The first focused on a dump of pesticide residues in the Spanish Basque Country, the second on the air pollution caused by the Ravenscraig steelworks in Motherwell, Scotland. For different reasons, both were discarded for further study (see Appendix 3 on the Basque case). In late 1991, the case of environmental pollution described below was selected for further research.

In August 1989, a report by the Strathclyde Regional Council Public Analyst on analyses of soil in Rutherglen stated '... our knowledge of this area of the city suggests that any fill in the area is likely to be contaminated by chromium waste from the former chromium works' and 'many of the chromium level(s) exceed the threshold level, even for open spaces' (Strathclyde Regional Council's Public Analyst, 1989).

The Environmental Health Department (EHD) of Glasgow District Council was approached in January 1991 by a company carrying out building work in Rutherglen. Its enquiry concerned the possible existence of landfill sites in Glasgow licensed to receive chromium contaminated waste.

The issue became public knowledge in March 1991, after a local newspaper announced that the Health and Safety Executive had ordered a ban on earth removal at the building site (Sunday Mail, 1991).

Consequently, the EHD carried out an investigation in order to assess the extent of chromium pollution. Local residents were interviewed and soil samples from a range of sites were analysed by the Regional Chemist. A preliminary Report on the findings was made public in August 1991. The origin of the chromium waste was ascertained to be White's factory in Rutherglen, closed since 1967, which had been active for up to 130 years. Fourteen sites were identified '...as potentially being contaminated by chromium waste'. Sample results for three of these sites showed a concentration in soil in excess of 20,000 mg/kg of total chromium in two sites and between 600-900 mg/kg at a third (Director of Environmental Health, Glasgow, 1991*a*). These levels were: '...23 times above normal safety guidelines' (Glasgow Herald, 1991) and in consequence, two sites were fenced off by the EHD. As in March, local newspapers reported the issue in a somewhat sensational manner (Daily Record, 1991).

In Britain, hexavalent Chromium [Cr(VI)] is a substance listed as 'dangerous to life' in The Control of Pollution (Special Waste) Regulations 1980. The meaning of substance dangerous to life, as defined in these Regulations is: a) a single dose of not more than five cubic centimetres would be likely to cause death or serious damage to tissue if ingested by a child of 20 kilograms body weight; or: b) exposure to it for fifteen minutes or less would be likely to cause serious damage to human tissue by inhalation, skin contact or eye contact (Department of the Environment, 1980). In the European Community, the compounds of hexavalent Chromium are listed among the 'toxic and dangerous substance(s) or material(s)' in the Directive (78/319/CEE), which defines toxic and dangerous wastes as: those containing these substances or materials in quantities such as to pose a danger to health or the environment (Conseil des Communautes Europeenes, 1978).

The reference levels used to assess the degree of pollution were those indicated in 1987 by the Inter Departmental Committee on the Redevelopment of Contaminated Land (ICRCL) and which are shown in **4.2.2** - Exposure levels in SE Glasgow , **Table 4-1.**

Further analyses in 1991 showed that the reference levels for both total [Cr(total)] and hexavalent chromium [Cr(VI)] were amply exceeded at several of the contaminated sites (Director of Environmental Health, Glasgow; 1991*b*). By early 1992, 13 of 29 investigated sites had been found to be contaminated (Director of Environmental Health, Glasgow; 1992). Ten of these had concentrations of chromium in soil above ICRCL threshold levels (Environmental Health Department, Glasgow; 1992).

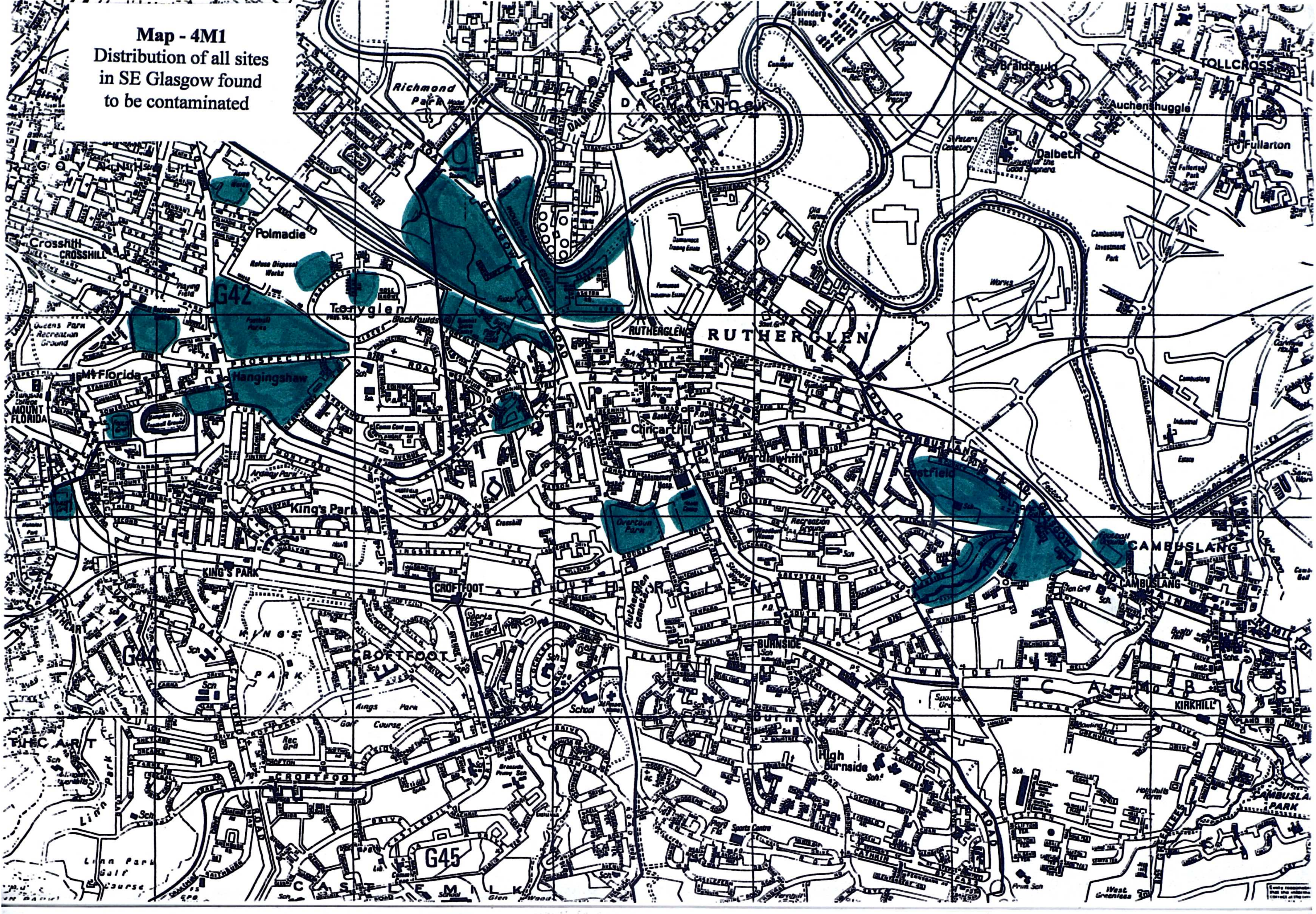
The distribution of all sites in SE Glasgow found to be contaminated with chromium is shown on **Map - 4M1**.

4.2- Human risk assessment of Chromium:

A format for the assessment of risks to human health due to a pollutant has been proposed by the American National Academy of Sciences. It follows four steps (Sheenan, 1991):

1. Hazard identification.
2. Dose-response analysis.
3. Exposure assessment
4. Risk characterization.

In this study, the first two steps are considered together: i.e., the hazards to human health posed by chromium, and the levels of pollutant thought necessary to cause them.



Map - 4M1
Distribution of all sites in SE Glasgow found to be contaminated

The third step takes into account the actual levels in Glasgow and deduces from them the likely exposure. The fourth associates the exposure to its possible health effects.

An important preliminary point is that chromium occurs almost exclusively in two states of oxidation: trivalent or Cr(III) and hexavalent or Cr(VI) (Bidstrup and Wagg, 1983). Total chromium levels are the sum of Cr(III) and Cr(VI). Nearly all Cr(VI) arises from human (industrial) activities (World Health Organization, 1988). Biologically, the key difference is that Cr(III) does not easily cross biological membranes (Health and Safety Executive, 1989). From the point of view of toxicity and carcinogenicity, Cr(VI) compounds are of much greater significance for human health. Accordingly, Cr(VI) and Cr(III) have to be considered separately (World Health Organization, 1987).

4.2.1 - Hazard identification, routes of exposure and dose-response analysis.

Hazards and risks differ depending on routes of exposure. These are: inhalation, skin contact and ingestion (Bidstrup and Wagg, 1983).

Inhalation: Toxicity of inhaled Cr(III) seems to be low or non existent. Clinical examination in 1974 of 106 West German factory workers exposed to air levels of 0.5-2 mg. Cr(III)/m3 failed to show evidence of respiratory problems, even though more than half the workers in the group had been working with chromium for more than ten years (Health and Safety Executive, 1989).

Historical concern about human exposure to chromium has focused primarily on airborne exposure to Cr (VI) (Anderson et al., 1992).

Occupational inhalation of dust or mist containing Cr(VI) is irritating to mucous membranes, causing sneezing, rhinorrhea, lesions of the nasal septum, irritation and redness of the throat and bronchospasm. Lesions of the nasal septum (ulceration, perforation) can partially be attributed to nosepicking with hands dirty with Cr(VI) compounds (Bidstrup and Wagg, 1983). Occupational studies have shown corrosive reactions in the bronchopulmonary tract, bronchitis and chronic obstructive pulmonary disease (COPD) in workers, attributable to Cr(VI) rather than to smoking (Bovet et al., 1977), as well as bronchial irritation and asthma (Novey et al., 1983).

It is difficult to determine a dose-response relationship, but slight effects start to appear above 2 microg Cr(VI)/m3 (0.002 mg/m3) (Lindberg and Hedenstierna, 1983). Levels of 20 microg Cr(VI)/m3 (0.02 mg/m3) have been reported to cause a decline in lung function in non-smokers (Health and Safety Executive, 1989).

Ulceration and perforation of the nasal septum were a common occurrence in chromium workers in the past (Langard and Norseth, 1975*a*). The Health and Safety Executive's occupational limit for Cr(VI) is 0.05mg/m3, but ulceration of the nasal septum has been found to occur at 0.002-0.02 mg Cr(VI)/m3. Atrophy of the septum may occur below 0.002 mg/m3 (Lindberg and Hedenstierna, 1983).

Cr(VI) is classified as a known (Class A) human respiratory carcinogen (Sheenan et al., 1991). For continuous exposure to an air level of 1 microg Cr(VI)/m3, the lifetime risk of lung cancer is between 1.2/100 (United States Environmental Protection Agency, 1984) and 4/100 (World Health Organization, 1988). There does not seem to be a safe threshold and, in consequence, no safe levels for Cr(VI) in air outside the occupational setting have been suggested by regulatory agencies or consensus groups (Sheenan et al., 1991; World Health Organization, 1987).

The first reliable study on the relationship between chromium and human cancer was conducted in seven USA factories in the late 1940s. It showed that crude death rates for lung cancer in chromate workers were 18 to 50 times higher than in a control group of oil refinery workers. The levels of exposure were 0.005-0.17 mg Cr(VI)/m3, and 0-0.89 mg Cr(III)/m3 (Machle and Gregorius, 1948). In the UK, the main study has been a follow-up of workers employed in chromium-related activities for at least one year. Its results were published in two stages covering the periods 1948-55 (Bidstrup and Case, 1956) and 1948-77 (Alderson et al., 1981). The first reported a relative risk of lung cancer of 3.6 for those exposed (1.0 for non exposed). The second reported a relative risk of 2.4. This study also reported a significant excess of deaths for nasal cancer, although based on small numbers. Levels of exposure were not measured in these studies, and neither the US nor UK studies undertook a detailed analysis of the smoking habits of the study populations.

A recent (1991) review of studies on lung cancer in the USA, Western Europe and China attributed a relative risk of 1.5 to workers with chromium exposure defined as low, and 1.4 to workers with any exposure to chromium (Vineis and Simonato, 1991).

There is also some evidence of an increased incidence of nasal and pharyngeal cancers in chromate workers (Alderson et al., 1981) (Machle and Gregorius, 1948).

Current occupational limits in the UK are 0.05 mg Cr(VI)/m3 and 0.5 mg Cr(III)/m3. US limits are 0.1 mg Cr(VI)/m3 (Occupational Safety and Health Administration - OSHA) or 0.05 mg Cr(VI)/m3 (American Conference of Governmental Industrial Hygienists-ACGIH) (Sheenan et al., 1991).

Outside the occupational setting, an epidemiological study of the carcinogenic potential of airborne chromium found no statistically significant difference between lung cancer mortality rates in persons living near chromium emitting industries (exposed to air levels of about 1 microg Cr(VI)/m3) and rural communities (Sheenan et al., 1991; World Health Organization, 1988). In a situation of widespread chromium contamination similar to that in Glasgow (Hudson County, New Jersey), the possibility of an increase in lung cancer incidence in the general population was ruled out after a risk assessment based on previous occupational studies (Harbison and Rinehart, 1990). Nevertheless, the US Environmental Protection Agency (USEPA) has withdrawn its Cr(III) and Cr(VI) inhalation values, and currently there are no exposure guidelines for the general population (Anderson et al., 1992).

Skin contact: Contact with Cr(III) compounds does not seem to cause allergic skin lesions (Bidstrupp and Wagg, 1983). Cr(III) compounds are unable to penetrate cellular membranes and most are insoluble in water. Accordingly, cases of skin irritation are a more likely health effect than allergic reaction (Anderson et al., 1992).

In contrast, contact with Cr(VI) can result in both acute irritative dermatitis and allergic eczematous dermatitis (World Health Organization, 1987). Irritative dermatitis is a consequence of the irritant and corrosive effects of Cr(VI) compounds, leading to skin ulceration (chrome sores), the most common occupational lesion due to exposure to chromium (Bidstrup and Wagg, 1983; World Health Organization, 1987), particularly in the case of skin already ruptured by small wounds, cuts or scratches (World Health Organization, 1988). The Bidstrup and Wagg study was carried out on workers in Rutherglen, where the present pollution problem arose.

Cr(VI) can cause allergic contact dermatitis (Adams, 1990) in the form of widespread, often persistent eczema (Anderson et al., 1992), particularly in persons sensitized by previous contact. There is no agreement on safe levels for contact with Cr(VI), and the distinction between previously sensitized and non-sensitized persons must be borne in mind. Levels in soil below 350 mg Cr(VI)/kg (350 parts per million-ppm) do not pose a dermatitis hazard (Paustenbach et al., 1991), but soil levels as low as 10 mg Cr(VI)/kg (10 ppm) might elicit dermatitis in sensitized persons (Bagdon and Hazen, 1991).

Epidemiological studies have not found Cr(VI) to be carcinogenic via the dermal exposure route (World Health Organization, 1988; Anderson et al., 1992; Harbison and Rinehart., 1990).

Eye irritation can occur through contact with chromium contaminated hands (World Health Organization, 1987).

Kidney damage has occurred following dermal exposure to large amounts of Cr(VI), especially when absorption has been facilitated by extensive skin ulceration (Sheenan et al., 1991; World Health Organization, 1988). There is also evidence of proteinuria and glucosuria from handling solid chromates (Health and Safety Executive, 1989). One study showed increased proteinuria in workers handling chromate (Lindberg and Vesterberg, 1983), but another could not prove higher mortality due to kidney disease among chromium workers (Hayes et al., 1979).

Studies on liver damage due to dermal absorption of Cr(VI) have been inconclusive or negative (Satoh et al., 1981).

Ingestion: As part of the diet, certain Cr(III) compounds are essential to man. Chromium deficiency has been described in humans. Daily requirements have not yet been defined (World Health Organization, 1988). The total chromium content of the typical North American diet is in the range of 0.05 - 0.2 mg/day. British beer typically contains 0.1-0.2mg/pint (World Health Organization, 1988; United States Environmental Protection Agency, 1984).

Diet supplements of 0.15-0.18 mg/day have proved useful for diabetic patients, and 0.25mg/day have proved useful for malnourished children (World Health Organization, 1988).

Vegetables grown on chromium rich soils can accumulate the pollutant. However, high levels of Cr inhibit growth. There has been no study of the effects on man of the ingestion of chromium rich vegetables (World Health Organization, 1988).

Effects on the digestive tract are usually secondary to inhalation or hand to mouth contamination after touching chromates or chromium contaminated soil. Secondary to this, old occupational reports indicate a high prevalence of inflammation and ulceration of the soft palate, tongue and epiglottis, inflammation of the oesophagus and even enteropathy. Levels in air and quantities handled were not recorded, but are thought to have been high (Health And Safety Executive, 1989).

Ingestion of chromium from contaminated soil may particularly affect children. Using tracer elements in faeces, a sample of US children of 2 to 7 years of age was found to ingest 25 to 81mg soil/day (Davis et al., 1990). Around 2% of children under ten suffer from the disorder called geophagia, an inordinate desire to eat dirt or soil, and ingest 1,000 to 5,000 mg soil/day (Harbison and Rinehart., 1990). A maximum typical soil ingestion rate of 200 mg/day for children under 6 years of age, and 100mg/day for persons over 6 years of age has been established by the US Environmental Protection Agency (United States Environmental Protection Agency, 1989).

The International Agency of Research on Cancer (IARC) and USEPA does not classify Cr(VI) as an oral carcinogen (Anderson et al., 1992), the reason being that Cr(VI) is converted to Cr(III) by acidity in the gastrointestinal tract, rendering it unable to cross cellular membranes (Sheenan et al., 1991). Nevertheless, two epidemiological studies have shown a possible increase in cancers of the digestive tract following exposure to Cr(VI). However, the evidence is weak, as one of the studies was based on only 33 individuals (Langard and Narseth, 1975*b*) and neither took account of social, economic or geographical factors (Sorahan et al., 1987).

The maximum safe daily dose established by USEPA for Cr(VI) is 5mg/kg(body weight)/day (United States Environmental Protection Agency, 1989).

Other effects: teratogenicity: There is little evidence of chromium producing teratogenic effects (Harbison and Rinehart, 1990). A study in Australia found no correlation between chromium in water and congenital malformations (Morton and Elwood, 1974). A study of pregnancy and childbirth in Russian women employed in a chromate production plant was inconclusive. A third study, also in Russia, claimed a higher incidence of pregnancy complications in those exposed to chromium, compared to a group without exposure. However, the level of exposure was not specified (Health and Safety Executive, 1989).

4.2.2 - Exposure levels in SE Glasgow.

Soil levels: As shown in **Map - 4 M1**, there are 30 sites in the SE of Glasgow which have been found to be contaminated with chromium (Director of Environmental Health, Glasgow, 1992 ; Environmental Health Department, Glasgow, 1992). There are data on levels of total chromium for 29 sites and data on Cr (total) and Cr(VI) for six sites. Several samples were taken at most sites.

A first step in assessing exposure to chromium is to classify contaminated sites according to reported chromium levels. In Britain, in 1987, the Interdepartmental Committee on the Redevelopment of Contaminated Land (ICRCL) suggested a two level 'trigger concentration' for soil contaminated by different metals. These consist of a 'threshold level', below which no investigation would be required, and an 'action level', above which remediation would be necessary, as shown in **Table 4-1**. Between these two levels, investigation would be deemed necessary to decide whether or not remedial measures (e. g. waste removal, capping) were required, taking account of the use to which the land would be put (e. g. residential, recreational, industrial) (Inter Departmental Committee on the Redevelopment of Contaminated Land, 1987). However, the ICRCL has not yet decided on an action level.

As a comparison, and another guideline, similar indicative values set by the Dutch Ministry of the Environment are shown in **Table 4-2**. It is worth noting that these values do set remediation (action) levels for total chromium (Davies, 1992).

Table 4 -1: ICRCL tentative 'trigger concentrations' for selected inorganic contaminants.

CONTAMINANTS	PLANNED USES	TRIGGER CONCENTRATIONS (mg/kg of air dried soil)	
		THRESHOLD	ACTION
ARSENIC	Domestic gardens and allotments.	10	Not yet set
	Parks, playing fields and open space.	40	Not yet set
CADMIUM	Domestic gardens and allotments.	3	Not yet set
	Parks, playing fields and open space.	15	Not yet set
TOTAL CHROMIUM	Domestic gardens and allotments.	600	Not yet set
	Parks, playing fields and open space.	1,000	Not yet set
HEXAVALENT CHROMIUM	Domestic gardens and allotments. Parks, playing fields and open space.	25	Not yet set
LEAD	Domestic gardens and allotments.	500	Not yet set
	Parks, playing fields and open space.	2,000	Not yet set
MERCURY	Domestic gardens and allotments.	1	Not yet set
	Parks, playing fields and open space.	20	Not yet set
SELENIUM	Domestic gardens and allotments.	3	Not yet set
	Parks, playing fields and open space.	6	Not yet set

Reference: (Inter Departmental Committee on the Redevelopment of Contaminated Land, 1987)

Table 4 -2: Dutch Ministry of Environment indicative values

	Soil and sludge (mg/kg dry matter)			Ground and surface water (microgrames/litre)		
Component (Heavy metals)	**A**	**B**	**C**	**A**	**B**	**C**
Hg	0.5	2	10	0.2	0.5	2
Cd	1	5	20	1	2.5	10
Pb	50	150	600	20	50	200
Zn	200	500	3000	50	200	800
As	20	30	50	10	30	100
Ni	50	100	500	20	50	200
Cr	100	250	800	20	50	200
Cu	50	100	500	20	50	200
Co	20	50	300	20	50	200
Mo	10	40	200	5	20	100
Sn	20	50	300	10	30	150
Ba	200	400	2000	50	100	500

Indicative values: A - reference value
B - value for investigation
C - value for remediation

Reference: (Davies, 1992)

Tables 4-1 and **4-2** show that there is no agreement between British and Dutch guidelines as to the maximum safe levels of Chromium in soil. Both these levels differ also from those recommended elsewhere for both Cr (total) and Cr (VI) (Strathclyde Regional Council's Public Analyst, 1989; Sheenan et al., 1991; Harbison and Rinehart, 1990). However, levels from all the above sources can be combined as follows:

a) Highest maximum safe level:
   - for Cr(total) : 1,000 mg/kg soil.
   - for Cr(VI) : 200 mg/kg soil.

b) Lowest maximum safe level:
   - for Cr(total) : 600 mg/kg soil.
   - for Cr(VI) : 25 mg/kg soil.

(**NOTE**: In order to simplify, 1 mg/kg will be substituted by its equivalent ppm -part per million- in soil levels)

Using these combined levels it is possible to classify contaminated sites into three categories:

1. High level: Those exceeding highest maximum safe level of Cr(total) or Cr(VI) for at least one sample.

2. Medium level: Those with figures for Cr(total) or Cr(VI) between highest and lowest maximum safe levels.

3. Low level: Those with figures for both Cr(total) and Cr(VI) below respective lowest maximum safe levels.

The resulting categorisation of sites in Glasgow is as follows:

Category	Number of sites
1- High level	12
2- Medium level	1
3- Low level	16

The only site classified in the medium level is adjacent to one in the high level category and may be considered as part of it.

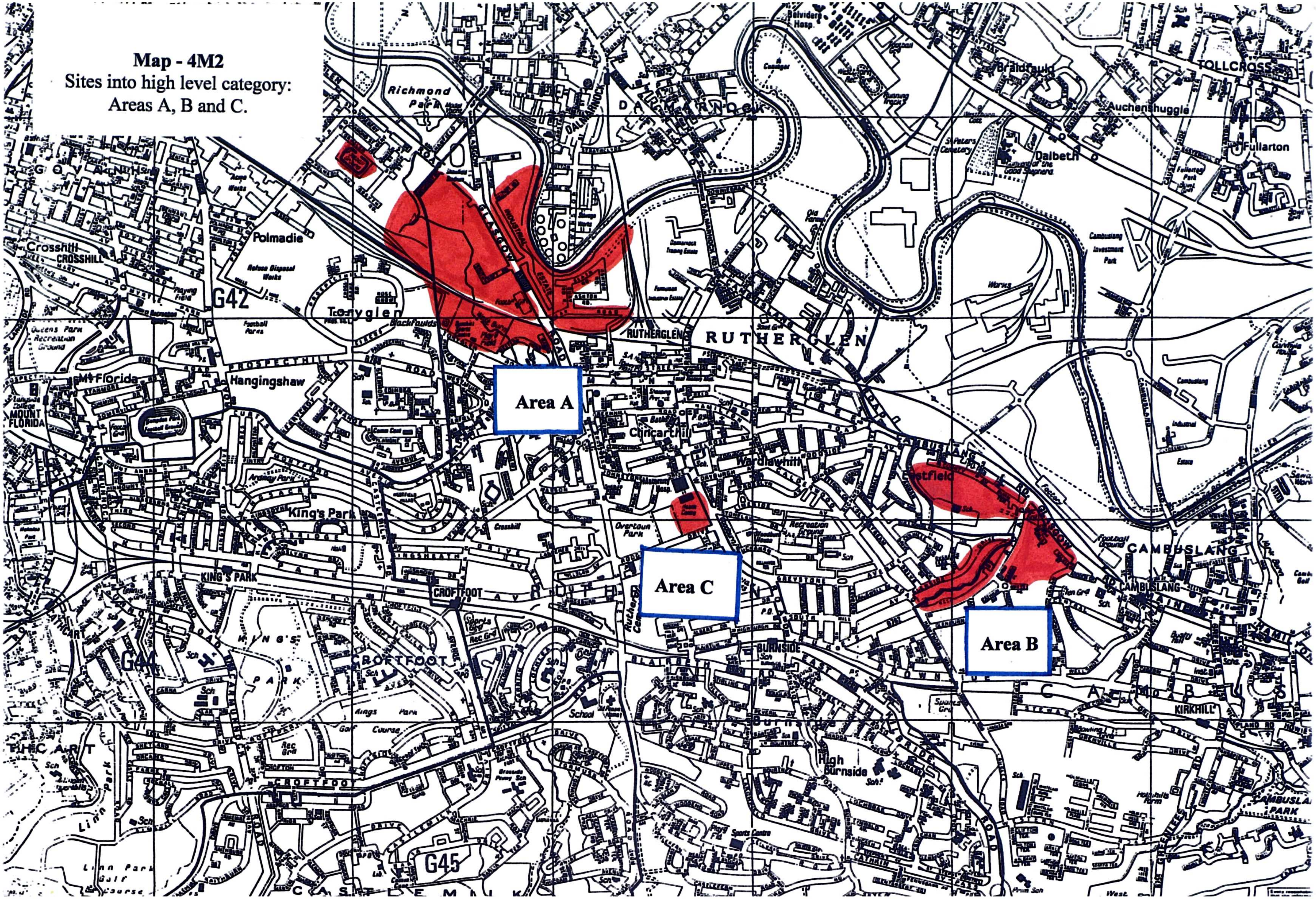
As seen on **Map - 4M2**, the sites into the High level category are grouped into three separate areas: a large area around the site where the chromium slag originated (A), a second group some two and a half kilometres to the SE (B) and a single site roughly midway between the other two (C). The rest of the sites, all Low level, are evenly spread around where the slag originated, all of them, except two, south of the River Clyde.

As appropriate measures of exposure, it is possible to use either the arithmetic or geometric means of the reported levels. Studies of soil pollution in the USA have used the geometric mean as a best estimate of typical exposure, which is considered to be that for a person living between 3 and 13 years in the same area. The arithmetic mean, which is higher, is used as a measure for the upper band value for typical exposure, i.e., that for a person living 23 to 33 years in the area (Sheenan et al., 1991). This length of residence seems closer to what is habitual in the UK, and, therefore, the arithmetic mean of the levels will be used as a measure of exposure.

Arithmetic means for the three groups of sites with high levels of chromium are:

Group	**Mean Cr (total)**	**Mean Cr(VI)**
A (8 sites)	8,164 ppm (63 samples)	848 ppm (15 samples)
B (3 sites)	3,606 ppm (39 samples)	454 ppm (9 samples)
C (1 site)	Undetermined (2 samples >20,000 ppm)	No data

The figure for C is unknown. The site was the first one in the area found to contain chromium (Sunday Mail, 1991) and has subsequently received remedial treatment. In September 1991, a note by Glasgow's Environmental Health Department stated that two soil samples taken within the site by Altec-Labs. had been found to contain over 20,000 mg/kg total chromium (Environmental Health Department, Glasgow; 1991). This would


Map - 4M2
Sites into high level category:
Areas A, B and C.
Area A
Area B
Area C
Richmond Park
Polmadie
Crosshill
Toryglen
Hangingshaw
Mt Florida
King's Park
Croftfoot
Rutherglen
Clincarthill
Wardlawhill
Eastfield
Cambuslang
Burnside
High Burnside
Dalbeth
Auchenshuggle
Tollcross
Fullarton
Kirkhill
G42
G44
G45

make the Cr(total) levels in C close to that in A, where seven samples were above 20,000 ppm, rather than B, where no sample was above that figure.

Arithmetic means for the Low level sites were:

Area	**Cr(total)**	**Cr(VI)**
South of the Clyde (14 sites)	104 ppm	No data
North of the Clyde (2 sites)	185 ppm	No data

Of the two sites north of the Clyde, on the opposite bank from the slag's primary source, the site with the highest mean (257 ppm) lies about half a kilometre from group A, between two bridges leading to that area. The other is an isolated dump some three kms. East of A.

Based on available data, soil pollution by chromium in SE Glasgow is characterized by:

a). A cluster of highly polluted sites (group A) surrounding the point of origin of the pollutant.

b). A smaller cluster (group B) 2-3 kilometres to the SE of group A, with levels of pollution 40-50% of those of the above.

c). A single site (Group C) between the two clusters, clean now, which might have had levels of pollutant close to those in group A.

d). Several scattered sites, almost all of them south of the Clyde, with levels of pollution much lower than those in A, B, or C.

e). In most sites, the pollutant has been present for at least 25 years and, possibly, for as long as 100 years.

Street dust levels: The data for Cr(total) in street dust are:

Group	Number of sites	Mean
A	3 (6 samples)	386 ppm
B	1 (3 samples)	237 ppm
C	1 (73 samples)	95 ppm

Air levels: A meter placed on the roof of a two storey building next to one of the most polluted sites (mean Cr(total) = 13,709 ppm) registered a weekly mean of 31 nanograms/m3 Cr(total) in air (0.031 microg/m3 air) over four weeks during August-September 1991.

At site C, levels for Cr(total) averaged 4.8 nanog/m3 air (0.0048 microg/m3 air) between March - September.

Typical airborne concentrations of Cr(III) in the USA are: <10 nanog./m3 in rural areas and 10-100 nanog/m3 in urban areas (Fishbein, 1981). Ranges of chromium levels in member states of the European Community are: remote areas 0-3 nanog/m3, urban areas 4-70 nanog/m3, industrial areas 5-200 nanog/m3 (Lahman, 1986). Also in Europe, the mean concentration in air of Cr (total) in Turin for 1986-88 was 28.6 nanog/m3 (Pavan et al., 1988).

Compared to the above figures, levels in Glasgow are perhaps lower than expected, particularly those measured near the highly polluted site, which has a bare, dusty surface, particularly during the summer, when monitoring was carried out, although it must be said that August and September of 1991 were noticeably wet. Also, from the relatively high levels in street dust, one might expect more chromium-carrying particles in the ambient air.

On the other hand, the ratio of levels Cr(total) in air/Cr(total) in soil is similar to that for the chromium-polluted area in Hudson County, New Jersey. There, the mean concentration of Cr(total) in soil was 3,079 ppm, between 1/3 and 1/4 of the level recorded at the Glasgow monitoring site, as was the level of Cr(total) in air: 9.2 nanog/m3, measured in both Glasgow and Hudson County from late summer to early autumn (Harbison et al., 1990).

4.2.3 - Risk characterization by route of exposure

Inhalation of airborne chromium, and its associated risk, is not likely to be restricted to any particular section of the population in the area in which it occurs. Ingestion particularly affects children. Contact with chromium contaminated soil is linked (at least in this case) to leisure and occupational activities.

Inhalation exposure: risks: Levels in air of Cr(total) around the most contaminated area (31 nanog/m3 = 0.000031 mg/m3) are 16,000 times lower than the current UK occupational limit for Cr(III) (0.5 mg/m3). The ratio of the mean concentrations of Cr(VI) and Cr(total) in the area is 848 ppm/8,164 ppm = 0.104. If we assume the same proportion in air, the Cr(VI) level would be 3.2 nanog/m3, also some 16,000 times below the corresponding occupational limit (0.05 mg/m3). A correction must be considered here, in that occupational levels assume an exposure of 8 hours a day for 2/3 of the year, for an average of 10 years. If a person was continuously exposed to 3.2 nanogram/m3 for a lifespan of 70 years, the occupational equivalent would be : 3.2 X 3 X 3/2 X 7 = 100.8 nanogram Cr(VI)/m3 (0.0001 mg/m3), which is still 500 times below the occupational limit.

As pointed out in **4.2.1**-Hazard identification, routes of exposure and dose-response analysis., the lowest level in air to have any detectable health effect is around 0.002 mg Cr(VI)/m3 (slight effects on lung function, atrophy and ulceration of nasal septum). This exposure is 20 times higher than the level (after correction) found in Glasgow. This seems to rule out the likelihood of a non-carcinogen respiratory health effect in the area.

As for respiratory cancer, it can be assumed that the risk is proportional to Cr(VI) levels in air (Sheenan et al., 1991). The lifetime cancer risk due to continuous exposure to 1 microg Cr(VI)/m3 is between 1.2/100 and 4/100. With levels of 3.2 nanograms/m3, the corresponding lifetime risk would be between 3.2/1,000 X 1.2/100 and 3.2/1,000 X 4/100, i.e., 4/100,000 to 13/100,000.

Estimates of lifetime risk of respiratory cancer in Glasgow are: males: 13,700/100,000; females: 5,400/100,000 (Hole, 1993). If the air levels of chromium in the most polluted area prevailed all over Glasgow (GGHB), non-occupational inhalation of Cr(VI) would be the cause of one of every 1,000 to 3,500 male lung cancers, and one of every 400 to 1,300 female cases.

A useful indicator of the geographical extent of chromium pollution by airborne spread could be provided by systematic monitoring of chromium levels in street dust. However, this has not been carried out. In the absence of such monitoring, it might be assumed that areas closer to the polluted areas and downwind from these sites have higher levels of chromium in air than those further away and upwind. However, given the variations in the prevailing winds and the unknown effects of local topography, it was decided in this analysis to make no assumption of wind influence.

Contact exposure: Risks: Soil with levels <350 ppm Cr(VI) do not pose a dermatitis hazard for non sensitized persons (Paustenbach et al., 1991). Nor do levels <10 for those sensitized. Both levels are greatly exceeded in the area. Contact with contaminated soil is more likely in the sites of Group A than in B or C. These last two areas are generally covered with grass. Nevertheless, there is a public park in C and a playground and a tennis court in B, which could create a greater risk of contact. In contrast, sites in Group A are largely devoid of vegetation, the chromium slag being highly visible. This area is highly frequented, both as a shortcut, crossed by several paths, and because of two football grounds. One has terraces on which chromium slag is visible. The other, covered in red blaes, represents a less obvious risk of contact.

Sites in Group A present the greatest risk of direct contact and, thus, of skin irritation. Eye irritation is also possible, through hand-eye contact. Systemic absorption of chromium may also occur through cuts and grazes sustained by those using the sporting facilities.

It is difficult to estimate how many people are at risk and their likely exposure as a result of single or cumulative incidents. It may be assumed, however, that the area is frequented mainly by those living in the proximity. Personal inspection of the area indicates that it is highly frequented as a thoroughfare by the general population and that it is used as playground and sporting area by the younger, particularly male, population which would therefore be the group most at risk of direct contact.

Ingestion: Risks: Maximum typical daily amounts of soil ingested, according to age and the presence or not of the disorder geophagia are tabulated below. Possible amounts of Cr(VI) ingested daily are shown. For this example, it is assumed that the soil ingested comes from the most polluted area (Group A).

Age	**Mean amount of soil ingested**	**Mean amount of Cr(VI) ingested**
2-6 years (normal)	200 mg/day	0.17 mg/day
2-6 years (geophagia)	3,000 mg/day	2,5 mg/day
over 6 years	100 mg/day	0.08 mg/day

Assuming a bodyweight of 12 to 25 kg for those 2 to 6 years old and 30 kg for those 6 and over, the daily amounts in mg/kg/day would be:

2-6 years (normal)	0.014 to 0.007 mg Cr(VI)/kg/day
2-6 years (geophagia)	0.20 to 0.1 mg Cr(VI)/kg/day
over 6 years	0.002 mg Cr(VI)/kg/day

For 2-6 years (normal) the amount ingested would be 2.8 - 1.4 times the USEPA recommended limit. For those suffering from geophagia the amount would be 20-10 times this limit. Only those older than 6 years would be below the limit. However, it is highly unlikely that children so young have so much contact with the polluted area that all the soil they ingest comes from there. Even in the case of the playground in area B, with levels of Cr(VI) half those in area A, only children with geophagia would be ingesting hexavalent chromium above the limit, those without the condition would be just on the limit. Again, this is unlikely, since children would have to spend all their playing time at the playground, every day. Also, the site is generally covered with grass, which reduces the likely contact with chromium.

A less improbable source of exposure is street dust. The highest level of Cr(total) registered in street dust (site B) is 386 ppm, some 20 times lower than that in soil in area A. Assuming the proportion of Cr(VI) to be the same as in soil, geophagic children would be ingesting 0.008 mg Cr(VI)/day from street dust, one and a half times the limit. Again, it is improbable that children so young spend all their playing time in the street.

The conclusion is that levels of ingested Cr(VI) are likely to be below the safe maximum. However, since it is not far below this limit (and above it if we consider the extreme scenario) there is still a slight possibility of upper digestive irritation due to ingestion by children.

Besides small children, young people playing in the area are at risk of ingesting chromium through contaminated hands.

There are no substantial market gardens in or near the polluted areas, which rules out the possibility of chromium ingestion through food.

4.2.4 - Risk characterization by area.

Three main hypotheses can be expressed as to how chromium may affect health in the area:

1. There is a health risk for the population in the whole area in which chromium deposits exist.
2. There is a health risk only for those living in the most polluted areas.
3. There is a main polluted area. Health risks will be higher for those living in or near this area than for those living further away.

Hypothesis 1, favoured by many local residents, can be rejected in the light of the exposure-risk assessment. For most polluted sites, the levels of Cr(VI) are too low to produce ill-health.

Hypothesis 2 is more reasonable, but must be qualified, in that not all polluted areas have equivalent exposure levels since:

a) Levels in Group A are double these in Group B. Those in C, from available data, may have been intermediate between the two.

b) In both Group B and site C the chromium slag is covered by soil and grass, which is not the case for most of the Group A sites, where contact with chromium is more likely.

c) Group A is much larger than the other two.

It should be said that all three areas are highly frequented. However, the levels of pollution, the easy contact with pollutant and the size of the area make group A potentially more hazardous than the other two areas.

Accordingly, hypothesis 3 seems to be the most plausible. Residents living near Group A are more likely to make use of the area as a thoroughfare and for its sporting facilities and, therefore, are more at risk through inhalation, direct contact and ingestion.

4.3 - The need for a public health risk assessment.

Three reasons warranted a study of health in the chromium polluted area:

1- As seen before, there are theoretical grounds to suggest that exposure to Cr(VI) may be sufficient to lead to health effects, including skin irritation as well as eye irritation due to contact, and systemic absorption of Cr(VI). Less likely, although possible, is the occurrence of upper digestive irritation in children.

2- The levels of both Cr(total) and Cr(VI) are higher than levels recommended as the maximum safe level in the UK (Inter Departmental Committee on the Redevelopment of Contaminated Land, 1987) and the USA (Sheenan et al., 1991). In the USA, chromium contaminated soils with mean levels for both Cr(total) and Cr(VI) similar to those found in Glasgow, have prompted health assessment of local residents (Sheenan et al., 1991; Anderson et al., 1992; Harbison and Rinehart, 1990).

3- Concern was high among people in the area, some of whom formed an action group. Fear has been voiced concerning leukaemia (Cambuslang Carmyle and Rutherglen against Pollution, 1992), lung and throat cancers, asthma (The Sunday Post, 1991) and skin cancer (Evening Times, 1991). Whether there are grounds for such concerns can only be decided after carrying out a health study.

5 - DATA AND METHODS

Summary: The health parameters chosen for analysis are listed. Routinely collected data on these parameters are chosen, in preference to data from a survey or medical examination, weighing the pros and cons for such a decision. All data under analysis are described, as well as their sources and accessibility. The study is defined as descriptive, of the geographical (ecological) type, in which standardization for possible confounders, summarised in a single indicator (deprivation) will be carried out in order to account as much as possible for the 'ecological fallacy'. The area of study and its population are defined. The methodology of the study, based on the aggregation of small areas in (ten) concentric rings around the focus of pollution, is described. The choice of this approach is based on the adoption of distance as a proxy for exposure levels. Examples of detection levels estimates are provided for several of the parameters. The convenience of basing the study on circular areas, the flexibility of this method, as well as its limitations, are discussed.

5.1 - Data and their sources.

5.1.1 - Health parameters.

All health effects possibly connected with exposure to chromium, as reviewed in the hazard-risk profile, were taken into consideration for the health study, even though the probabilities for some of them to be manifest are low. These are listed below, coded according to the International Classification of Diseases (WHO, 1977).

1- Lung cancer (ICD code 162)

2- Pharyngeal cancer (ICD 146-148)

3 - Nasal cancer (ICD 160)

4- Chronic obstructive pulmonary disease-COPD, excluding asthma, (ICD 490-492 and 494-496)

5- Upper respiratory irritation (ICD 470-478)

6- Skin irritation (ICD 690-709)

7- Eye irritation (ICD 370-372)

8- Upper digestive tract irritation (528-536)

9- Kidney dysfunction (580-588)

10-Asthma (ICD 493)

Several other health parameters were also selected for analysis. Although there is no evidence in the medical literature of these being linked to exposure to Cr(VI) they were included in response to concerns expressed by residents in the area and reflected in the local Press. These were:

11- Leukaemia (ICD 204-208)

12- Skin cancer (ICD 173)

13- Congenital Abnormalities

5.1.2 - Reasons for the use of routine health data.

Two different approaches to investigating the health of residents can be considered:

1) Survey of population at risk by using medical examination, biological monitoring and questionnaires.

2) Analysis of routinely collected data.

The first would involve selecting and examining local residents, looking for signs and symptoms of ill-health due to chromium pollution, taking and analysing urine and blood samples (Minoa and Cavalleri, 1988) and completing a questionnaire on past and current health and lifestyle. There are several drawbacks to this approach.

a) It is difficult to quantify individual exposure to chromium in the environment, needed to allocate those under study to different groups according to these levels .

b) The persons under study are exposed to levels much lower than those in an occupational setting. Routine biomonitoring, using standard industrial techniques, will not detect this level of exposure. Even using more refined detection methods, factors such as diet, exercise, cigarette smoking, age or sex may affect normal chromium levels in blood and urine (Bukowski et al., 1991). These confounding factors, unimportant in industrial settings, may complicate interpretation of variations in the pollutant between individuals.

c) Given the concern among residents regarding chromium pollution, answers to a questionnaire may be biased towards reporting a state of health worse than it actually is (Howe, 1988).

In the case of chromium pollution in Rutherglen and Cambuslang, direct health assessments were confined to people with a history of potential occupational exposure. To this end, the Occupational Health Service of the Greater Glasgow Health Board carried out these assessments on forty-three employees of the Glasgow Parks Department. The workers were suspected of having been exposed to chromium through contact and inhalation during routine maintenance work in some of the polluted areas. The assessment involved an enquiry on chromium-related symptoms, inspection of skin and nose, lung function test, chest x-ray and urine sampling. In the event, no significant excess of chromium in samples or adverse health effects were detected (Symington, 1993).

The use of existing, routinely collected health data provides a more objective approach, with several advantages:

a) They cover the whole population, which a survey cannot, without going to great expense.

b) Data are available for a number of years. The total number of cases collected over a long time period increases the statistical power of the study, and also avoids recall bias.

c) They are relatively easy (and cheap) to access.

d) This analysis can be a first, exploratory step. Depending on its findings, a more detailed, more expensive study may or not be justified.

However, this approach also has disadvantages:

a) Diagnoses can not be expected to be totally accurate. Depending on their degree of sensitivity, and in spite of case ascertainment, there is always the possibility of missing genuine cases (false negatives) and conversely, depending on specificity, including individuals without a given disease as genuine cases (false positives).

b) Accuracy in the registration of data is further affected by the degree of utilization of health services and by changes in registration coding and methods

c) Minor problems, not requiring hospital attendance, are not registered.

The ability to detect any significant increase of a health parameter in an area depends on the relative frequency of its overall occurrence and on the population size of the area. This is further explained in this chapter, along with expected sizes of detectable differences for each health parameter.

Accepting these possible flaws, the analysis of routine data provides a global, quick and economic picture of health which, if needed, can be made more accurate by further studies taking this analysis as reference. Accordingly, the investigation carried out for this thesis was based entirely on analysis of routine data.

5.1.3 - Main sources of data.

All the health data analysed had been routinely collected, and were obtained from two main sources: a) Registers, for cancers and congenital malformations; and b) Hospital Discharge Records (SMR1) for the other health parameters. Census data on population and on Social Deprivation were also obtained.

5.1.4 - Cancer data:

Registration of cancer in Scotland is carried out by five Regional Registers (Aberdeen, Dundee, Edinburgh, Glasgow and Inverness), and derives from hospital inpatient records, pathology, radiotherapy, outpatient and haematology notes (Information & Statistics Division, 1991). Quality and completeness of data follow the International Agency for Research on Cancer (IARC) standards. Their completeness is 95% two years after diagnosis (Hole, 1993; Information & Statistics Division, 1991). The system has been favourably reviewed (Currie, 1990).

To obtain cancer data for the present study there were two options: a) the West of Scotland (WoS) Cancer Register, at Ruchill Hospital, Glasgow, and b) the Scottish Cancer Registration, Branch 6 of the Information Services Division (ISD) of the Scottish Health Service (Common Services Agency), at Edinburgh, which centralizes data from all five Regional Registers. Both were equally suitable, since the WoS Register gathered data for all Health Boards partially included in the study area (mainly Greater Glasgow, but also small portions of Lanarkshire and Argyle and Clyde). In the end, it was decided to obtain these data from ISD, since it was also providing the SMR1 data (see below).

The data requested were for the five cancers under study: lung, skin, leukaemia, pharyngeal, and nasal cancer, coded according to ICD's 9th. revision (WHO, 1977). These were for cancers registered (diagnosed) between January 1st. 1975 and December 31st. 1989 (fifteen year period), for persons residing at the time of diagnosis at any of the Post Code Sectors totally or partially inside a circle 10 km. in radius, centred on the midpoint of the site of the former White's factory, origin of the pollution, in the Main Polluted Area (see **5.2.2** - Area of study). The year 1975 is the first for which Cancer Register data is considered reliable (De Vos, 1991). ISD was asked to provide the data by individual Enumeration Districts inside these PCSs, distributed by eighteen 5-year age group (0-4, 5-9, ..., 79-84, 85+), separately for males and females. An alphanumeric code (e.g., 41BT22) identified each individual ED, and a six-digits grid reference the Ordnance Survey coordinates of its centroid, both to be used in the analysis of the data (see **Ch. 6** -Analysis).

These data, like all the others, were obtained as computer files on diskette. As explained in **6.1** - Computer and programs, the analyses of data were carried out on a desktop personal computer and therefore, in order to facilitate the handling of this large amount of information (5.3 Mb), the whole period 1975-89 was subdivided into three five-year periods, each in a separate diskette containing in turn five files, one for each of the types of cancer. Of 32,565 registrations during the 1975-89 period, ISD excluded 1.2% due to invalid postcoding. A total of 3,780 EDs were included (Finlayson, 1993).

5.1.5 - Hospital discharges (SMR1)

A register of GP records would be an ideal source for data on minor morbidity, but there is no such register as yet. The next best data are the Scottish Morbidity Record 0 (SMRO 0) Outpatient System, for all new patients at consultant clinics in specialities other than Accident and Emergency, Psychiatry and Genito-Urinary Medicine. Such data began to be collected only in April 1991 and have not been available in time to be included in the analyses for the present study, although they will be useful for future studies (Information & Statistics Division, 1991).

The best available morbidity data other than cancer, are those derived from SMR1, on all patients discharged from non-psychiatric, non-obstetric wards, following day treatment or a longer admission. There is a principal diagnosis for each discharge (DG1C) and five co-diagnoses (DG2C to DG6C), all of them transcribed from the case-notes. These records are held in Edinburgh by the Information and Statistics Division (ISD) of the Common Services Agency of the Scottish Health Service. SMR1 records distinguish between different admissions of the same patient. Through the Record Linkage computing system, the number of individual patients can be worked out from the total number of discharges (Information & Statistics Division, 1991). A weakness of these data is that some minor illnesses suspected to be derived from exposure to Cr(VI) (e.g., eye or skin irritation) more often than not do not require hospitalization. It is known that discrepancies due to errors exist between SMR1 principal diagnoses (DG1C) and those in the corresponding hospital case-notes, and levels of agreement between the two have been investigated. In 1971, a study found an agreement of 94% (Lockwood, 1971). In the particular case of gastrointestinal morbidity, SMR1's first diagnoses and case-note diagnoses have been found to coincide in 73.6% of cases (Kohli and Knill-Jones, 1992). Levels of agreement for the other five co-diagnoses seem to be lower. Although SMR1 data have deficiencies, these are unlikely to introduce bias with respect to the hypotheses to be tested.

SMR1 provided data for seven morbidity parameters: skin irritation, eye irritation, chronic obstructive pulmonary disease, upper respiratory irritation, upper digestive tract irritation, kidney dysfunction and asthma. As with cancers (see above), these data were obtained from the Scottish Health Service's Information and Statistics Division, Edinburgh, the section in charge being Branch 5 (Non-obstetric, non psychiatric hospitals). Also as with cancers, the data were for all EDs inside PCSs totally or partially included in a ten-kilometre circle centred on the White's factory.

Cases were those with a diagnosis for any of the seven morbidity parameters as principal or co-diagnosis (i.e., the diagnosis, following ICD coding, was any of six possible diagnoses per case, DG1C to DG7C).

For each of the seven morbidity parameters, the data were of two kinds: a) number of patients (first admissions), b) number of discharges. It was decided to analyse both since each contains different information. The number of cases indicates how many individuals were affected over a period of time by morbidity allegedly connected with Cr(VI). The number of discharges gives an indication of the persistence and seriousness of that morbidity. Numbers of patients (linked data) were obtained 'ad hoc' by ISD from total numbers of discharges through Record Linkage, software for which has been developed since 1989 (Information & Statistics Division, 1991).

At the time of data request, data could be linked back to 1981. Therefore, it was decided that the study period should be 1981-91 (eleven years) for both patients and discharges. There is, nevertheless a caveat concerning numbers of patients. These may be swollen for the first few years after 1981, since these will comprise real new patients, along with second readmissions of patients first seen prior to 1981. Nevertheless, according to ISD-SHS, these readmissions can, in theory, be assumed to be evenly distributed over the study period and, therefore, not to accumulate during the first years of the period under study (Clarke and Redpath, 1993). As with cancer, data were aggregated over the study period for each of the seven parameters, at ED level, by 18 five-year age groups (0-4 to 79-84-85+), for males and for females separately.

5.1.6 - Congenital abnormalities

As indicated (**5.1.1** - Health parameters), there is no evidence that Cr(VI) has any teratogenic effects. Nevertheless, this health parameter was included due to the concern of local residents.

A Register of Congenital Anomalies (malformations) is kept by Greater Glasgow Health Board-GGHB (Stone, 1989) as part of the European Registration of Congenital Anomalies and Twins (EUROCAT) network (Dolk et al., 1991). It is the only well organised such Register in any Scottish Health Board. As an indication of its completeness, data from it on microphthalmos were used in one of the studies on the Bonnybridge incinerator (Strong, 1988), while, in order to ensure case ascertainment, similar data were also collected from twenty-three other sources. Glasgow's Register contained 90% of all cases identified in its Health Board (Russell, 1993).

Data on congenital malformations for this study were provided by the Register, through the Health Information Unit (Department of Public Health) of the Greater Glasgow Health Board (GGHB). Since the Register covers only the Health Board's area, only that portion of the ten-kilometre circle inside the area could be taken into account (see **Map - 5M1**). Of a total 2,780 EDs inside the ten-kilometre circle, 2,535 are inside GGHB.

Data, provided in the usual computer file format, were of two types: a) individual cases (registered births with one or more abnormalities), and b) total numbers of births. In both, deliveries were those included in EUROCAT's Registers. These were: (1) live, (2) stillbirth, (3) spontaneous abortion, (4) induced abortion, (5) not known. Cases were at the Post Code Unit level (subdivisions of EDs), corresponding to that of residence of the mother at the time of delivery (as with other data in this study, length of residence is unknown). GGHB could not provide software to link PCUs to their corresponding EDs, and the linking had to be done manually, case by case, with the help of a General Register Office's (Scotland) guide to PCUs within EDs (1981 Census). A total of 2,567 cases in 1,365 EDs (those having at least one case during the study period) were linked in this way. The equivalent to the population data (denominator) were numbers of births at ED level (totals for each for the study period). These, as with cases, were requested for the part of the GGHB inside the 10 km. circle. The study covered the eight-year period 1982-89.

5.1.7 - Population data.

The above mentioned health data provided the numerators for the calculation of rates, while population data were their corresponding denominators. Data for population correspond to the 1981 Census. At the time of analysis, this was the latest available data. Also, it was deemed as being the most appropriate, given the study periods, 1975-89 for cancers and 1981-89 or 91 for other parameters. The data were at the ED level, with totals by 18 five-year age groups (0-4, 5-9,...,79-84, 85+), separately for males and females.

The data were obtained from ISD-Scottish Health Service (Edinburgh), as a diskette file. These corresponded to EDs whose centroids were within a square 30 km. of side, loosely centred on the Main Polluted Area. Since the whole study area was included into a single 100,000 Metre Grid Square of the Ordnance Survey, the NS Square, the area was a subsector of this Grid Square, Eastings: 46 to 76; Northings: 47 to 77 (Ordnance Survey, 1990). Each ED had its corresponding identification code and the Ordnance Survey grid reference of its centroid.

5.1.8 - Socio-economic deprivation.

Since at least the studies of William Farr in the 1870's, socio-economic deprivation and disease have been known to be closely related. For most diseases showing a socio-economic gradient, the more disadvantaged individuals are found to be at higher risk (Leon, 1988). Besides environmental pollution, multiple factors, such as poor housing, inadequate diet or stress due to unemployment may influence health. Usually, people living near industrial areas belong to disadvantaged social categories, and are subjected to the above factors. Unless these factors are taken into account, any study on the relationship between distance to a pollution source and health would be biased (Jolley et al., 1992). Since the factors are multiple, it is convenient to sum them up into a single socio-economic index or score.

To account for these factors in Scotland, (and later in the whole of the UK) the Carstairs' Deprivation Score and Deprivation Category have been developed (Carstairs and Morris, 1991). The score applies to individual EDs, or PCSs, and is derived from the following census variables: percentage of economically active males who are unemployed, percentage of individuals in private households without access to a car, percentage of private households with more than one person per room, percentage of private households with head of the household in social class IV or V. These are derived from the 1981 Census.

The Deprivation Score is a continuous variable which, after calculations using the variables above indicated, ranges for EDs in Scotland from -8.48 (most affluent) to +12.82 (most deprived). The Deprivation Category is a simplification of the Score and ranges, for EDs, from 1 (most affluent) to 7 (most deprived). Both the Deprivation Score and Deprivation Category can be used to standardize health data for socio-economic deprivation. Carstairs' Deprivation Scores and Deprivation Categories, for EDs inside PCSs total or partially inside the ten-kilometre circle, were sent by the Medical Statistics Unit (Medical School) at the University of Edinburgh, after request to Dr. Vera Carstairs, at the Health Services Research Network Office, Edinburgh. The file also contained the variable TAG (see **5.2.2** - Area of study and population).

5.1.9 - Accessibility.

All the data analysed in the present study were available, upon request, from the different sources above mentioned. The data are kept in 'raw' form, and, therefore, each request has to clearly specify the kind of data required (i.e., specific health parameters, population, etc.), as well as the particular characteristics of these data (i.e., area and period of study). In the present study, most of 1992 was spent in defining the kind of data to analyse, as well as area and study periods. The majority of data were requested in late 1992 and early 1993. The periods of time between (final) request and arrival of the data were as follows:

- Population data, 6 days (June 1992).

- SMR1 data, 27 days (February - March 1993), for Greater Glasgow's Health Board area; a further 94 days for the whole study area (March - June 1993). The delay was due to a misunderstanding (for which the author assumes full responsibility) as to the extent of the study area. It must also be taken into account that linking of discharges had to be carried out by ISD-SHS in order to obtain numbers of patients, and that this linking, although based on preexistent computing software, requires new programming according to the health parameters and area required (Adam Redpath, personal communication).

- Cancer data, 48 days (February - April 1993). The extraction of the specific data from the Scottish Cancer Register files required 'ad hoc' programming, since it was the first time cancer data had been requested at individual ED level for an extensive area (Dr. Roger Black, personal communication).

- Congenital abnormalities, 6 days (February 1993) for cases; 17 days (February - March 1993) for births. The delay in receiving the latter data was due to an error in their definition, all births, instead of, mistakenly, live births.

- Socio-economic deprivation, 42 days (December 1992 - January 1993). It should be noted that the period included the Christmas session.

During 1992, some SMR1 and cancer data had been obtained from ISD-SHS. These data become insufficient as the study area was expanded, and the number of health parameters increased, during that year. Once the definite data were requested, it was judged simpler to process data for the whole new area.

5.2. - Methodology.

5.2.1 - General methodology.

As already stated, the present study intends to explore the feasibility of a health assessment of a polluted area, following a methodology based on previously tested ones, used in environmental health studies of polluted areas in the UK (**2** - Aim and Objective). After a critical appraisal of twenty-five studies carried out between 1982 and 1996 (Ch. **3**), it was concluded that a standard methodology should be adopted for future similar studies, at least as a first step on which, if necessary, further investigation should be based. By reason of its simplicity and ability to incorporate different factors (distance as surrogate for exposure, deprivation), the methodology developed by the Small Area Health Statistics Unit (SAHSU) was recommended as the model from which the standard method should be developed (see **3.4.7**).

The methodology from which the model derives assumes that the source of pollution is relatively small in extension and that pollution emanating from it spreads evenly around the source, its levels being inversely proportional to distance from it. A circular area centred on the source of pollution is divided into concentric rings, each built from small areas: Enumeration districts and Post Code Units in SAHSU's study. Levels of disease (Standardized ratios) are assessed inside each of the rings, using standard (overall area) rates to test for statistical significance. Possible trends of these ratios to increase or decrease with growing distance (and therefore diminishing levels of pollution) are assessed by means of their regression lines over distance and their slopes, and with the Stone statistic, from the corresponding test (Stone, 1988). The standard method based on these premises will be henceforth denominated Small Areas and Rings.

Although soil pollution by chromium in Glasgow is widespread, there is a relatively small area whose levels are much higher than anywhere else, the cluster of contaminated sites known in this study as Group A (see **4.2.4** - Risk characterization by area). Placed next to the river Clyde, across from Dalmarnock, and next to the West Rutherglen area of Toryglen, Group A is polygonal in shape, with dimensions of some 0.5 X 0.3 miles (800 X 500 mts.), and includes the site from where all the chromium slag allegedly responsible for the pollution originated, the former White's factory. Although there are two other, much smaller, areas with levels above these deemed as safe (Group B, 2 kms.

to the East of A, next to Cambuslang; and Group C, roughly midway between A and B, slightly to the South; see **Map - 4M2**) and a scattering of other sites (mostly South of the Clyde, as are A, B and C; see **Map - 4M1**), the Risk Characterization by Area included in this study (see **4.2.4**) concluded that health risks would be higher for those living in or near Group A than for those living further away. This was based on: a) the levels of soil pollution found in Group A were double those found in the other two, b) whereas in B and C the contaminated soil was generally covered with grass, therefore greatly reducing the risk of exposure, Group A consisted mostly of barren, dusty ground covered in chromium slag; and c) Group A had a much larger area than the other two.

Therefore, it can reasonably be concluded that there is an area (Group A) where most of the pollution is concentrated, small enough to be considered punctual (provided the study area is relatively large), the health risks derived from which diminish with distance from it. In consequence, the Small Areas and Rings standard method can be applied for the study of this case. Group A will be denominated henceforth Main Polluted Area, although the location of groups B and C will be taken into account when interpreting the results.

Following the Small Areas and Rings method, a circular extension centred on the Main Polluted area was divided into concentric rings and Standardized Ratios for the health parameters (listed in **4.1.1** - Health parameters) were calculated. As standard for each parameter, the overall rate for the whole study area was applied. The reason for the use of this overall study area rate instead of regional rates (e.g., Strathclyde's or West of Scotland's), as in the case of SAHSU's study, was that rates inside the study area were judged as more convenient, since it covers almost exclusively a major urban setting (Glasgow), whose health rates may differ markedly from those from the surrounding, rural area. In short, rather than comparing levels of disease between a standard area and the study one, the distribution of these levels inside the study area (by ring) was analysed. To account for social deprivation, the data were also Standardized by Carstair's index.

To assess a possible gradient of Standardized Ratios with distance from the Main Polluted Area, the (simple) regression slope for each set of Ratios was also calculated, the sign (positive or negative) and absolute value of this slope giving an indication as to whether disease levels diminish with distance from the Main Polluted Area (as speculated) and how steep this possible diminution may be. To cross-check this simple regression analysis, a Logistic regression was also carried out for some set of data.


Map - 5M1
Ten kilometres circle around former site of White's chromium factory
STRATHKELVIN
KIRKINTILLOCH
BISHOPBRIGGS
GLASGOW
RUTHERGLEN
CAMBUSLANG
EAST KILBRIDE
EASTWOOD
HAMILTON
COATBRIDGE
BEARSDEN
Milngavie
G15
G13
G14
G12
G11
G20
G21
G22
G23
G33
G34
G40
G41
G42
G43
G44
G45
G46
G51
G52
G53
G61
G62
G64
G65
G66
G69
G71
G72
G73
G74
G75
G76
G77
ML3
ML5

Also, the Stone statistic (actually the Stone test without testing for significance) will be applied to each set of observed and expected figures (Stone, 1988). It indicates the distance (ring) from the centre at which the maximum cumulative-observed/cumulative-expected ratio takes place. The nearer to the Main Polluted Area this ratio occurs, the stronger the evidence of a relationship between the chromium pollution and health outcomes.

Since the pollutant has been in the ground for, at least, thirty years, no time lag was considered for the study.

In consequence, the methodology is that of a Descriptive, Geographical - Ecological study, since the place of residence (the ring) is used to create surrogate measures of the real exposure of interest (English, 1992). The main drawback of this kind of study is what is known as the 'geographical fallacy', i.e., attributing to total populations over an area a level of risk greatly derived from risky conditions or behaviour among subsets of individuals. To account for this as much as possible, health data have been Standardized by deprivation score (Carstairs').

5.2.2 - Area of study and population.

The study area covers all Enumeration Districts whose centroids lie inside a circle 10 kilometres in radius, centred on the pollutant's point of origin, the site of White's factory. The Ordnance Survey coordinates of this point are: East 608, North 622 (Ordnance Survey, 1990). The circle covers most of the Greater Glasgow Health Board (GGHB) and parts of Lanarkshire and Argyle & Clyde Health Boards. The radius is arbitrary, large enough with respect to the dimensions of the Main Polluted Area and allowing division into areas of adequate extension, 10 rings one kilometre wide in this case. Each of the rings is made up of the Enumeration Districts whose centroids lie between the circumferences limiting it. In the cases when a centroid lies exactly on a circumference, the ED is allocated to the innermost ring. The area comprises 2,780 EDs, with a total population of 873,643 at the 1981 Census.

The river Clyde divides the area from SE to NW into almost identical halves. If we deem the chance of approaching the Main Polluted Area a surrogate for exposure, it could be argued that the river, as a physical barrier, greatly reduces the risk for those living on its Northern bank. There are two main footbridges (Dalmarnock and Rutherglen bridges, the latter leading straight into the Main Polluted Area) and a minor one within one kilometre of the Main Polluted Area, and a third main bridge just outside this distance (King's bridge). As can be seen, communication is relatively easy between the river banks at the area of pollution. Although the analysis was carried out for the whole 10 km. circle, it is equally easy to do it for either the South or the North side only. To that effect, the variable TAG was requested to be included in the file containing Deprivation Categories (DEPCAT) by ED, with '1' indicating EDs North of the Clyde and '2' those South of it (see **5.1.8** - Socio-economic deprivation). As a comparative exercise, such an analysis was performed for Lung Cancer (see **Ch. 7** - Results).

All those living in the study area were considered as study population. As it is later explained in **Ch. 6** - Analysis, they were grouped as total population (i.e., all age groups, both sexes) for some analyses, while males, females and some age groups were considered separately for others.

The 1981 Census data were deemed as being the most appropriate for the study. As already explained (**5.1.4** - Cancer data), data for cancer covered the period 1975-89, while those for other health parameters were for 1981-91. For cancers, 1981 lies roughly in the middle of their data period, which is convenient (Gilmour, 1990). For other health data 1981 is at the beginning of their period, which still makes it appropriate. No other population data with the degree of reliability of a Census was available (the Strathclyde Region 1987 Voluntary Population Survey is an estimate based on a 10% sample), and statistical methods such as Proportional Morbidity (Breslow and Day, 1987) were considered of little accuracy for a case in which large differences in health parameters between polluted and non polluted areas were unlikely. Since the 1991 Census was not available in time for the analysis, the 1981 Census remained the most adequate source of population data.

5.2.3 - Power of the study: Sizes of detectable differences.

That a subdivision (e.g., ring) of the overall, standard area has an Standardized Ratio of, for instance, 120 for a particular health parameter, means that it has a 20% excess morbidity compared to the overall area. This excess, or part of it, can be due to underlying causes which do not act on the whole area, such as soil pollution by chromium. Alternatively, the excess can be due to random variations in the number of cases over the years, without any extra reason to account for it. Conversely, a Standardized Ratio of 80 in a subdivision indicates a 20% defect in morbidity when compared to the overall area. Again, the causes for this deviation from the overall morbidity can be due to underlying causes, to simple random variation, or both.

Statistical analysis can determine the probability of a difference (excess or defect) being real (i.e., higher or lower than would expected due to simple random variation) or not (i.e., random variation can explain the size of the difference). To decide on the statistical significance of a difference, each study has to define its significance level.

In this study the significance level is set at 0.05 (two-tailed), i.e., there is less than a 5% probability that a deviation from the norm (expressed as an Standardized Ratio of 100, or whatever other parameter we choose) is due solely to chance. Being two-tailed means that there is less than a 2.5% probability of a chance excess difference, and, likewise, of a chance deficit.

Along with this, the probability of considering as due to chance a difference which is not, must be included. The level of this second probability is usually chosen to be four times that of the significance level, i.e., 0.20 in this case. The complementary level (1 - 0.20) would be that of the probability of correctly considering a difference as being due to chance. This second level, i.e., 0.8 in this case, is called the power of the study (Mausner and Kramer, 1985; Kirkwood, 1990).

For a given health parameter, that a difference in an area be statistically significant depends on: a) the standard deviation of the parameter, b) the size of the population in the area, c) the difference between the local incidence and that taken as a standard, and d) the significance level and, therefore, the power of the study. All the above can be combined to find the size of the minimum significant difference that can be detected statistically (Mausner and Kramer, 1985).

A statistically significant excess difference in a polluted area does not necessarily mean that the excess is due to the presence of the pollutant; it could be due to other known or unknown factors. Nevertheless this excess would justify a more detailed study of that area in order to see if there is a causal relationship between chromium and the excess morbidity. Such a study would not be justified in the absence of a significant excess, assuming satisfactory power.

The size of the minimum detectable significant difference for a disease can be expressed as numbers of extra cases per 1000, 10,000, etc., population at risk, or as a percentage increase. Once the significance level, the power of the study and the size of the population have been defined, these numbers or percentages will be a function of the standard and local incidence rates of the disease.

Incidence rates can be used to work out expected number of cases in an area, and there are tables relating these to corresponding minimum significant excesses (Breslow and Day, 1987, Table 7.3). Nevertheless, an estimate of significant excess (or defect) can be worked out independently of tables with the following formula:

$$P = \frac{[u \sqrt{R(1-R)} + v \sqrt{R_0(1-R_0)}]^2}{(R - R_0)^2}$$

(Kirkwood, 1990, Table 26.1), where:

R = Standard incidence rate as a ratio , e. g. 45/1,000 = 0.045.
R_0 = Incidence rate in the study area as a ratio.
u = One-sided percentage point of the Normal distribution corresponding to 1 - the power of the study ($u = 0.84$ in this case).
v = Percentage point of the normal distribution corresponding to the two-sided significance level ($v = 1.96$ in this case) .
P = All above variables defined, minimum population necessary to find significant the difference between the rates.

Calculations are straightforward: e. g., if $R = 0.045$ (45 cases per 1000 population), an increase of 1 case/1,000 population makes $R = 0.046$. Using these figures in the formula, the population in which this increase would be found as significant would be:

$$P = \frac{0.339}{0.001^2} = 339{,}000$$

Therefore, with an incidence rate of 45/1000 over a given period of time and a significance level of 0.05, a study with a power of 0.8 would need an estimated population of 339,000 to detect as significant an increase of 1 case per 1000 population.

In the area under such study, if the significant relative increase in incidence is not expected to be too high, we can consider the numerator as constant and calculate an estimate of such increase, keeping in mind that the estimate will be less accurate as the difference between the rates increases. Calling the numerator 'A', it can be concluded from the above formula that:

$$d^2 = \frac{A}{P}$$

Where d is the difference between rates (e.g. 46/1000 - 45/1000 = 1/1000).

Therefore, if the study population is 10,000:

$$d^2 = \frac{0.339}{10,000} \quad , \qquad d = \pm 5.82/1000$$

In this case, an excess (or defect) of 6 cases per 1,000 population is necessary to find a significant difference in a population of 10,000. With a standard incidence of 45/1,000, 5.82/45 = 0.129, or approximately 13%, would be an estimate of the excess disease required.

All other factors being constant, the minimum significant difference will decrease as the population of the area increases. As examples of significant excesses to be expected in this study, a health parameter with high incidence is selected (lung cancer), also a parameter with very low incidence (nasal cancer) and another with an incidence intermediate between those (leukaemia). Their minimum significant excesses for two different types of areas are shown. These areas are Post Code Sector and ring (as defined in **5.2.2** - Area of study and population). There are 100 PCSs in the City of Glasgow, with a mean population of 7,500, of which approximately 3,900 are females and 3,600 males. Using the above formulae, estimates of minimum significant excess differences for the three health parameters mentioned, for the average PCS are shown in **Table 5-1**. These appear as both excess number of cases in the corresponding area (in brackets), or as percentage increase. Both figures have been rounded to their nearest higher integer, with percentages above 100 rounded to their nearest (up or down) multiple of ten.

Table 5 -1 : Minimum detectable excess (cases and percentages) in average PCS

Type of cancer	Total population	Male	Female
Lung cancer	(32) 24%	(24) 24%	(18) 45%
Leukaemia	(9) 87%	(7) 120%	(6) 120%
Nasal cancer	(3) 330%	(2) 450%	(2) 460%

(significance level = 0.05, two-tailed; period 1975-89)

Table 5-1 shows that analyses confined to a single PCS are only able to detect relatively large excesses in the occurrence of known health effects of chromium exposure, even in the case of conditions with relatively large numbers of events, such as lung cancer. The Main Polluted Area straddles two PCSs (G 5.0 and G73.1), touches the boundaries of a third (G 42.0), and is just across the Clyde from a fourth (G 40.4). A study analysing individual Post Code Sectors would consider separately cases and populations in these four PCSs, thus reducing the possibilities of detecting possible excesses of disease. Furthermore, each PCS has different significance thresholds for such excesses according to their populations. This means that, with equal rates of disease, some PCSs could be found significant (those with higher populations) while others are not. One way to circumvent these two inconveniences is to group the PCSs into a larger area. If the four PCSs in or next to the Main Polluted Area are grouped, estimates of the detection levels would be as shown in **Table 5 - 2**:

Table 5 -2 : Minimum detectable excess (cases and percentages) for a grouping of Post Code Sectors covering the Main Polluted Area (Group A)

Type of cancer	Total population	Male	Female
Lung cancer	(58) 13%	(44) 13%	(32) 25%
Leukaemia	(17) 48%	(12) 66%	(12) 69%
Nasal cancer	(5) 180%	(4) 240%	(3) 250%

(significance level = 0.05; two-tailed; period 1975-89)

As **Table 5-2** shows, after the grouping of PCSs the detection levels become considerably lower. Nevertheless, the grouping of these four PCSs is far from satisfactory as a study area. It is very irregular in shape, including populated areas to the North West (Crown St.) nearly two kilometres from the outside boundaries of the Main Polluted Area, while not including most of Rutherglen, the neighbourhood most at risk due to its proximity to the this Area, lying only 200-300 metres from it **(See Map - 5M2)**. This problem of greatly variable distances cannot be solved by adding new PCSs (e.g., G73.2 and 3) to the study area. Due to their pronounced irregularity in shape, new PCSs would, while including areas close to the hazard, also incorporate areas far more distant, which is not appropriate in a situation in which distance to the hazard is taken as a surrogate for exposure, as in this study.

As already seen, the Small Areas and Rings method makes use of Enumeration Districts as the building block for study areas. As EDs are 20-30 times smaller than PCs, the irregularity of their shape represents less of a problem than it does in the case of PCs. It has already been explained (**5.2.2** - Area of study and population) how EDs can be grouped into approximately circular areas (rings) centred on the source of pollution, or the appropriate point of an extensive polluted area.

A circle one kilometre in radius, centred on the origin of chromium slag (the former site of White's factory) covers the whole of the Main Polluted Area and incorporates nearby populated areas equidistant from it (see **Map - 5M3)**. The area covered by EDs whose centroids lie inside this 1 km. circle does not differ much from that covered by the circle itself, since EDs are small, particularly in a densely populated, urban area as in this case.

This 1 km. circle is the innermost of ten in this study (see **6.2.2**). Taking as population and cases those for the EDs inside the circle, estimates of the minimum detectable excesses, in percentages and number of cases, for the example parameters would be as shown in **Table 5 - 3:**

Map - 5M2
Post Code Sectors in or next to the Main Polluted Area.

Table 5 - 3: Minimum detectable excess (cases and percentages) in innermost ring.

Type of cancer	Total population	Male	Female
Lung cancer	(37) 20%	(27) 21%	(18) 39%
Leukaemia	(10) 75%	(7) 110%	(7) 110%
Nasal cancer	(3) 290%	(2) 390%	(2) 400%

(significance level = 0.05, two-tailed; period 1975-89)

Although the area is more appropriate, the minimum detection levels for the 1 km. innermost circle are higher than for the grouping of PCSs, but lower than those for a single PCS. As seen above in this section, besides incidence rates, the main variable having an effect on detection levels is population size. The population (1981) of the average PCS in Glasgow is 7,500; that of the four grouped PCSs 25,060, and that of the EDs inside the innermost 1 km. circle 9,854. Enlarging the radius of the circle to two kilometres (two innermost 1 km. rings), the population under analysis would be 51,336, and the estimates for detection levels as follows:

Table 5 -4: Minimum detectable excess (cases and percentages) for the grouping of two innermost rings

Type of cancer	Total population	Male	Female
Lung cancer	(85) 9%	(62) 9%	(47) 17%
Leukaemia	(24) 33%	(17) 47%	(17) 48%
Nasal cancer	(7) 120%	(5) 170%	(4) 170%

(significance level = 0.05, two-tailed; period 1975-89)

These levels are lower than those for the grouping of PCSs. The study area now includes the populated tracts most at risk, equidistant up to 2 km. from the Main Polluted Area (see **Map - 5M3**), while leaving out the most outlying (and, therefore, least at risk) part of the PCSs grouping.

Since the radius of the central circle can be of any desired length, the level of detection can be altered at will by changing it, as long as the central circle contains (approximately or totally) the focus of pollution; e.g., an area in the case of the present study, a punctual focus in a study around an incinerator. Once this length has been chosen, it should also coincide with the width of the successive rings, in order to maintain a regular spacing, since it has been assumed that distance from the focus is used as an indicator of exposure levels. The radius judged satisfactory for this study is 1 kilometre, but it can be extended (or reduced) to 2 km. (five rings), or to any chosen length. The methodology allows for further analysis with equal populations inside the rings, by adding populations in Enumeration Districts; or, after estimates of incidence rates with distance, equal minimum levels of detection for all rings.

Also, circular areas, made up of EDs, are more appropriate than irregular ones consisting of PCSs, since their boundaries are equidistant from the health hazard and, therefore, risk uniformly increases with decreasing distance from one such boundary to the centre (the hazard), which does not happen in the case of highly variable hazard-boundary distances in an irregular area made up of PCSs.

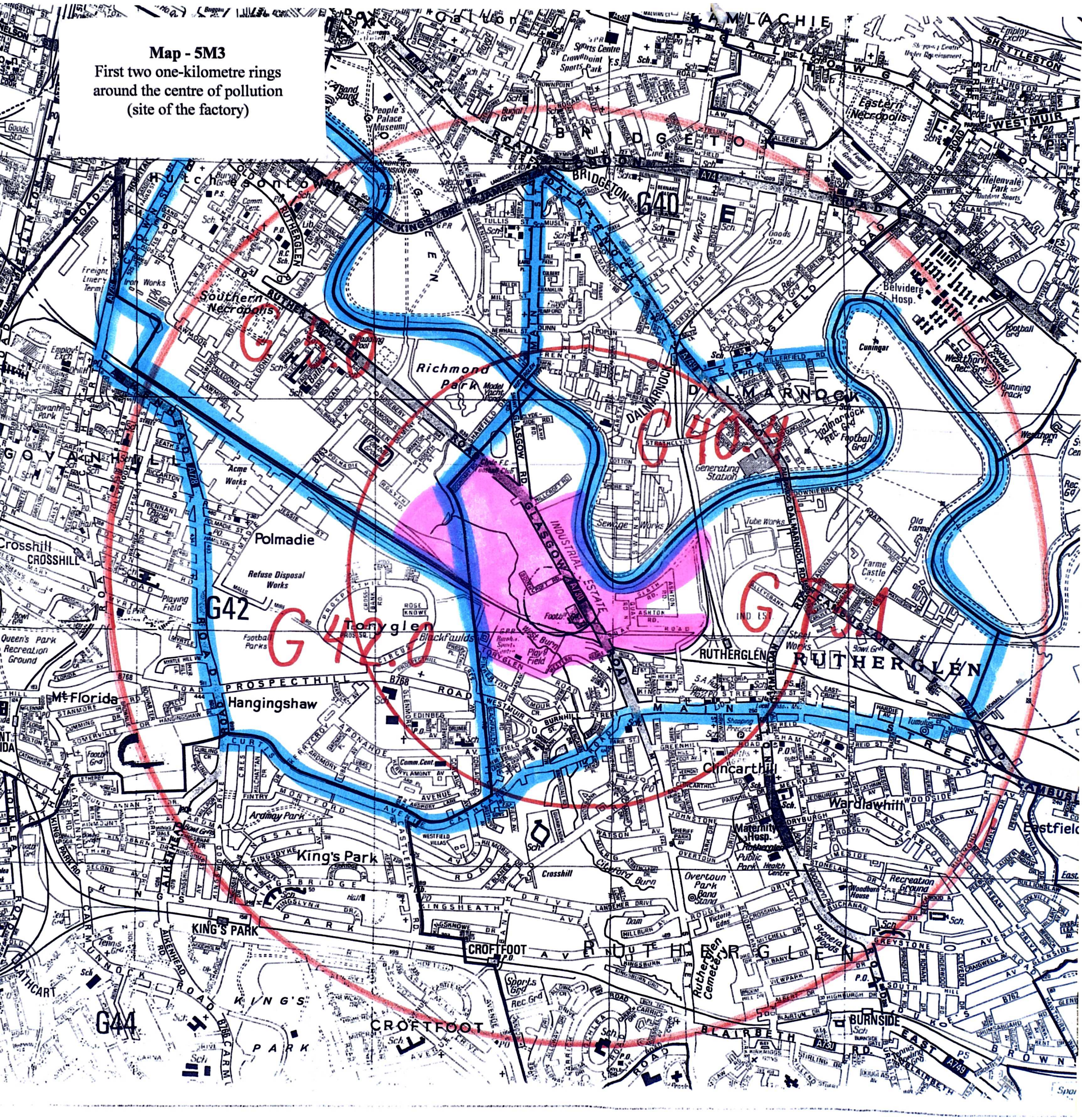
The analysis is still only capable of detecting quite large differences in the occurrence of relatively rare conditions, as shown in the tables above. In the case of such conditions, simple counting of cases may suffice to assess whether a problem is likely to exist.

In summary, analyses are based within rather tight constraints, with respect to the size of differences which can be detected, given the expected rates within particular study populations. In practical terms, the consequence of a large 'minimum detectable' difference, is that lesser differences cannot be excluded with confidence (i. e. there is the possibility of reaching a false negative conclusion). Accordingly, negative results must be reported and interpreted with caution.

In the case of lung cancers, the smallest detectable excess percentage is still higher than the excess we could expect from the risk assessment in the polluted areas (see **4.2.3**). It

Map - 5M3

First two one-kilometre rings around the centre of pollution (site of the factory)



is likely that the detectable excesses for some other parameters are also higher than the possible actual ones.

In spite of the limitations in statistical power, mainly imposed by the possible ways in which populations can be grouped, the study provides a reasonable 'ceiling' for estimating the amount of any excess in disease occurrence in the area. Although this ceiling may seem to be high in the case of more uncommon diseases, it has to be taken into account that a few extra cases in a ring, over a period of fifteen years, for total population or for each sex, could make the total for that ring significantly high. Accordingly, as already pointed out above, for rarer diseases simple counting of cases may be sufficient in order to assess whether there is a health problem.

6 - ANALYSIS

<u>Summary</u>: Using personal computers, a series of commercially available and 'ad hoc' programmes were used to process and analyse the data. Numerator and denominator data for the study area were selected and allocated to one of ten rings into which the area was subdivided. Cancer, SMR1 and Congenital Malformations data were then analysed by Standardized Registration Ratio by ring (standardized by age group only and by age group and Carstairs' Deprivation Category). Subgroup analyses included specific diseases, males and females, particular age groups and particular areas. Trends of increase or decrease in SMR with distance from the centre of pollution were analysed using regression techniques and the statistic taken from the Stone Test. Possible confounders and the rationale to standardize by them were reviewed. Also, for cases and for deprivation, inaccuracies leading to missing data were considered. In order to check the sensitivity of the method, analyses using dummy centres of pollution were carried out. Finally, as an alternative to linear regression, Logistic regression analyses were also tried.

6.1 - Computers and programmes:

All the analyses were carried out using Personal Computers (microcomputers). During the analysis process, three different models were used at different times. The first one operated at 25 Megahertzs (Mhz), with 8 Megabytes (Mb) of Random Access Memory (RAM) and 90 Mb of memory in its Hard Disk (HD). The second one operated at 65 Mhz, with 16 Mb RAM and a 500 Mb HD. The third computer was a 90 Mhz, with 32 Mb RAM and a 500 Mb HD. The main reason for the use of models of increasing processing speed and capacity was that these were made available at different stages of the analysis.

Programmes fell into one of two categories: a) Short programmes 'ad hoc', i.e., suited for the particular needs of the data under analysis, and: b) Commercially available programmes.

Three programmes were included into the first category, all of them in the Fortran 77 programming language. These were: SRRPRG.FOR, to work out Standardized Registration Ratios (SMRs) and their Confidence Intervals (CIs); PSSNPRB.FOR, to calculate the corresponding p-values; and STONE.FOR, to investigate trends of SRRs with distance from the Main Polluted Area. Primary versions of these programmes were obtained from the Cancer Surveillance Unit, at Ruchill Hospital, Glasgow. The PROFOR compiler was utilised with these Fortran programmes..

The commercially available packages were: SPSS/PC+, version 3.1, for the processing of raw health and population data prior to calculation of SMRs and their CIs, both non-standardized and standardized by Deprivation Category; EXCEL 5.0, to plot the Regression Graph; and MINITAB 10.51, to calculate the Regression Slope and its corresponding p-value.

6.2 - Selection of Enumeration Districts under study and their populations:

As explained in Methods (**5.1.7**- Population data), data on population by Enumeration District were obtained for a rectangle 30 kilometres in side, containing a circle 10 km in radius which, centred on the designed centre of the Main Polluted Area, delimited the study area. In order to select EDs whose centroids lay on or inside this circumference, i.e., those under study, the file CENDEP10.SYS was created using SPSS/PC+ (see **Appendix 4**). The original (larger) population data file had been requested to include the variables EAST and NORTH for each ED. These three-figure variables corresponded to the National Grid eastings and northings, accurate to the nearest 100 metres, for the centroids of each of the EDs as measured inside the 100,000 m. Grid square. Using these pairs of coordinates and those of the chosen centre of pollution (EAST-608, NORTH-622), the file CENDEP10.SYS worked out the linear distance centroid-centre of pollution as the hypotenuse of a right-angled triangle, thus :

Compute dist = sqrt (((east - 608)**2) + ((north - 622)**2)).

Then, the relevant EDs were selected, thus:

Select if (dist le 100.00).
Save outfile = 'Census10.sys'.

A total of 2,780 Enumeration Districts had their centroids on or inside the 10 km radius circumference, with a total population (1981) of 873,643 (416,855 males and 456,788 females). A further variable: CIRCLE, was created by recoding distance: 0.00 to 10.00 = 1, 10.00 thru 20.00 = 2, ... , 90.00 thru 100.00 = 10, therefore allocating each ED to one of ten 1-km wide rings into which the study area was subdivided.

It must be remembered that the choice of a 10 km. radius for the study area was made because this distance was considered as an appropriate one to include all possible affected individuals, but the choice was arbitrary. Also arbitrary was the subdivision of this area into rings 1 km. wide, which was done as a first approach to a general methodology. This methodology allows to subdivide any chosen (circular) study area into rings of equal width, as in the present study, or their aggregations (see section **5.2.3** - Power of the study, and **Table 5-4**). Equal populations inside each ring can be obtained by altering the corresponding diameters. This allows SMRs to be estimated with similar precision for each ring, which would be more convenient than equal widths for comparison purposes, provided the rings are not too different in width if distance is still taken as a surrogate for exposure. If desired, equal area rings can also be obtained. The populations inside each of the rings appear in **Table 6 - 1**.

Table 6 -1: Populations inside rings in study area

Ring	Males	Females
1	4,676	5,178
2	19,420	22,062
3	40,373	43,396
4	47,106	53,072
5	38,958	44,095
6	48,408	52,360
7	56,685	61,481
8	58,226	64,268
9	60,696	65,274
10	42,307	45,602

Since it was intended to standardize SRRs by Deprivation Category, this variable was added to the data file. This was done by matching by ED (six digits identifying each individual ED) the 10 km. population file with that listing Carstairs' Deprivation Category as the variable DEPCAT (again, a file covering an area larger than that intended for study), and selecting those EDs having the new variable CIRCLE from the resulting CENDEP10.SYS file. According to ISD, all EDs in the area requested appeared in the population data file, irrespective of their population. This was not the case with the file containing DEPCAT, since the Deprivation Category for some EDs was not available (mostly due to their small population). Out of 2780 EDs under study, 209 (7%) had their DEPCAT listed as MISSING (see **6.5** - Confounders).

In order to investigate the possible effect of the River Clyde as a physical barrier between the polluted area and part of the population, the variable TAG had been included in the file also containing DEPCAT (this file covered only Post Code Sectors total or partially inside the 10 km. circle, therefore making easy the allocation of TAG upon request, which would have been more difficult in the much larger raw population file). TAG was 1 for EDs North of the Clyde, and 2 for those South of it. The appropriate TAGs were allocated manually to those EDs with a missing DEPCAT using a list of EDs by Post Code Sector (a PCS belongs entirely to one or the other side of the river).

The final CENDEP10.SYS was then used as the population data file for the analysis of cancer and SMR1 data.

6.3 - Analysis by Standardized Registration Ratio (SRR).

6.3.1 - Cancers: Standardization by age.

Standardized Registration Ratios for each of the five cancers were obtained. Standardization was indirect. Standard rates were the incidence rates over the period 1975-89 by five-year age group (arithmetic yearly means, per 100,000 population) in the whole study area. These were applied to the 1981 Census' age groups. For each cancer, total population was analysed. In some cases, each sex separately, or a particular set of age groups, or a particular subarea were analysed too, as it will be detailed.

In all cases, the Standardized Registration Ratios obtained corresponded to cases and populations (total or partial, according to the analysis) inside each of the 1-kilometre wide rings into which the corresponding study area was subdivided, all centred on the Main Polluted Area's centre.

To obtain rates, numbers of observed registrations and populations prior to standardization, the commands file CANCER.PAD was created in SPSS/PC+ (see **Appendix 4**). Using this file, the Enumeration Districts inside the study area and their 1975-89 numbers of registrations for each age group were selected from the raw data, using the same Pythagorean principle as with population, since each ED in the cancer data file also had its centroid's coordinates attached (see **6.2**, above). In the same way, total numbers of registrations for each of the ten rings were obtained next (see **Section 1a** in CANCER.PAD). This resulted in the corresponding OBSERVED file, containing the numerators for the obtention of SRRs by ring (see **Section 1b**).

The next step with CANCER.PAD consisted in obtaining the (mean) rates per 100,000 population by age group (**Section 2**). For that, total registrations by age group for the study area were obtained (**Section 2a**). Then, using the previously obtained CENDEP10.SYS file (see **6.2**, above) total populations by age group for the study area were obtained (**Sections 2b** and **c**). After joining total registrations and populations, mean rates 1975-89 by age group were worked out (**Section 2d**).

Finally in CANCER.PAD, total populations by ring and age group were calculated (**Section 3**) using files derived from CENDEP10.SYS (**Sections 2b** and **c**). These constituted the POPULATION file, to which the rates were applied.

Observed, Population and Rates were combined using the Fortran 77 programme SRRPRG.FOR. As shown in Chapter **8** - Results **(Tables)**, the programme produced, besides expected numbers of cases, Standardized Registration Ratios (1975-89) and their 95% Confidence Intervals for each of the ten rings. For significantly high SRRs (i.e., those with a lower limit above 100) p-values (i.e., the probability of a result further away from 100) were calculated using the file PSSNPRB.FOR (see **Appendix 4**), into which the corresponding number of observed and expected cases had to be written. For significantly low CIs (those with a higher limit below 100), p-values were also worked out. For Expected numbers of cases up to 100, the Poisson Distribution was used (one-tailed). For numbers above 100, the Normal approximation to Poisson (two-tailed) was used (Armitage, 1971). Confidence Intervals were exact for numbers of Observed <30, using the Byars approximation for higher numbers (see Breslow and Day, 1987).

Analyses for particular sex, age group or area.

The CANCER.PAD file, as it appears in Appendix 4, exemplifies the process of editing data for total population (both sexes and all age groups) for the whole of the 10 km circle (North and South of the Clyde). In the case of Lung Cancer, standardizations by age were also carried out for each sex, for each side of the Clyde, for particular age groups and for combinations of all three. These analyses were as follows:

1. Total study area, a) total population, b) males, c) females.

2. South of the Clyde, a) males, b) females, c) males under 65 years of age, d) males 65 or over, e) males under 55, f) males 55 or over.

3. North of the Clyde: the same groups as in the South.

Also, for leukaemia, total population and the age group 0-14 were analysed separately, since local concern for childhood leukaemia had been voiced. To allow for that, copies of CANCER.PAD were tailored in the following ways:

- If only one of the sexes was analysed, the other was excluded from the 'data list file' command in (Section A in CANCER.PAD), as well as from calculation of total populations (**Section 2b**).

- If only particular age groups were analysed, the rest were excluded from the same sections as with sex.

- If data for only one side of the Clyde was analysed, the command 'select if tag = ... ' was used before computing the distance, as well as with CENDEP10.SYS before computing total populations.

As seen above, all three modifications could be used in combination.

Missing EDs in cancer registrations.

The files containing the cancers had a total each of 2,585 EDs, i.e., 195 fewer than the total EDs inside the 10 km circle, according to the population file. The search of data by Edinburgh's Information and Statistics Division (ISD) was carried out by applying the list of EDs in the area requested (slightly larger than the study area) to the database for cancers, so there was no reason for the missing EDs not to appear, since this was not a case of omitting those EDs without registrations. To confirm this, EDs without cases were selected. All five cancer files were found to have some EDs without registrations between 1975 and 1989 (although no ED was found without a registration for at least one of the types of cancer). The missing EDs had a joint population of 12,937 (7,362 males, 6,575 females), i.e., below 2% of the total study population. By rings, the highest relative loss was that of a 3.8% of males in Ring 3: 1,536 (but only 376 females), which, after finding a similar loss for missing Deprivation Categories, was attributed to the presence in the ring of Strathclyde University (see **6.5** - Confounders).

The reason for this loss was probably due to uncorrected changes in EDs' coding over time, and it was likely that most relevant registrations were included in the files, with some misclassified, probably still inside their corresponding ring. In any case, it was unlikely that percentages of registrations much higher than those for population were missing, since that would not have escaped the attention of ISD. The loss was judged to be small enough not to alter the reliability of the results and it was decided to use the data provided. These percentages compared favourably with those for missing or incomplete postcoding in the study of larynx cancer around incinerators carried out by London's Small Areas Health Statistics Unit: 10% initially and over 5% after recoding (Elliott et al., 1992*b*).

6.3.2 - Cancers: standardization by age and deprivation category.

Besides age, standardization by Carstair's deprivation category was carried out. Standardization by sex was not deemed necessary, since the ratio between numbers of males and females inside any particular age group in different areas appeared to be much more constant than the distribution of population by age in these areas. Nevertheless, separate analyses by sex were carried out in the cases where a particular disease was suspected to have a different impact in each of the sexes. These separate analyses by sex have been already listed on **6.3.1** above. Deprivation category was seen to differ widely between areas (Carstairs and Morris, 1991). It is known that differences in socio-economic status, summarised by the deprivation category variable, are linked to differences in disease incidence. This is because there is a relationship between the presence of risk factors and social class (Jolley et al., 1992). Since some of these factors can be confounders in a study such as this (see **6.5** - Confounders), a standardization by deprivation category and age was carried out to account for these and, when comparing its results to those standardized by age only, as an indicator of the impact of deprivation on the case under study. As with standardization by age only, the programme used allowed for analysis of male and female separately, of either side of the River Clyde, of chosen age groups and of combinations of all three. The analyses standardized by age and deprivation category were the same as those for age only, listed on **6.3.2**.

Deprivation category (depcat) was added to standardization by age by working out the ratios between overall (whole study area) registration rates by depcat and age group, and overall registration rates by age group. The resulting ratios were then multiplied by the numbers in each age group by depcat and by ring, to obtain depcat standardized populations. Each resulting age group was then added for all depcats inside each ring. The final depcat standardized population by age group and ring was then used, along with total number of observed cases by ring and overall study area's incidence rates by age group, to work out SRRs by ring using the SRRPRG.FOR file, as with standardization by age only. Confidence intervals and p-values were also obtained.

Editing of data and population was done in SPSS/PC+ with the command file CANCERS.PAD (see **Appendix 4**). With this file: **a)** cases for the whole 10 km.-radius study area were summed by age group and deprivation category **(Section 1 of the file)**; **b)** populations were also summed by age group and deprivation category **(Section 2)**; **c)** by dividing these numbers of cases by their corresponding populations (i.e., same derivation category) rates for the 15-year period by age group and deprivation category were obtained; **d)** from these rates, annual arithmetic mean rates were obtained by dividing them by 15 (15 year-period) and each of these was divided in turn by their equivalent rate (whole 10 km area) by age group only **(Section 3)**; the resulting ratios were matched by depcat to their equivalent age-group populations inside each ring and multiplied by them, the results were then summed by age group inside each ring **(Section 4)**.

6.3.3 - Data from Scottish Morbidity Record 1 (SMR1): standardization by age and by age and deprivation category.

As explained in Chapter **5** - Data and Methods, data on diseases other than cancer and congenital malformations, seven in all, were obtained from the Scottish Morbidity Record1 (SMR1) system. The analyses on these data were conducted in the same way as with data on cancer, i.e., the data were edited through command files in SPPSS/PC+ and the resulting incidence rates, total numbers of observed cases by ring and populations by age group and ring were combined through a SRRPRG.FOR file to obtain Standardized Registration Ratios (by age and by age and depcat) and their 95% confidence intervals. Also, p-values for the SRRs were obtained using the PSSNPRB.FOR programme, as with cancers.

The differences between the cancer and SMR1 data resided in that for each disease registered through SMR1, 2 sets of data existed: 1) numbers of cases (individual patients) and 2) numbers of discharges (one or more for each patient). Each of these two parameters were analysed separately, but using the same SPSS/PC+ command files (which allowed for modifications to retrieve either parameter from the raw data files). Also, the format of the SMR1 data files differed from that of the cancer files, and the adequate modifications had to be introduced in the early sections of the programmes. Finally, the period studied covered eleven years, instead of the fifteen years for cancer. The SPSS/PC+ command files appear in **Appendix-4**, where SMR1.PAD is the file used to edit data prior to standardization by age, and SMR1S.PAD the file used prior to standardization by age and deprivation category.

Since the layout of these files is similar to that in the corresponding files for cancer, they also allow separate analyses by sex, age groups and either side of the Clyde. For both cases and discharges, Chronic Obstructive Pulmonary Disease was analysed for total population and for males and females separately, since occupational factors and possible, but unknown, differences in smoking prevalence could have an incidence in the numbers of registrations. For skin and for eye irritation, total population for all ages, and total population under 20 years of age, were analysed separately, since this second group was more likely to have direct dermal and ocular contact (eye rubbing) with the contaminant through use of the local playgrounds and football pitch (see Contact exposure, in **4.2.3**). Also, total population and the age group under 10 years of age were analysed separately to account for geophagia (see Ingestion: risks, in **4.2.3**). Finally, asthma was analysed for total population and for the under 25, since, as with childhood leukaemia, above, juvenile asthma was a local concern. All these analyses were standardized for age and for age and depcat.

Missing EDs in SMR1 registrations.

A total of 102 EDs did not appear in the SMR1 data. As with cancer, this seems to be a case of miscoding. The total population in these missing EDs was 7,066 , i.e., under 1% of the total study population. Again, the highest relative loss was for males inside the 3rd. ring: 2.4%. Nevertheless, these figures of lost data were well below those judged as acceptable for this kind of study.

6.3.4 - Analysis of Congenital Malformations:

All congenital malformations were analysed together, since the number of individual conditions were small and since no particular condition was suspected of being connected with the presence of Chromium. As with cancers and SMR1 data, SRRs by ring, their 95% confidence intervals and p-values were obtained for congenital malformations. The data on congenital malformations required manual editing prior to that through SPSS/PC+ command files (see **5.1.6** - Congenital abnormalities). These command files followed the same general layout as those utilised with the other data in the study. Obviously, standardization by incidence by age group (i.e., standardization by age) has no place with this type of data, but standardization for overall incidence was carried out, with the study area's overall incidence (1982-89 in this case) again as standard). The corresponding SPSS/PC+ file was CM.PAD, as it appears in **Appendix-4**. It was used to obtain total numbers of observed registrations by ring (**Section 1**), total births by ring (as with cases, numbers of births were for the part of the GGHB inside the 10 km. circle), equivalent to the population in the analysis of other data (**Section 2**), and the study area's overall incidence rate of congenital malformations per 100,000 births (**Section 3**). All three were combined with SRRPRG.FOR to obtain SRRs and confidence intervals by ring. Given the catchment area of the Register, the study area comprised only that part of the 10 km circle inside the Greater Glasgow Health Board (see **5.1.6**).

Standardization by overall incidence and deprivation category was also carried out. The SPSS/PC+ command file editing data for this is the CMS.PAD in **Appendix-4**. This file aggregated registrations inside study area by depcat (**Section 1**), aggregated births by depcat (**Section 2**), worked out the study area's rates by depcat and divided them by their overall equivalent (**Section 3**), multiplied the resulting ratios by their corresponding numbers of births by depcat inside each ring, and added the resulting figures to obtain totals inside each of the rings (**Section 4**). As above, SRRPRG.FOR and PSSNPRB.FOR were then utilised to obtain SRRs, confidence intervals and p-values.

Congenital malformations with a missing ED.

Prior to selecting those cases inside the (GGHB) 10 km circle, the cases were allocated to their corresponding EDs (and, therefore, to their coordinates) manually, using the correspondence Post Code Unit (available with cases) - ED. Of a total 2,937 registered cases 186 had a Post Code Unit code which did not correspond to any (1981) Enumeration District. The list of these codes was sent to the General Register Office (Scotland) - Census Customers, in an effort to identify the corresponding EDs. As a result, 117 cases were identified as belonging to EDs introduced after 1981 (and codes for corresponding pre-1981 EDs provided). EDs for the remaining 69 (2.3%) could not be identified, due to typing errors in their PCUs (59), and their belonging to Large Users PCUs, which correspond to no ED.

6.4 - Analyses of trends with distance:

The general null hypothesis of the study was that the presence of pollution by Chromium did not have any effect on the health of the population. If this null hypothesis were true, SRRs would not follow any trend with distance from the chosen centre of pollution, i.e., they would not increase or decrease in any statistically significant way. In contrast, in the case of a false null hypothesis, higher SRRs would be found towards the central rings (i.e., in areas closer to the pollutant) and these SRRs would probably be statistically high in respect to the whole 10 km circle, acting as standard background, i.e., with a SRR equal to 100.

To test the above, a test was carried out and a statistic calculated. The test consisted on the obtention of the regression line of each set of ten SRRs on distance (rings), its slope and the significance or not of the deviation of this slope from unity. The statistic was based on the Stone test, based on the analysis of cumulative numbers of observed and expected cases over successive rings.

6.4.1 - Regression analyses:

The regression line of each set of ten SRRs on distance (1 km. wide rings) was obtained using the EXCEL 5.0 statistical package. The graph included both low and high limits for each of the SRRs 95% confidence intervals. It provided a visual representation of possible increasing or decreasing trends with distance for SRRs (see Chapter **7** - Results: **Tables 1** to **94**). The slope of each of these lines was calculated using MINITAB 10.51, as well as the statistical significance of its difference from zero (i.e., the null trend). The regression was that of SRRs on 100 X Distance, i.e., both parameters were on the same scale. The algorithm was weighted on the inverses of widths of the Confidence Intervals, to account for standard error. The significance test for difference from zero (0.05 significance level) was equivalent to a t-test, using slopes instead of means.

As a possible alternative, already indicated in **5.2.1**, the Logistic regression was also tried out on a limited set of data. Details on these analysis and their results appear at the end of Chapter **7**.

6.4.2 - Ratio of cumulative Observed/Expected cases (the Stone statistic).

Based on the test described by Stone (Stone, 1988), this statistic obtains the distance (ring) at which the ratio between cumulative observed and expected cases is highest. This means that inside this distance SRRs follow a generally increasing pattern, and a decreasing pattern beyond it. Along with the regression line and its slope, the statistic helped decide whether SRRs, and therefore levels of disease, increased or decreased with distance to the Main Polluted Area. In some cases, an outer ring obtained through Stone and a negative slope for the regression line seemed to contradict each other. But visual examination of the SRRs' plot against distance confirmed both, the cause being that after a general increase of SRRs with distance, marked decreases in the outermost rings resulted in an overall negative regression slope. Cases where an inner ring and a positive slope coincided occurred less frequently. The complete test includes statistical significance of this divergence, but its calculation was beyond the computing power utilised in this study. In **Chapter 7** - Results, only those apparently paradoxical Stone results (20 out of 94) are examined.

6.5 - Confounders.

Several factors appear as confounders when investigating a possible relationship between pollution by chromium and some of the diseases being considered. Sex (gender) is an obvious one, since males, at least until recently, were more likely than women to be connected with risk factors such as working in an industrial environment and smoking, both of which could lead to effects similar to those suspected from chromium. It was to account for this gender-related confounders that lung cancer and chronic obstructive respiratory disease were analysed separately for males and for females. For the general population these and other possibly confounding risk factors not obviously connected to gender (such as quality of housing or income) can be found summarised in variables such as Deprivation Category (Depcat). There is a direct relationship between occupation and this variable, as there is one between higher prevalence of smoking (in males and in females) and higher deprivation categories (Whitehead, 1987). It was to account for these confounders that an indirect standardization by Deprivation Category (and age) was conducted for all health parameters. Since this variable was considered at the Enumeration District level, the possibility of incurring the so called 'ecological fallacy', (i.e., that the presence of small numbers of people with high risk factors can lead to mistaken conclusions over the health status of large numbers), is greatly lowered, since EDs have small populations of a few hundred at most, over a small area, and therefore tend to be more homogeneous than larger units, such as Post Code Sectors.

6.5.1 - EDs with missing Deprivation Category.

When conducting the standardization by Depcat, it was noticed that 209 Enumeration Districts inside the 10 km radius study area did not possess the variable. It is known that EDs with a population of 50 or less are considered too small to have a Depcat associated (Dolk et al., 1995), and the average population of these with the variable missing was 35. Also, their total population (7,415) represented 0.8% of the study population, in line with the 0.66% for the whole of Scotland (Carstairs and Morris, 1991). These figures were thought to be low enough for them not to have a significant impact on the standardization results, although these EDs were grouped together under the extra (eighth) deprivation category of 'missing'. Nevertheless, as with missing EDs in cancer and SMR1 data, there was an unusual number of males in these EDs in the third ring: 1,463, as compared to 348 females. In this case, it was not the EDs which were missing, only their Depcat variable, and therefore it was possible to locate them North or South of the Clyde by using their TAG variable. As it turned out, 1334 of the 1463 males in these EDs in the third ring were located North of the Clyde. It is likely that most of these are temporary local residents (Strathclyde University is in the area).

6.6 - Testing the method's sensitivity.

In order to test the sensitivity of the SRR analyses by rings, further analyses were conducted using four false centres of pollution. Each of these centres was situated five kilometres away from the real one: to the North, South, East and West. The rationale behind these analyses was that, if the method was sensitive enough, results from the new rings would be different, but in agreement with those resulting from the original set of circles; i.e., an excess (or defect) in a given ring in the original results would also appear using new centres, but in a different ring, displaced from the original ring as much as the new centre was from the original one. Conversely, if results obtained using different centres turned out to be the same, the reason could not be other than a methodological artifact and the methodology, therefore, would be useless.

Results from these analyses, as well as their tables, appear after those from the main results, at the end of Chapter **7**.

7 - RESULTS

__Summary__: **This section is divided between results for health parameters for which a possible connection with exposure to Chromium was found in the literature review, however speculative this connection might be, and other parameters for which no mention of connection with Chromium was found in the medical literature, but which were nevertheless the subject of public concern. A higher incidence of Lung Cancer was observed in the five innermost rings, with decreasing incidence with increasing distance from the centre of pollution. This tendency was most evident for men, particularly middle-aged men, living North of the Clyde, away from the main source of chromium pollution, where it also affected females. The opposite trend was observed for Chronic Obstructive Pulmonary disease and, markedly, Skin Irritation, Skin Cancer, Upper Digestive Tract Irritation and Kidney Dysfunction. In general, after standardization by deprivation category these trends were less evident.**

7.1- Health parameters possibly linked to Chromium exposure:

7.1.1 - Lung Cancer:

For the total population, the Registration Ratios standardized by age (SRRs) for rings 1 to 3 are statistically high at the two-tailed $p<0.05$ level. Also, these are the highest SRRs for the ten rings, in decreasing order from the innermost ring (the highest). This decrease continues until the 5th ring, with the 6th also statistically raised, but lower than any of the other three. The regression line shows a decrease of SRR with distance, with a slope significantly different from zero, at $p=0.001$ [Table 1]. After standardization for deprivation category, these trends remain, but are attenuated. The SRR for the innermost ring is no longer statistically high (fourth out of ten), while those for the second and third rings are still high, but at lower levels. The regression slope is still negative and significant, at $p=0.01$ [Table 2].

For males only, results mirror closely the above. Standardized by age only, SRRs for the three innermost rings are statistically raised and are the highest, again decreasing from the innermost ring (126.65) to the 5th, increasing again in the 6th, and generally decreasing afterwards. The regression line SRR/distance has a negative slope, statistically different from zero [Table 3]. Standardized for deprivation, the SRR for the innermost ring ceases to be statistically high (but it is still the second highest). The 2nd and 3rd remain significantly high, as does the slope of the regression line [Table 4].

For females, results differ greatly from those for males. Standardized by age, none of the inner rings has a significantly high SRR, with the 1st. ranking as seven, 2nd 4, 3rd 3, and 4th 4. While still relatively high, inner SRRs are lower than those for males, while the second peak already observed for males in ring 6 remains. The slope of the regression line is not significantly different from zero [Table 5]. After standardizing for deprivation, SRRs for the three innermost rings fall, with that for the innermost one as the lowest of all ten. The slope becomes positive, slightly above zero (0.000446), therefore non-significant. The result of Stone's statistic is 3, an inner ring, which seems to contradict the slope. Nevertheless, observation of the regression pattern shows that it is the permanence of the second peak which makes the slope slightly positive [Table 6].

Analyses South of the Clyde, males only:

In view of the persistence of raised SRRs for males, it was decided to further study this particular group. Although the river Clyde does not totally separate populations North of it from the contaminated area, due to relatively easy communications between its banks (see **5** - Methods), male population in the South Bank was separately analysed. Since females did not seem to be particularly affected in the central rings, occupational, rather than environmental factors had to be taken into consideration (among men, standardization by social deprivation accounts, to some extent, for smoking). It was thought possible that most men having been employed in Chromium processing would have resided in the South bank, where the factory itself was sited. Also, they would have lived inside a radius of only a few kilometres from that site, therefore inside the first few rings in the analysis, and, the Chromium-processing factory having been operational until 1967, it is also likely that many of its former employees would still have lived in the same areas between 1975-89.

Standardized by age only, the two central half-rings had statistically raised SRRs. The SRRs steadily decreased between the first and 6th rings, with a new significant peak at the 8th, although lower than the central figures [Table 7]. After standardization by deprivation category, only the second ring had a significantly high SRR, with that for the innermost ring ranking third at 106.43, less than one unit below that for the outermost ring [Table 8]. Both regression lines showed general trends of SRRs decreasing from the central point, although their slopes were not significantly different from zero.

Occupational exposure periods South of the Clyde:

Males most likely to have been employed in the Chromium industry, i.e., residing in the South bank, were also analysed taking into account two possible exposure periods, thirty and twenty years. For a thirty-year period, males employed from the age of about twenty would have been fifty in 1967, and sixty-five by 1982, the mid-period year for cancer data. Lung cancer data for men under that age (0-64) and living South of the Clyde, were analysed and compared with the results for those over 65.

In the 0-64 range, standardized for age only, SRRs for the first two rings were the only ones to be significantly high [Table 9]. Standardized for age and deprivation, the SRR for the second ring was still significant, not so that for the innermost, although it ranked second [Table 10]. Regression lines continued to show a general trend of decrease with distance. For the over 65, standardized by age group, no SRR was significantly high, that for the innermost ring ranked first (117.53), that for the second was fourth, and that for the third was fifth out of ten. The regression slope still showed an outwards decrease [Table 11]. Standardized by age and deprivation, only the outermost ring had a significant SRR, that for the second ranked second and that for the innermost fourth. The overall decreasing trend with distance is not reflected by the regression slope (+0.001642, non-significant) because of relatively high SRRs in rings 8 and 10, although Stone's statistic peaks at ring 2 [Table 12].

For a twenty-year occupational exposure period, data for the male population were divided between those 54 years old and under (less exposed) and those over 54 (likely longer exposure). For the group 0-54, the only significantly high SRR corresponded to the innermost ring for age standardization only. The SRRs for that and the second ring ranked first and second (age and age-deprivation standardizations). The regression slope was negative in both cases, but not significant [Tables 13 and 14]. In the 65+ group, SRRs for the two innermost rings were the only significantly high after age standardization. After standardizing for both age and deprivation category, the SRR for the second ring still was (the only one) significant, with that for the first ring ranking fourth. Regression slopes were negative [Tables 15 and 16].

Analyses North of the Clyde, males only:

Analyses for males South of the Clyde were replicated North of the river. As explained above, it was judged likely that most of those employed in the Chromium processing factory at the centre of the polluted area would have lived South from the river and, therefore, analyses for that particular sub-area were carried out, centred on possible occupational exposure periods. Nevertheless, this was a simple assumption, impossible to substantiate without data on residence for both former employees and for other people living in the area. But obtaining and processing residence data, if available, would have enormously complicated the present work, removing it from its purpose of being a model for quick assessment into a massive case-control study.

Therefore, to take into account the residential factor, as well as the possible role of the river Clyde as a barrier between areas, the same kind of analyses conducted South of the river were applied to the area North of it. As before, it was assumed that only males had been employed at the Chromium factory and, therefore, only data for men were analysed. To challenge this hypothesis, analyses for women were also carried out for both sides of the Clyde, as will be seen below.

For males of all ages, both standardized by age and by age and deprivation, a clear trend of diminishing SRR with distance appeared, with the four innermost SRRs significantly high in both cases. The slope of the regression SRR/distance was significantly different from zero prior to standardization by deprivation category (p=0.001), and not so after, mainly because the outermost SRRs ceased to be significantly low [Tables 17 and 18].

Occupational exposure periods North of the Clyde:

As seen above, those with a possible occupational exposure period of at least 30 years were to be found among those over 64 years of age. In the age group 0-64 years of age, standardized by age only, SRRs for rings 2, 3, 4 and 6 were significantly high, those for rings 7, 9 and 10 significantly low. After standardization by deprivation category, rings 2, 3 and 4 still had high SRRs, with only ring 7 low. In both cases, regression slopes were significantly different from zero (p=0.001 and p=0.004 respectively) [Tables 19 and

20]. For the 65-85+ age group, standardized by age only, rings 1, 2, 3 and 6 had high SRRs, rings 9 and 10 low, and the regression line was significant (p=0.023). Standardized by deprivation category (Carstairs'), rings 1, 2 and 3 were high again, 7 low, the regression line being non-significant [Tables 21 and 22].

For an occupational exposure period of at least 20 years, the age of cases was most likely over 54 in the mid year of the data period (1982). In the general age group below that age, i.e., 0-54 years, standardized only by age, rings 2, 3 and 4 had significantly high SRRs, rings 7 and 9 significantly low. Standardized by age and deprivation category, only ring 4 was significantly high, ring 7 significantly low. In both cases, the regression line was significant (p=0.001 and p=0.033 respectively) [Tables 23 and 24]. In the age group 55-85+ years, standardized by age, rings 1, 2, 3, 4 and 6 were significantly high, rings 8, 9 and 10 significantly low. The regression line was significant (p=0.001) [Table 25]. Standardized also by deprivation, rings 1, 2 and 3 were significantly high, ring 7 low, and the regression line was non-significant [Table 26].

It must be pointed out that the population of the first half-ring North of the Clyde is quite low and, therefore, the numbers of observed and expected cases are also low and their SRRs have wide confidence intervals. These numbers ranged from a total of 15 to, in the studies for the 0-54 age group, two.

Observed excess cases in males.

The observed excess cases in males, North and South of the Clyde, were distributed as follows:

- North of the Clyde, the number of excess cases (i.e., those above the expected number at the overall rate) of male Lung Cancer in the first three rings combined peaks in the 65+ age group, both after standardization by age only (0-54 years: 23 to 24 excess cases; 55-64 years: 62 to 63 excess cases; 65+ years: 79 to 80 excess cases) and by age and deprivation (0-54 years: 13 to 14 excess cases; 55-64 years: 54 to 55 excess cases; 65+ years: 70 to 71 excess cases). The same peak is evident for the first four rings combined.

- South of the Clyde, the number of excess cases of male Lung Cancer in the first two rings peak in the 55-65 age group, both standardized by age (0-54 years: 18-19 ; 55-

64 years: 47-48 ; 65+ years: 40-41) and by age and deprivation (0-54 years: 14-15 ; 55-64 years: 37-38 ; 65+ years: 23-24), with those above 65 following a pattern similar to female Lung Cancer.

Three rings were included North of the Clyde because of the small population of the innermost one.

Not all the excess cases indicated above occurred in rings with significantly high excesses of disease. Once the significance level of the study was chosen (in this case 0.05, two-tailed) all non-statistically significant excesses had to be rejected as due to chance. On the other hand, when a ring was found to have a significantly high SRR, a minimum excess number of cases could be worked out, according to the lower limit of its 95% confidence interval. Standardized by age and deprivation, statistically significant excess cases by ring and their corresponding minimums were as indicated below. The age group 55-64 is now omitted, since no analysis was carried out for it, its figures above having been calculated from the tables.

1 - South of the Clyde (where the polluted areas are sited).

- Males, all ages. Excess of 64-65 cases (minimum 22-23) between 1 and 2 kilometres from the centre. An increase of 13.94% (minimum 4.4%), or 4-5 extra cases (minimum 1-2) over 15 years per 1,000 men. The overall rate South of the Clyde (1975-89) for all men was 24.63/1000.

- Males aged 55 years and over. Excess of 55-56 cases (min. 14-15) between 1 and 2 kilometres from the centre. An increase of 12.95% (min. 3.1%), or 13-14 extra cases (min. 3-4) per 1000 men aged over 55 years. The overall rate South of the Clyde for men 55 and over was 101.3/1000.

2 - North of the Clyde (the first two rings were combined, since figures in the first one were often very small. Minimums are worked out conservatively, using the second ring's lower limit for its confidence interval).

- Males, all ages (1). Excess of 57-58 cases (min. 23-24) inside 2 km. from the centre. An increase of 34.65% (min. 11.7%), or 12-13 extra cases (min. 4-5) per 1000 men. The overall rate North of the Clyde for all men was 28.78/1000 (South of the Clyde: 24.63/1000).

- Males, all ages (2). Excess of 82-83 cases (min. 42-43) between 2 and 3 km. from the centre. An increase of 19.45% (min. 9.3%), or 7-8 extra cases (min 3-4) per 1000 men.

- Males, all ages (3). Excess of 52-53 cases (min. 3-4) between 3 and 4 km. from the centre. An increase of 8.52% (min. 0.5%), or 3-4 extra cases (min. 1) per 1000 men.

- Males aged under 55 years. Excess of 17-18 cases (min. 1-2) between 3 and 4 km. from the centre. An increase of 30.7% (min. 2.6%), or 1-2 extra cases (min. 1) per 1000 men under 55. The overall rate North of the Clyde for this age group was 3.87/1000 (South of the Clyde: 3.26/1000).

- Males aged 55 years and over (1). Excess of 40-41 cases (min. 18-19) inside 2 km. from the centre. An increase of 34.38% (min. 10.3%), or 34-35 extra cases (min. 10-11) per 1000 men 55 and over. The overall rate North of the Clyde for this age group was 116.76/1000 (South of the Clyde: 101.3/1000).

- Males aged 55 years and over (2). Excess of 75-76 cases (min. 37-38) between 2 and 3 km. from the centre. An increase of 19.91% (min. 9.1%), or 23-24 extra cases (min. 11-12) per 1000 men 55 and over.

- Males aged 65 years and over (1). Excess of 34-35 cases (min. 4-5) inside 2 km. from the centre. An increase of 34.61% (min. 3.8%), or 60-61 extra cases (min. 8-9) per 1000 men 65 and over. The overall rate North of the Clyde for this age group was 159.94/1000 (South of the Clyde: 139.06/1000).

- Males aged 65 years and over (2). Excess of 36-37 cases (min. 4-5) between 2 and 3 km. from the centre. An increase of 14.06% (min. 1.5%), or 22-23 extra cases (min. 2-3) per 1000 men 65 and over.

Analyses for women only on each side of the Clyde:

Unlike those for men, the results for women over the whole area had not showed a trend of high central SRRs diminishing with distance [Tables 5 and 6]. To assess possible local trends for women living on either side of the Clyde, data for the North and the South were analysed separately, although no possible occupational periods were taken into account. South of the river, standardized by age, ring 7 was significantly high and rings 5 and 9 significantly low. SRRs for rings 1, 2, 3 and 4 ranked 2nd, 3rd, 6th and 5th respectively. The regression slope was non-significant. Standardized by age and deprivation, also ring 7 was high and rings 5 and 9 low. Rings 1 to 4 ranked 8th, 2nd, 6th and 3rd respectively. The regression slope changes from negative (-0.01124, Stone = ring 1) to slightly positive (0.00126, Stone = ring 7). This reversal was mainly due to a decrease in SRR for the first ring from 106.93 to 88.41 [Tables 27 and 28].

North of the Clyde, standardized by age, rings 2, 3 and 6 had significantly high SRRs and rings 9 and 10 significantly low. The regression slope was negative and significant ($p = 0.022$) [Table 29]. After standardization by deprivation category, only ring 3 was high, the regression slope being non-significant [Table 30].

As with males, standardized by age and deprivation, the excess cases for women in the only ring with statistically raised SRR were:

- Females, all ages, North of the Clyde. Excess of 29-30 cases (min. 3-4) between 2 and 3 km. from the centre. An increase of 17.16% (min. 1.6%), or 2-3 extra cases (min. 1) per 1000 women. The overall rate North of the Clyde for all women was 11.7/1000 (South of the Clyde: 9.50/1000).

7.1.2 - Pharyngeal cancer:

Only analysis for total population were conducted, since the numbers were low. Neither standardization for age nor for age-deprivation showed any statistically high SRR, although that could have been due to the mentioned low numbers and the consequently wide confidence intervals. Those above 100 clustered in the 3-7 km.

distance. Regression slopes were negatives in spite of Stone peaking at ring 7 in both cases, because of low SRRs in the last three rings [Tables 31 and 32].

7.1.3 - Nasal cancer:

The analyses were for total population only. No statistically significant SRR was found either after standardization by age or by age and deprivation category. The numbers of registrations by ring (WoS Cancer Register, 1975-89) were low (1, 8 and 8 respectively for the first three rings, overall maximum of 13 for the fourth ring). The regression lines were negative, indicating a decreasing trend for SRRs with distance from the centre, and non-significant [Tables 33 and 34].

7.1.4 - Chronic obstructive pulmonary disease (COPD):

This analysis was based on SMR1 data, cases (patients, linked) and discharges (number of episodes). Since influencing factors like smoking (although to some degree accounted for by standardization by deprivation category) are still more prevalent in males, each sex was also analysed separately, the relatively high numbers allowing this.

For individual patients of both sexes admitted to hospital between 1981-91, standardization by age produced statistically high SRRs in the 6th, 7th and 8th rings, that for the second ring being statistically low. The SRR for the innermost ring ranked fifth, that for the third was fourth. The regression line showed a non-significant increase with distance [Table 35]. Standardized by age and deprivation, the four innermost rings had statistically low SRRs, with that for the innermost being the lowest of the ten. SRRs were statistically raised between the 6th. and 9th. rings. The regression line showed a significant ($p=0.045$) increase of SRR with distance from the polluted areas [Table 36].

The results for SMR1 discharges in total population were almost identical as for cases. Standardized by age group, rings 6 to 8 had significantly high SMRs, that for the second ring was statistically low, and the regression line showed a non-significant increase with distance [Table 37]. Standardized by age and deprivation, SMRs were significantly high for rings 6 to 9 and those for 1 to 4 significantly low. The regression slope was not significant, with a p=0.068 [Table 38].

In the analyses of numbers of cases, for males only, after standardization by age, SRRs were significantly high in rings 6 to 8. The SRR for the first ring ranked 5th, 8th for the second, and 4th for the third ring. Standardized by age and deprivation, the SRRs for rings 7 and 8 were significantly high, and significantly low for rings 1 and 2. The SRR for the 3rd ring ranked 6th. Standardized by age only, the regression slope was slightly negative (-0.00956) and non-significant, although Stone was highest at ring 8, because of very low SRRs in the two last rings. The slope became positive (0.010961, Stone also highest at ring 8), but non-significant, after standardization by deprivation, because the trend of increase with distance became more steady [Tables 39 and 40].

Numbers of discharges for males, standardized by age, had a significantly high SRR at the first ring. Those for rings 2 and 4 were significantly low, with that for ring 3 ranking in 5th position out of the ten. In rings 6, 7 and 8, SRRs were significantly raised. The regression line was negative (-0.00874, Stone = ring 1) and non-significant [Table 41]. Standardized by age and deprivation, the first ring did not have a significant SRR. Rings 2 and 4 had, again, statistically low SRRs, while those for rings 6 to 8 were high. The regression slope became positive (0.01447, Stone = ring 9) [Table 42].

For females, numbers of cases standardized by age had significantly low SRRs in rings 2 and 4. The first ring ranked 4th and the second was 6th. Rings 6 and 7 had significantly high SRRs. The regression slope was non-significant and negative (-0.00367) in spite of a Stone = ring 8, because of significantly low SRRs in the outermost rings [Table 43]. Standardized by age and deprivation, the SRR for the innermost ring was significantly low and that for the second ring ranked 7th. Rings 3 and 4 had, again, significantly low SRRs. Rings 6 and 7 had statistically raised SRRs. The regression slope became positive (0.020668, p = 0.063, Stone = ring 9) once the outer rings were no longer significantly low [Table 44].

Hospital discharges of females, standardized by age, had SRRs for rings 2 to 4 significantly low, that for the innermost ring ranked 5th and for rings 6 to 8 were high. Standardized by age and deprivation, the four innermost rings had SRRs significantly low, those for the five outermost were significantly high, and both regression slopes were positive, non-significant [Tables 45 and 46].

7.1.5 - Upper respiratory irritation:

Males and females were analysed together, as total population. In cases, standardized by age, none of the five inner rings had a significant SRR. The innermost ring ranked 4th by SRR, the second was 8th and the third was 2nd. Only ring 6 had a significantly high SRR. Standardized by age and deprivation category, only the outermost ring had a significant (low) SRR. Ring 1 (innermost) ranked 6th and ring 3 was 3rd. There was no evident trend with distance, with both regression slopes only slightly negatives (-0.008627 and -0.004947 after standardization by deprivation). That the Stone statistic was highest at ring 8 after standardization by deprivation is explained by a lower SRR at the first ring, while the slight peak in the mid-to-outer rings and the significantly low SRR at the outermost ring remain [Tables 47 and 48].

For discharges, and for all standardizations, the pattern was very similar. No significant SRR appeared for the first five rings, and only rings 6 and 8 were significantly high. Of the first four rings, only the third. had an SRR above 100, with SRRs for the other rings slightly below this figure. Regression slopes were slightly negative (-0.008909 and -0.004248), in spite of a paradoxical Stone = 8 in both cases, because, as with cases, SRRs were significantly low at the outermost rings [Tables 49 and 50].

7.1.6 - Skin irritation:

This parameter was analysed for the whole population and also for the age group 0-19 years (again, both sexes together), since this age group was the most likely to come in contact with Chromium slag at playgrounds and sports pitches.

For numbers of cases in total population, for all standardizations, all four innermost rings had SRRs significantly low, while the three outermost rings had SRRs statistically high. Regression lines indicated an increase in SRR with distance from the polluted areas, and their slopes were significantly different from zero, both at p=0.001 [Tables 51 and 52].

The results were virtually identical in the analysis of numbers of discharges, with rings 1 to 5 significantly low and 8 to 10 significantly high after age standardization. After standardization by age and deprivation category, rings 1 to 7 showed significantly low SRRs, while rings 8 to 10 had theirs statistically raised again. The increase of SRRs with distance was also evident, and regression slopes were significant, at p=0.001 [Tables 53 and 54].

In the age group 0-19 years, both standardizations (by age and by age and deprivation) of numbers of cases, gave identical results, with rings 3 and 4 showing low SRRs, rings 9 and 10 high. In both cases, SRRs for the innermost ring were the lowest. Regression slopes were significant, at p=0.001 [Tables 55 and 56].

For the analysis of discharges in the 0-19 year group, standardizations by age and by age and deprivation, gave identical results for rings 1, 3, 4 and 5, all with significantly low SRRs. Standardized by age, ring 10 had a statistically high SRR; by age and deprivation, those for rings 9 and 10 were high. Regression slopes were significant, again at p=0.001 [Tables 57 and 58].

7.1.7 - Eye irritation:

For the same reason as with the preceding parameter, eye irritation was analysed for the whole population and for the age group 0-19 years (both sexes together). In cases for total population, after standardizations by both age and age and deprivation, the third ring showed a significantly high SRR, while the SRR for the innermost ring was the highest (but with the smallest number of observed cases). Regression slopes were negative but non-significant [Tables 59 and 60].

In discharges for total population, again after both standardizations, the 3rd ring had a significantly high SRR, with rings 1 and 2 having theirs also above 100, but not significant. Regression slopes were negative, but non-significant [Tables 61 and 62].

In the age group 0-19, the analysis of case numbers did not yield any significant SRR. In rings 1, 2 and 4 SRRs were above 100, but the number of observed cases were low, particularly for the two innermost rings [Tables 63 and 64]. Regression slopes were negative and non-significant. For numbers of discharges, again, no significantly high SRR was found. SRRs for discharges in the inner rings were lower than for cases, particularly after standardizing for age and deprivation. Regression slopes were negative, although Stone was = 5 after standardization by deprivation [Tables 65 and 66].

7.1.8 - Upper digestive tract irritation:

The parameter was analysed for total population and for the age group 0-9 years, to account for geophagia (i.e., the pathological ingestion of soil or dirt that occurs in some children). In the analysis of SMR1 registered cases, for total population, after standardizations by both age and age and deprivation, the four innermost rings had SRRs significantly low (lowest at the first ring), while the three most external rings had significantly high SRRs [Tables 67 and 68]. For discharges, after standardization by age, the four internal rings had significantly low SRRs, while rings 6 to 10 had theirs significantly high. After standardizing by age and deprivation, rings 8 to 10 had statistically raised SRRs [Tables 69 and 70]. All four regression slopes were positive (SRR increasing with distance) and significantly different from zero (p=0.001).

For cases in the age group 0-9 years, after both standardizing by age and by age and deprivation, the third ring had a significantly low SRR, while the innermost ring had the lowest SRR in both cases (but also the smallest number of cases, 3, and therefore the widest confidence interval). Among the five rings nearer to the Main Polluted Area there were three with SRRs above 100, none statistically significant. Ring 2 had an SRR of 104.74 (1-2 extra cases in eleven years a population of 4,420 children under ten years in the whole ring). Ring 4, next to the contaminated Duke's Road playground had an SRR of 104.77 for cases (4 to 5 extra cases in a population of 11,727 children), and ring 5 had an SRR of 120.47 (12 to 13 extra cases in a population of 8,633 children, almost one extra case per year) [Tables 71 and 72]. For discharges, rings 1 and 3 had statistically low SRRs, ring 4 had a (non-significant) SRR of 108.73 (10-11 extra discharges), and rings 5 and 9 statistically high (32-33 extra discharges in ring 5), again for both standardizations [Tables 73 and 74]. All four regression slopes indicated increase of SRR with distance, but none were significant.

7.1.9 - Kidney dysfunction:

Cases and discharges for this pathology were analysed for total population only. Numbers of cases, standardized by age, did not show any significant SRR, with ring 1 having the lowest one, ring 2 ranking 8th, and ring 3 ranking 4th. The regression slope was positive and non-significant [Table 75]. Once standardized by age and deprivation category, ring 4 had a significantly low SRR, while that for ring 10 was significantly high. By SRR, the three innermost rings ranked 10th, 8th and 6th respectively. The regression slope was positive and significant, at p=0.009 [Table 76].

In the analysis of discharges, standardized by age, rings 1, 2 and 4 had statistically low SRRs, while rings 6 and 8 had statistically high ones [Table 77]. Standardized by age and deprivation, the four innermost rings had significantly low SRRs, and the three most external had theirs statistically high [Table 78]. Regression slopes for both standardizations were positive, indicating increasing SRRs with distance from the centre, and significantly different from zero, at p=0.044 (standardized by age) and p=0.006 (standardized by age and deprivation category).

7.1.10 - Asthma:

Asthma was analysed for total population and for the age group 0-24, to account for juvenile asthma. In cases for general population, after standardization by age, SRRs for rings 5, 6 and 7 were significantly high, while SRRs for rings 9 and 10 were significantly low. SRRs for rings 1 to 4 ranked 8th, 7th, 5th and 4th, respectively. After standardization by age and deprivation category, only SRRs for rings 5 (high) and 9 (low) were significant. The rankings of SRRs for the first four rings were 10th (lowest), 7th, 5th and 4th. Both regression slopes were slightly negative, in spite of both having a Stone = 7, because of significantly low SRRs in rings 9 and 10 [Tables 79 and 80].

In discharges for total population, after standardizing for age, rings 5, 6 and 7 had significantly high SRRs, and rings 9 and 10 had theirs significantly low. The regression slope was negative and non-significant because, as with cases, of significantly low outermost SRRs (Stone = 7) [Table 81]. After standardization by both age and deprivation, again rings 5, 6 and 7 had significantly high SRRs, while rings 1, 3, 9 and

10 had SRRs significantly low. Significantly low central SRRs made the regression slope positive in this case (Stone also = 7), but non-significant [Table 82].

In SMR1 cases for the age group 0-24, both after standardization by age and by age and deprivation, only ring 10 had a significant SRR (low). The rankings of SRRs for the first four rings were 9th, 7th, 3rd and 1st (age standardization), and 10th, 7th, 3rd and 1st (age and deprivation standardization). Significantly low SRRs on ring 9 made both regression slopes slightly negative, although standardized by age only Stone was highest at ring 6 (ring 4 after standardization by deprivation) [Tables 83 and 84].

For discharges in the age group 0-24, after standardization by age, rings 6 and 7 had significantly high SRRs, and rings 9 and 10 significantly low ones. With the two outermost SRRs significantly low, the regression slope was negative (and nearly significant at $p = 0.065$), in spite of a Stone = 7 [Table 85]. Standardized by both age and deprivation, again rings 6 and 7 had statistically high SRRs, but only ring 10 had a significantly low one. The SRR for ring 2, although non-significant, ranked first. Even though Stone was, again, highest at ring 7, with a significantly low SRR in ring 10 the regression slope was again negative and non-significant [Table 86].

7.2 - Other health parameters:

7.2.1 - Leukaemia:

This parameter was analysed for total population and for the age group 0-14 years, to investigate both all-age groups and childhood leukaemia. In total population, for the number of registrations (West of Scotland Cancer Register's), after standardizations for both age and age and deprivation, the only significant SRR (high) in both cases was that for the 5th. ring. Also, none of the first four rings had an SRR above 100. The regression slopes were positive, indicating a growing trend with distance for SRRs, and non-significant, although Stones peaked at rings 5 because of their very high SRRs [Tables 87 and 88].

In the age group 0-14 (also males and females together), there was no statistically significant SRR after standardization by age, and three significantly low SRRs (rings 3, 7 and 9) after standardization by age and deprivation. The numbers of registrations by ring were small (0, 7 and 4 respectively for the first three rings, with an overall maximum of 17 for ring 4). There were some non-significant SRRs above 100 in the five inner rings, with an excess of 2-3 cases in the second ring between 1975 and 1989 in a population of 7,507 under 15 in the whole ring (this excess virtually disappeared, 0-1 cases, after standardization by deprivation category), an excess of 6-7 cases in ring 4 in a population of 16,947 under 15s (2-3 after standardization by deprivation) and an excess of 6-7 in ring 5 in a population of 15,007 (4-5 after standardization by deprivation). The regression slopes were positive (Stone after standardization by deprivation again peaking at ring 5) and non-significant [Tables 89 and 90]. With the first ring (no cases) left out of the regression analysis, slopes turned from slightly positives to slightly negatives (Tables 80-90 b).

7.2.2 - Skin cancer:

This was also analysed for total population only (males and females together). After standardization by age, SRRs for rings 1, 3 and 4 were significantly low, with SRRs for rings 5 and 10 significantly high. The regression slope was positive and significantly different from zero, at p=0.011 [Table 91]. Standardized by age and deprivation category, SRRs for the three innermost rings were significantly low, while SRRs for rings 5, 9 and 10 were found to be significantly high. The regression slope in this case was also positive and significant, with p=0.005 [Table 92].

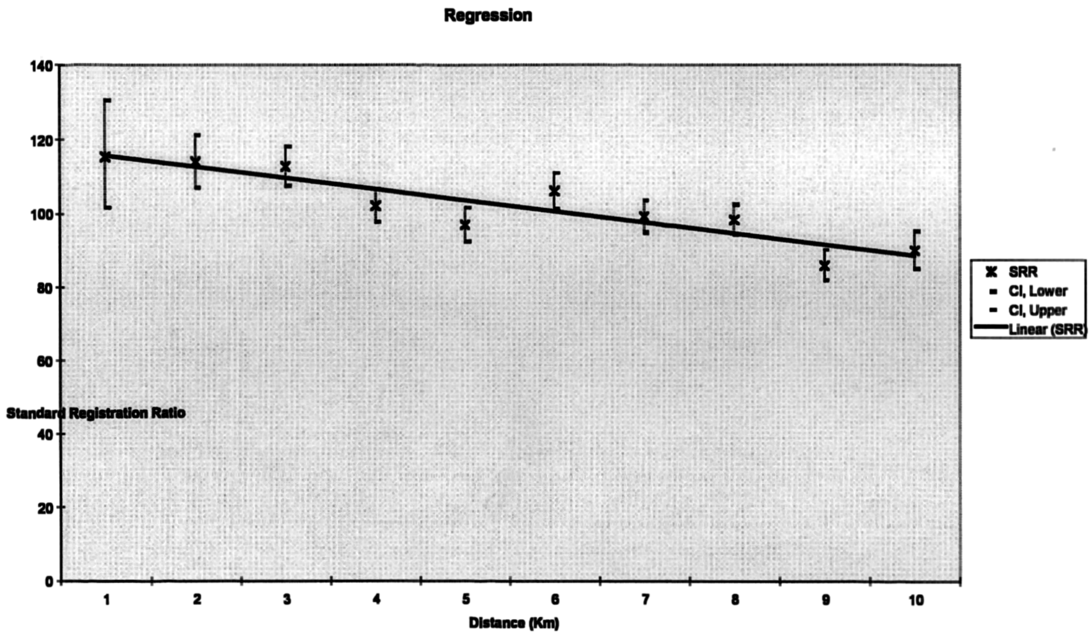
7.2.3 - Congenital abnormalities:

The population under study was that of total births (live, stillbirths and induced abortions). Standardized by overall prevalence in the study area, ring 2 had a significantly low SRR, while rings 3 and 4 had significantly high SRRs. This was also the case after standardization by overall prevalence and deprivation category. In both sets of standardizations, rings 1 and 2 had the lowest SRRs (with ring 1 having the lowest overall) and rings 3 and 4 the highest (that for ring 3 being the highest overall). Standardized by age only and by age and deprivation, both regression slopes were positive (trend of increasing SRR with distance) and non-significant, although Stone was highest for both at ring 4 because of the peaks at rings 3 and 4 [Tables 93 and 94].

Table 1

LUNG CANCER, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	254	220.06	115.42	101.7 - 130.5	(high: p < 0.015)
2	1030	903.05	114.06	107.2 - 121.2	(high: p < 0.005)
3	1823	1616.61	112.77	107.6 - 118.1	(high: p < 0.005)
4	2002	1960.90	102.10	97.7 - 106.7	
5	1778	1832.84	97.01	92.6 - 101.6	
6	1906	1797.40	106.04	101.3 - 110.9	(high: p < 0.01)
7	2075	2092.85	99.15	94.9 - 103.5	
8	2192	2231.40	98.23	94.2 - 102.4	
9	1632	1901.17	85.84	81.7 - 90.1	(low: p < 0.0005)
10	1225	1361.37	89.98	85.0 - 95.2	(low: p < 0.005)



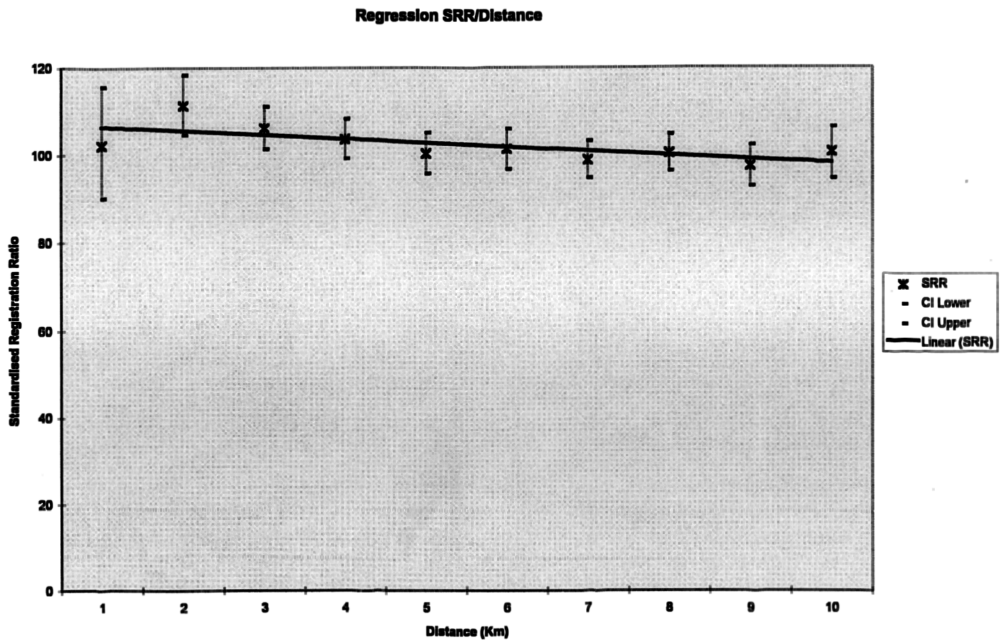
Slope = -0.030005, p<0.001

Max. O/E (Stone) at ring 1.

Table 2

LUNG CANCER, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	254	248.57	102.19	90.0 - 115.6	
2	1030	925.39	111.30	104.6 - 118.3	(high: p< 0.005)
3	1823	1718.01	106.11	101.3 - 111.1	(high: p< 0.01)
4	2002	1933.20	103.56	99.1 - 108.2	
5	1778	1774.68	100.19	95.6 - 105.0	
6	1906	1881.92	101.28	96.8 - 105.9	
7	2075	2103.38	98.65	94.5 - 103.0	
8	2192	2186.05	100.27	96.1 - 104.6	
9	1632	1677.63	97.28	92.6 - 102.1	
10	1225	1219.45	100.46	94.9 - 106.2	



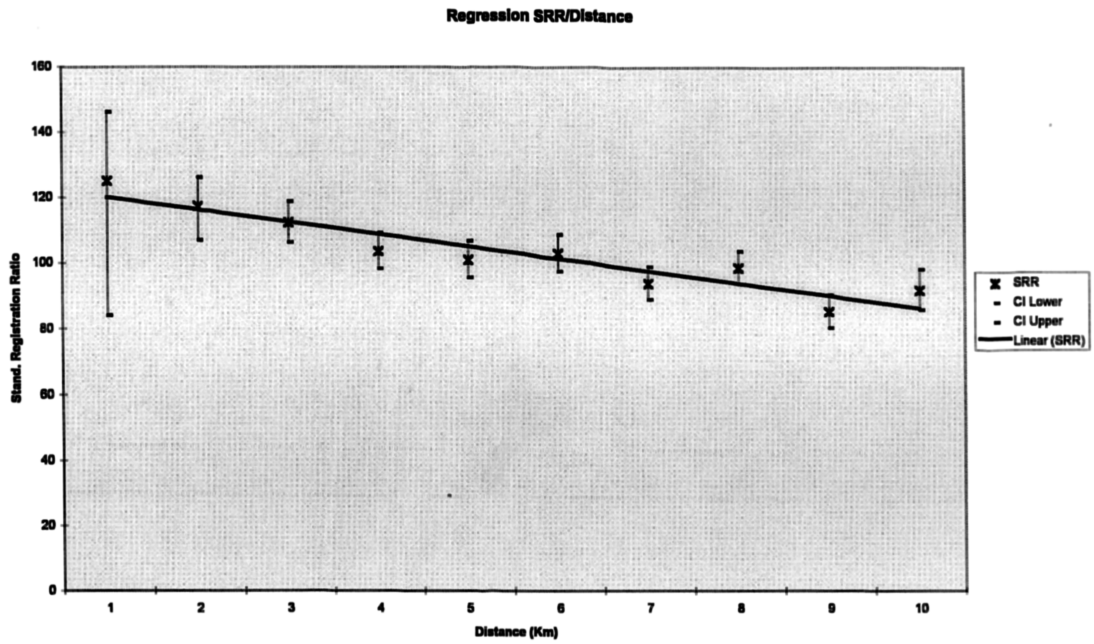
Slope = -0.010717, p<0.01

Max. O/E (Stone) at ring 2

Table 3

LUNG CANCER, MALES.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Expected	SRR	95% CI	
1	189	149.23	126.65	109.2 - 146.1	(high: p< 0.005)
2	737	628.24	117.31	109.0 - 126.1	(high: p< 0.005)
3	1284	1142.77	112.36	106.3 - 118.7	(high: p< 0.005)
4	1392	1344.60	103.53	98.2 - 109.1	
5	1271	1259.08	100.95	95.5 - 106.7	
6	1321	1282.71	102.99	97.5 - 108.7	
7	1386	1477.32	93.82	88.9 - 98.9	(low: p< 0.01)
8	1515	1536.66	98.59	93.7 - 103.7	
9	1135	1331.99	85.21	80.3 - 90.3	(low: p< 0.005)
10	873	950.13	91.88	85.9 - 98.2	(low: p< 0.005)



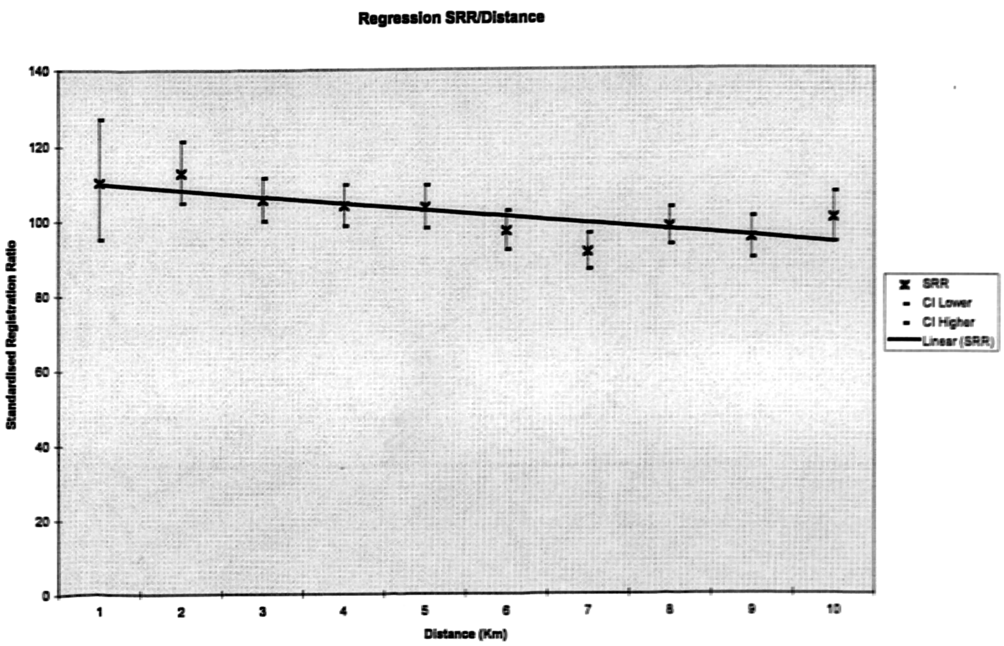
Slope = -0.035286 p < 0.001

Max. O/E (Stone) at ring 1.

Table 4

LUNG CANCER, MALES.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY.

Rings	Obs.	Exp.	SRR	95% CI	
1	189	171.15	110.43	95.2 - 127.3	
2	737	652.68	112.92	104.9 - 121.4	(high: p<0.005)
3	1284	1215.20	105.66	100.0 - 111.6	(high: p<0.025)
4	1392	1338.36	104.01	98.6 - 109.6	
5	1271	1227.71	103.53	97.9 - 109.4	
6	1321	1362.53	96.95	91.8 - 102.3	
7	1386	1518.99	91.24	86.5 - 96.2	(low : p<0.005)
8	1515	1545.78	98.01	93.1 - 103.1	
9	1135	1198.06	94.74	89.3 - 100.4	
10	873	872.25	100.09	93.6 - 107.0	



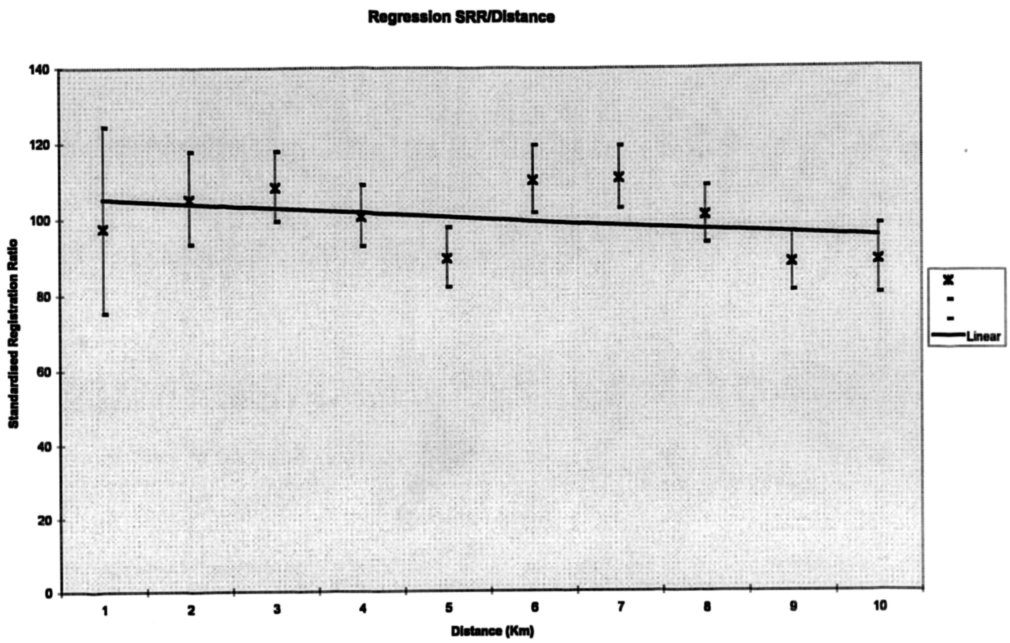
Slope = -0.018115 **p < 0.009**

Max. O/E (Stone) at ring 2.

Table 5

LUNG CANCER, FEMALES.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	65	66.54	97.69	75.4 - 124.5	
2	293	278.34	105.27	93.6 - 118.0	
3	539	497.63	108.31	99.4 - 117.9	
4	610	607.08	100.48	92.7 - 108.8	
5	507	566.83	89.45	81.8 - 97.6	(low: p< 0.01)
6	585	531.29	110.11	101.4 - 119.4	(high: p< 0.01)
7	689	623.31	110.54	102.4 - 119.1	(high: p< 0.005)
8	677	673.99	100.45	93.0 - 108.3	
9	497	568.35	87.45	79.9 - 95.5	(low: p< 0.005)
10	352	401.41	87.69	78.8 - 97.3	(low: p< 0.01)



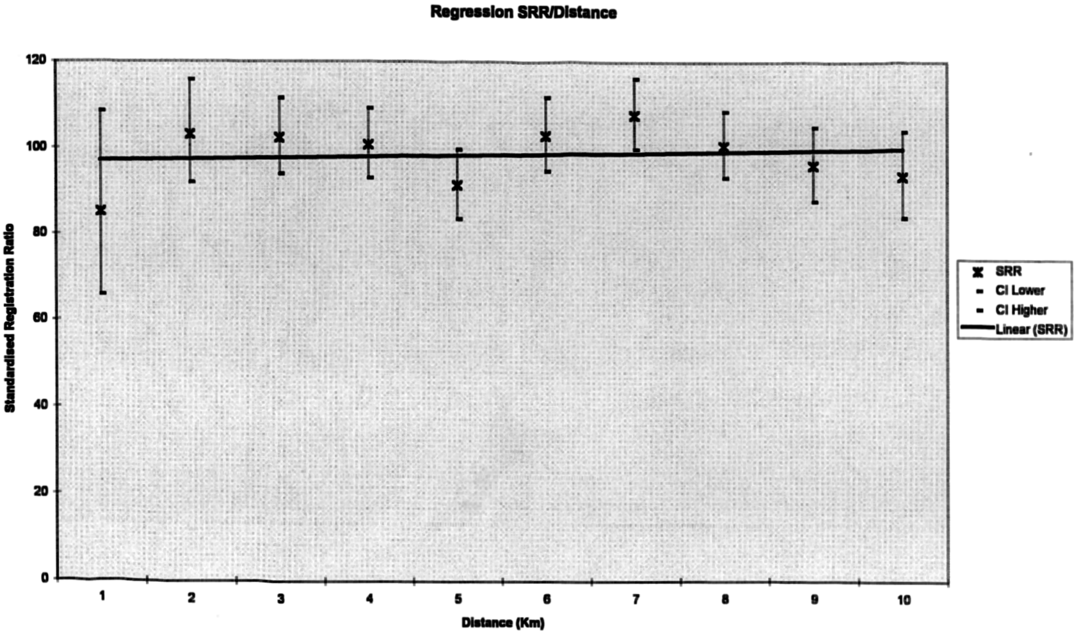
Slope = - 0.01546 p = 0.184

Max. O/E (Stone) at ring 3.

Table 6

LUNG CANCER, FEMALES.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RING , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	65	76.38	85.10	65.7 - 108.5	
2	293	283.93	103.20	91.7 - 115.7	
3	539	526.20	102.43	94.0 - 111.5	
4	610	604.50	100.91	93.1 - 109.2	
5	507	554.13	91.49	83.7 - 99.8	(low:p< 0.025)
6	585	567.50	103.08	94.9 - 111.8	
7	689	638.76	107.86	100.0 - 116.2	(high: p<0.025)
8	677	671.49	100.82	93.4 - 108.7	
9	497	516.35	96.25	88.0 - 105.1	
10	352	375.52	93.74	84.2 - 104.1	



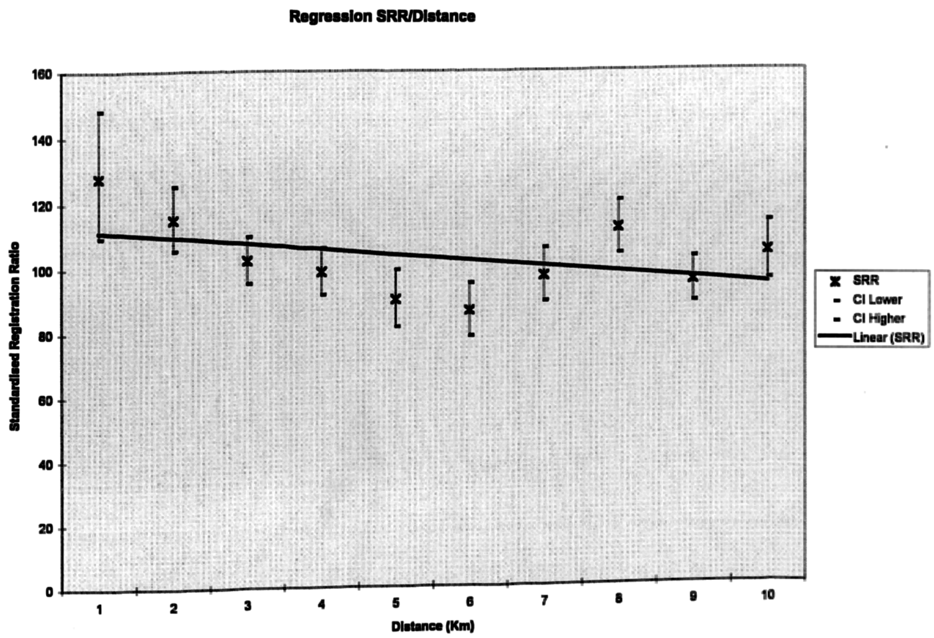
Slope = 0.000446 p < 0.955

Max. O/E (Stone) at ring 3.

Table 7

LUNG CANCER, MALES. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE SOUTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	174	136.08	127.86	109.6 - 148.3	(high:p<0.005)
2	530	461.59	114.82	105.3 - 125.0	(high:p<0.005)
3	779	763.87	101.98	94.9 - 109.4	
4	718	732.48	98.02	91.0 - 105.5	
5	397	444.82	89.25	80.7 - 98.5	(low:p<0.015)
6	415	486.87	85.24	77.2 - 93.8	(low:p<0.005)
7	515	537.12	95.88	87.8 - 104.5	
8	705	637.91	110.52	102.5 - 119.0	(high:p<0.005)
9	701	746.75	93.87	87.1 - 101.1	
10	502	488.45	102.77	94.0 - 112.2	



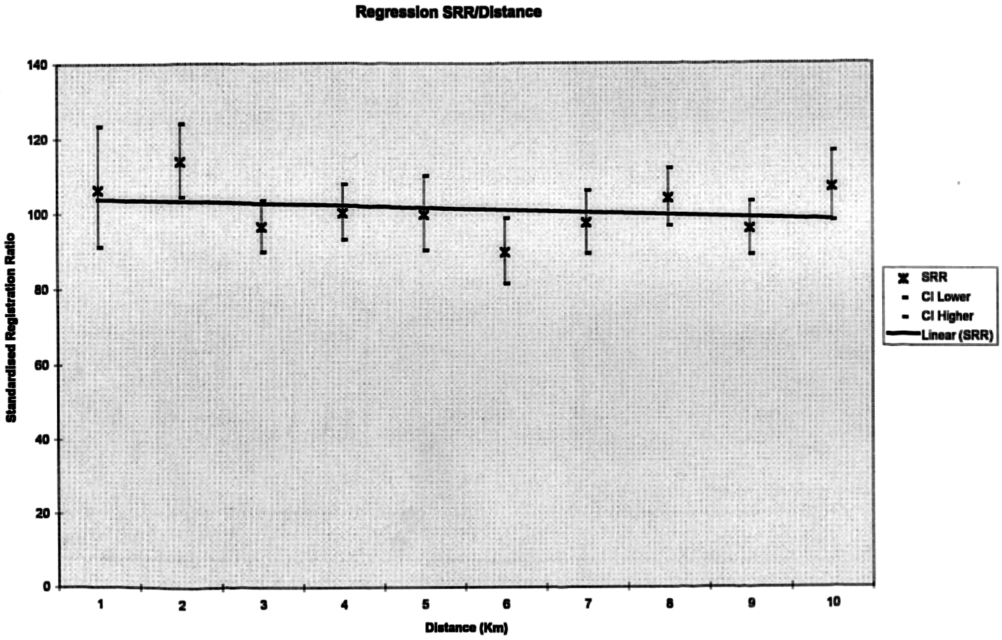
Slope = - 0.01377 **p = 0.309**

Max. O/E (Stone) at ring 1.

Table 8

LUNG CANCER, MALES. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	174	163.48	106.43	91.2 - 123.5	
2	530	465.17	113.94	104.4 - 124.1	(high: p<0.005)
3	779	808.13	96.39	89.7 - 103.4	
4	718	718.24	99.97	92.8 - 107.6	
5	397	399.03	99.49	89.9 - 109.8	
6	415	464.45	89.35	81.0 - 98.4	(low: p<0.015)
7	515	530.52	97.07	88.9 - 105.8	
8	705	679.64	103.73	96.2 - 111.7	
9	701	734.31	95.46	88.5 - 102.8	
10	502	470.98	106.59	97.5 - 116.3	



Slope = -0.005139 p = 0.543

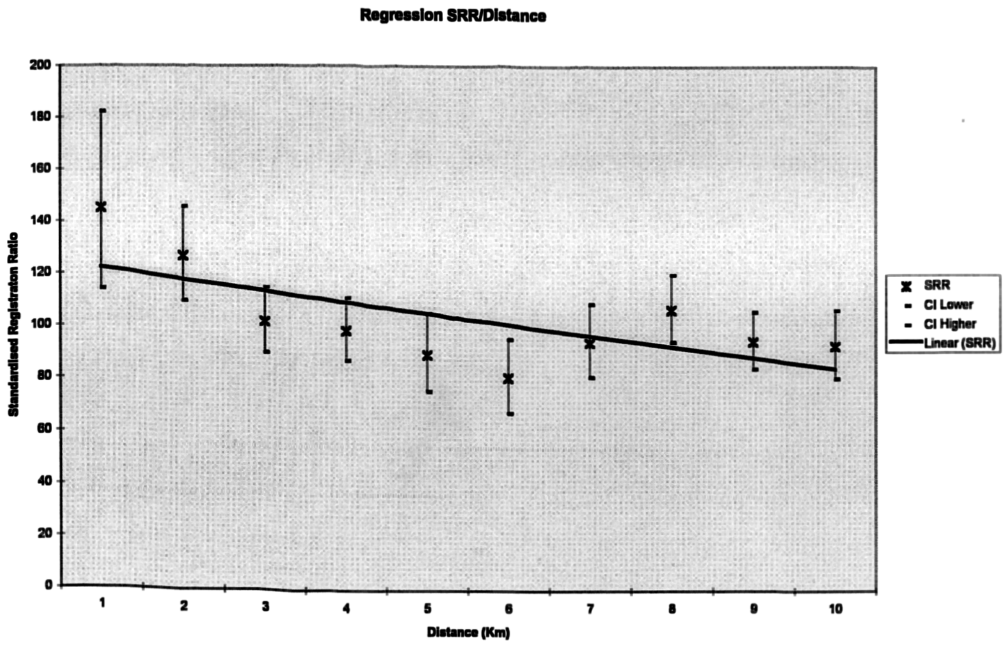
Max. O/E (Stone) at ring 2.

Table 9

LUNG CANCER, MALES, 0-64 YEARS OF AGE. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE SOUTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	74	50.99	145.11	113.9 - 182.2	(high:p<0.0005)*
2	199	156.59	127.08	110.0 - 146.0	(high:p<0.005)
3	272	266.08	102.23	90.4 - 115.1	
4	272	275.01	98.91	87.5 - 111.4	
5	147	163.45	89.94	76.0 - 105.7	
6	136	167.68	81.11	68.0 - 95.9	(low: p<0.01)
7	185	195.12	94.82	81.6 - 109.5	
8	279	259.91	107.34	95.1 - 120.7	
9	307	322.17	95.29	84.9 - 106.6	
10	207	221.02	93.65	81.3 - 107.3	

(*) Exact Poisson



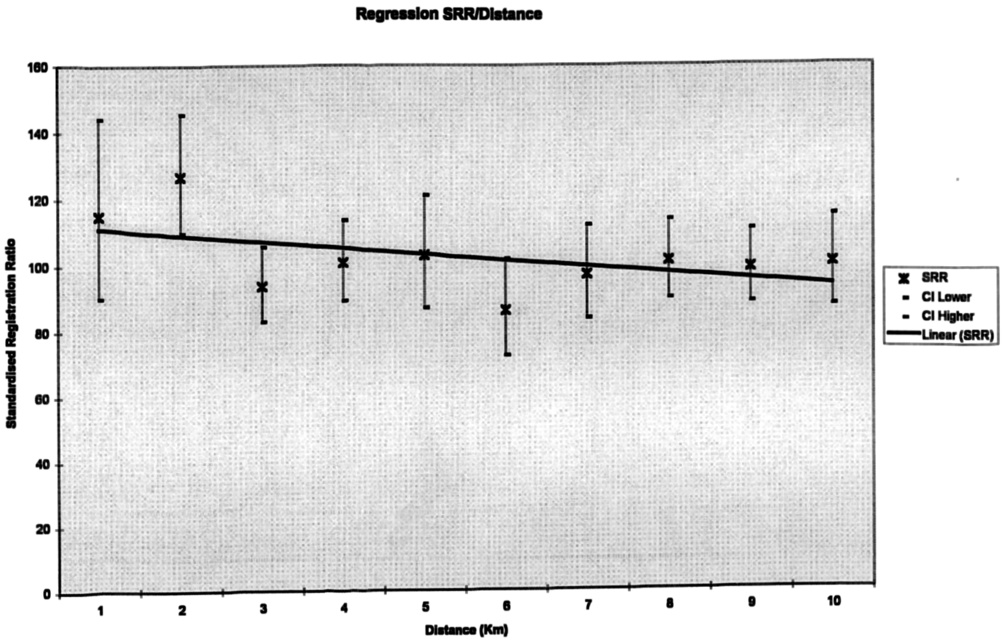
Slope = -0.02845 p = 0.108

Max. O/E (Stone) at ring 1.

Table 10

LUNG CANCER, MALES, 0-64 YEARS OF AGE. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	74	64.36	114.98	90.3 - 144.3	
2	199	156.99	126.76	109.8 - 145.6	(high:p<0.005)
3	272	290.25	93.71	82.9 - 105.5	
4	272	270.61	100.51	88.9 - 113.2	
5	147	143.35	102.54	86.6 - 120.5	
6	136	159.07	85.49	71.7 - 101.1	
7	185	192.35	96.18	82.8 - 111.1	
8	279	278.62	100.14	88.7 - 112.6	
9	307	313.59	97.90	87.3 - 109.5	
10	207	208.82	99.13	86.1 - 113.6	



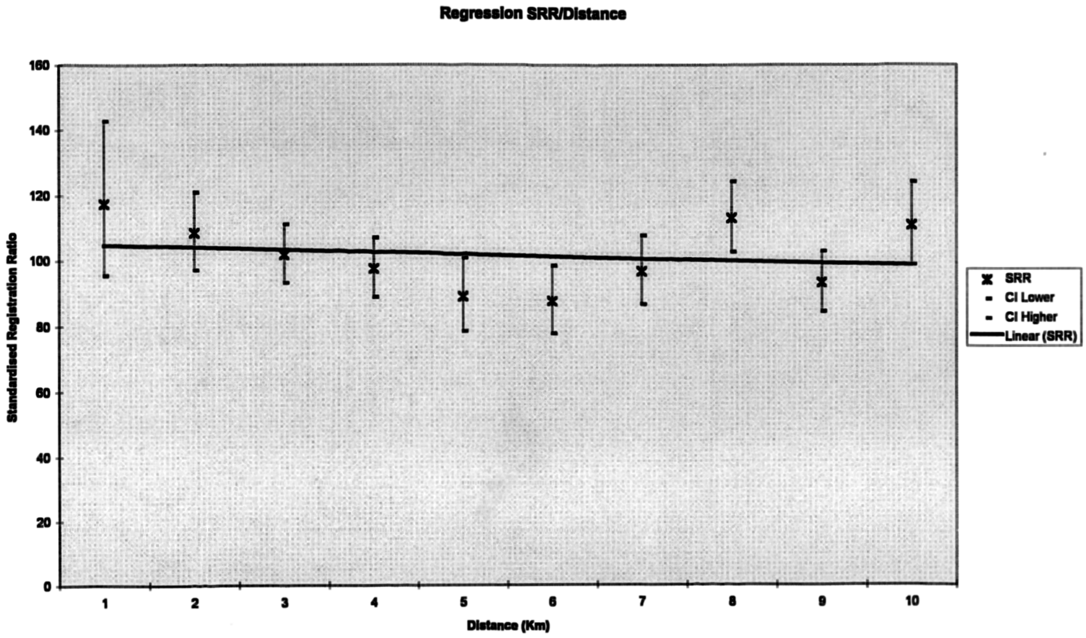
Slope = -0.01556 **p = 0.206**

Max. O/E (Stone) at ring 2.

Table 11

LUNG CANCER, MALES, 65 TO 85+ YEARS OF AGE. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	100	85.09	117.53	95.6 - 142.9	
2	331	305.00	108.52	97.1 - 120.9	
3	507	497.80	101.85	93.2 - 111.1	
4	446	457.47	97.49	88.7 - 107.0	
5	250	281.37	88.85	78.2 - 100.6	
6	279	319.19	87.41	77.5 - 98.3	(low: p<0.015)
7	330	342.00	96.49	86.4 - 107.5	
8	426	378.00	112.70	102.2 - 123.9	(high:p<0.0005)
9	394	424.58	92.80	83.9 - 102.4	
10	295	267.43	110.31	98.1 - 123.6	



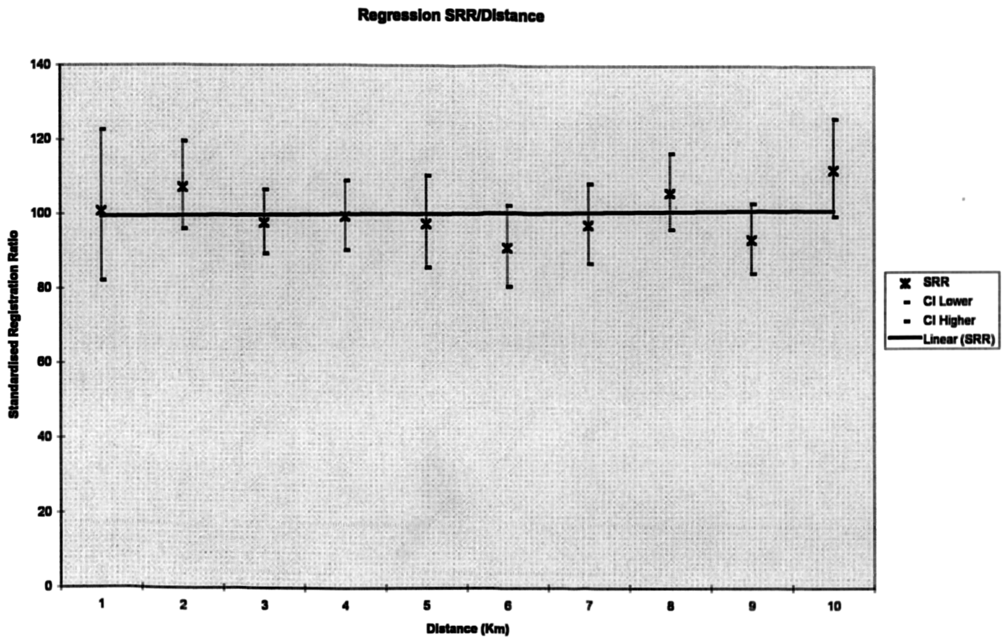
Slope = -0.00416 **p = 0.738**

Max. O/E (Stone) at ring 1.

Table 12

LUNG CANCER, MALES, 65 TO 85+ YEARS OF AGE. SOUTH OF THE CLYDE. OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	100	99.12	100.89	82.1 - 122.7	
2	331	308.18	107.41	96.1 - 119.6	
3	507	517.88	97.90	89.6 - 106.8	
4	446	447.63	99.64	90.6 - 109.3	
5	250	255.68	97.78	86.0 - 110.7	
6	279	305.38	91.36	81.0 - 102.7	
7	330	338.17	97.58	87.3 - 108.7	
8	426	401.02	106.23	96.4 - 116.8	
9	394	420.72	93.65	84.6 - 103.4	
10	295	262.16	112.53	100.1 - 126.1	(high:p<0.025)



Slope = 0.001642 **p = 0.839**

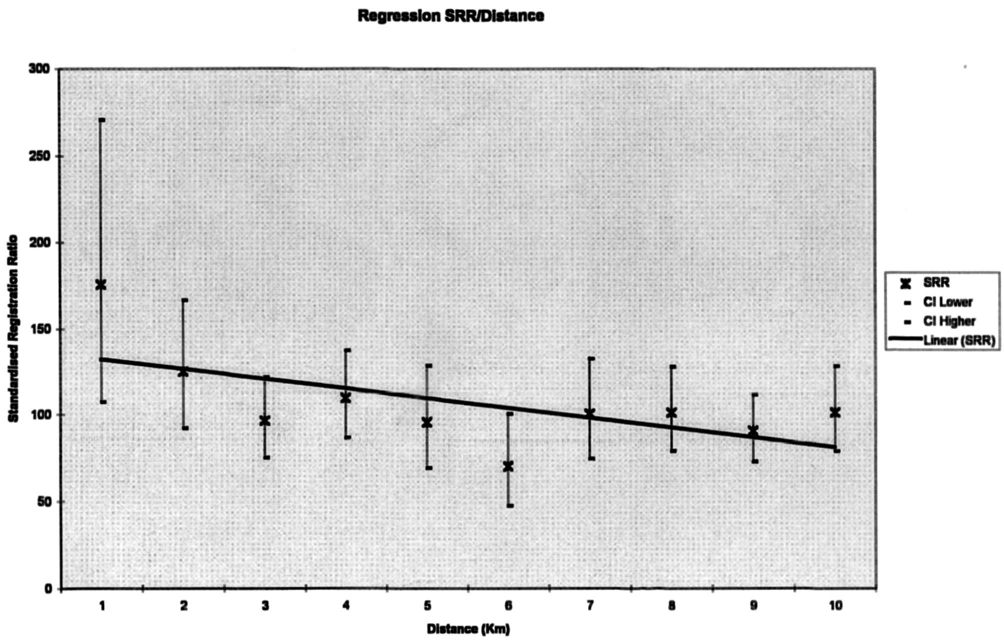
Max. O/E (Stone) at ring 2.

Table 13

LUNG CANCER, MALES, 0-54 YEARS OF AGE. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE SOUTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	20	11.39	175.58	107.3 - 270.4	(high:p<0.013)*
2	47	37.56	125.12	91.9 - 166.4	
3	69	71.55	96.43	75.0 - 122.0	
4	77	70.21	109.67	86.5 - 137.1	
5	43	45.03	95.50	69.1 - 128.6	
6	30	42.75	70.17	47.4 - 100.3	
7	50	49.74	100.53	74.6 - 132.5	
8	70	69.23	101.11	78.8 - 127.7	
9	88	97.22	90.51	72.6 - 111.5	
10	69	68.19	101.19	78.7 - 128.1	

*** - Exact Poisson.**



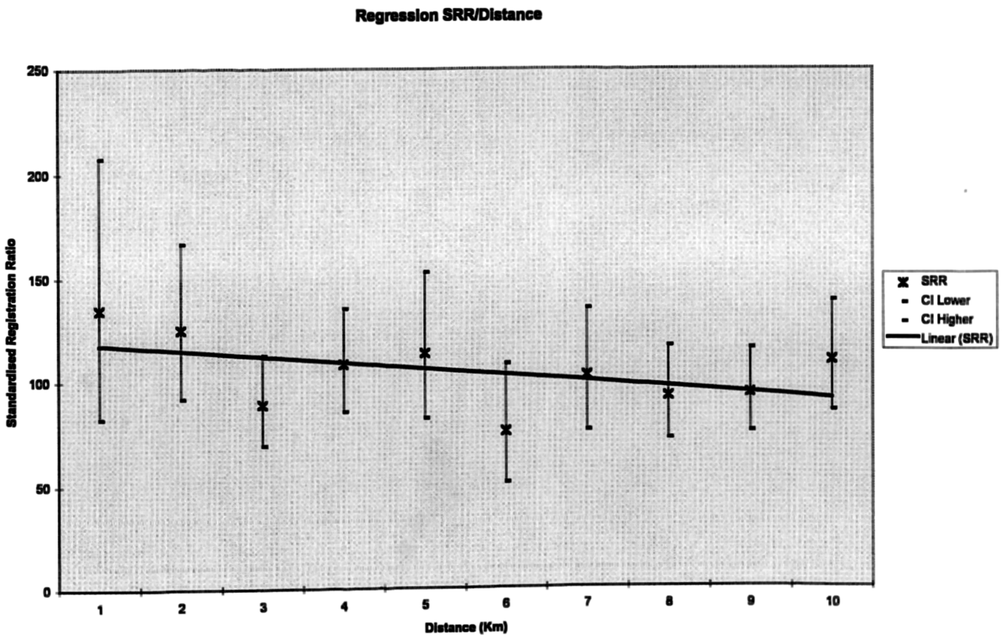
Slope = - 0.03309 **p = 0.171**

Max. O/E (Stone) at ring 1.

Table 14

LUNG CANCER, MALES, 0-54 YEARS OF AGE. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI
1	20	14.83	134.87	82.4 - 207.7
2	47	37.56	125.12	91.9 - 166.4
3	69	77.68	88.83	69.1 - 112.4
4	77	71.36	107.90	85.2 - 134.9
5	43	38.05	113.00	81.8 - 152.2
6	30	39.83	75.32	50.8 - 107.7
7	50	49.07	101.90	75.6 - 134.3
8	70	76.41	91.61	71.4 - 115.7
9	88	94.62	93.00	74.6 - 114.6
10	69	63.46	108.73	84.6 - 137.6



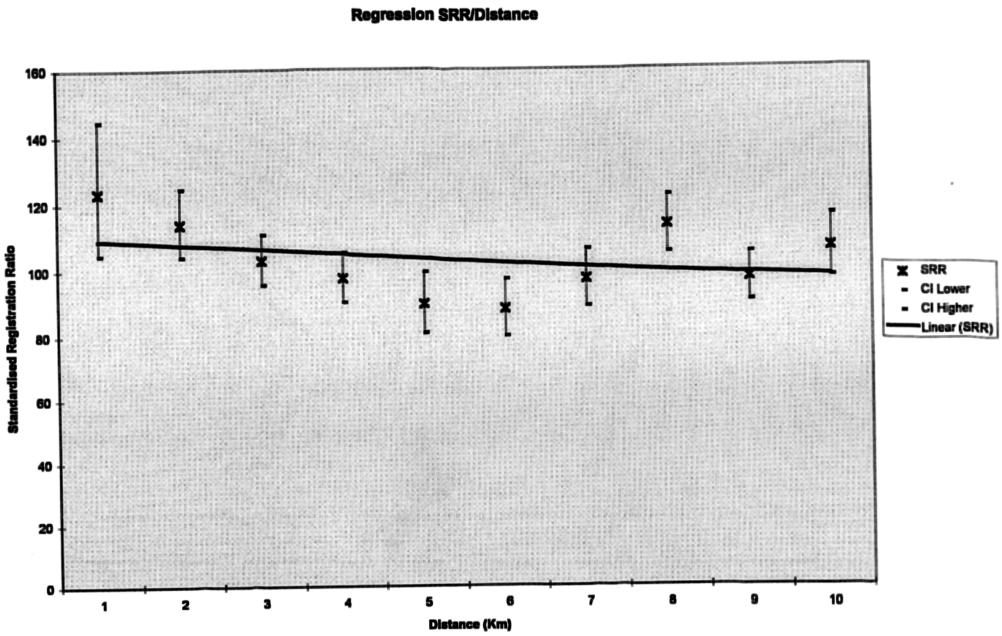
Slope = -0.01983 **p = 0.298**

Max. O/E (Stone) at ring 1.

Table 15

LUNG CANCER, MALES, 55 TO 85+ YEARS OF AGE. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE SOUTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI
1	154	124.69	123.50	104.8 - 144.6(high:p<0.005)
2	483	424.03	113.91	104.0 - 124.5(high:p<0.0005)
3	710	692.32	102.55	95.1 - 110.4
4	641	662.26	96.79	89.4 - 104.6
5	354	399.79	88.55	79.6 - 98.3(low: p<0.015)
6	385	444.12	86.69	78.2 - 95.8(low: p<0.005)
7	465	487.38	95.41	86.9 - 104.5
8	635	568.68	111.66	103.1 - 120.7(high: p<0.005)
9	613	649.52	94.38	87.1 - 102.2
10	433	420.26	103.03	93.6 - 113.2



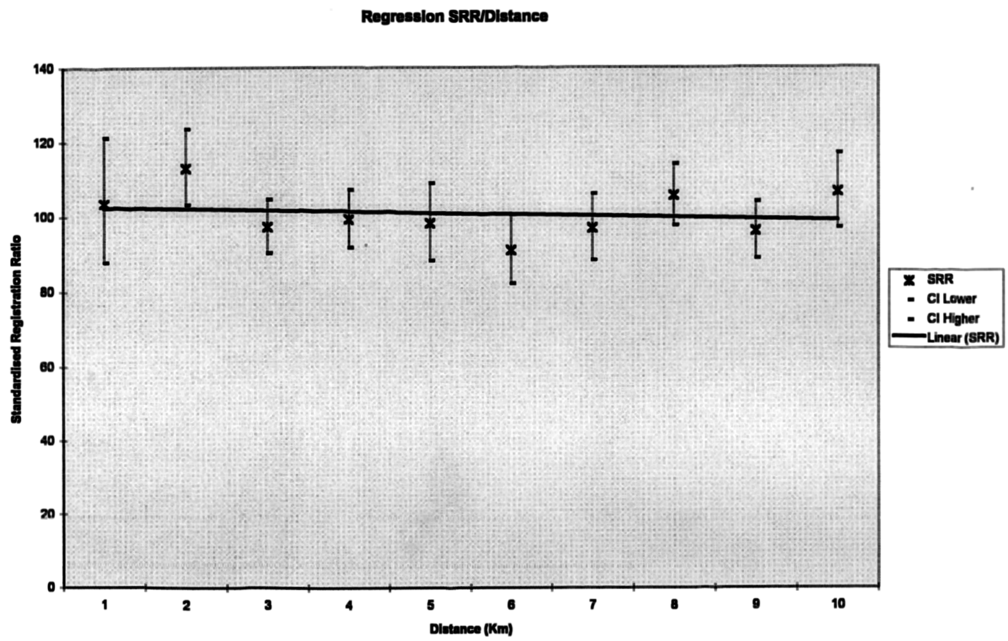
Slope = -0.01145 **p = 0.377**

Max. O/E (Stone) at ring 1.

Table 16

LUNG CANCER, MALES, 55 TO 85+ YEARS OF AGE. SOUTH OF THE CLYDE. OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	154	148.65	103.60	87.9 - 121.3	
2	483	427.61	112.95	103.1 - 123.5	(high: p<0.005)
3	710	730.46	97.20	90.2 - 104.6	
4	641	646.88	99.09	91.6 - 107.1	
5	354	360.98	98.07	88.1 - 108.8	
6	385	424.62	90.67	81.8 - 100.2	
7	465	481.45	96.58	88.0 - 105.8	
8	635	603.23	105.27	97.2 - 113.8	
9	613	639.69	95.83	88.4 - 103.7	
10	433	407.52	106.25	96.5 - 116.7	



Slope = -0.00345 p = 0.664

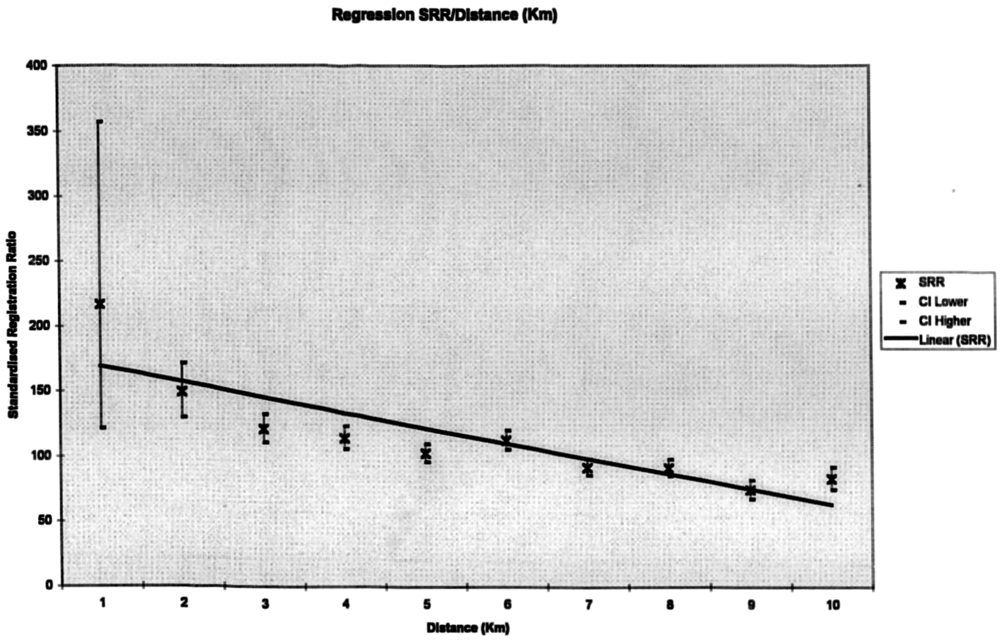
Max. O/E (Stone) at ring 2.

Table 17

LUNG CANCER, MALES. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE NORTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	15	6.93	216.43	121.2 - 357.1	(high:p<0.00524)*
2	207	138.69	149.25	129.6 - 171.0	(high:p<0.0005)
3	505	416.19	121.34	111.0 - 132.4	(high:p<0.005)
4	674	587.26	114.77	106.3 - 123.8	(high:p<0.005)
5	874	849.10	102.93	96.2 - 110.0	
6	906	803.68	112.73	105.5 - 120.3	(high:p<0.005)
7	871	948.46	91.83	85.8 - 98.1	(low: p<0.01)
8	810	886.63	91.36	85.2 - 97.9	(low: p<0.01)
9	434	582.71	74.48	67.6 - 81.8	(low: p<0.0005)
10	371	446.81	83.03	74.8 - 91.9	(low: p<0.005)

* - Exact Poisson.



Regression slope = -0.07701 p < 0.001

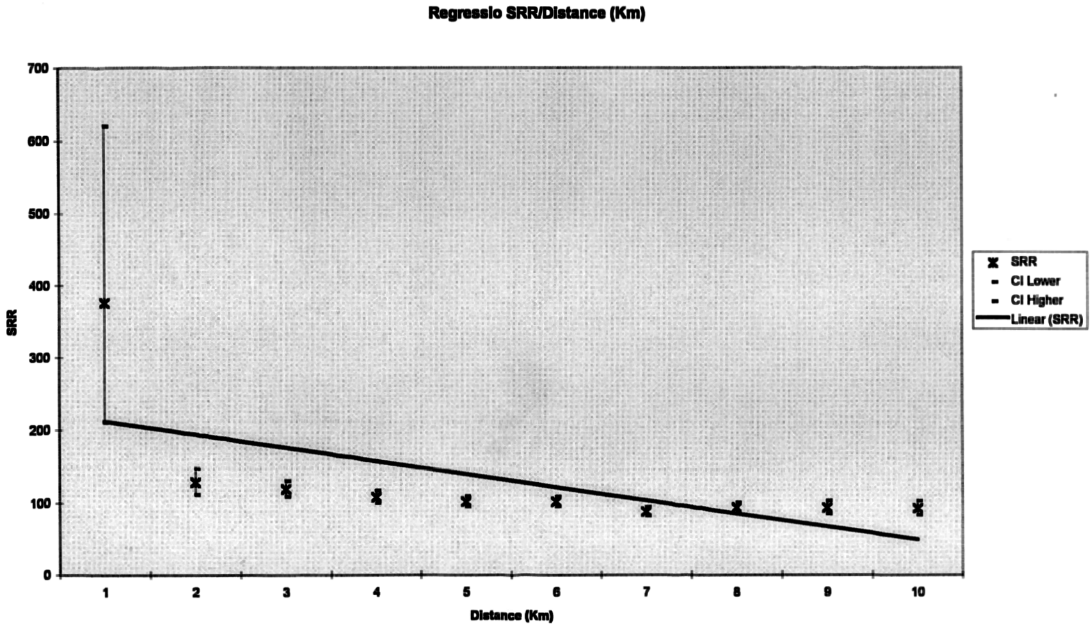
Max. O/E (Stone) at ring 1.

Table 18

LUNG CANCER, MALES. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	15	3.99	375.95	210.5 - 620.3	(high:p<0.00002)*
2	207	160.88	128.67	111.7 - 147.4	(high:p<0.005)
3	505	422.79	119.45	109.3 - 130.3	(high:p<0.005)
4	674	621.07	108.52	100.5 - 117.0	(high:p<0.02)
5	874	855.35	102.18	95.5 - 109.2	
6	906	888.67	101.95	95.4 - 108.8	
7	871	988.39	88.12	82.4 - 94.2	(low: p<0.005)
8	810	862.95	93.86	87.5 - 100.6	
9	434	463.53	93.63	85.0 - 102.9	
10	371	398.82	93.02	83.8 - 103.0	

*** - Exact Poisson.**



Regression slope = - 0.05207 p< 0.089

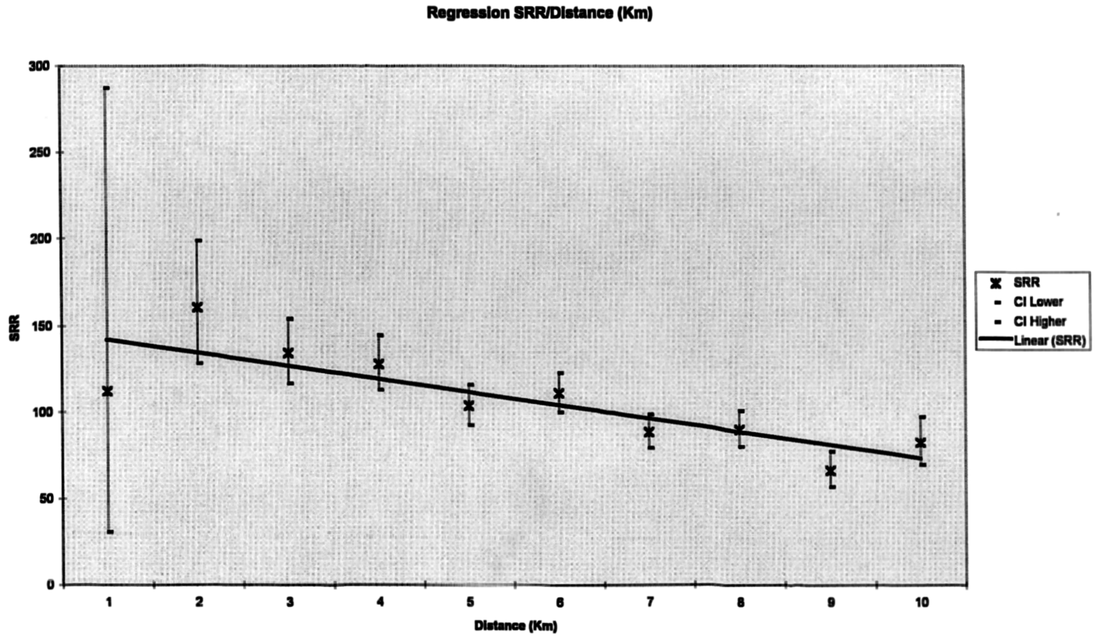
Max. O/E (Stone) at ring 1.

Table 19

LUNG CANCER, MALES, 0 TO 64 YEARS OF AGE. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE NORTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	4	3.57	112.20	30.5 - 287.2	
2	85	52.90	160.68	128.3 - 198.7	(high:p<0.00003) *
3	208	154.65	134.50	116.8 - 154.1	(high:p<0.005)
4	259	202.39	127.97	112.9 - 144.5	(high:p<0.005)
5	312	300.63	103.78	92.6 - 116.0	
6	371	334.11	111.04	100.0 - 122.9	(high:p<0.025)
7	337	380.33	88.61	79.4 - 98.6	(low: p<0.015)
8	300	332.93	90.11	80.2 - 100.9	
9	166	249.94	66.42	56.7 - 77.3	(low: p<0.005)
10	144	174.00	82.76	69.8 - 97.4	(low: p<0.015)

* - Exact Poisson.



Regression slope = -0.09094 p < 0.001

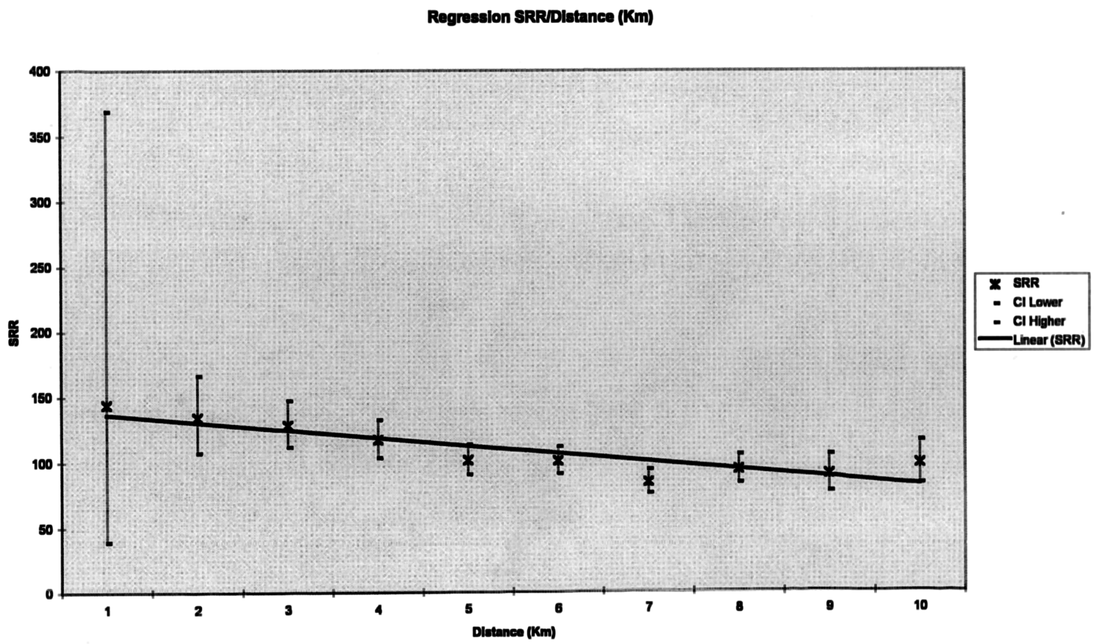
Max. O/E (Stone) at ring 2.

Table 20

LUNG CANCER, MALES, 0 TO 64 YEARS OF AGE. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	4	2.78	144.12	39.2 - 368.9	
2	85	63.29	134.31	107.3 - 166.1	(high:p<0.00531)*
3	208	162.41	128.07	111.3 - 146.7	(high:p<0.005)
4	259	221.79	116.78	103.0 - 131.9	(high:p<0.01)
5	312	308.57	101.11	90.2 - 113.0	
6	371	370.33	100.18	90.2 - 110.9	
7	337	401.76	83.88	75.2 - 93.3	(low: p<0.005)
8	300	321.24	93.39	83.1 - 104.6	
9	166	185.51	89.48	76.4 - 104.2	
10	144	147.77	97.45	82.2 - 114.7	

* - Exact Poisson.



Regression slope = -0.05341 $p < 0.004$

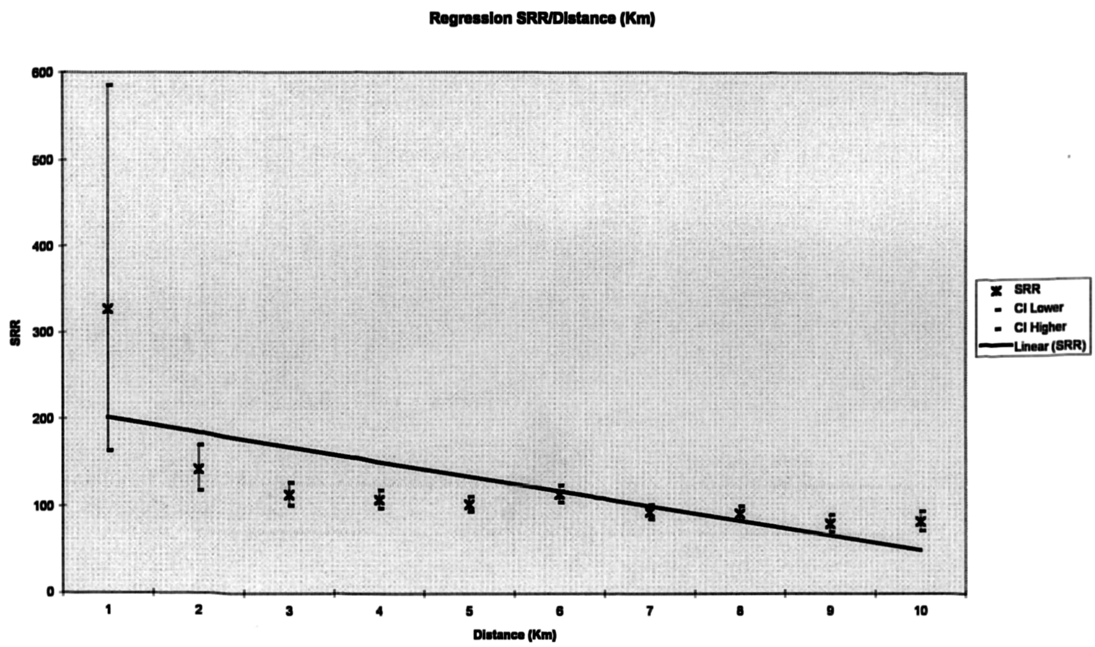
Max. O/E (Stone) at ring 1.

Table 21

LUNG CANCER, MALES, 65 TO 85+ YEARS OF AGE. NORTH OF THE CLYDE. OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE NORTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	11	3.37	326.86	163.1 - 585.1	(high:p<0.00075)*
2	122	85.79	142.21	118.1 - 169.8	(high:p<0.005)
3	297	261.54	113.56	101.0 - 127.2	(high:p<0.015)
4	415	384.87	107.83	97.7 - 118.7	
5	562	548.48	102.47	94.2 - 111.3	
6	535	469.57	113.94	104.5 - 124.0	(high:p<0.005)
7	534	568.13	93.99	86.2 - 102.3	
8	510	553.70	92.11	84.3 - 100.5	
9	268	332.77	80.54	71.2 - 90.8	(low: p<0.005)
10	227	272.81	83.21	72.7 - 94.8	(low: p<0.005)

*** - Exact Poisson.**



Regression line = -0.06662 $p < 0.023$

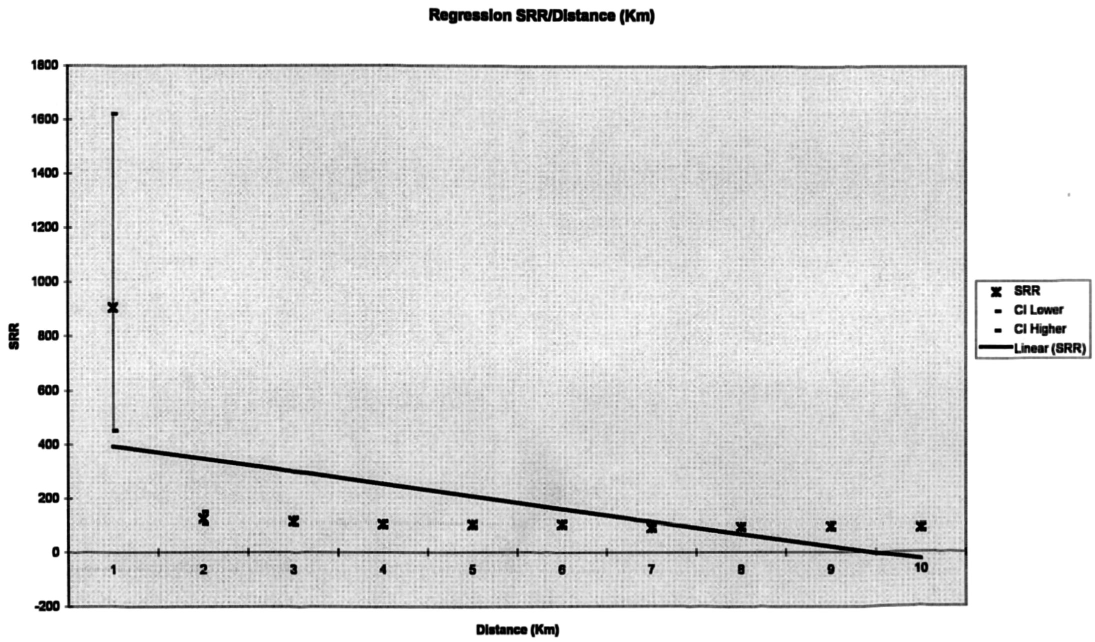
Max. O/E (Stone) at ring 1.

Table 22

LUNG CANCER, MALES, 65 TO 85+ YEARS OF AGE. NORTH OF THE CLYDE. OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	11	1.21	905.79	452.0 - 1621.4	(high:p<0.00001)*
2	122	97.59	125.01	103.8 - 149.3	(high:p<0.01)
3	297	260.38	114.06	101.5 - 127.8	(high:p<0.015)
4	415	399.28	103.94	94.2 - 114.4	
5	562	546.79	102.78	94.5 - 111.6	
6	535	518.34	103.21	94.7 - 112.3	
7	534	586.63	91.03	83.5 - 99.1	(low: p<0.01)
8	510	541.71	94.15	86.2 - 102.7	
9	268	278.02	96.40	85.2 - 108.7	
10	227	251.05	90.42	79.0 - 103.0	

*** - Exact Poisson.**



Regression slope = -0.04947 p < 0.385

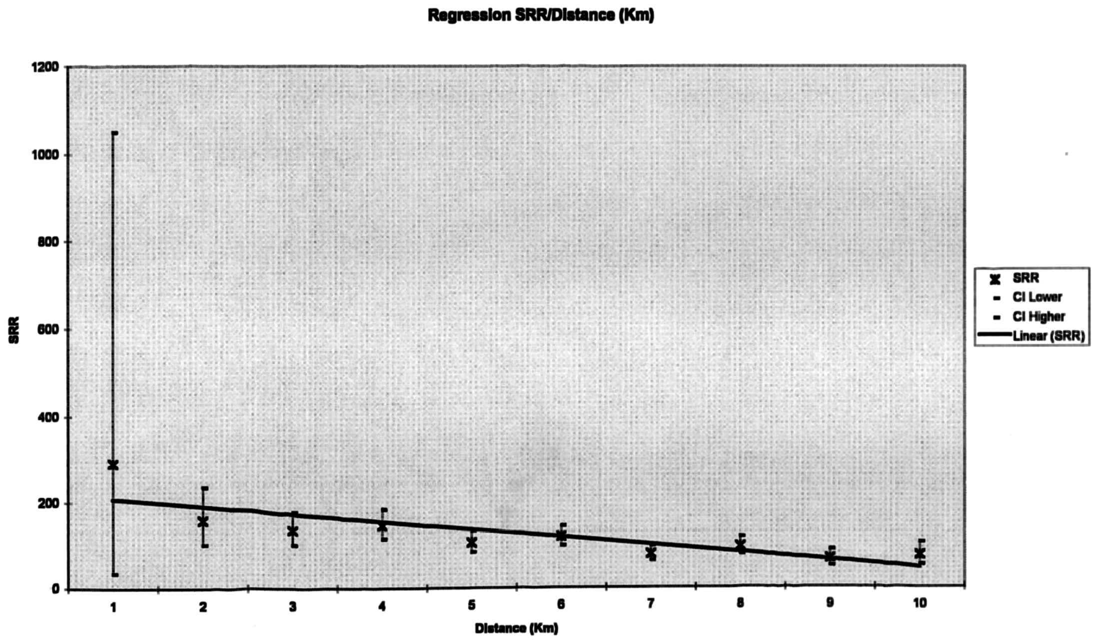
Max. O/E (Stone) at ring 1.

Table 23

LUNG CANCER, MALES, 0 TO 54 YEARS OF AGE. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE NORTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	2	0.69	290.61	35.2 - 1049.1	
2	24	15.18	158.09	101.3 - 234.0	(high:p<0.02197)*
3	52	38.62	134.66	100.6 - 176.6	(high:p<0.02294)*
4	74	50.89	145.42	114.2 - 182.6	(high:p<0.00139)*
5	75	71.26	105.24	82.8 - 131.9	
6	109	91.77	118.77	97.5 - 143.3	
7	85	109.27	77.79	62.1 - 96.2	(low: p<0.015)
8	87	91.98	94.58	75.8 - 116.7	
9	51	77.08	66.16	49.3 - 87.0	(low: p<0.00103)*
10	35	46.81	74.76	52.1 - 104.0	

* - Exact Poisson.



Regression Slope = -0.11719 $p < 0.001$

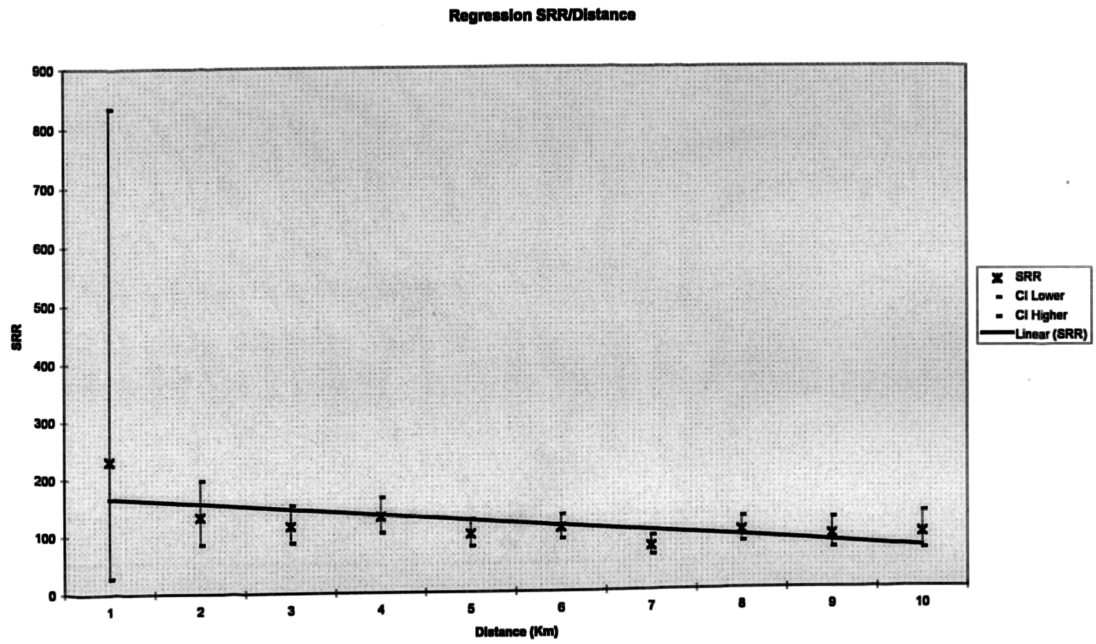
Max. O/E (Stone) at ring 2.

Table 24

LUNG CANCER, MALES, 0 TO 54 YEARS OF AGE. NORTH OF THE CLYDE. OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	2	0.86	231.26	28.0 - 834.8	
2	24	18.15	132.25	84.8 - 195.7	
3	52	45.02	115.51	86.3 - 151.5	
4	74	56.62	130.70	102.6 - 164.1	(high:p<0.0152)*
5	75	75.91	98.80	77.7 - 123.9	
6	109	100.69	108.25	88.9 - 130.6	
7	85	114.47	74.25	59.3 - 91.8	(low: p<0.005)
8	87	87.76	99.13	79.4 - 122.3	
9	51	56.33	90.53	67.4 - 119.0	
10	35	37.75	92.72	64.6 - 129.0	

*** - Exact Poisson.**



Regression slope = - 0.6000 p < 0.033

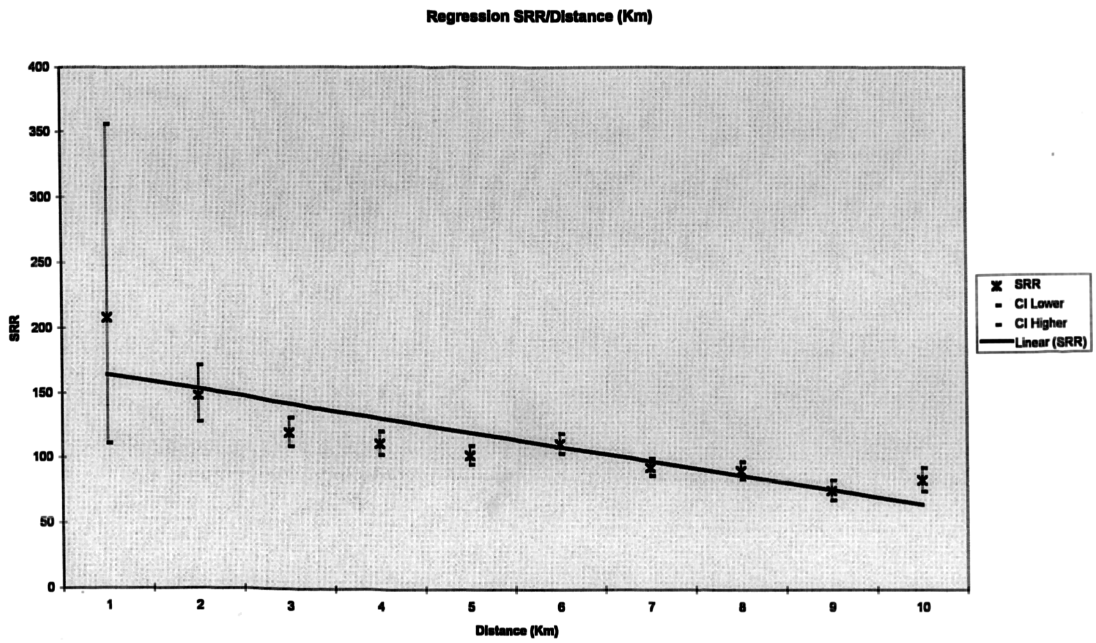
Max. O/E (Stone) at ring 2.

Table 25

LUNG CANCER, MALES, 55 TO 85+ YEARS OF AGE. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE NORTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	13	6.24	208.26	110.8 - 356.1	(high:p<0.01187)*
2	183	123.51	148.17	127.5 - 171.3	(high:p<0.005)
3	453	377.58	119.98	109.2 - 131.5	(high:p<0.005)
4	600	536.37	111.86	103.1 - 121.2	(high:p<0.005)
5	799	777.84	102.72	95.7 - 110.1	
6	797	711.90	111.95	104.3 - 120.0	(high:p<0.005)
7	786	839.18	93.66	87.2 - 100.4	
8	723	794.64	90.98	84.5 - 97.9	(low: p<0.01)
9	383	505.62	75.75	68.4 - 83.7	(low: p<0.005)
10	336	399.99	84.00	75.3 - 93.5	(low: p<0.005)

* - Exact Poisson.



Regression slope = - 0.07223 p < 0.001

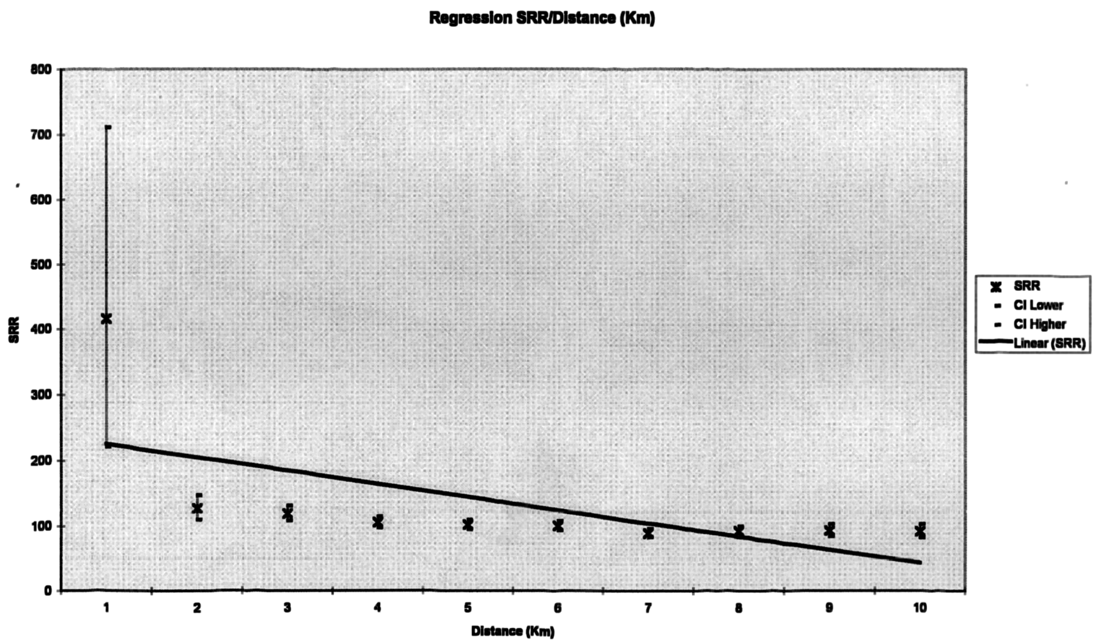
Max. O/E (Stone) at ring 1.

Table 26

LUNG CANCER, MALES, 55 TO 85 YEARS OF AGE. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	13	3.13	415.99	221.3 - 711.3	(high:p<0.00002)*
2	183	142.73	128.21	110.3 - 148.2	(high:p<0.005)
3	453	377.77	119.91	109.1 - 131.5	(high:p<0.005)
4	600	564.45	106.30	98.0 - 115.2	
5	799	779.45	102.51	95.5 - 109.9	
6	797	787.98	101.14	94.2 - 108.4	
7	786	873.91	89.94	83.8 - 96.5	(low: p<0.005)
8	723	775.19	93.27	86.6 - 100.3	
9	383	407.20	94.06	84.9 - 104.0	
10	336	361.07	93.06	83.4 - 103.6	

*** - Exact Poisson.**



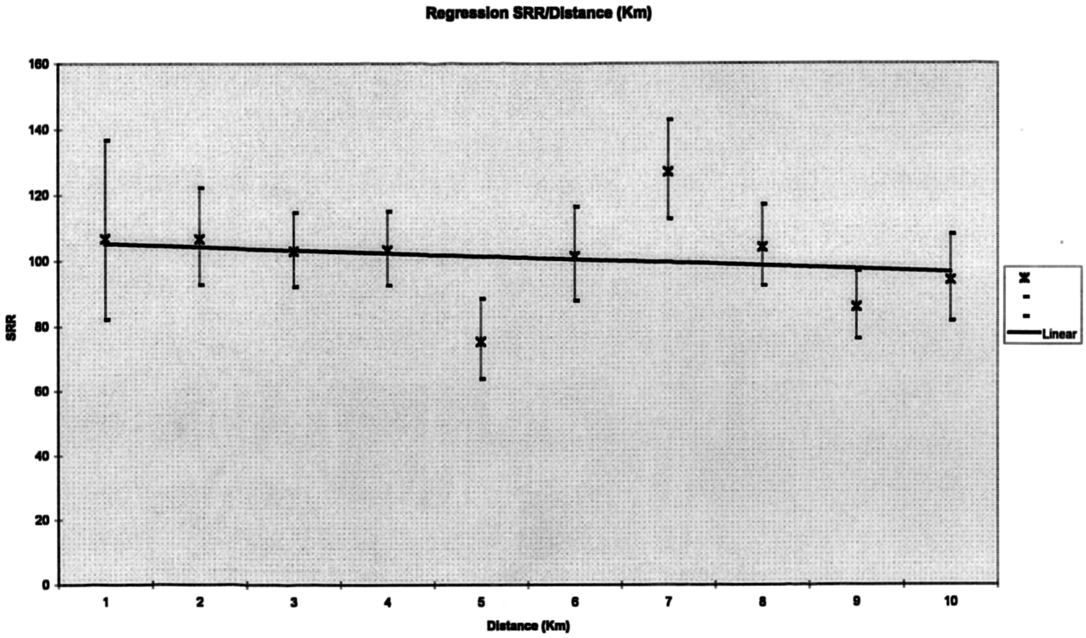
Regression line = - 0.05096 p < 0.117

Max. O/E (Stone) at ring 1.

Table 27

LUNG CANCER, FEMALES. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE SOUTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	63	58.92	106.93	82.2 - 136.8	
2	212	198.63	106.73	92.8 - 122.1	
3	335	325.17	103.02	92.3 - 114.7	
4	334	323.49	103.25	92.5 - 114.9	
5	148	196.82	75.20	63.6 - 88.3	(low: p = 0.005)
6	199	196.76	101.14	87.6 - 116.2	
7	276	217.62	126.83	112.3 - 142.7	(high: p = 0.005)
8	279	269.07	103.69	91.9 - 116.6	
9	269	314.77	85.46	75.6 - 96.3	(low: p = 0.005)
10	198	211.60	93.57	81.0 - 107.6	



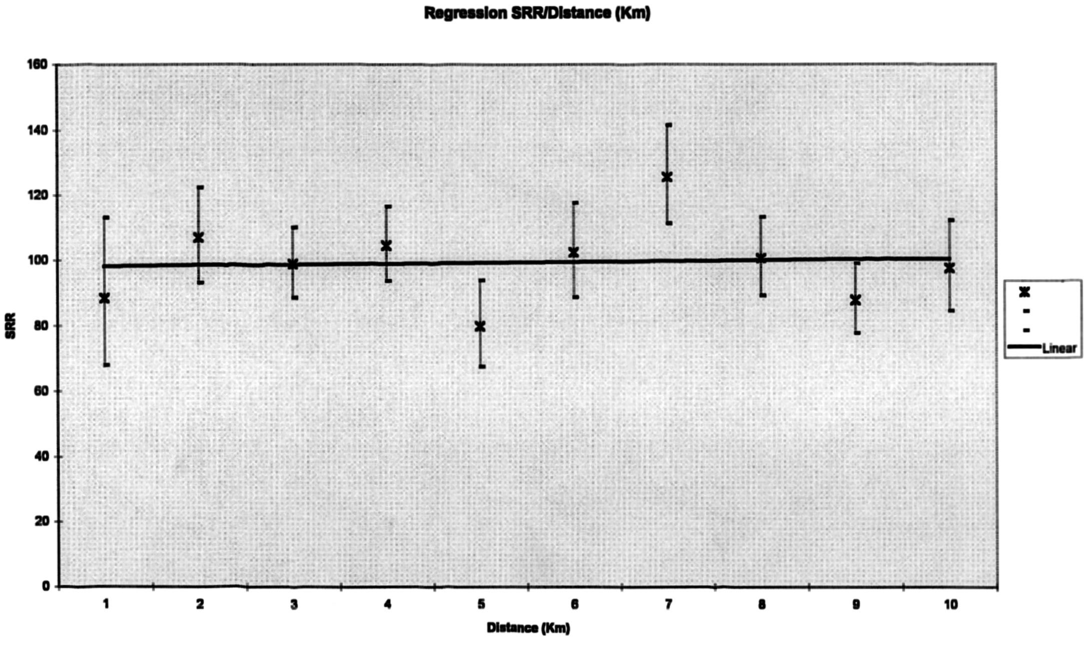
Regression slope = - 0.01124 p = 0.511

Max. O/E (Stone) at ring 1.

Table 28

LUNG CANCER, FEMALES. SOUTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	63	71.26	88.41	67.9 - 113.1	
2	212	198.44	106.83	92.9 - 122.2	
3	335	338.69	98.91	88.6 - 110.1	
4	334	319.42	104.57	93.7 - 116.4	
5	148	185.28	79.88	67.5 - 93.8	(low: p = 0.005)
6	199	194.25	102.44	88.7 - 117.7	
7	276	219.52	125.73	111.3 - 141.5	(high: p = 0.005)
8	279	277.16	100.66	89.2 - 113.2	
9	269	306.23	87.84	77.7 - 99.0	(low: p = 0.02)
10	198	202.60	97.73	84.6 - 112.3	



Regression slope = 0.00126 p = 0.934

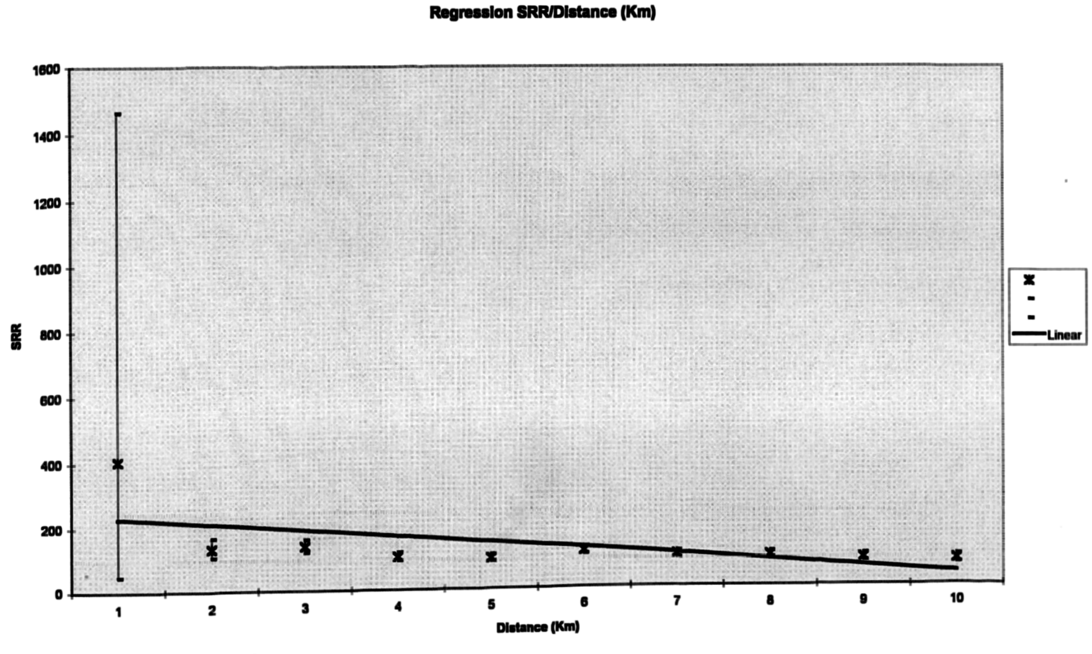
Max. O/E (Stone) at ring 7.

Table 29

LUNG CANCER, FEMALES. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE NORTH OF THE CLYDE.

Rings	Obs.	Exp.	SRR	95% CI	
1	2	0.49	405.81	49.1 - 1465.0	
2	81	60.83	133.15	105.7 - 165.5	(high: p = 0.00772)*
3	204	148.03	137.81	119.5 - 158.1	(high: p = 0.005)
4	276	267.76	103.08	91.3 - 116.0	
5	359	378.30	94.90	85.3 - 105.2	
6	386	341.01	113.19	102.2 - 125.1	(high: p = 0.01)
7	413	417.23	98.99	89.7 - 109.0	
8	398	418.64	95.07	86.0 - 104.9	
9	228	270.48	84.29	73.7 - 96.0	(low: p = 0.005)
10	154	197.90	77.82	66.0 - 91.1	(low: p = 0.005)

(*) Exact Poisson



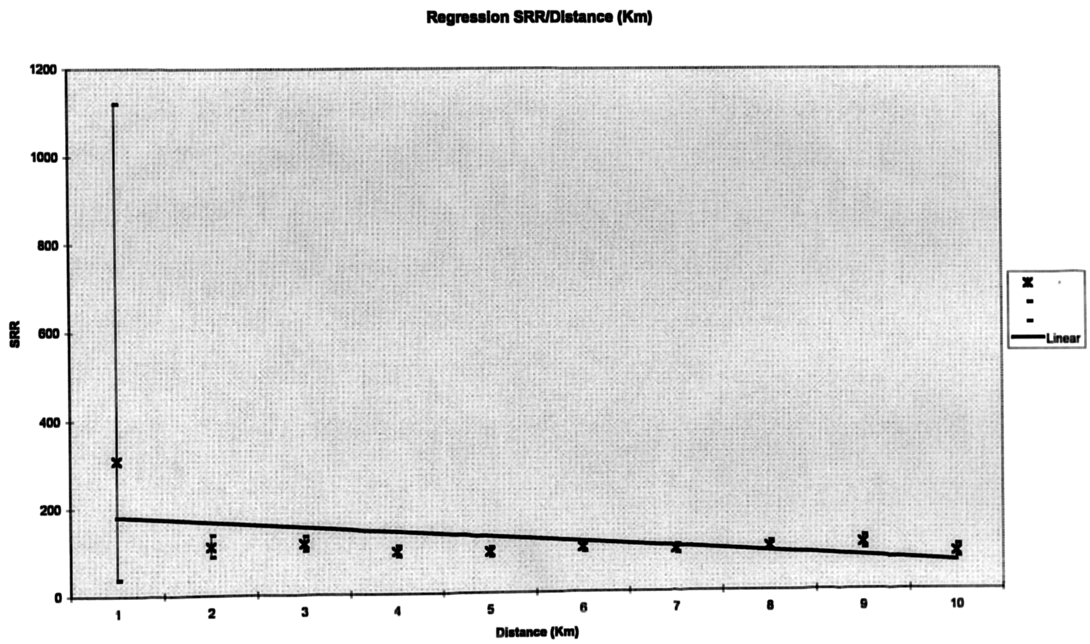
Regresion slope = - 0.06441 **p = 0.022**

Max. O/E (Stone) at ring 3.

Table 30

LUNG CANCER, FEMALES. NORTH OF THE CLYDE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	2	0.64	310.42	37.6 - 1120.6	
2	81	72.53	111.68	88.7 - 138.8	
3	204	174.12	117.16	101.6 - 134.4	(high: p = 0.015)
4	276	285.59	96.64	85.6 - 108.7	
5	359	383.59	93.59	84.2 - 103.8	
6	386	375.44	102.81	92.8 - 113.6	
7	413	427.88	96.52	87.4 - 106.3	
8	398	391.21	101.74	92.0 - 112.2	
9	228	211.29	107.91	94.4 - 122.9	
10	154	178.39	86.33	73.2 - 101.1	



Regression slope = - 0.02074 p = 0.306

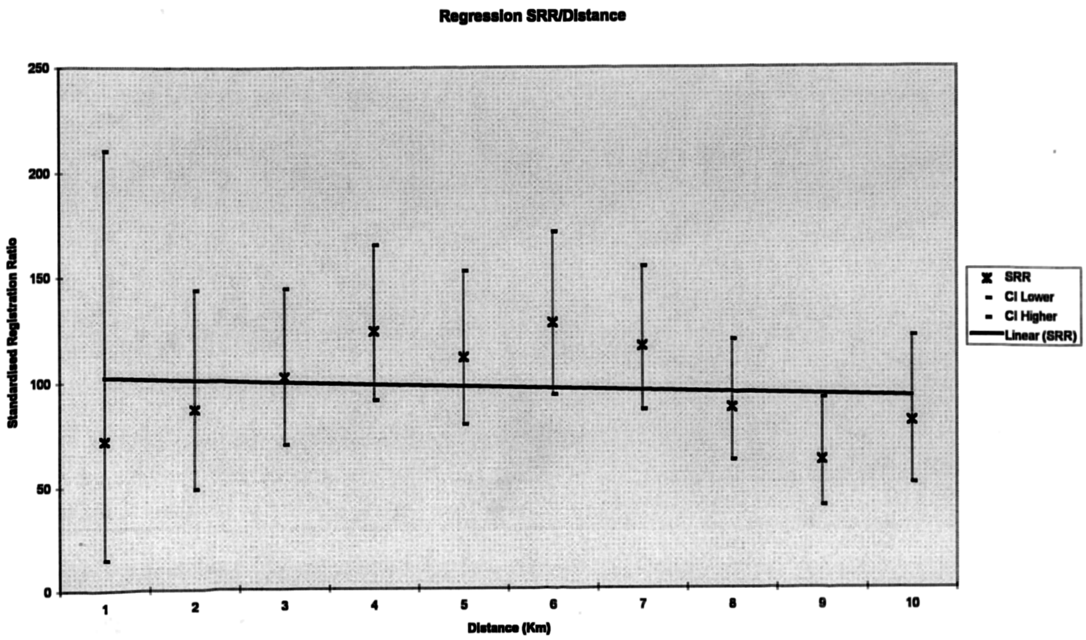
Max. O/E (Stone) at ring 3.

Table 31

PHARINX CANCER, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	3	4.16	72.05	14.8 - 210.4	
2	15	17.18	87.30	48.9 - 144.0	
3	32	31.24	102.43	70.0 - 144.6	
4	47	37.86	124.15	91.2 - 165.1	
5	39	34.97	111.52	79.3 - 152.5	
6	45	35.24	127.70	93.1 - 170.9	
7	48	41.28	116.29	85.7 - 154.2	
8	38	43.87	86.62	61.3 - 118.9	
9	24	39.07	61.43	39.4 - 90.9	(low: p< 0.0066)*
10	22	27.64	79.59	49.9 - 120.2	

(*) Exact Poisson



Slope = -0.03347 p = 0.244

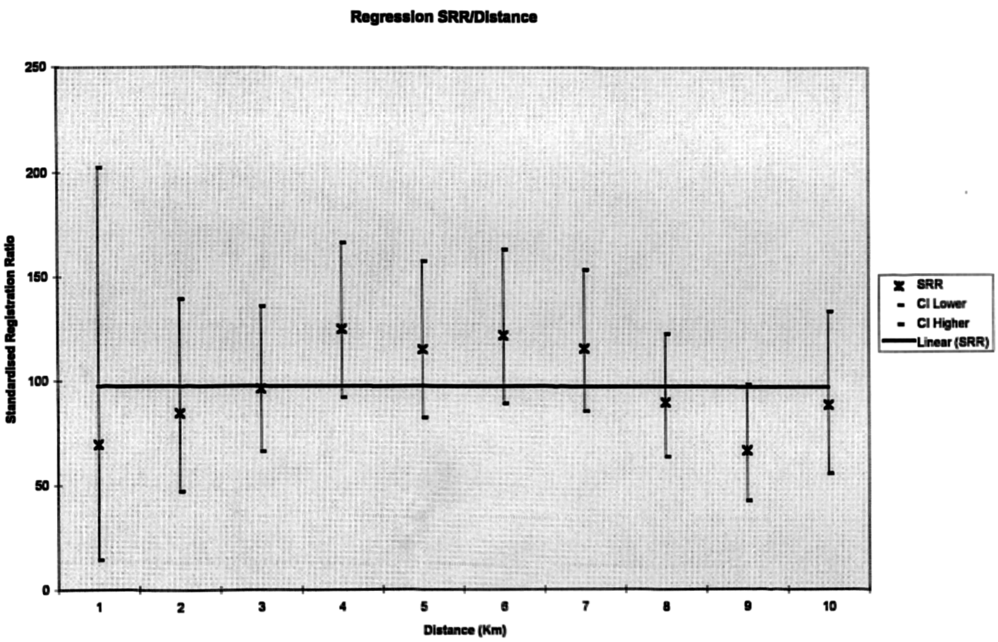
Max. O/E (Stone) at ring 7.

Table 32

PHARYNGEAL CANCER, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95%CI	
1	3	4.33	69.31	14.3 - 202.4	
2	15	17.78	84.36	47.2 - 139.2	
3	32	33.23	96.30	65.9 - 135.9	
4	47	37.58	125.08	91.9 - 166.3	
5	39	33.89	115.09	81.8 - 157.3	
6	45	36.93	121.84	88.9 - 163.0	
7	48	41.54	115.56	85.2 - 153.2	
8	38	42.51	89.39	63.3 - 122.7	
9	24	36.20	66.30	42.5 - 98.1	(low: p< 0.02)*
10	22	24.89	88.37	55.4 - 133.4	

(*) Exact Poisson



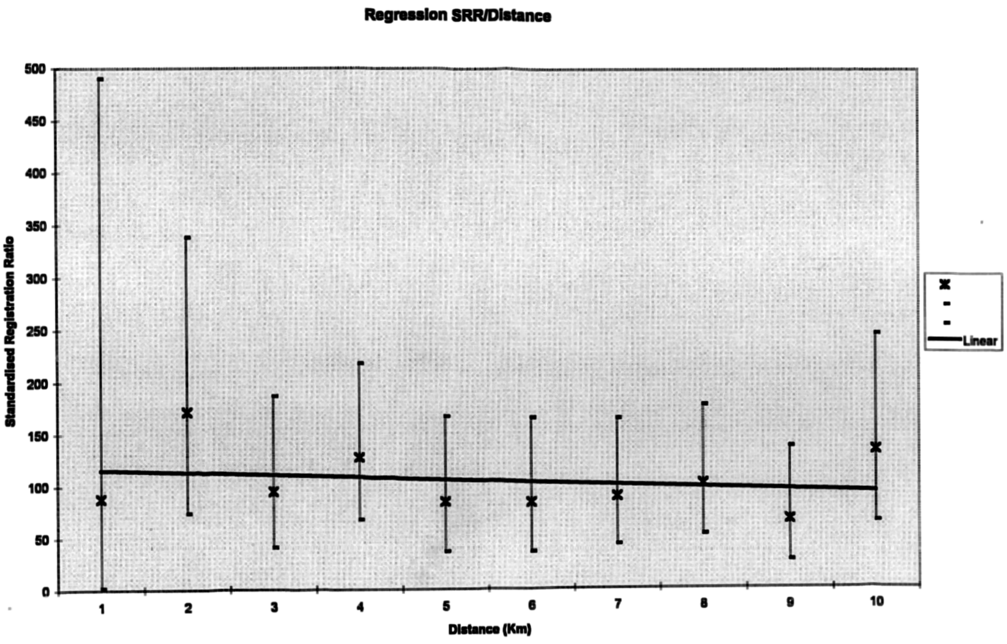
Slope = -0.01852   p = 0.489

Max. O/E (Stone) at ring 7.

Table 33

NASAL CANCER, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI
1	1	1.14	88.03	2.2 - 490.3
2	8	4.66	171.55	73.9 - 338.0
3	8	8.45	94.64	40.8 - 186.4
4	13	10.24	126.97	67.5 - 217.1
5	8	9.47	84.51	36.4 - 166.5
6	8	9.55	83.74	36.1 - 165.0
7	10	11.22	89.16	42.8 - 164.1
8	12	11.86	101.15	52.3 - 177.0
9	7	10.56	66.30	26.6 - 136.6
10	10	7.52	133.05	63.9 - 244.8



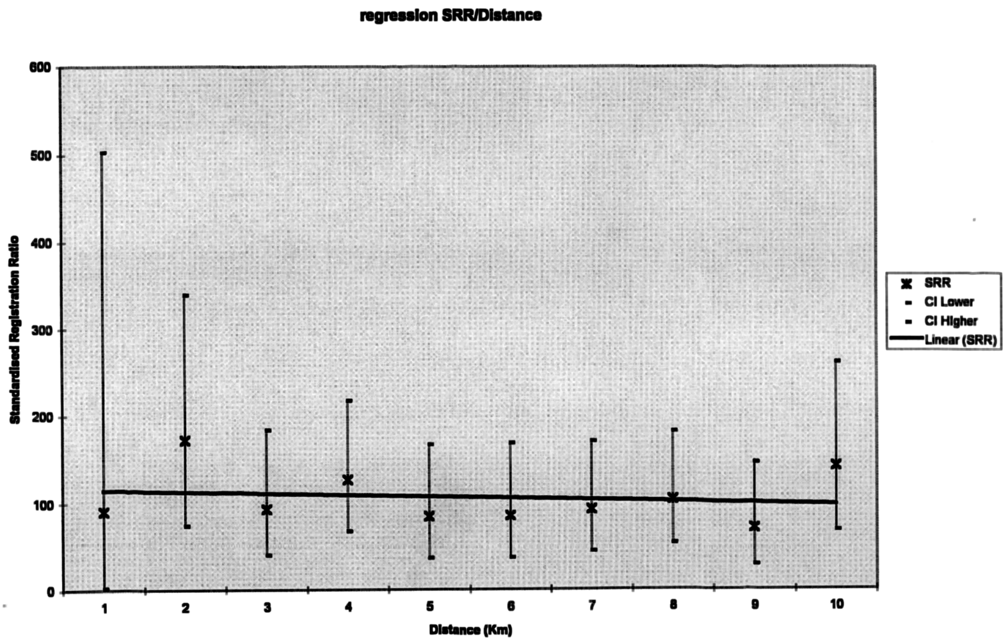
Slope = -0.03219 **p = 0.388**

Max. O/E (Stone) at ring 2.

Table 34

NASAL CANCER, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI
1	1	1.11	90.29	2.3 - 502.9
2	8	4.65	172.05	74.2 - 338.9
3	8	8.61	92.95	40.1 - 183.1
4	13	10.28	126.46	67.3 - 216.2
5	8	9.50	84.23	36.3 - 165.9
6	8	9.42	84.94	36.6 - 167.3
7	10	10.86	92.08	44.2 - 169.4
8	12	11.63	103.19	53.3 - 180.6
9	7	9.92	70.58	28.3 - 145.4
10	10	7.07	141.43	67.9 - 260.2



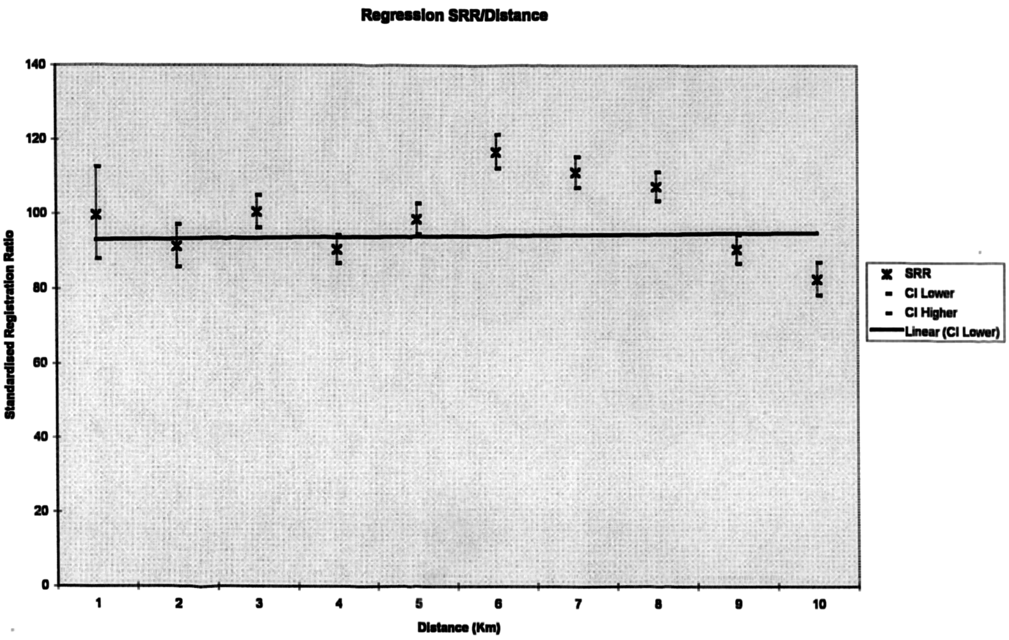
Slope = -0.02421 **p = 0.524**

Max. O/E (Stone) at ring 2.

Table 35

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), TOTAL POPULATION. CASES OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	261	261.92	99.65	87.9 - 112.5	
2	1016	1113.12	91.28	85.7 - 97.1	(low: p < 0.005)
3	2043	2032.62	100.51	96.2 - 105.0	
4	2215	2447.59	90.50	86.8 - 94.3	(low: p < 0.005)
5	2224	2255.34	98.61	94.6 - 102.8	
6	2596	2222.25	116.82	112.4 - 121.4	(high: p < 0.0005)
7	2875	2584.01	111.26	107.2 - 115.4	(high: p < 0.005)
8	2962	2756.35	107.46	103.6 - 111.4	(high: p < 0.005)
9	2167	2391.11	90.63	86.9 - 94.5	(low: p < 0.005)
10	1406	1699.57	82.73	78.5 - 87.2	(low: p < 0.0005)



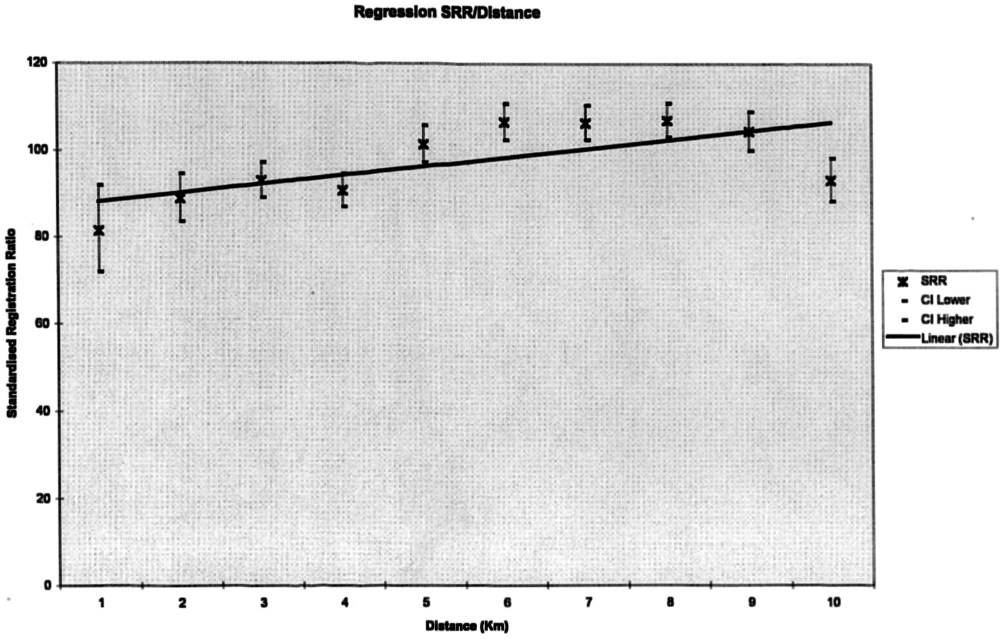
Slope = 0.00354 p = 0.803

Max. O/E (Stone) at ring 8.

Table 36

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), TOTAL POPULATION. CASES OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	261	320.50	81.43	71.9 - 91.9	(low: p< 0.005)
2	1016	1141.96	88.97	83.6 - 94.6	(low: p< 0.005)
3	2043	2194.33	93.10	89.1 - 97.2	(low: p< 0.005)
4	2215	2441.60	90.72	87.0 - 94.6	(low: p< 0.005)
5	2224	2191.66	101.48	97.3 - 105.8	
6	2596	2433.54	106.68	102.6 - 110.9	(high: p< 0.005)
7	2875	2697.47	106.58	102.7 - 110.6	(high: p< 0.005)
8	2962	2764.81	107.13	103.3 - 111.1	(high: p< 0.005)
9	2167	2071.79	104.60	100.2 - 109.1	(high: p< 0.02)
10	1406	1506.22	93.35	88.5 - 98.4	(low: p< 0.005)



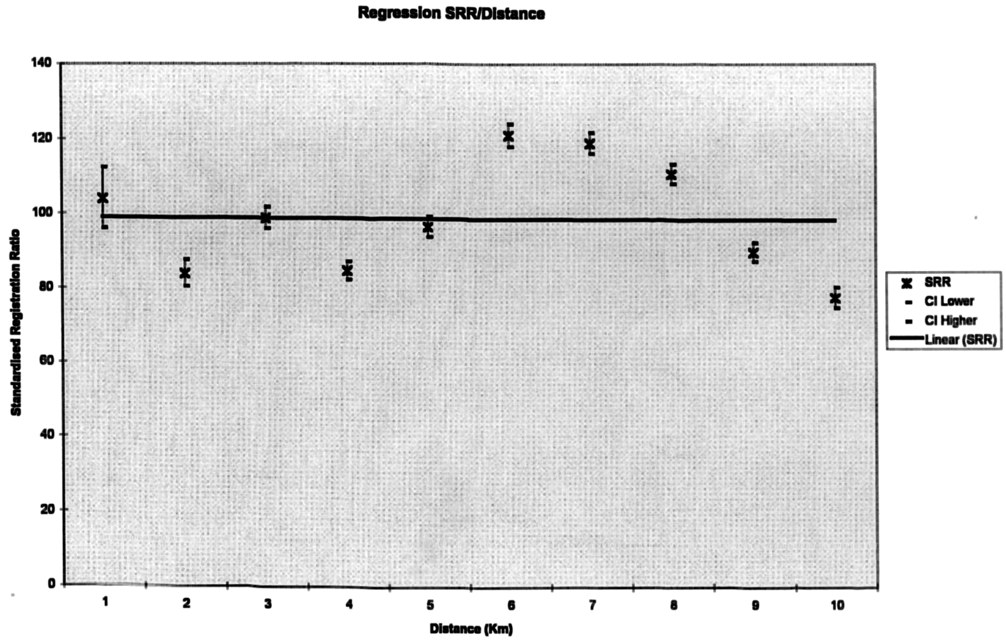
Slope = 0.019141 $p < 0.045$

Max. O/E (Stone) at ring 9.

Table 37

CHRONIC OBSTRUCTIVE PULMONARY DIESASE (COPD), TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	633	609.13	103.92	96.0 - 112.3	
2	2139	2545.77	84.02	80.5 - 87.7	(low: p< 0.0005)
3	4584	4633.85	98.92	96.1 - 101.8	
4	4730	5573.70	84.86	82.5 - 87.3	(low: p< 0.0005)
5	5003	5174.51	96.69	94.0 - 99.4	(low: p< 0.01)
6	6175	5099.69	121.09	118.1 - 124.1	(high: p< 0.0005)
7	7069	5939.24	119.02	116.3 - 121.8	(high: p< 0.0005)
8	6986	6306.85	110.77	108.2 - 113.4	(high: p< 0.0005)
9	4955	5515.64	89.84	87.4 - 92.4	(low: p< 0.0005)
10	3034	3910.14	77.59	74.9 - 80.4	(low: p< 0.0005)



Slope = 0.00017 p = 0.993

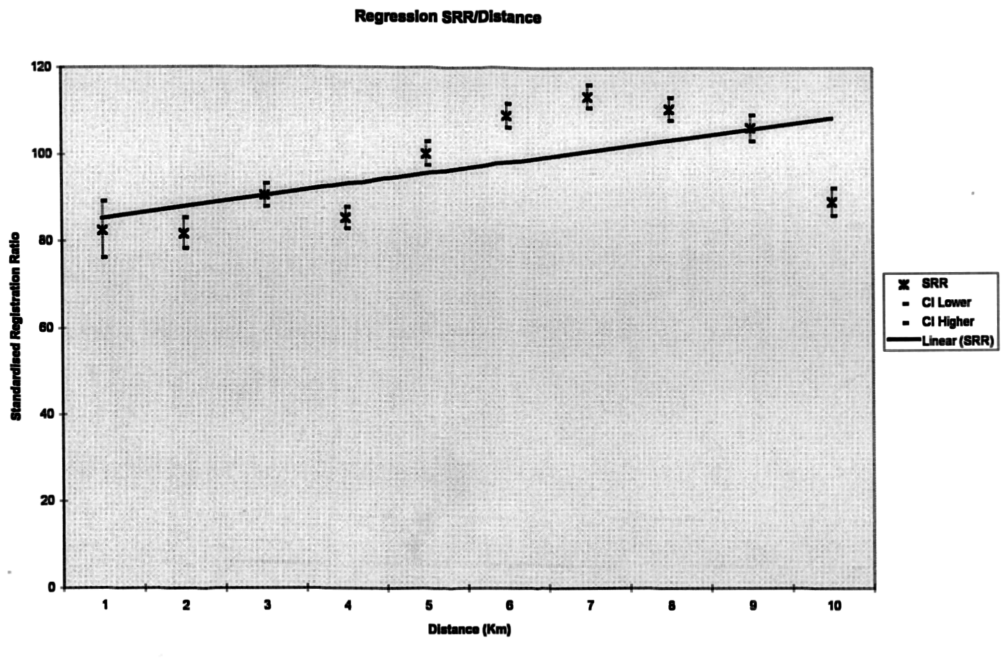
Max. O/E (Stone) at ring 8.

Table 38

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), TOTAL POPULATION. DISCHARGES.

OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	633	767.63	82.46	76.2 - 89.1	(low: p< 0.005)
2	2139	2620.58	81.62	78.2 - 85.2	(low: p< 0.0005)
3	4584	5069.25	90.43	87.8 - 93.1	(low: p< 0.0005)
4	4730	5554.99	85.15	82.7 - 87.6	(low: p< 0.0005)
5	5003	4997.69	100.11	97.4 - 102.9	
6	6175	5667.83	108.95	106.2 - 111.7	(high: p< 0.0005)
7	7069	6234.64	113.38	110.8 - 116.1	(high: p< 0.0005)
8	6986	6324.71	110.46	107.9 - 113.1	(high: p< 0.0005)
9	4955	4666.77	106.18	103.2 - 109.2	(high: p< 0.005)
10	3034	3404.43	89.12	86.0 - 92.3	(low: p< 0.0005)



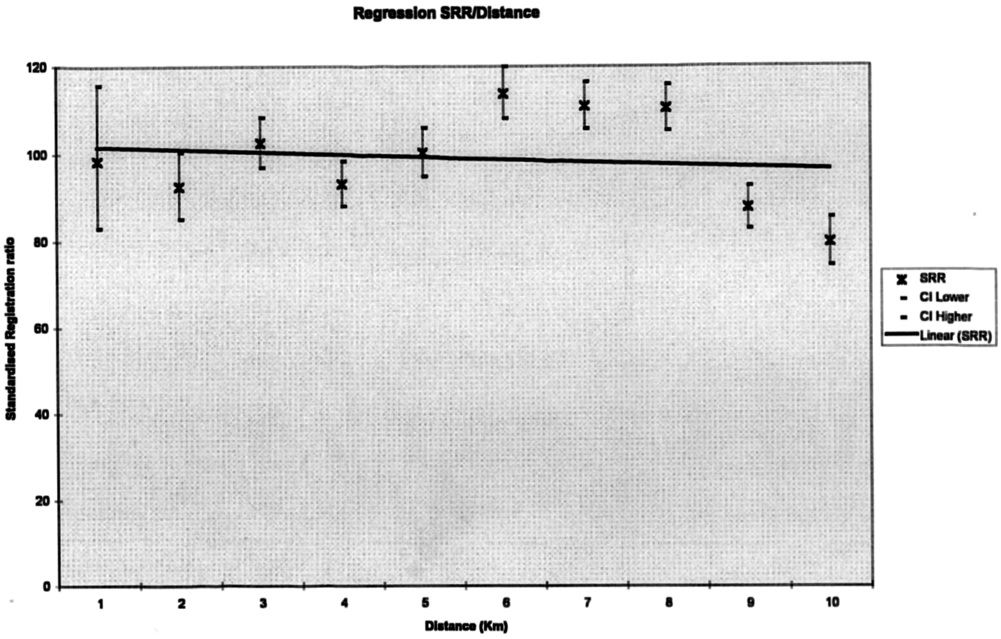
Slope = 0.2596 p < 0.068

Max. O/E (Stone) at ring 9.

Table 39

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), MALES. CASES
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	145	147.36	98.40	83.0 - 115.8	
2	569	614.99	92.52	85.1 - 100.4	
3	1236	1205.14	102.56	96.9 - 108.4	
4	1250	1343.56	93.04	87.9 - 98.3	(low: p<0.01)
5	1256	1254.03	100.16	94.7 - 105.9	
6	1461	1283.16	113.86	108.1 - 119.9	(high: p<0.005)
7	1633	1472.31	110.91	105.6 - 116.4	(high: p<0.005)
8	1705	1544.02	110.43	105.2 - 115.8	(high: p<0.005)
9	1217	1396.17	87.17	82.3 - 92.2	(low: p<0.005)
10	794	1004.76	79.02	73.6 - 84.7	(low: p<0.0005)



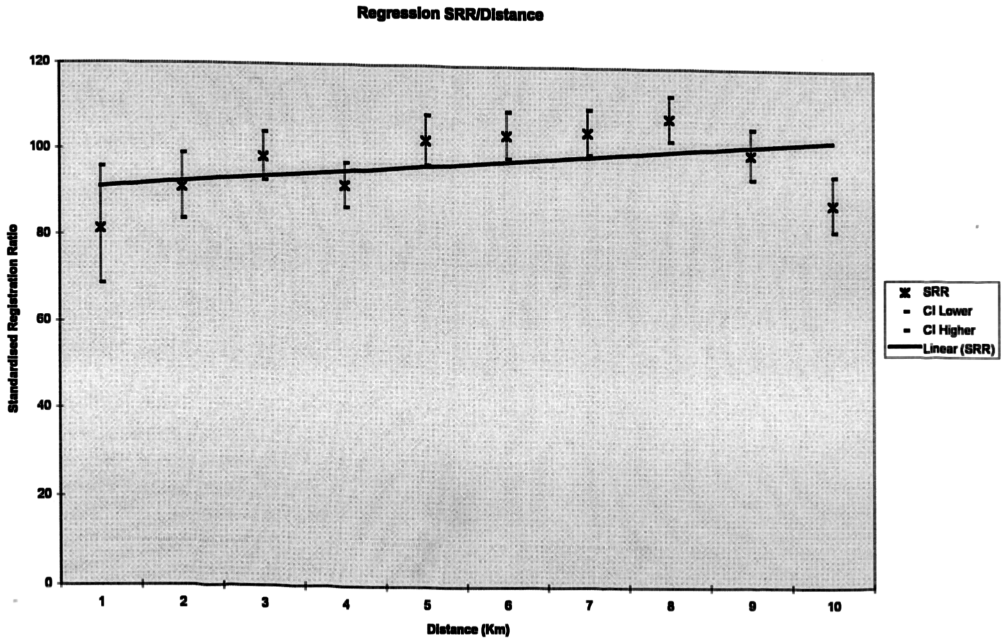
Slope = -0.00956 p = 0.522

Max. O/E (Stone) at ring 8.

Table 40

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), MALES. CASES OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	145	178.23	81.35	68.7 - 95.7	(low: p<0.01)
2	569	624.04	91.18	83.8 - 99.0	(low: p<0.015)
3	1236	1255.90	98.42	93.0 - 104.1	
4	1250	1358.87	91.99	87.0 - 97.2	(low: p<0.005)
5	1256	1223.66	102.64	97.0 - 108.5	
6	1461	1403.15	104.12	98.9 - 109.6	
7	1633	1553.10	105.14	100.1 - 110.4	(high: p<0.025)
8	1705	1572.01	108.46	103.4 - 113.7	(high: p<0.005)
9	1217	1210.45	100.54	95.0 - 106.4	
10	794	886.60	89.56	83.4 - 96.0	(low: p<0.005)



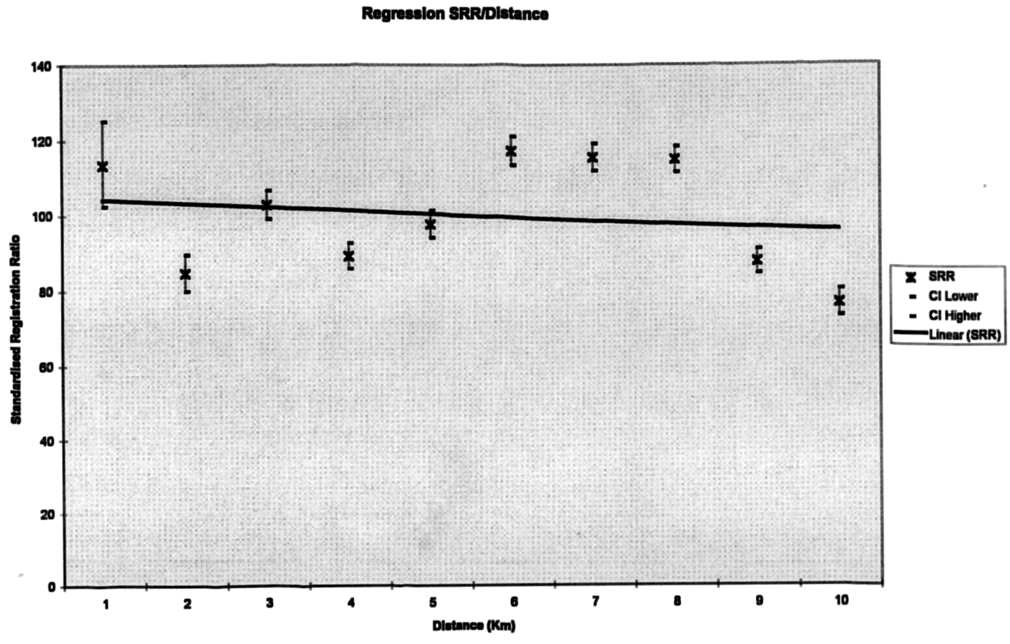
Slope = 0.010961 p = 0.253

Max. O/E (Stone) at ring 8.

Table 41

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), MALES. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	392	345.69	113.40	102.4 - 125.2	(high: p<0.01)
2	1201	1419.43	84.61	79.9 - 89.5	(low: p<0.0005)
3	2852	2778.11	102.66	98.9 - 106.5	
4	2748	3090.86	88.91	85.6 - 92.3	(low: p<0.0005)
5	2825	2905.12	97.24	93.7 - 100.9	
6	3456	2957.84	116.84	113.0 - 120.8	(high: p<0.0005)
7	3914	3400.03	115.12	111.5 - 118.8	(high: p<0.0005)
8	4071	3559.21	114.38	110.9 - 117.9	(high: p<0.0005)
9	2793	3223.09	86.66	83.5 - 89.9	(low: p<0.0005)
10	1741	2313.00	75.27	71.8 - 78.9	(low: p<0.0005)



Slos

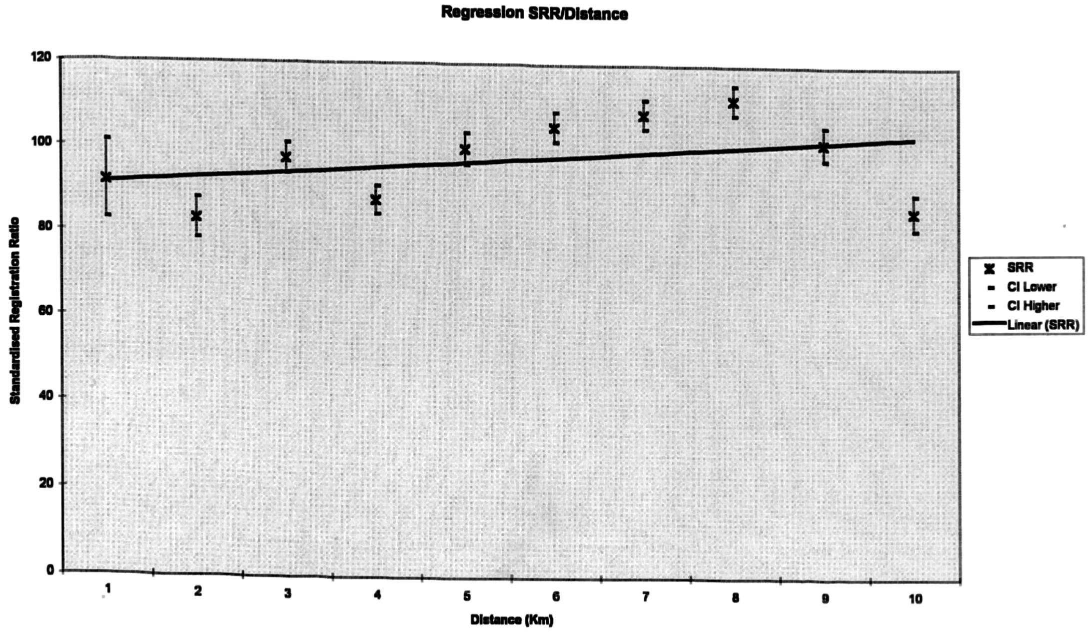
Slope = -0.00874 p = 0.653

Max. O/E (Stone) at ring 1.

Table 42

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), MALES. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	392	427.90	91.61	82.8 - 101.1	
2	1201	1446.05	83.05	78.4 - 87.9	(low: p<0.0005)
3	2852	2925.24	97.50	94.0 - 101.1	
4	2748	3123.56	87.98	84.7 - 91.3	(low: p<0.0005)
5	2825	2820.57	100.16	96.5 - 103.9	
6	3456	3274.34	105.55	102.1 - 109.1	(high: p<0.005)
7	3914	3602.25	108.65	105.3 - 112.1	(high: p<0.005)
8	4071	3628.06	112.21	108.8 - 115.7	(high: p<0.0005)
9	2793	2730.91	102.27	98.5 - 106.1	
10	1741	2014.13	86.44	82.4 - 90.6	(low: p<0.0005)



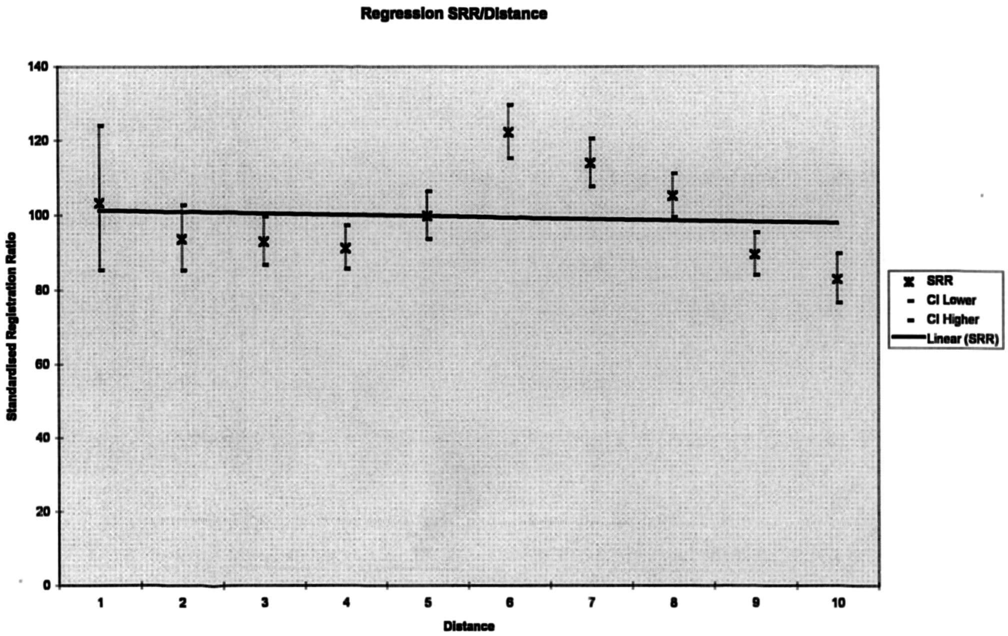
Slope = 0.01447 $p < 0.247$

Max. O/E (Stone) at ring 9.

Table 43

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), FEMALES. CASES OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	116	112.31	103.29	85.3 - 123.9	
2	447	477.32	93.65	85.2 - 102.7	
3	807	867.31	93.05	86.7 - 99.7	(low: p<0.025)
4	965	1056.68	91.32	85.7 - 97.3	(low: p<0.005)
5	968	970.11	99.78	93.6 - 106.3	
6	1135	928.32	122.26	115.3 - 129.6	(high: p<0.0005)
7	1242	1089.53	113.99	107.7 - 120.5	(high: p<0.005)
8	1257	1195.30	105.16	99.4 - 111.1	
9	950	1061.78	89.47	83.9 - 95.3	(low: p<0.005)
10	612	739.54	82.75	76.3 - 89.6	(low: p<0.005)



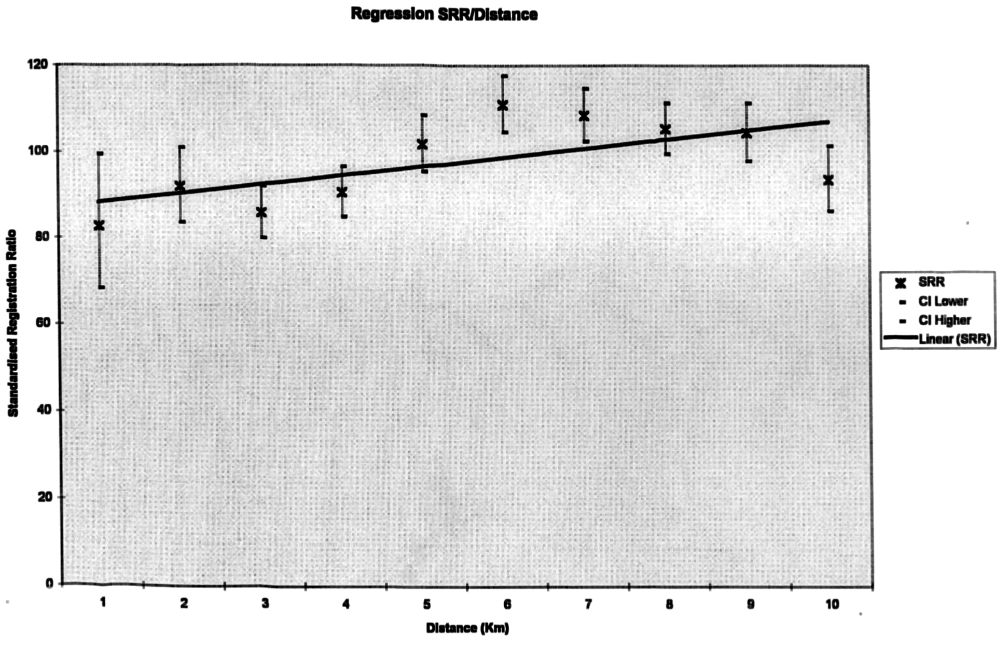
Slope = - 0.00367 **p < 0.817**

Max. O/E (Stone) at ring 8.

Table 44

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), FEMALES. CASES OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI		
1	116	140.16	82.76	68.4 -	99.3	(low: p<0.025)
2	447	485.77	92.02	83.7 -	101.0	
3	807	938.79	85.96	80.1 -	92.1	(low: p<0.005)
4	965	1064.39	90.66	85.0 -	96.6	(low: p<0.005)
5	968	950.53	101.84	95.5 -	108.5	
6	1135	1021.93	111.06	104.7 -	117.7	(high: p<0.005)
7	1242	1143.82	108.58	102.6 -	114.8	(high: p<0.005)
8	1257	1192.14	105.44	99.7 -	111.4	
9	950	908.60	104.56	98.0 -	111.4	
10	612	652.90	93.74	86.5 -	101.5	



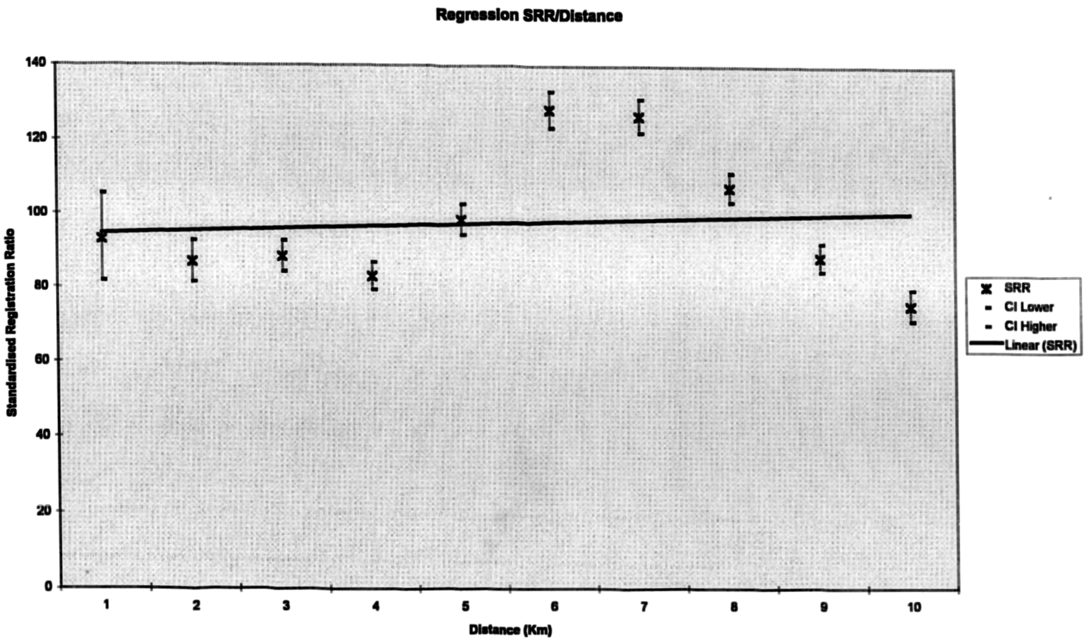
Slope = 0.020668 **p < 0.063**

Max. O/E (Stone) at rings 9.

Table 45

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), FEMALES. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	241	259.63	92.82	81.5 - 105.3	
2	938	1079.79	86.87	81.4 - 92.6	(low: p<0.005)
3	1732	1958.51	88.43	84.3 - 92.7	(low: p<0.005)
4	1982	2381.41	83.23	79.6 - 87.0	(low: p<0.0005)
5	2178	2205.69	98.74	94.6 - 103.0	
6	2719	2118.72	128.33	123.6 - 133.2	(high: p<0.0005)
7	3155	2490.44	126.68	122.3 - 131.2	(high: p<0.0005)
8	2915	2703.28	107.83	104.0 - 111.8	(high: p<0.005)
9	2162	2424.87	89.16	85.4 - 93.0	(low: p<0.005)
10	1293	1692.48	76.40	72.3 - 80.7	(low: p<0.0005)



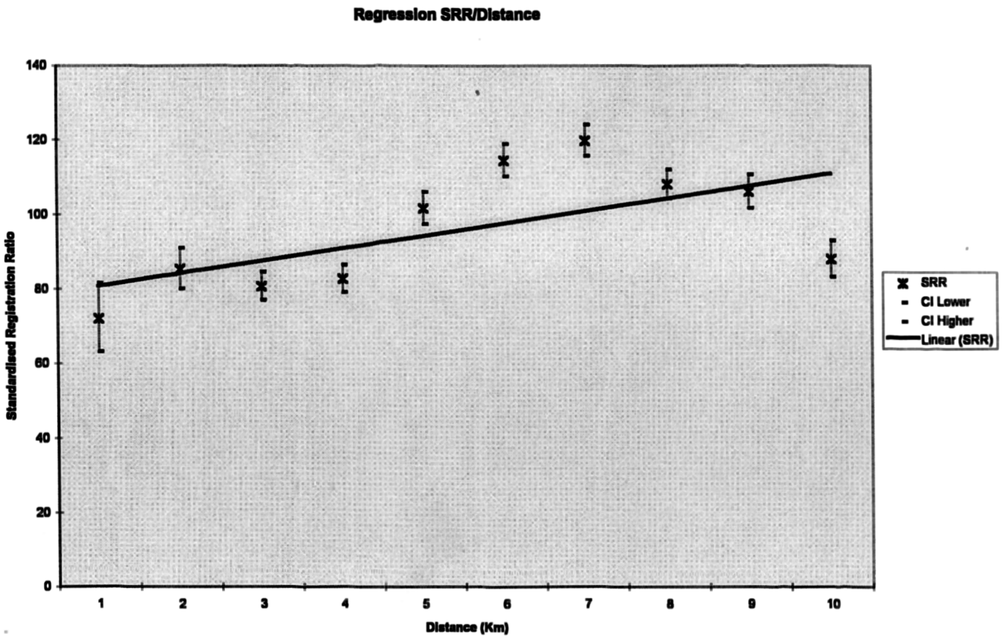
Slope = 0.00547 p = 0.813

Max. O/E (Stone) at ring 8.

Table 46

CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD), FEMALES. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	241	335.06	71.93	63.1 - 81.6	(low: p<0.005)
2	938	1099.14	85.34	80.0 - 91.0	(low: p<0.005)
3	1732	2145.95	80.71	77.0 - 84.6	(low: p<0.0005)
4	1982	2393.24	82.82	79.2 - 86.5	(low: p<0.0005)
5	2178	2140.89	101.73	97.5 - 106.1	
6	2719	2372.48	114.61	110.3 - 119.0	(high: p<0.0005)
7	3155	2630.69	119.93	115.8 - 124.2	(high: p<0.0005)
8	2915	2693.50	108.22	104.3 - 112.2	(high: p<0.005)
9	2162	2035.18	106.23	101.8 - 110.8	(high: p<0.005)
10	1293	1468.86	88.03	83.3 - 93.0	(high: p<0.005)



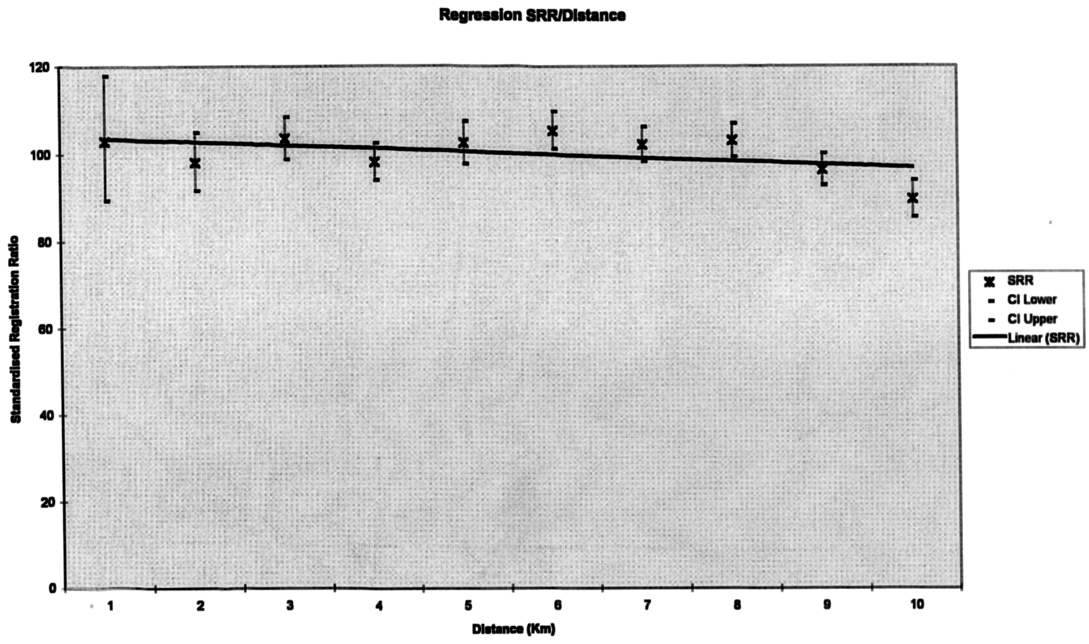
Slope = 0.03290 **p = 0.072**

Max. O/E (Stone) at ring 9.

Table 47

UPPER RESPIRATORY IRRITATION, TOTAL POPULATION. CASES OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	209	202.95	102.98	89.5 - 117.9	
2	844	859.68	98.18	91.7 - 105.0	
3	1821	1756.76	103.66	98.9 - 108.5	
4	2098	2138.43	98.11	94.0 - 102.4	
5	1737	1694.42	102.51	97.7 - 107.4	
6	2326	2208.73	105.31	101.1 - 109.7	(high: p< 0.01)
7	2631	2574.92	102.18	98.3 - 106.2	
8	2724	2644.60	103.00	99.2 - 106.9	
9	2682	2784.92	96.30	92.7 - 100.0	
10	1752	1957.98	89.48	85.3 - 93.8	(low: p< 0.005)



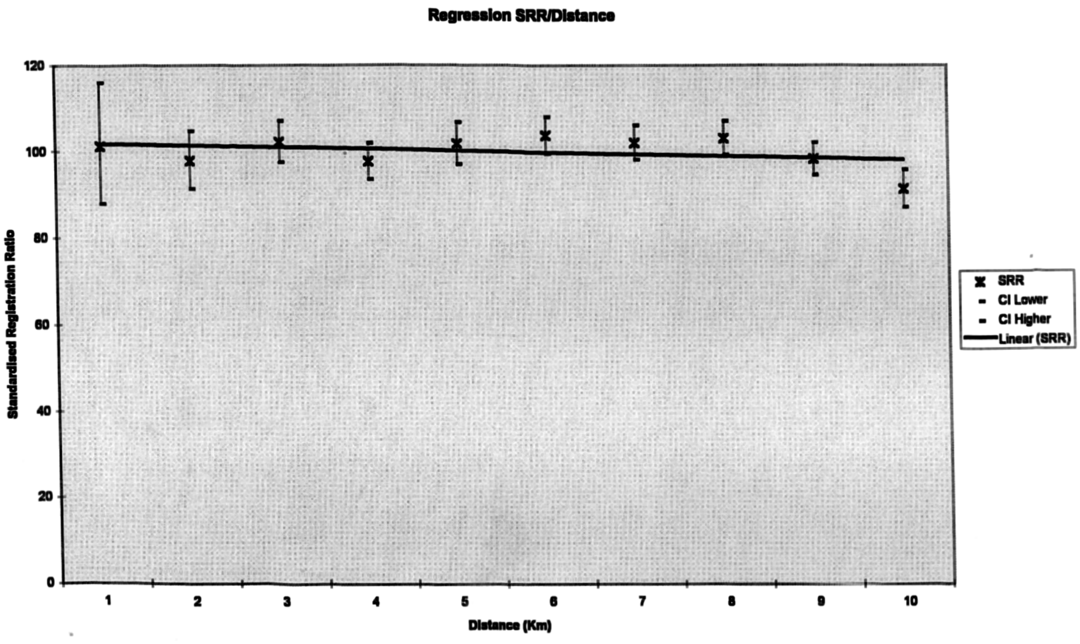
Slope = - 0.008627 p = 0.153

Max. O/E (Stone) at ring 1.

Table 48

UPPER RESPIRATORY IRRITATION, TOTAL POPULATION. CASES OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	209	206.40	101.26	88.0 - 116.0	
2	844	862.21	97.89	91.4 - 104.7	
3	1821	1782.11	102.18	97.5 - 107.0	
4	2098	2149.29	97.61	93.5 - 101.9	
5	1737	1706.85	101.77	97.0 - 106.7	
6	2326	2243.10	103.70	99.5 - 108.0	
7	2631	2579.30	102.00	98.1 - 106.0	
8	2724	2643.80	103.03	99.2 - 107.0	
9	2682	2731.16	98.20	94.5 - 102.0	
10	1752	1919.16	91.29	87.1 - 95.7	(low: p< 0.005)



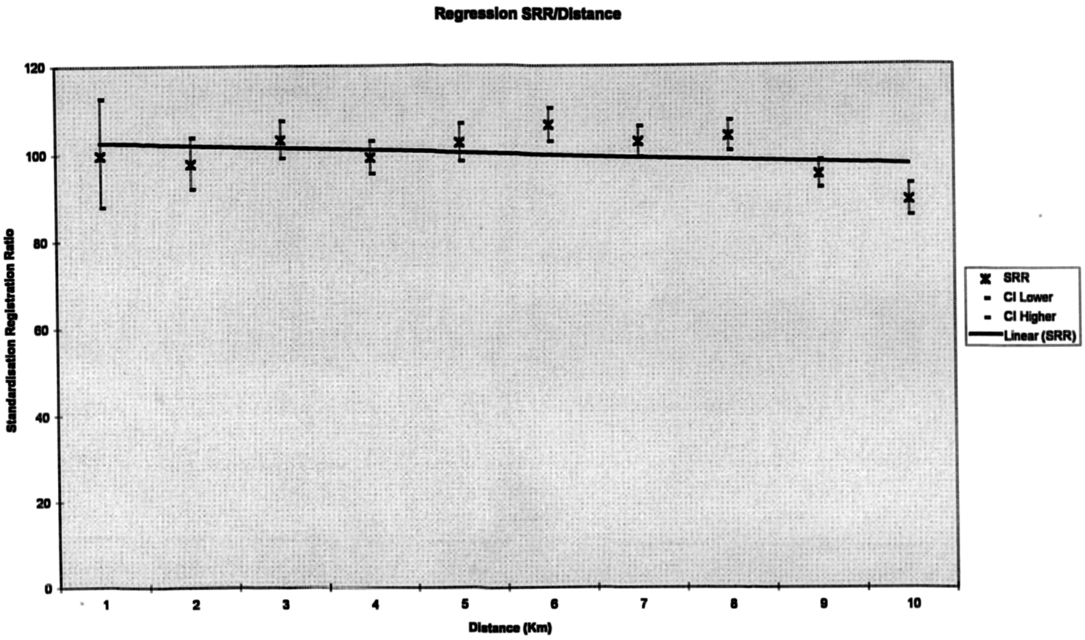
Slope = -0.004947 **p = 0.318**

Max. O/S (Stone) at ring 8.

Table 49

UPPER RESPIRATORY IRRITATION, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	258	258.55	99.79	88.0 - 112.7	
2	1072	1095.63	97.84	92.1 - 103.9	
3	2308	2235.60	103.24	99.1 - 107.5	
4	2695	2721.25	99.04	95.3 - 102.8	
5	2212	2159.38	102.44	98.2 - 106.8	
6	2985	2804.52	106.44	102.7 - 110.3	(high: p< 0.005)
7	3357	3272.28	102.59	99.1 - 106.1	
8	3490	3362.63	103.79	100.4 - 107.3	(high: p< 0.015)
9	3347	3532.71	94.74	91.6 - 98.0	(low: p< 0.005)
10	2200	2481.16	88.67	85.0 - 92.5	(low: p< 0.005)



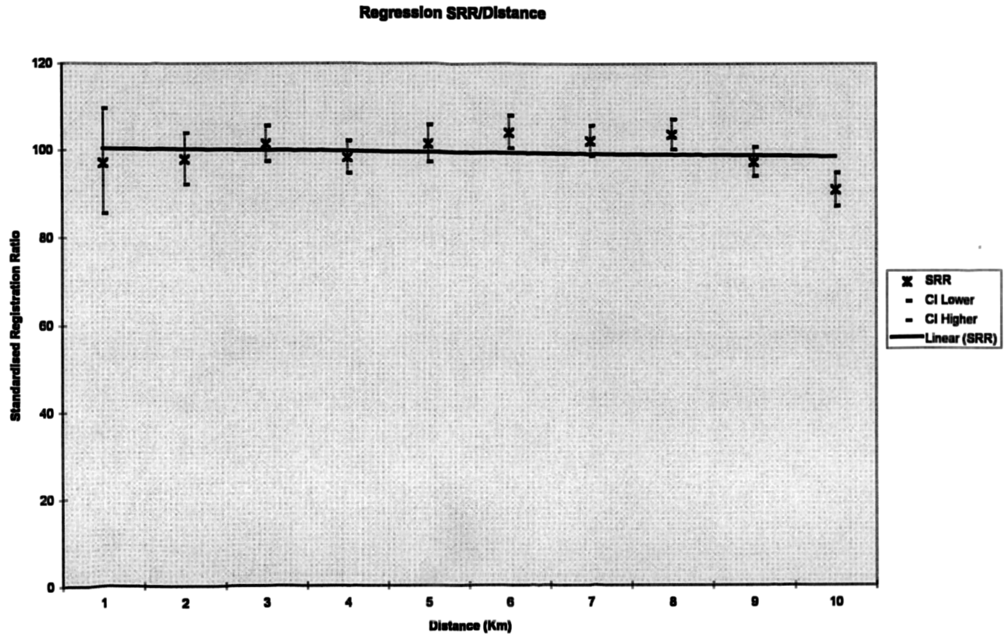
Slope = -0.008909 **p = 0.190**

Max. O/E (Stone) at ring 8.

Table 50

UPPER RESPIRATORY IRRITATION, TOTAL POPULATION. DISCHARGES. OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	258	265.78	97.07	85.6 - 109.7	
2	1072	1094.84	97.91	92.1 - 104.0	
3	2308	2273.87	101.50	97.4 - 105.7	
4	2695	2739.38	98.38	94.7 - 102.2	
5	2212	2178.35	101.54	97.4 - 105.9	
6	2985	2865.92	104.16	100.5 - 108.0	(high: p< 0.015)
7	3357	3283.32	102.24	98.8 - 105.8	
8	3490	3364.13	103.74	100.3 - 107.2	(high: p< 0.015)
9	3347	3439.09	97.32	94.1 - 100.7	
10	2200	2419.03	90.95	87.2 - 94.8	(low: p< 0.005)



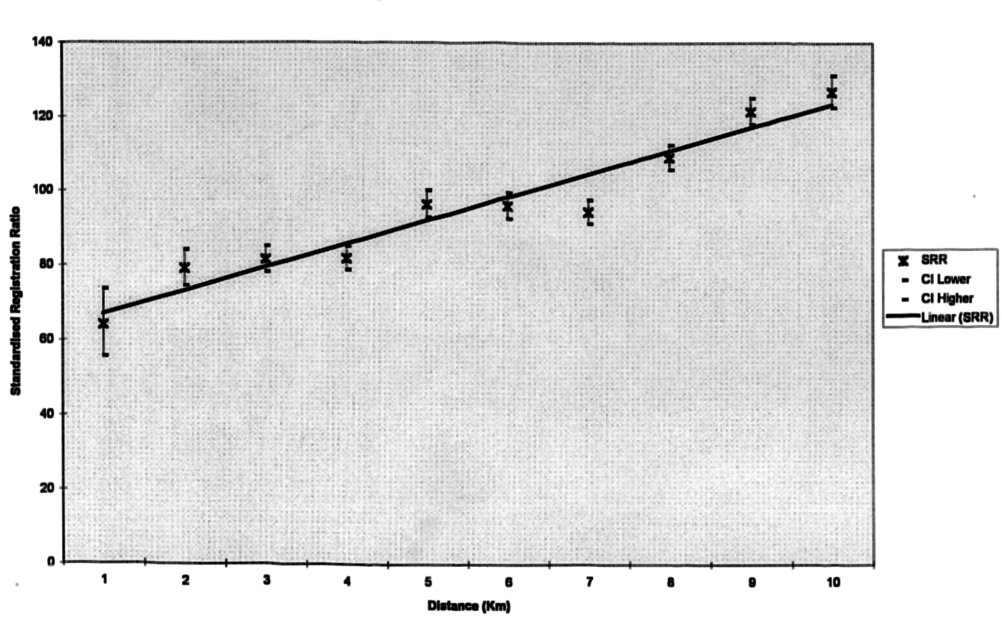
Slope = -0.004248 p = 0.425

Max. O/E (Stone) at ring 8.

Table 51

SKIN IRRITATION, TOTAL POPULATION. CASES
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	202	315.18	64.09	55.6 - 73.6	(low: p< 0.0005)
2	1073	1353.03	79.30	74.6 - 84.2	(low: P< 0.0005)
3	2165	2654.54	81.56	78.2 - 85.1	(low: p< 0.0005)
4	2639	3222.50	81.89	78.8 - 85.1	(low: p< 0.0005)
5	2589	2684.48	96.44	92.8 - 100.2	
6	3031	3157.10	96.01	92.6 - 99.5	(low: p< 0.015)
7	3499	3700.93	94.54	91.4 - 97.7	(low: p< 0.005)
8	4212	3859.09	109.14	105.9 - 112.5	(high: p< 0.005)
9	4627	3806.75	121.55	118.1 - 125.1	(high: p< 0.0005)
10	3382	2664.97	126.91	122.7 - 131.3	(high: p< 0.0005)



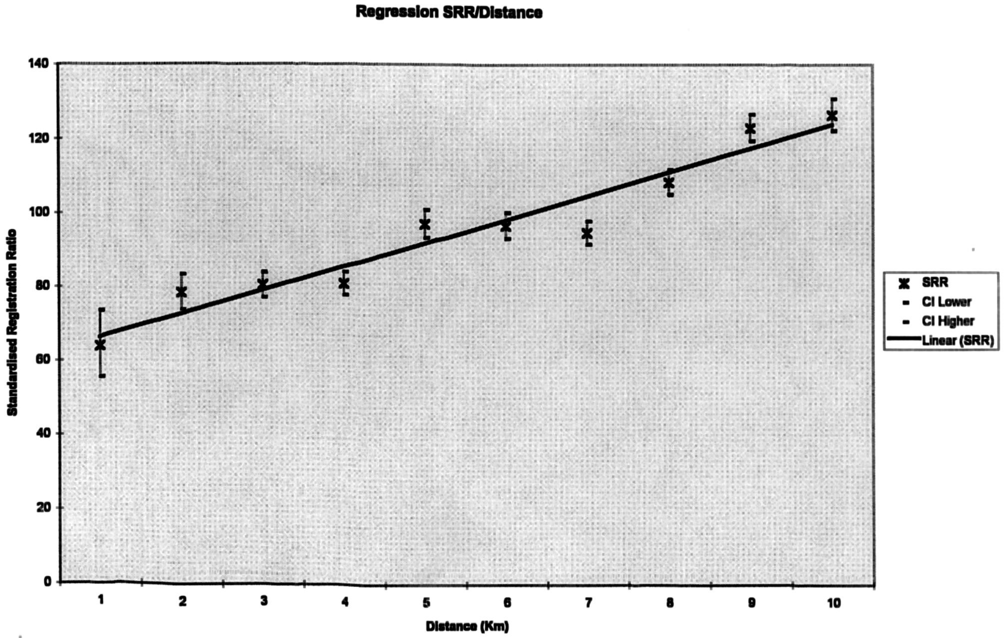
Slope = 0.061995 $p < 0.001$

Max. O/E (Stone) at ring 10.

Table 52

SKIN IRRITATION, TOTAL POPULATION. CASES
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	202	315.51	64.02	55.5 - 73.5	(low: p< 0.0005)
2	1073	1366.51	78.52	73.9 - 83.4	(low: p< 0.0005)
3	2165	2687.45	80.56	77.2 - 84.0	(low: p< 0.0005)
4	2639	3259.70	80.96	77.9 - 84.1	(low: p< 0.0005)
5	2589	2664.39	97.17	93.5 - 101.0	
6	3031	3127.98	96.90	93.5 - 100.4	
7	3499	3683.23	95.00	91.9 - 98.2	(low: p< 0.005)
8	4212	3881.66	108.51	105.3 - 111.8	(high: p< 0.005)
9	4627	3758.71	123.10	119.6 - 126.7	(high: p< 0.0005)
10	3382	2673.43	126.50	122.3 - 130.8	(high: p< 0.0005)



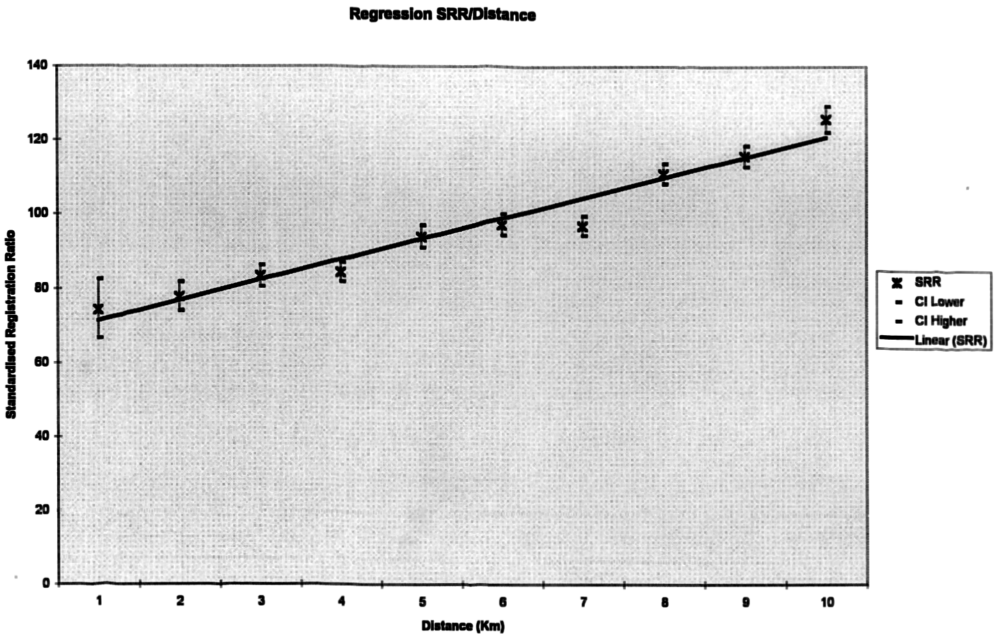
Slope = 0.063433 p < 0.001

Max. O/E (Stone) at ring 10.

Table 53

SKIN IRRITATION, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	352	473.83	74.29	66.7 - 82.5	(low: p< 0.005)
2	1577	2025.34	77.86	74.1 - 81.8	(low: p< 0.0005)
3	3298	3959.64	83.29	80.5 - 86.2	(low: p< 0.0005)
4	4055	4801.75	84.45	81.9 - 87.1	(low: p< 0.0005)
5	3780	4027.74	93.85	90.9 - 96.9	(low: p< 0.005)
6	4576	4712.85	97.10	94.3 - 100.0	
7	5348	5521.88	96.85	94.3 - 99.5	(low: p< 0.01)
8	6382	5755.42	110.89	108.2 - 113.6	(high: p< 0.0005)
9	6566	5675.81	115.68	112.9 - 118.5	(high: p< 0.0005)
10	4992	3971.02	125.71	122.2 - 129.2	(high: p< 0.0005)



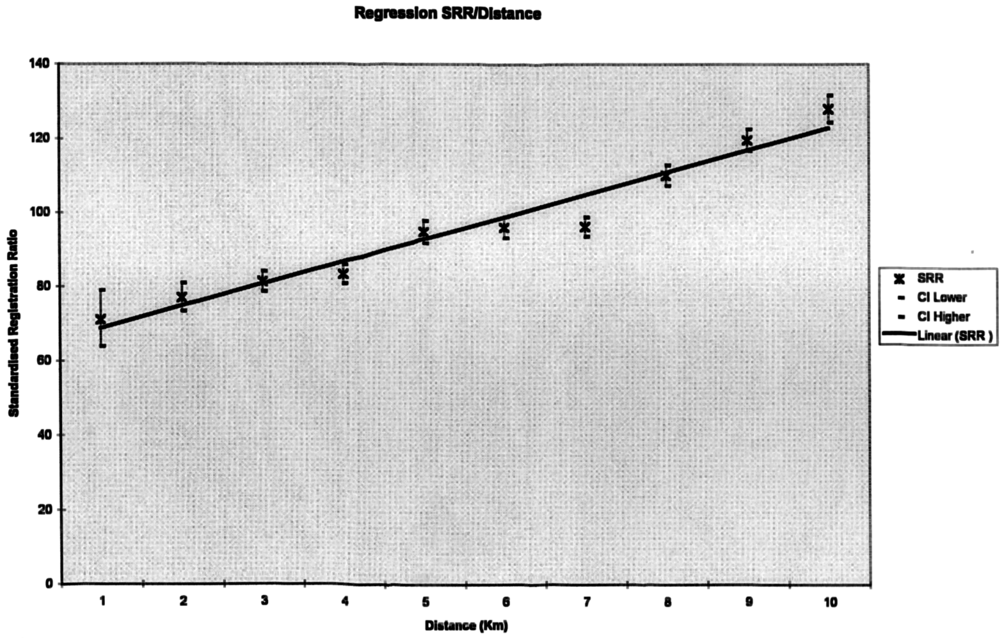
Slope = 0.055945 **p < 0.001**

Max. O/E (Stone) at ring 10.

Table 54

SKIN IRRITATION, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	352	494.84	71.13	63.9 - 79.0	(low: p< 0.0005)
2	1577	2046.70	77.05	73.3 - 80.9	(low: p< 0.0005)
3	3298	4050.97	81.41	78.7 - 84.2	(low: p< 0.0005)
4	4055	4857.61	83.48	80.9 - 86.1	(low: p< 0.0005)
5	3780	3986.00	94.83	91.8 - 97.9	(low: p< 0.005)
6	4576	4756.99	96.20	93.4 - 99.0	(low: p< 0.005)
7	5348	5553.88	96.29	93.7 - 98.9	(low: p< 0.005)
8	6382	5794.99	110.13	107.4 - 112.9	(high: p< 0.0005)
9	6566	5485.33	119.70	116.8 - 122.6	(high: p< 0.0005)
10	4992	3897.98	128.07	124.5 - 131.7	(high: p< 0.0005)



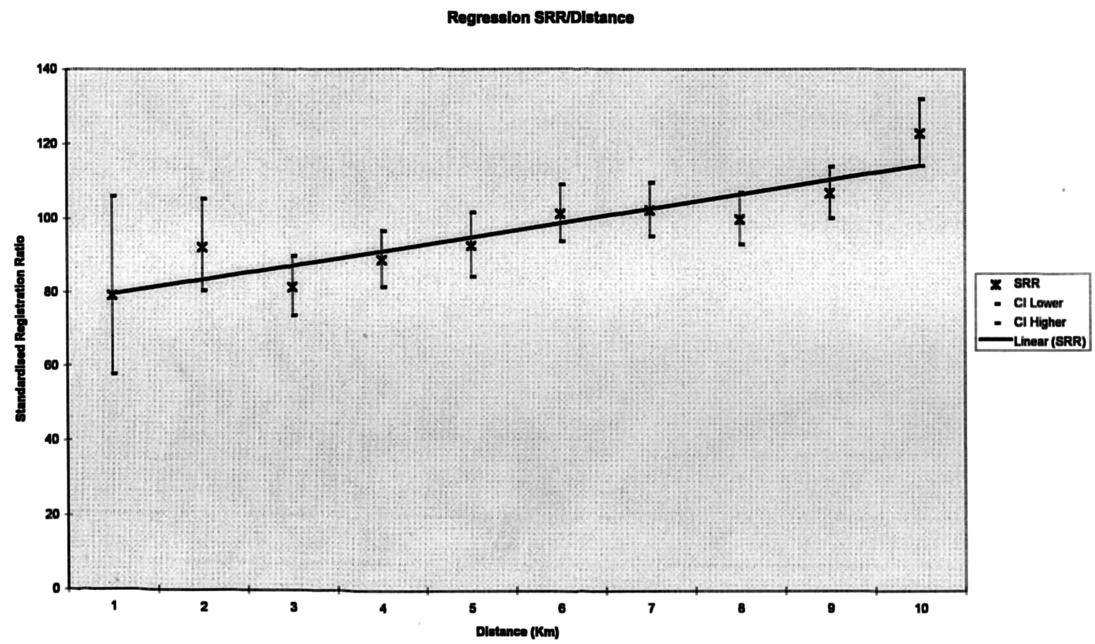
Slope = 0.060963 **p < 0.001**

Max. O/E (Stone) at ring 10.

Table 55

SKIN IRRITATION, POPULATION 0 TO 19 YEARS OF AGE. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	45	56.84	79.17	57.7 - 105.9	
2	222	240.75	92.21	80.5 - 105.2	
3	411	503.79	81.58	73.9 - 89.9	(low: p<0.005)
4	542	609.86	88.87	81.5 - 96.7	(low: p<0.005)
5	451	486.17	92.77	84.4 - 101.7	
6	692	683.08	101.31	93.9 - 109.1	
7	794	775.92	102.33	95.3 - 109.7	
8	804	804.89	99.89	93.1 - 107.0	
9	942	881.31	106.89	100.2 - 113.9	(high: p<0.025)
10	747	607.84	122.89	114.2 - 132.0	(high: p<0.005)



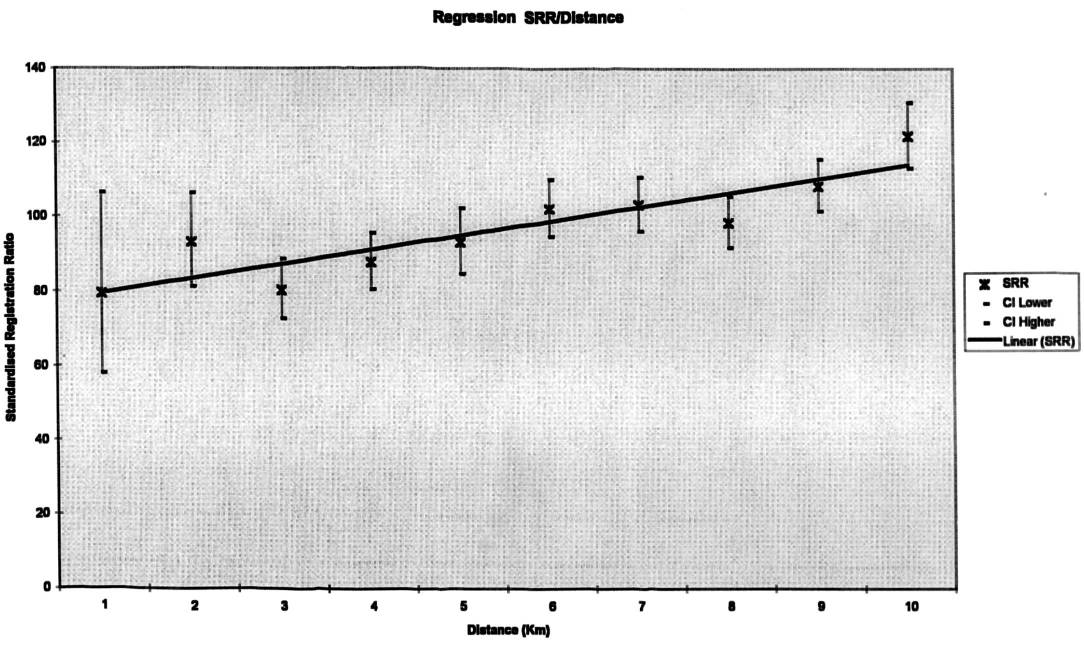
Slope = 0.039324 $p < 0.001$

Max. O/E (Stone) at ring 10.

Table 56

SKIN IRRITATION, POPULATION 0 TO 19 YEARS OF AGE. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	45	56.60	79.51	58.0 - 106.4	
2	222	238.20	93.20	81.3 - 106.3	
3	411	510.62	80.49	72.9 - 88.7	(low: p<0.005)
4	542	617.03	87.84	80.6 - 95.6	(low: p<0.005)
5	451	483.70	93.24	84.8 - 102.3	
6	692	676.87	102.24	94.8 - 110.1	
7	794	768.95	103.26	96.2 - 110.7	
8	804	815.72	98.56	91.9 - 105.6	
9	942	868.86	108.42	101.6 - 115.6	(high: p<0.01)
10	747	613.46	121.77	113.2 - 130.8	(high: p<0.005)



Slope = 0.039636 **p < 0.001**

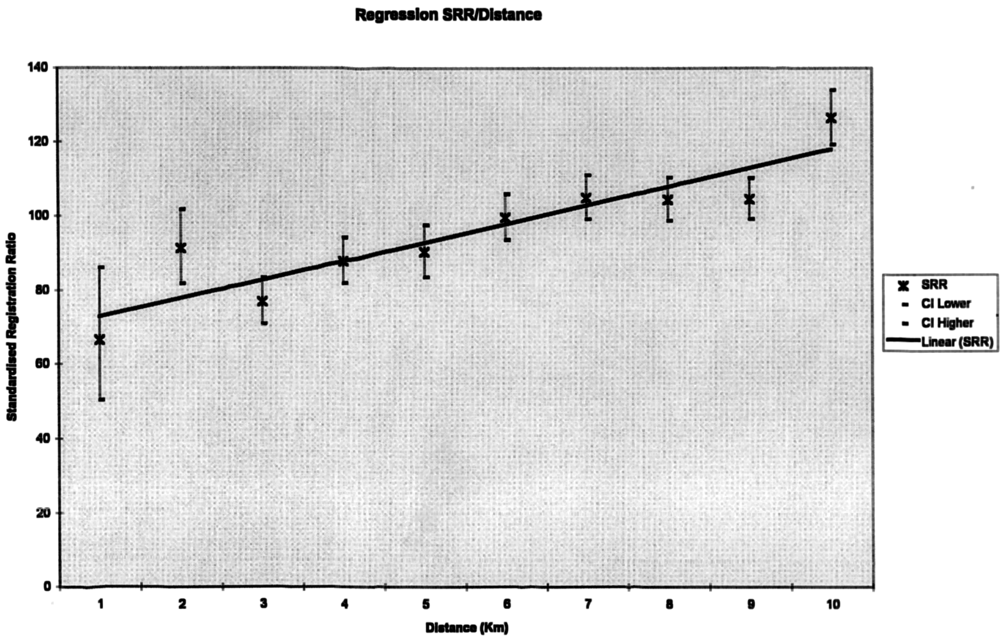
Max. O/E (Stone) at ring 10.

Table 57

SKIN IRRITATION, POPULATION 0 TO 19 YEARS OF AGE. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	57	85.73	66.48	50.4 - 86.1	(low: p<0.0006)*
2	331	362.20	91.39	81.8 - 101.8	
3	582	756.22	76.96	70.8 - 83.5	(low: p<0.0005)
4	804	914.90	87.88	81.9 - 94.2	(low: p<0.005)
5	663	732.55	90.51	83.7 - 97.7	(low: p<0.01)
6	1025	1027.29	99.78	93.8 - 106.1	
7	1227	1168.22	105.03	99.2 - 111.1	
8	1266	1210.74	104.56	98.9 - 110.5	
9	1387	1325.57	104.63	99.2 - 110.3	
10	1154	912.47	126.47	119.3 - 134.0	(high: p<0.0005)

* - Exact Poisson.



Slope = 0.048934　　　　p < 0.001

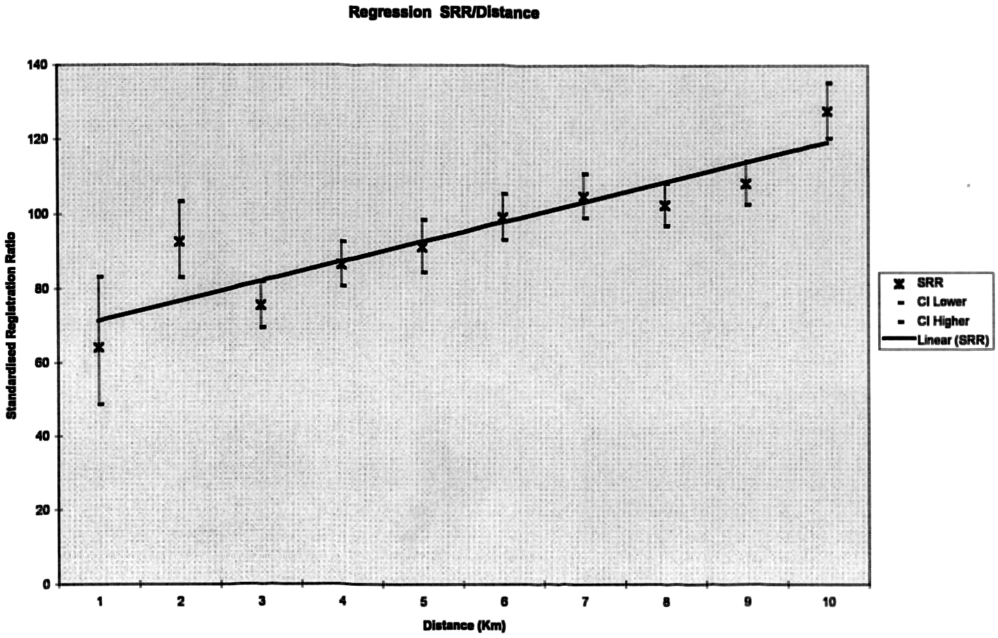
Max. O/E (Stone) at rings 10.

Table 58

SKIN IRRITATION, POPULATION 0 TO 19 YEARS OLD. DISCHARGES. OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	57	88.89	64.13	48.6 - 83.1	(low: p<0.00001)*
2	331	357.03	92.71	83.0 - 103.3	
3	582	771.40	75.45	69.4 - 81.8	(low: p<0.0005)
4	804	930.18	86.43	80.6 - 92.6	(low: p<0.005)
5	663	726.79	91.22	84.4 - 98.4	(low: p<0.01)
6	1025	1032.94	99.23	93.2 - 105.5	
7	1227	1169.96	104.88	99.1 - 110.9	
8	1266	1234.59	102.54	97.0 - 108.4	
9	1387	1280.47	108.32	102.7 - 114.2	(high: p<0.005)
10	1154	903.75	127.69	120.4 - 135.3	(high: p<0.0005)

*** - Exact Poisson.**



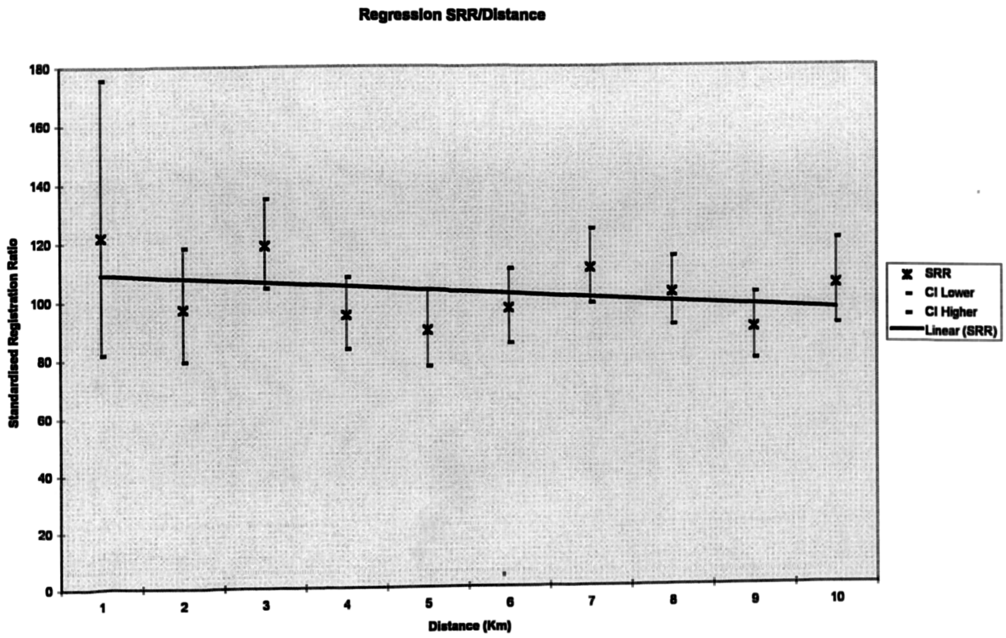
Slope = 0.052366 **p < 0.001**

Max. O/E (Stone) at ring 10.

Table 59

EYE IRRITATION, TOTAL POPULATION. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	29	23.77	122.02	81.8 - 175.7	
2	101	103.93	97.18	79.2 - 118.1	
3	238	200.56	118.67	104.1 - 134.7	(high: p< 0.005)
4	230	243.36	94.51	82.7 - 107.5	
5	184	206.87	88.95	76.6 - 102.8	
6	221	229.78	96.18	83.9 - 109.7	
7	292	265.85	109.83	97.6 - 123.2	
8	286	282.43	101.26	89.9 - 113.7	
9	235	265.14	88.63	77.7 - 100.7	
10	195	188.23	103.60	89.6 - 119.2	



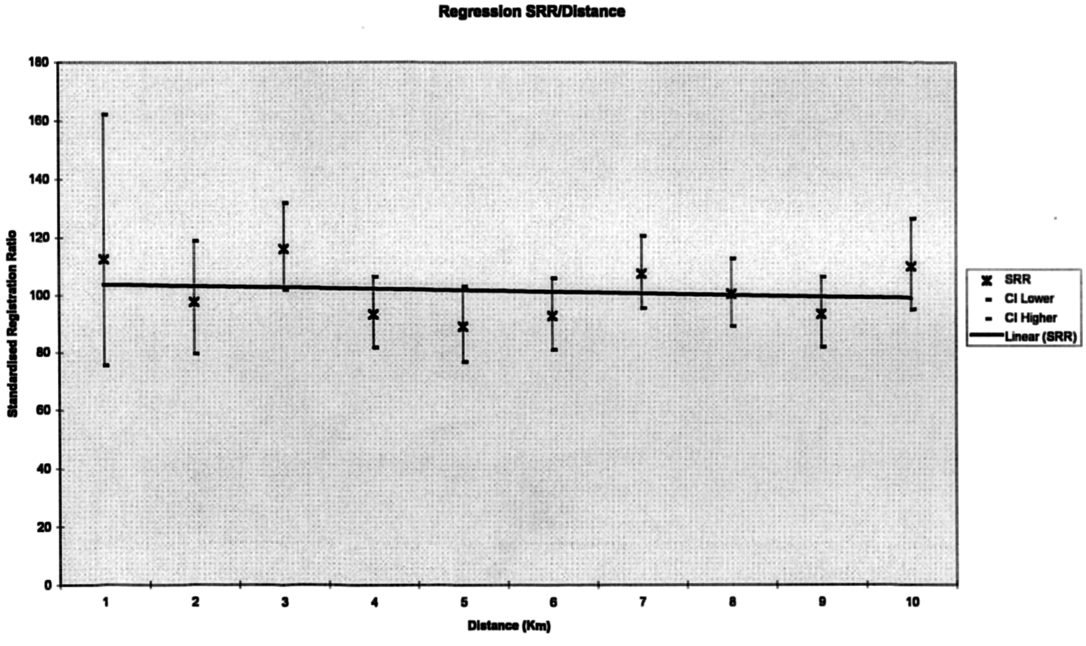
Slope = -0.01021 p = 0.451

Max. O/E (Stone) at ring 1.

Table 60

EYE IRRITATION, TOTAL POPULATION. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	29	25.74	112.65	75.5 - 162.2	
2	101	103.16	97.91	79.7 - 119.0	
3	238	204.94	116.13	101.8 - 131.9	(high: p< 0.015)
4	230	246.22	93.41	81.7 - 106.3	
5	184	206.61	89.06	76.7 - 102.9	
6	221	238.26	92.76	80.9 - 105.8	
7	292	271.72	107.46	95.5 - 120.5	
8	286	284.67	100.47	89.2 - 112.8	
9	235	251.12	93.58	82.0 - 106.3	
10	195	177.50	109.86	95.0 - 126.4	



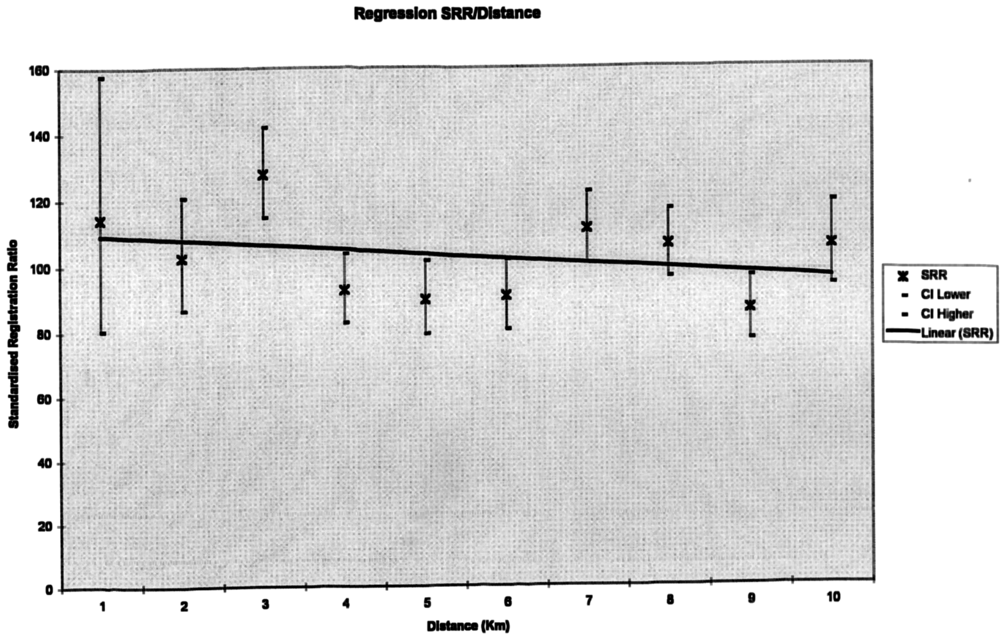
Slope = -0.00162 **p = 0.896**

Max. O/E (Stone) at ring 1.

Table 61

EYE IRRITATION, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	37	32.37	114.31	80.5 - 157.6	
2	144	140.66	102.37	86.3 - 120.5	
3	344	269.88	127.46	114.3 - 141.7	(high: p< 0.005)
4	301	327.29	91.97	81.9 - 103.0	
5	249	280.17	88.87	78.2 - 100.6	
6	276	308.16	89.56	79.3 - 100.8	
7	393	357.71	109.87	99.3 - 121.3	
8	397	379.16	104.71	94.7 - 115.5	
9	300	354.57	84.61	75.3 - 94.7	(low: p< 0.005)
10	262	251.72	104.08	91.9 - 117.5	



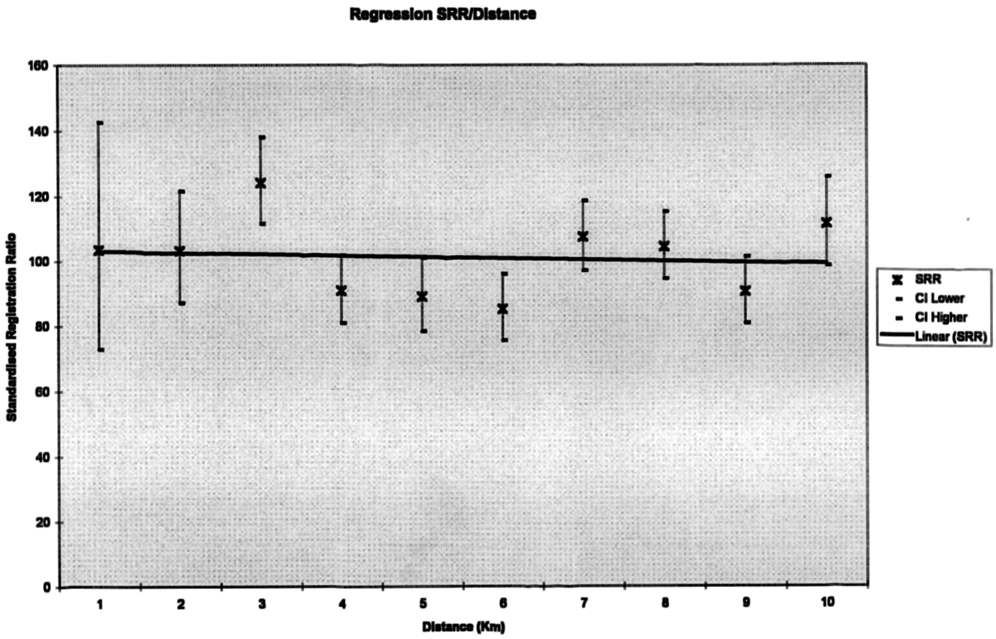
Slope = - 0.01414 **p = 0.411**

Max. O/E (Stone) at ring 3.

Table 62

EYE IRRITATION, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	37	35.77	103.43	72.8 - 142.6	
2	144	139.44	103.27	87.1 - 121.6	
3	344	276.81	124.27	111.5 - 138.1	(high: p< 0.005)
4	301	331.09	90.91	80.9 - 101.8	
5	249	279.77	89.00	78.3 - 100.8	
6	276	324.16	85.14	75.4 - 95.8	(low: p< 0.005)
7	393	366.29	107.29	96.9 - 118.4	
8	397	380.75	104.27	94.3 - 115.0	
9	300	332.19	90.31	80.4 - 101.1	
10	262	235.41	111.30	98.2 - 125.6	



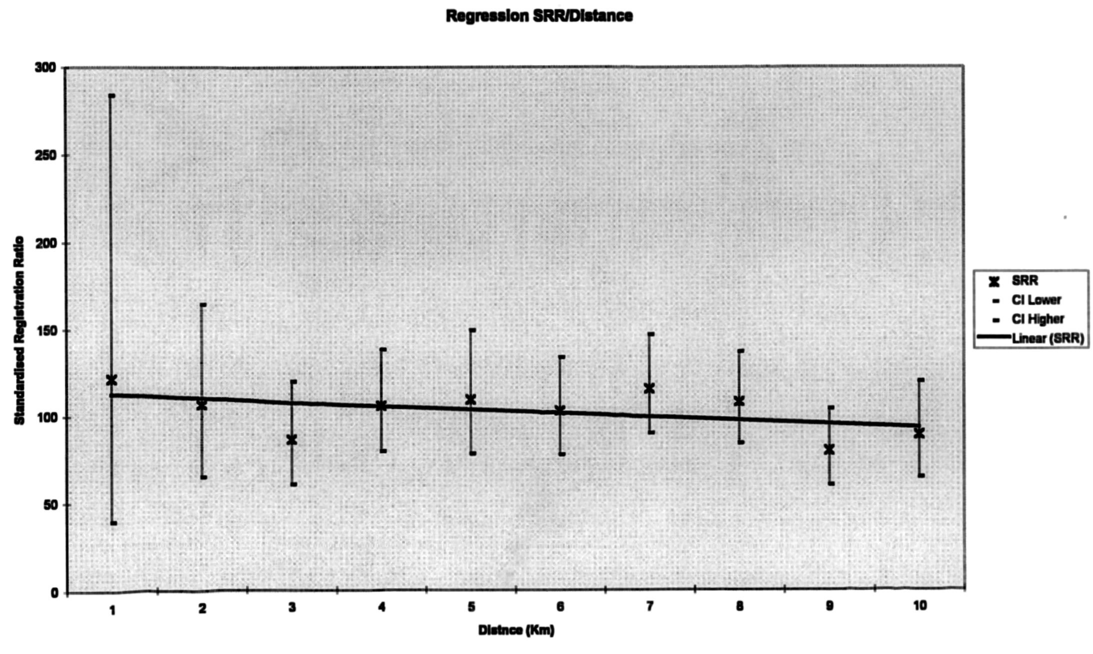
Slope = -0.00380 **p = 0.819**

Max. O/E (Stone) at ring 3.

Table 63

EYE IRRITATION, POPULATION 0 TO 19 YEARS OF AGE. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI
1	5	4.10	121.80	39.5 - 283.8
2	20	18.70	106.96	65.3 - 164.7
3	36	41.26	87.25	61.1 - 120.8
4	54	50.62	106.68	80.1 - 139.2
5	40	36.39	109.91	78.5 - 149.7
6	55	53.39	103.02	77.6 - 134.1
7	68	58.70	115.84	90.0 - 146.9
8	68	62.98	107.97	83.8 - 136.9
9	54	67.98	79.43	59.7 - 103.6
10	43	48.56	88.55	64.1 - 119.3



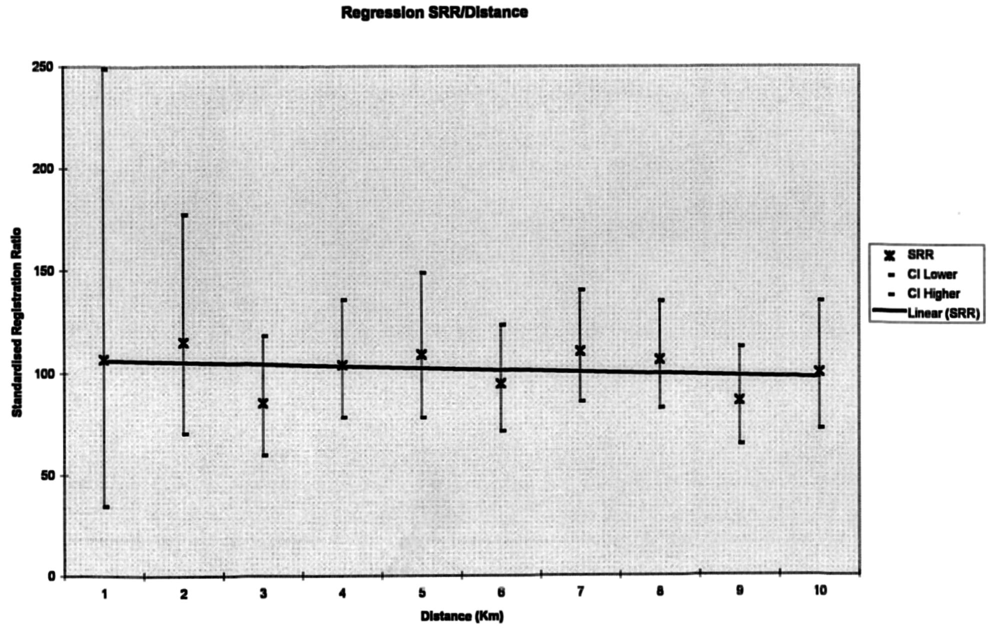
Slope = -0.01962 p = 0.244

Max. O/E (Stone) at ring 1.

Table 64

EYE IRRITATION, POPULATION 0 TO 19 YEARS OF AGE. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Cases	Obs.	Exp.	SRR	95% CI
1	5	4.68	106.83	34.6 - 248.9
2	20	17.37	115.12	70.3 - 177.3
3	36	42.23	85.25	59.7 - 118.0
4	54	51.95	103.94	78.1 - 135.6
5	40	36.69	109.02	77.9 - 148.5
6	55	58.15	94.59	71.3 - 123.1
7	68	61.68	110.25	85.6 - 139.8
8	68	64.19	105.94	82.3 - 134.3
9	54	62.86	85.90	64.5 - 112.1
10	43	43.20	99.54	72.0 - 134.1



Slope = -0.00703 **p = 0.607**

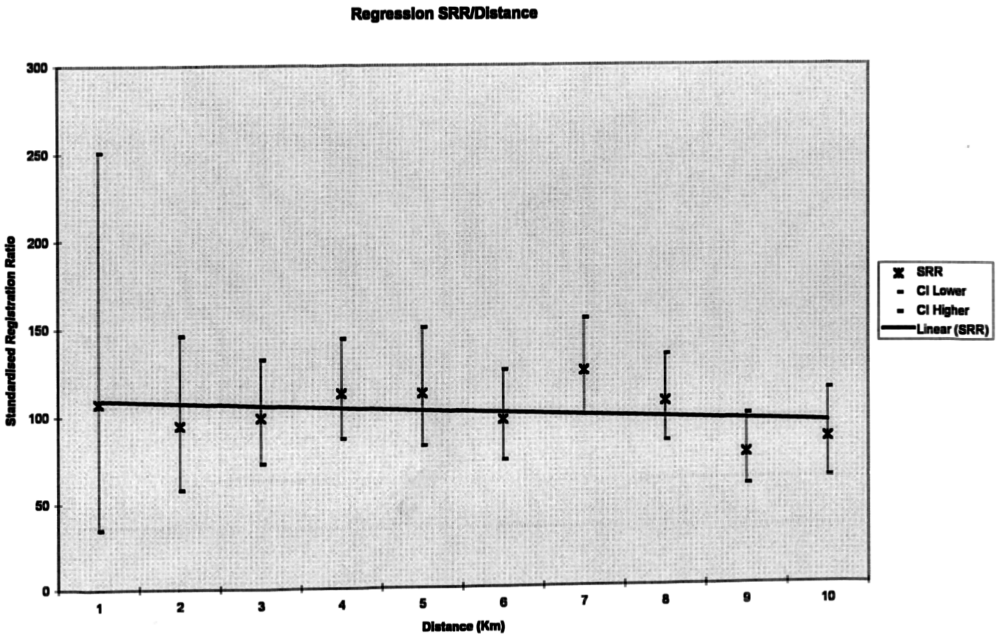
Max. O/S (Stone) at ring 2.

Table 65

EYE IRRITATION, POPULATION 0 TO 19 YEARS OF AGE. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	5	4.64	107.66	34.9 - 250.8	
2	20	21.11	94.76	57.9 - 145.9	
3	46	46.50	98.93	72.4 - 132.0	
4	64	57.03	112.22	86.4 - 143.3	
5	46	41.12	111.87	81.9 - 149.2	
6	58	60.25	96.26	73.1 - 124.4	
7	82	66.32	123.64	98.3 - 153.5	
8	75	71.06	105.54	83.0 - 132.3	
9	58	76.79	75.54	57.4 - 97.6	(low: p < 0.0154)*
10	46	54.82	83.92	61.4 - 111.9	

* - Exact Poisson.



Slope = -0.02502 p = 0.194

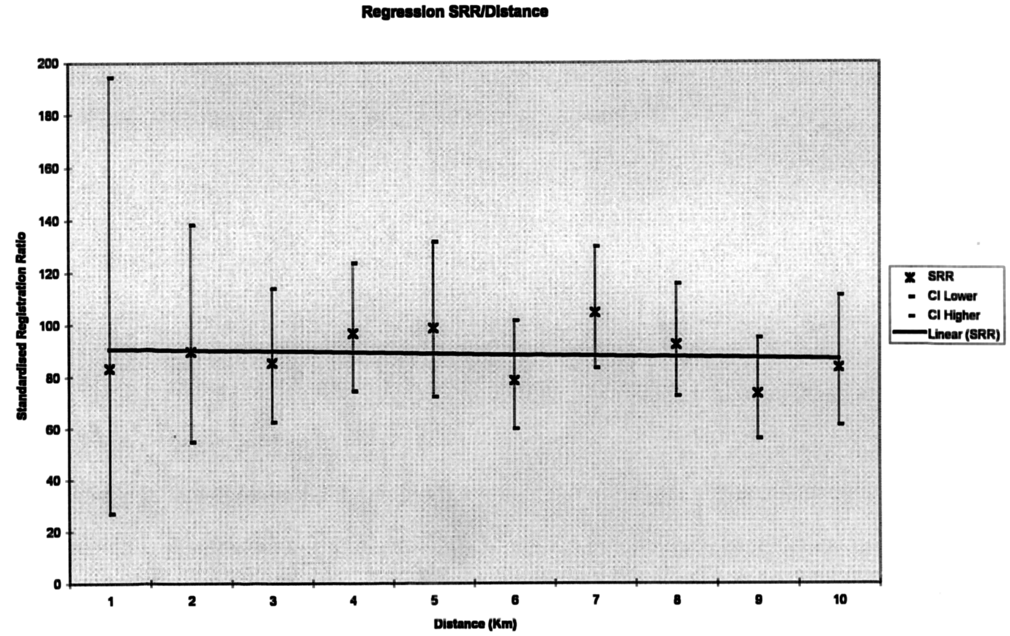
Max. O/E (Stone) at ring 1.

Table 66

EYE IRRITATION, POPULATION 0 TO 19 YEARS OF AGE. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	5	5.99	83.47	27.0 - 194.5	
2	20	22.27	89.80	54.9 - 138.3	
3	46	53.94	85.28	62.4 - 113.8	
4	64	66.31	96.52	74.3 - 123.3	
5	46	46.68	98.53	72.1 - 131.4	
6	58	73.98	78.39	59.5 - 101.3	
7	82	78.75	104.12	82.8 - 129.2	
8	75	81.88	91.60	72.0 - 114.8	
9	58	79.74	72.74	55.2 - 94.0	(low: p < 0.0066)*
10	46	55.71	82.57	60.4 - 110.1	

* - Exact Poisson.



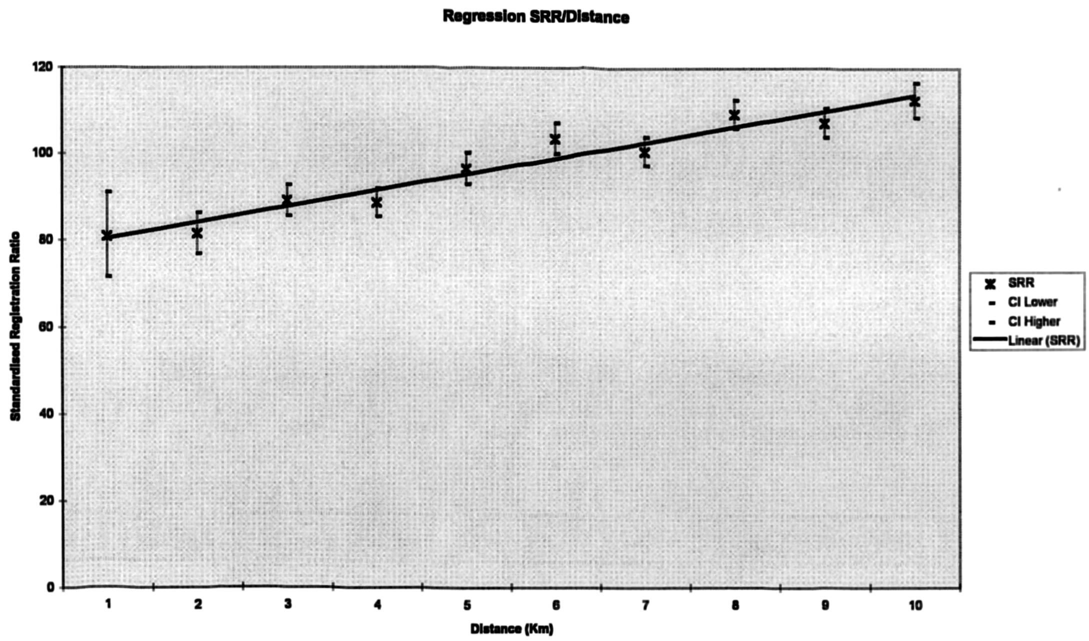
Slope = -0.01109   p = 0.412

Max. O/E (Stone) at ring 5.

Table 67

UPPER DIGESTIVE TRACT IRRITATION, TOTAL POPULATION. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	271	334.98	80.90	71.6 - 91.1	(low: p< 0.005)
2	1172	1437.27	81.54	76.9 - 86.3	(low: p< 0.0005)
3	2445	2741.17	89.20	85.7 - 92.8	(low: p< 0.005)
4	2939	3314.42	88.67	85.5 - 91.9	(low: p< 0.0005)
5	2775	2873.33	96.58	93.0 - 100.2	
6	3266	3153.35	103.57	100.1 - 107.2	(high: p< 0.025)
7	3734	3708.53	100.69	97.5 - 104.0	
8	4248	3888.63	109.24	106.0 - 112.6	(high: p< 0.0005)
9	3986	3711.95	107.38	104.1 - 110.8	(high: p< 0.005)
10	2938	2609.38	112.59	108.6 - 116.7	(high: p< 0.0005)



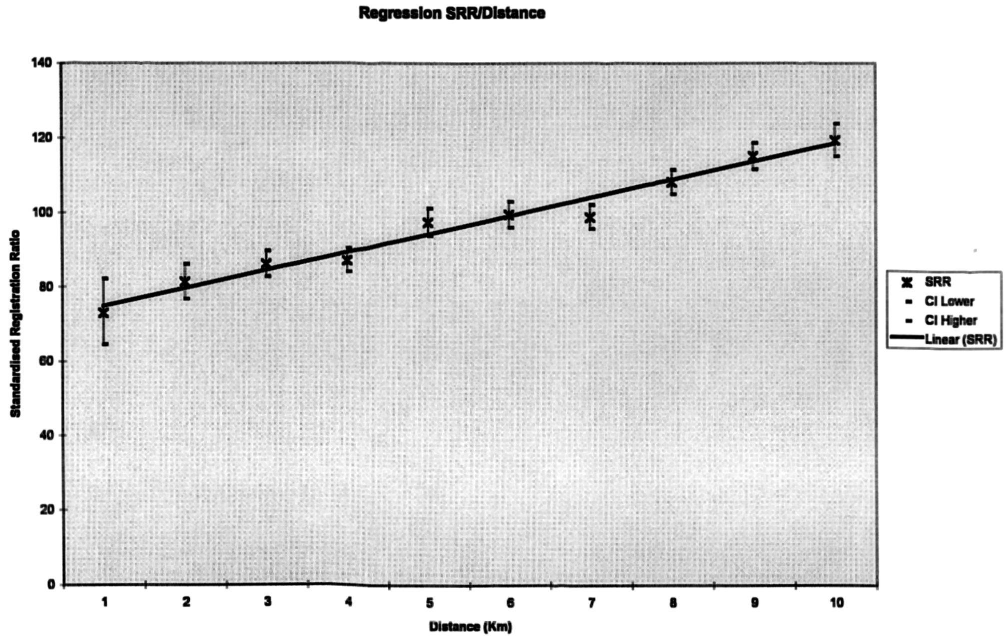
Slope = 0.036929 p = 0.001

Max. O/E (Stone) at ring 10.

Table 68

UPPER DIGESTIVE TRACT IRRITATION, TOTAL POPULATION. CASES. OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	271	371.45	72.96	64.5 - 82.2	(low: p< 0.005)
2	1172	1438.99	81.45	76.8 - 86.2	(low: p< 0.0005)
3	2445	2836.17	86.21	82.8 - 89.7	(low: p< 0.0005)
4	2939	3371.43	87.17	84.1 - 90.4	(low: p< 0.0005)
5	2775	2846.06	97.50	93.9 - 101.2	
6	3266	3282.27	99.50	96.1 - 103.0	
7	3734	3777.73	98.84	95.7 - 102.1	
8	4248	3925.10	108.23	105.0 - 111.5	(high: p< 0.005)
9	3986	3463.01	115.10	111.6 - 118.7	(high: p< 0.0005)
10	2938	2460.80	119.39	115.1 - 123.8	(high: p< 0.0005)



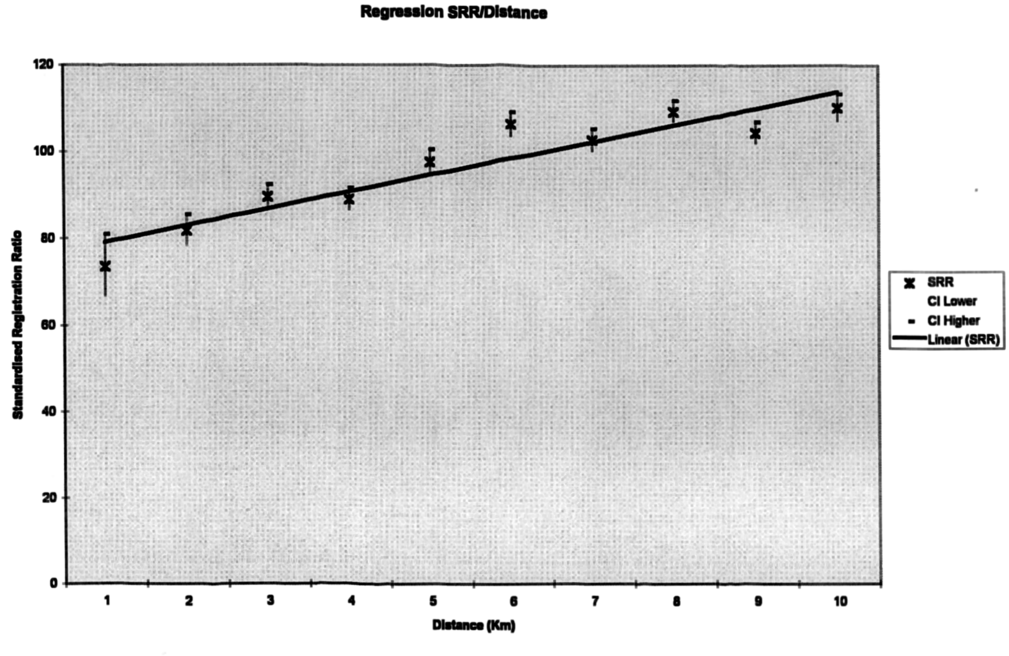
Slope = 0.047787 **p < 0.001**

Max. O/E (Stone) at ring 10.

Table 69

UPPER DIGESTIVE TRACT IRRITATION, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	416	565.77	73.53	66.6 - 80.9	(low: p< 0.0005)
2	1981	2423.36	81.75	78.2 - 85.4	(low: p< 0.0005)
3	4126	4607.55	89.55	86.8 - 92.3	(low: p< 0.0005)
4	4956	5570.25	88.97	86.5 - 91.5	(low: p< 0.0005)
5	4723	4847.06	97.44	94.7 - 100.3	
6	5619	5286.82	106.28	103.5 - 109.1	(high: p< 0.005)
7	6385	6216.59	102.71	100.2 - 105.3	(high: p< 0.02)
8	7125	6521.51	109.25	106.7 - 111.8	(high: p< 0.0005)
9	6463	6195.69	104.31	101.8 - 106.9	(high: p< 0.005)
10	4799	4358.40	110.11	107.0 - 113.3	(high: p< 0.0005)



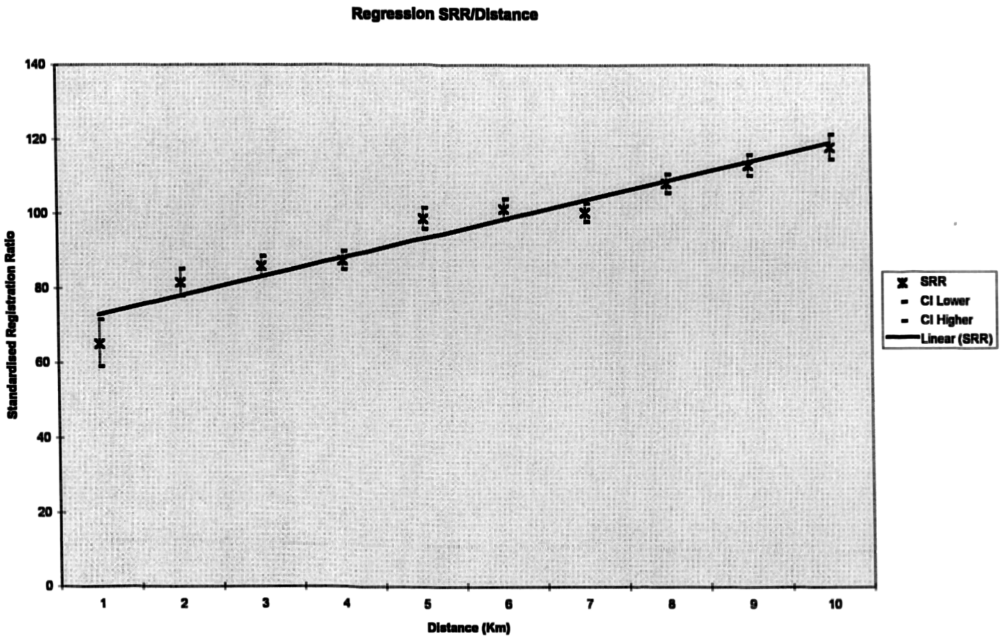
Slope = 0.036046 **p < 0.001**

Max. O/E (Stone) at ring 10.

Table 70

UPPER DIGESTIVE TRACT IRRITATION, TOTAL POPULATION. DISCHARGES. OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	416	640.07	64.99	58.9 - 71.5	(low: p< 0.0005)
2	1981	2428.62	81.57	78.0 - 85.2	(low: p< 0.0005)
3	4126	4800.65	85.95	83.3 - 88.6	(low: p< 0.0005)
4	4956	5664.08	87.50	85.1 - 90.0	(low: p< 0.0005)
5	4723	4782.70	98.75	96.0 - 101.6	
6	5619	5548.33	101.27	98.6 - 104.0	
7	6385	6358.69	100.41	98.0 - 102.9	
8	7125	6586.72	108.17	105.7 - 110.7	(high: p< 0.0005)
9	6463	5715.36	113.08	110.3 - 115.9	(high: p< 0.0005)
10	4799	4067.78	117.98	114.7 - 121.4	(high: p< 0.0005)



Slope = 0.048806 **p < 0.001**

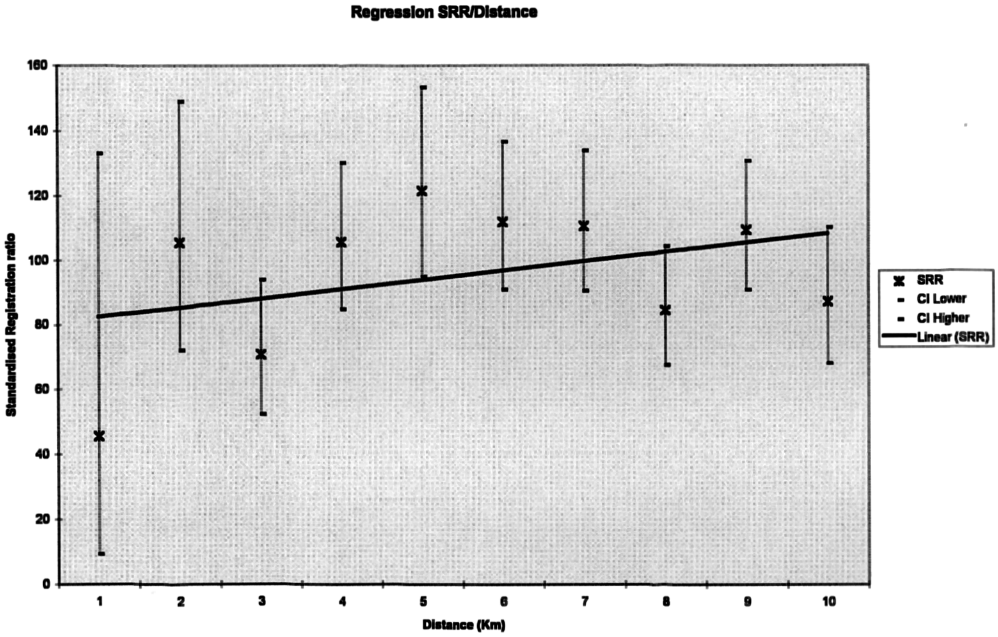
Max. O/E (Stone) at ring 10.

Table 71

UPPER DIGESTIVE TRACT IRRITATION, POPULATION 0 TO 9 YEARS OF AGE. CASES. OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	3	6.59	45.54	9.4 - 133.0	
2	32	30.34	105.49	72.1 - 148.9	
3	48	67.71	70.90	52.3 - 94.0	(low: p<0.007)*
4	88	83.27	105.68	84.8 - 130.2	
5	71	58.42	121.54	94.9 - 153.3	
6	97	86.65	111.94	90.8 - 136.6	
7	105	94.97	110.57	90.4 - 133.8	
8	86	101.89	84.40	67.5 - 104.2	
9	121	110.68	109.32	90.7 - 130.6	
10	70	80.35	87.12	67.9 - 110.1	

* - Exact Poisson.



Slope = 0.01586 p = 0.524

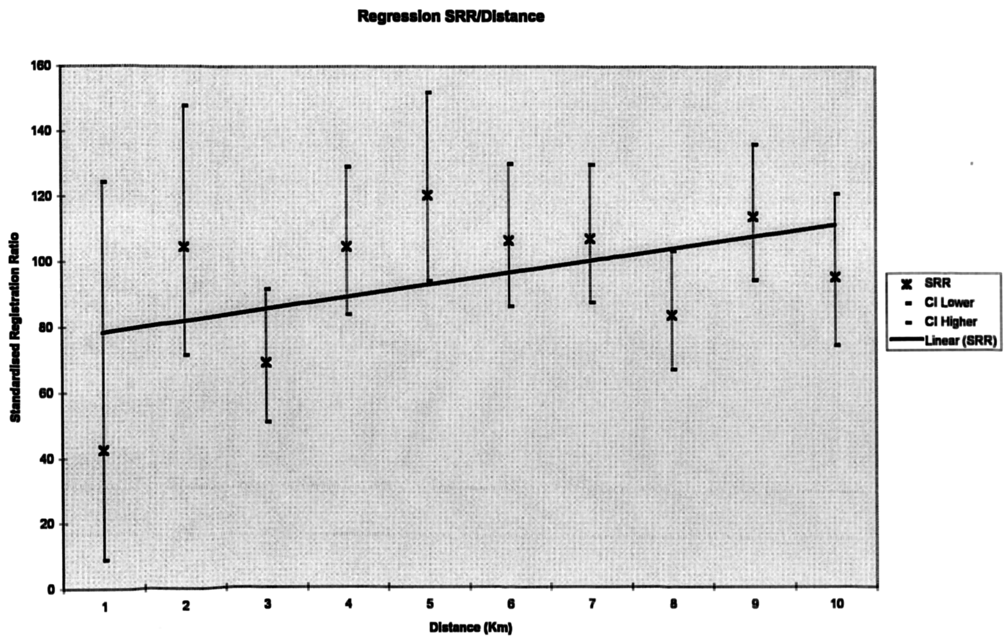
Max. O/E (Stone) at ring 7.

Table 72

UPPER DIGESTIVE TRACT IRRITATION, POPULATION 0 TO 9 YEARS OF AGE. CASES. OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	3	7.06	42.52	8.8 - 124.2	
2	32	30.55	104.74	71.6 - 147.9	
3	48	69.40	69.17	51.0 - 91.7	(low: p<0.004)*
4	88	83.99	104.77	84.0 - 129.1	
5	71	58.94	120.47	94.1 - 152.0	
6	97	91.00	106.59	86.4 - 130.0	
7	105	97.96	107.19	87.7 - 129.8	
8	86	102.69	83.74	67.0 - 103.4	
9	121	106.25	113.88	94.5 - 136.1	
10	70	73.16	95.68	74.6 - 120.9	

*** - Exact Poisson.**



Slope = 0.02673 **p = 0.282**

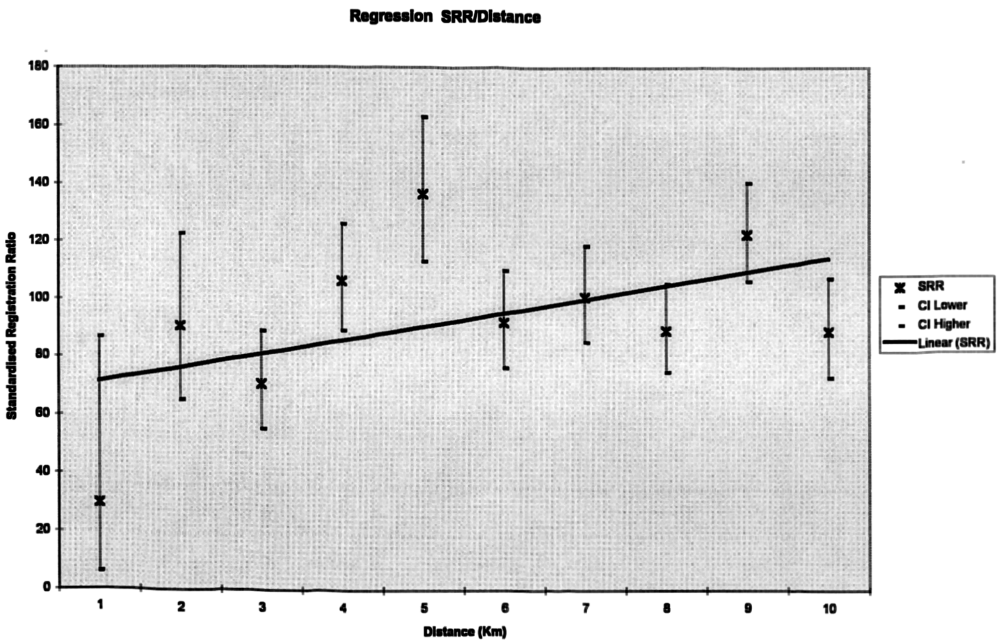
Max. O/E (Stone) at ring 7.

Table 73

UPPER DIGESTIVE TRACT IRRITATION, POPULATION 0 TO 9 YEARS OF AGE. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	3	10.11	29.66	6.1 - 86.6	(low: p< 0.009)*
2	42	46.32	90.68	65.3 - 122.6	
3	73	103.09	70.81	55.5 - 89.0	(low: p< 0.005)
4	135	126.69	106.56	89.3 - 126.1	
5	122	89.32	136.58	113.4 - 163.1	(high: p< 0.005)
6	122	132.23	92.26	76.6 - 110.2	
7	147	145.34	101.14	85.5 - 118.9	
8	139	155.33	89.49	75.2 - 105.7	
9	208	169.31	122.85	106.7 - 140.7	(high: p< 0.005)
10	110	122.97	89.45	73.5 - 107.8	

* - Exact Poisson.



Slope = 0.03561 p = 0.227

Max. O/E (Stone) at ring 9.

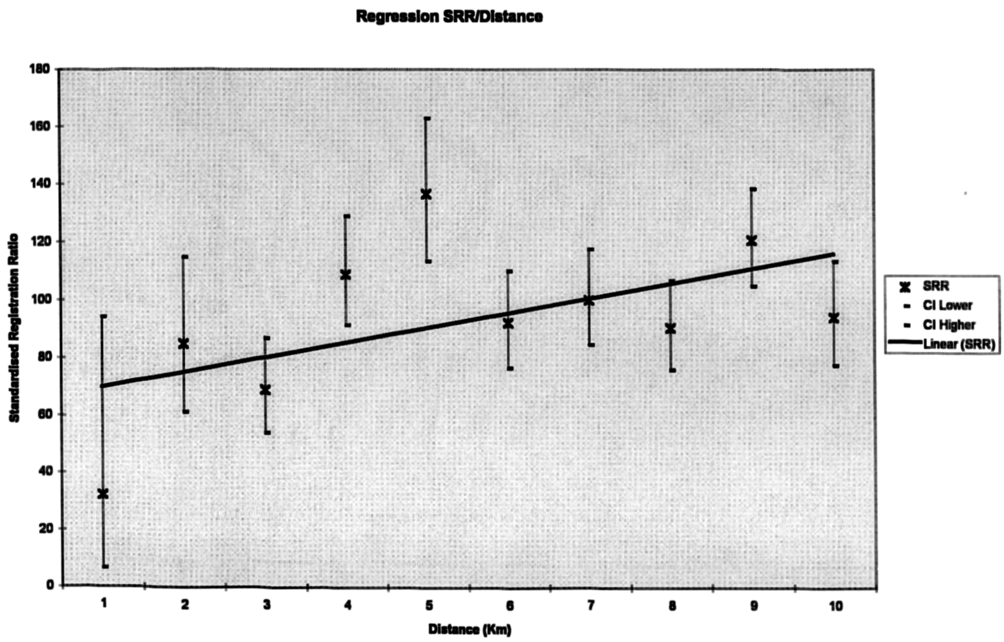
Table 74

UPPER DIGESTIVE TRACT IRRITATION, POPULATION 0 TO 9 YEARS OF AGE. DISCHARGES.

OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	3	9.32	32.17	6.6 - 94.0	(low: p< 0.017)*
2	42	49.57	84.72	61.1 - 114.5	
3	73	105.96	68.89	54.0 - 86.6	(low: p< 0.005)
4	135	124.16	108.73	91.2 - 128.7	
5	122	89.45	136.39	113.3 - 162.9	(high: p< 0.005)
6	122	132.45	92.11	76.5 - 110.0	
7	147	146.88	100.08	84.6 - 117.6	
8	139	153.87	90.33	75.9 - 106.7	
9	208	172.46	120.61	104.8 - 138.2	(high: p<0.005)
10	110	116.87	94.12	77.4 - 113.4	

*** - Exact Poisson.**



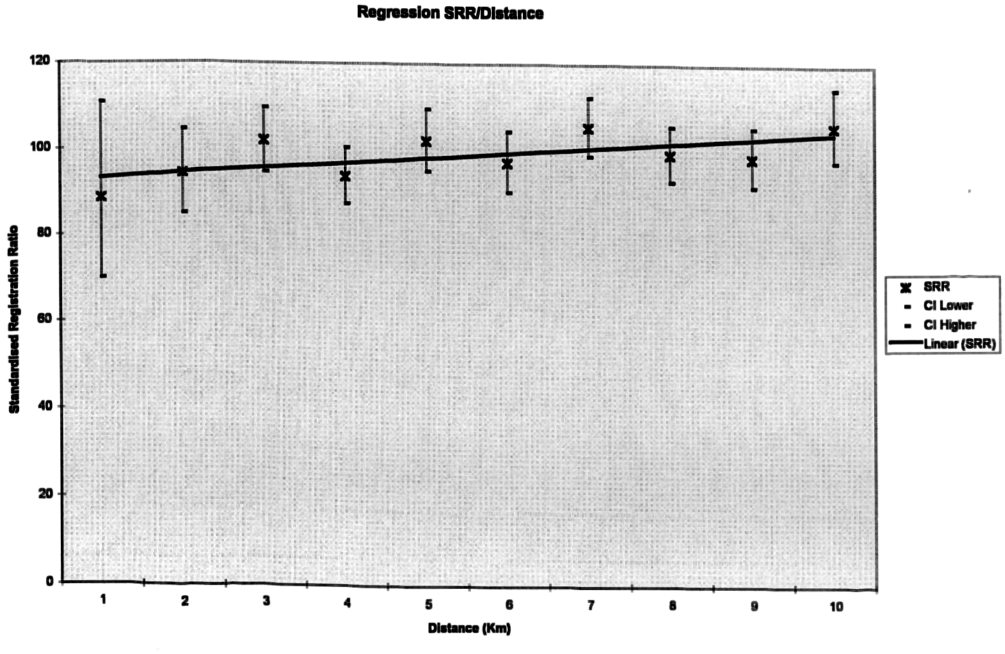
Slope = 0.03895 **p = 0.172**

Max. O/E (Stone) at ring 9.

Table 75

KIDNEY DYSFUNCTION, TOTAL POPULATION. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI
1	77	86.87	88.63	69.9 - 110.8
2	368	389.96	94.37	85.0 - 104.5
3	736	721.29	102.04	94.8 - 109.7
4	820	873.07	93.92	87.6 - 100.6
5	801	783.61	102.22	95.3 - 109.6
6	760	780.15	97.42	90.6 - 104.6
7	964	912.57	105.64	99.1 - 112.5
8	977	981.64	99.53	93.4 - 106.0
9	842	851.68	98.86	92.3 - 105.8
10	643	605.91	106.12	98.1 - 114.7



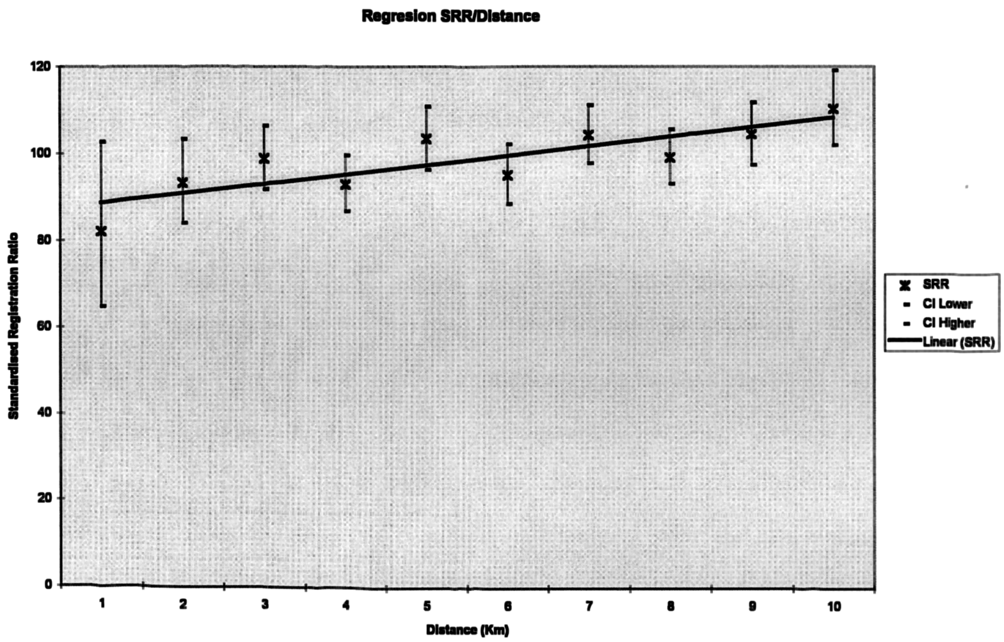
Slope = 0.010064 **p = 0.079**

Max. O/E (Stone) at ring 10.

Table 76

KIDNEY DYSFUNCTION, TOTAL POPULATION. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND BY DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	77	93.71	82.16	64.8 - 102.7	
2	368	394.41	93.30	84.0 - 103.3	
3	736	744.41	98.87	91.9 - 106.3	
4	820	881.32	93.04	86.8 - 99.6	(low: p< 0.02)
5	801	774.45	103.43	96.4 - 110.8	
6	760	798.47	95.18	88.5 - 102.2	
7	964	924.62	104.26	97.8 - 111.1	
8	977	985.80	99.11	93.0 - 105.5	
9	842	806.13	104.45	97.5 - 111.7	
10	643	583.43	110.21	101.9 - 119.1	(high: p< 0.01)



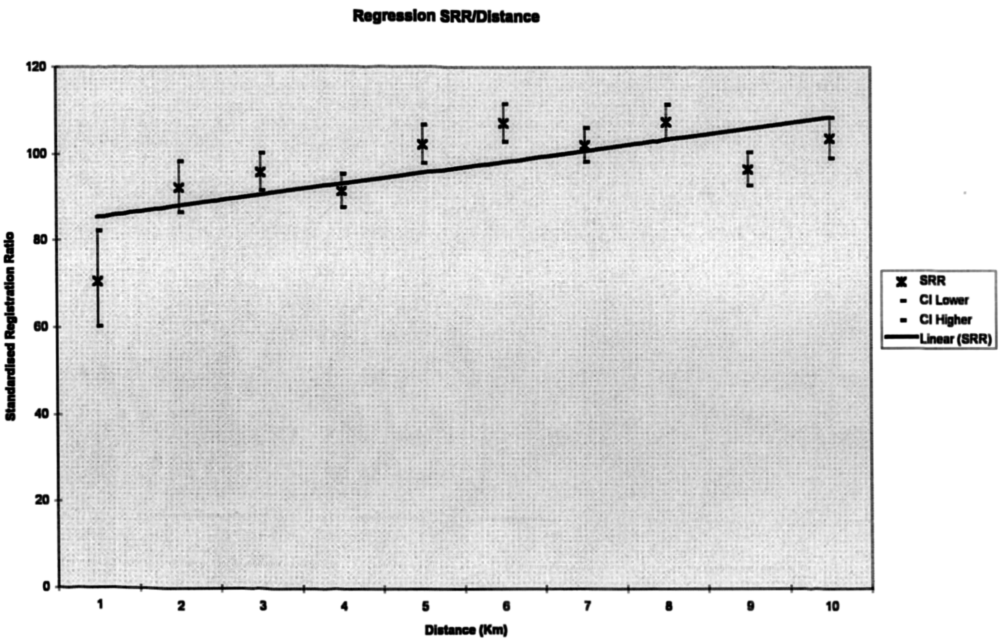
Slope = 0.018603 p = 0.009

Max. O/E (Stone) at ring 10.

Table 77

KIDNEY DYSFUNCTION, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	167	236.77	70.53	60.2 - 82.1	(low: p< 0.005)
2	942	1022.67	92.11	86.3 - 98.2	(low: p< 0.01)
3	1846	1929.29	95.68	91.4 - 100.1	
4	2129	2331.38	91.32	87.5 - 95.3	(low: p< 0.005)
5	2099	2055.91	102.10	97.8 - 106.6	
6	2355	2196.46	107.22	102.9 - 111.6	(high: p<0.005)
7	2633	2577.30	102.16	98.3 - 106.1	
8	2919	2717.64	107.41	103.5 - 111.4	(high: p< 0.005)
9	2459	2546.43	96.57	92.8 - 100.5	
10	1857	1792.28	103.61	99.0 - 108.4	



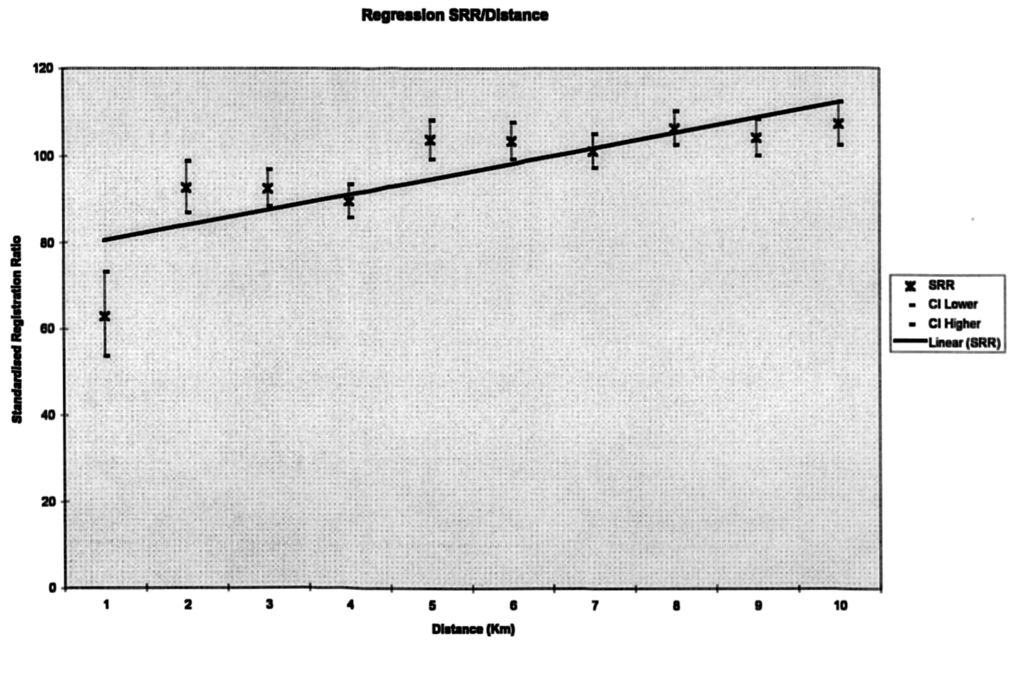
Slope = 0.019753 p = 0.044

Max. O/E (Stone) at ring 8.

Table 78

KIDNEY DYSFUNCTION, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	167	265.40	62.92	53.7 - 73.2	(low: p< 0.0005)
2	942	1016.24	92.69	86.9 - 98.8	(low: p< 0.01)
3	1846	1994.40	92.56	88.4 - 96.9	(low: p< 0.005)
4	2129	2376.53	89.58	85.8 - 93.5	(low: p< 0.005)
5	2099	2025.93	103.61	99.2 - 108.1	
6	2355	2278.71	103.35	99.2 - 107.6	
7	2633	2606.66	101.01	97.2 - 104.9	
8	2919	2748.14	106.22	102.4 - 110.1	(high: p< 0.0005)
9	2459	2362.88	104.07	100.0 - 108.3	(high: p< 0.025)
10	1857	1731.27	107.26	102.4 - 112.3	(high: p< 0.005)



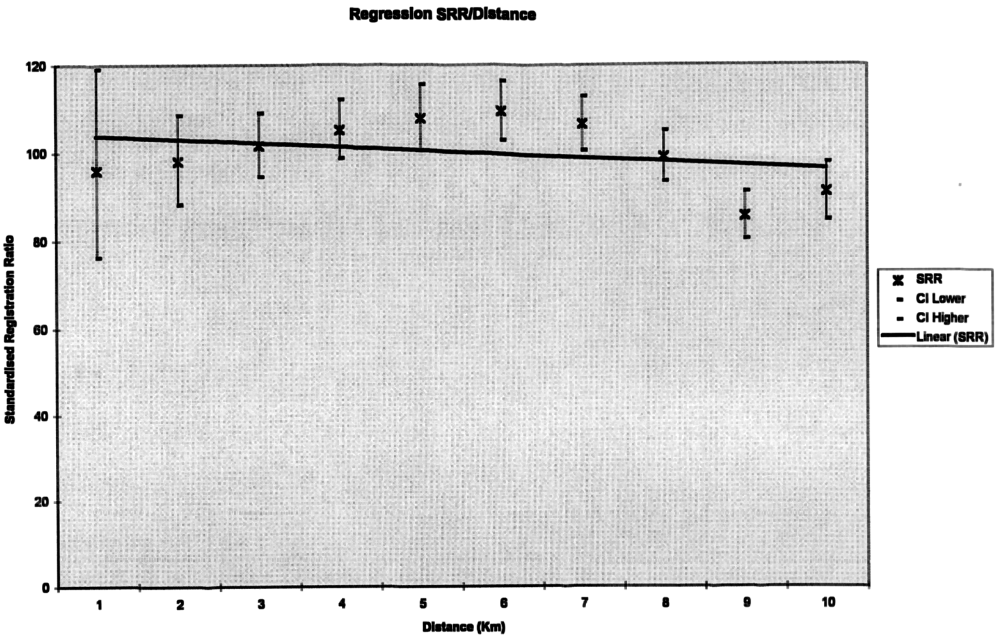
Slope = 0.029804 **p = 0.006**

Max. O/E (Stone) at ring 10.

Table 79

ASTHMA, TOTAL POPULATION. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	82	85.46	95.95	76.3 - 119.1	
2	362	369.56	97.95	88.1 - 108.6	
3	765	752.92	101.60	94.5 - 109.1	
4	963	916.15	105.11	98.6 - 112.0	
5	786	730.06	107.66	100.3 - 115.5	(high: p< 0.02)
6	1011	924.47	109.36	102.7 - 116.3	(high: p< 0.005)
7	1130	1061.68	106.44	100.3 - 112.8	(high: p< 0.02)
8	1098	1112.05	98.74	93.0 - 104.8	
9	975	1144.58	85.18	79.9 - 90.7	(low: p< 0.005)
10	734	809.92	90.63	84.2 - 97.4	(low: p< 0.005)



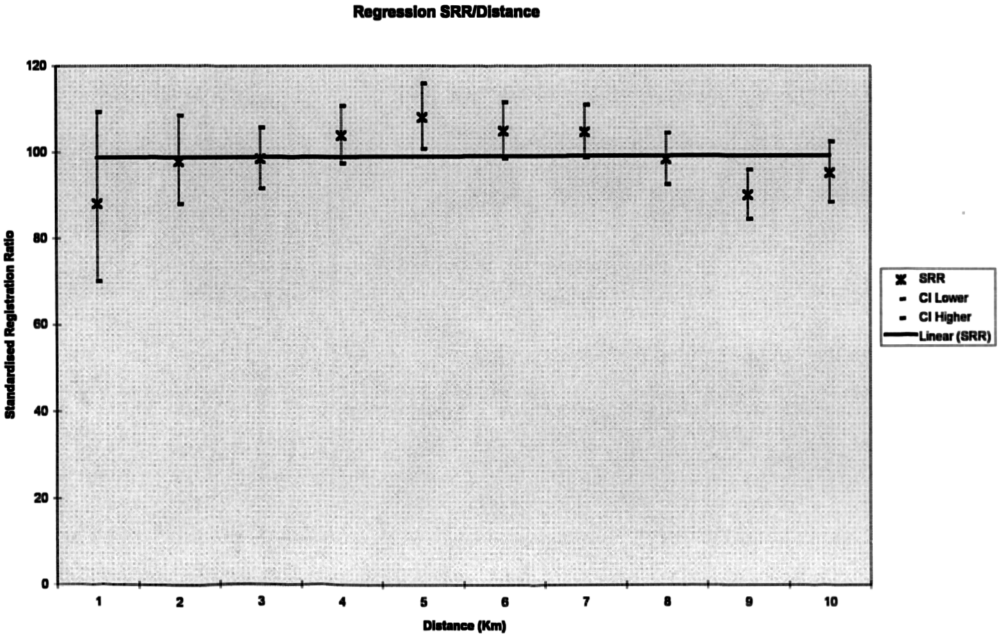
Slope = -0.015326 **p = 0.133**

Max. O/E (Stone) at ring 7.

Table 80

ASTHMA, TOTAL POPULATION. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	82	93.10	88.08	70.1 - 109.3	
2	362	370.00	97.84	88.0 - 108.5	
3	765	777.02	98.45	91.6 - 105.7	
4	963	927.05	103.88	97.4 - 110.7	
5	786	727.13	108.10	100.7 - 115.9	(high: p< 0.015)
6	1011	963.76	104.90	98.5 - 111.6	
7	1130	1079.54	104.67	98.7 - 111.0	
8	1098	1116.28	98.36	92.6 - 104.4	
9	975	1082.53	90.07	84.5 - 95.9	(low: p< 0.005)
10	734	770.44	95.27	88.5 - 102.4	



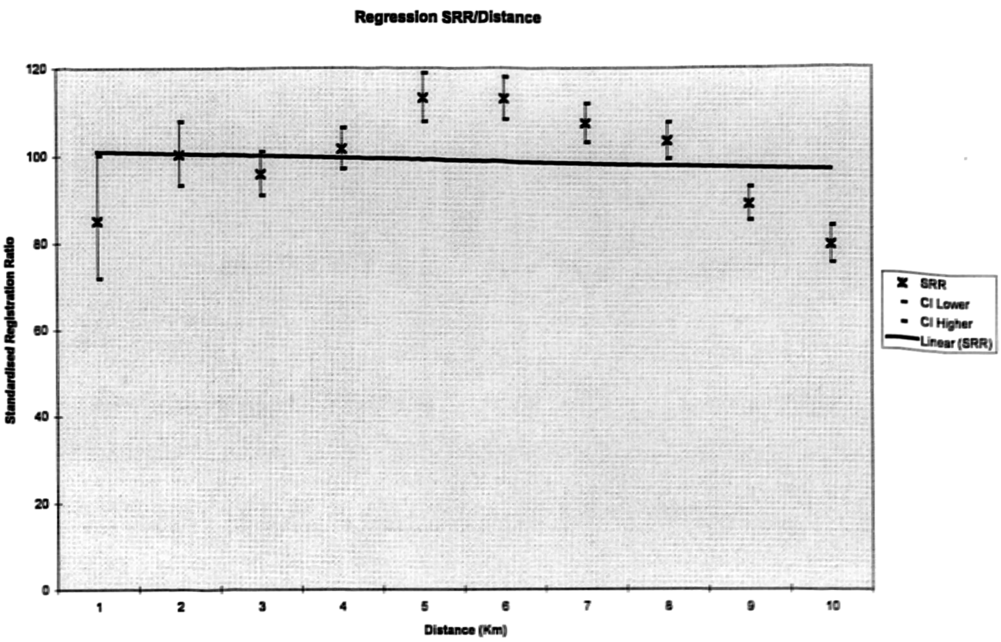
Slope = -0.005640 **p = 0.478**

Max. O/E (Stone) at ring 7.

Table 81

ASTHMA, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS ASTHMA, 1981-91, TOTAL POPULATION.

Rings	Obs.	Exp.	SRR	95% CI	
1	145	170.22	85.19	71.9 - 100.2	
2	742	739.29	100.37	93.3 - 107.9	
3	1451	1513.95	95.84	91.0 - 100.9	
4	1871	1841.84	101.	97.0 - 106.3	
5	1652	1459.03	1123	107.8 - 118.8	(high: p< 0.005)
6	2110	1867.78	112.97	108.2 - 117.9	(high: p< 0.005)
7	2302	2143.80	107.38	103.0 - 111.9	(high: p< 0.005)
8	2317	2244.59	103.23	99.1 - 107.5	
9	2068	2331.84	88.69	84.9 - 92.6	(low: p< 0.005)
10	1305	1649.54	79.11	74.9 - 83.5	(low: p< 0.0005)



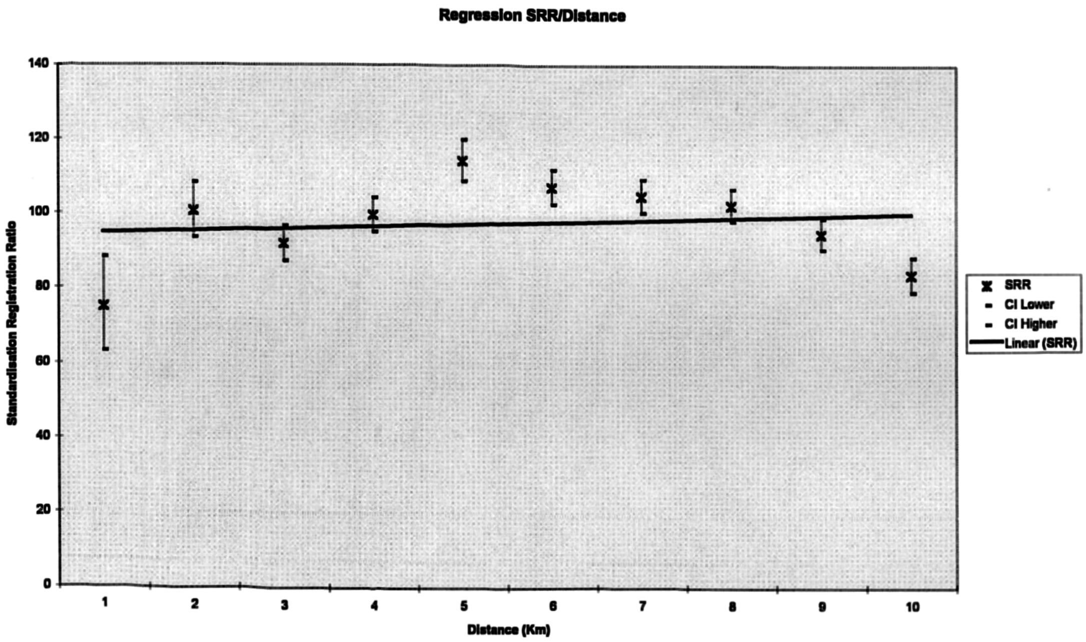
Slope = -0.01450 **p = 0.314**

Max. O/E (Stone) at ring 7.

Table 82

ASTHMA, TOTAL POPULATION. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	145	193.69	74.86	63.2 - 88.1	(low: p< 0.005)
2	742	736.32	100.77	93.6 - 108.3	
3	1451	1575.85	92.08	87.4 - 96.9	(low: p< 0.005)
4	1871	1874.42	99.82	95.3 - 104.4	
5	1652	1444.01	114.40	109.0 - 120.1	(high: p< 0.005)
6	2110	1964.80	107.39	102.9 - 112.1	(high: p< 0.005)
7	2302	2190.33	105.10	100.8 - 109.5	(high: p< 0.01)
8	2317	2256.42	102.68	98.5 - 107.0	
9	2068	2174.67	95.10	91.0 - 99.3	(low: p< 0.015)
10	1305	1551.38	84.12	79.6 - 88.8	(low: p< 0.0005)



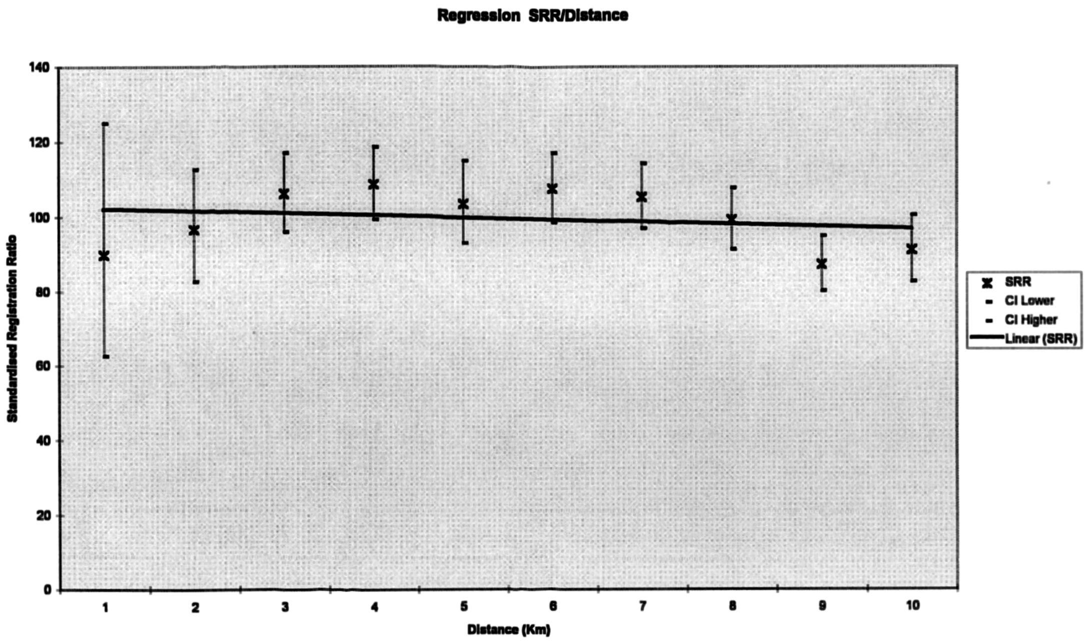
Slope = 0.00189 **p = 0.885**

Max. O/S (Stone) at ring 7.

Table 83

ASTHMA, POPULATION 0 TO 24 YEARS OF AGE. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS.

Rings	Obs.	Exp.	SRR	95% CI	
1	35	38.94	89.88	62.6 - 125.0	
2	167	172.75	96.67	82.6 - 112.5	
3	403	380.07	106.03	95.9 - 116.9	
4	505	465.45	108.50	99.2 - 118.4	
5	350	338.45	103.41	92.9 - 114.8	
6	529	492.70	107.37	98.4 - 116.9	
7	578	550.22	105.05	96.7 - 114.0	
8	573	579.07	98.95	91.0 - 107.4	
9	543	624.20	86.99	79.8 - 94.6	(low: p<0.005)
10	403	443.25	90.92	82.3 - 100.2	



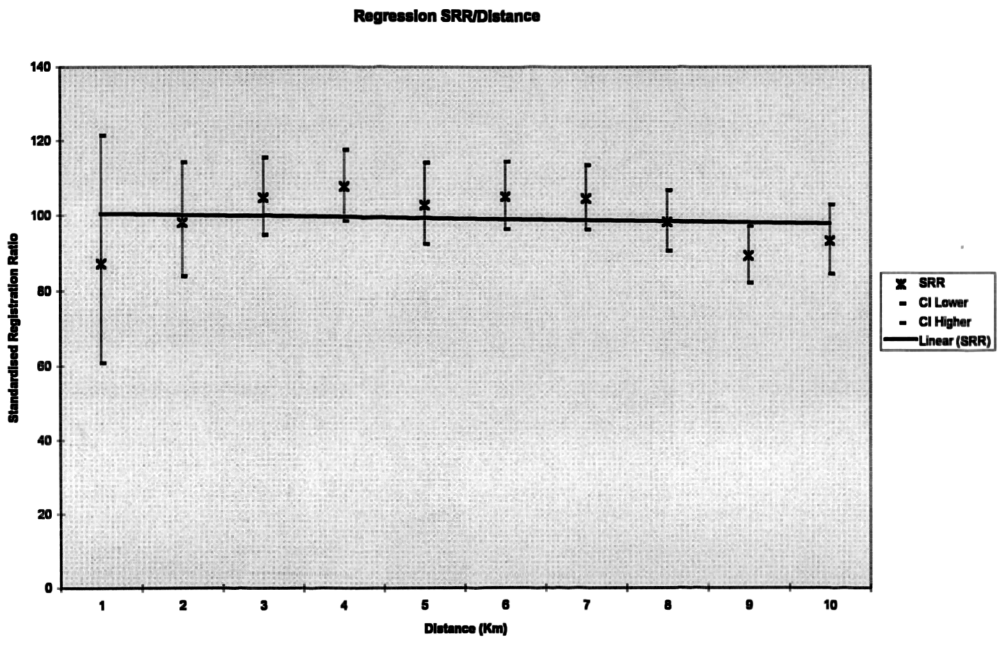
Slope = -0.015046 **p = 0.124**

Max. O/E (Stone) at ring 6.

Table 84

ASTHMA, POPULATION 0 TO 24 YEARS OF AGE. CASES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	35	40.10	87.28	60.8 - 121.4	
2	167	170.06	98.20	83.9 - 114.3	
3	403	384.95	104.69	94.7 - 115.4	
4	505	468.90	107.70	98.5 - 117.5	
5	350	340.50	102.79	92.3 - 114.1	
6	529	503.51	105.06	96.3 - 114.4	
7	578	553.16	104.49	96.1 - 113.4	
8	573	583.28	98.24	90.4 - 106.6	
9	543	608.76	89.20	81.9 - 97.0	(low: p<0.005)
10	403	432.77	93.12	84.3 - 102.7	



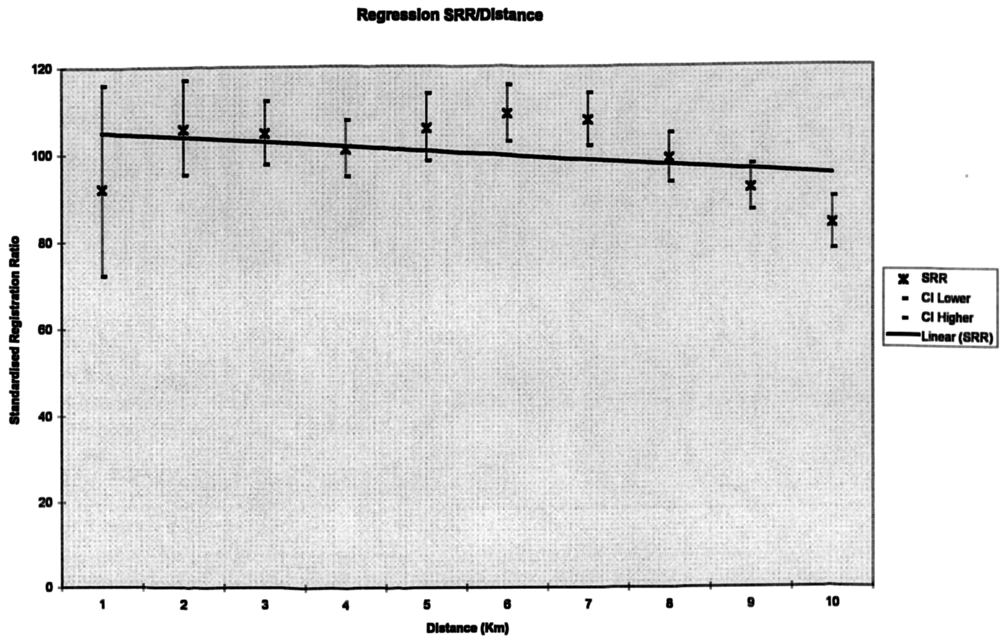
Slope = -0.011525 p = 0.170

Max. O/E (Stone) at ring 4.

Table 85

ASTHMA, POPULATION 0 TO 24 YEARS OF AGE. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1981-91) OF REGISTRATIONS.

Rings	Obs.	Exp.	SRR	95% CI	
1	73	79.19	92.18	72.3 - 115.9	
2	373	352.79	105.73	95.3 - 117.0	
3	814	777.51	104.69	97.6 - 112.1	
4	962	952.67	100.98	94.7 - 107.6	
5	730	690.30	105.75	98.2 - 113.7	
6	1097	1006.54	108.99	102.6 - 115.6	(high: p<0.005)
7	1206	1121.60	107.52	101.5 - 113.8	(high: p<0.01)
8	1167	1183.63	98.59	93.0 - 104.4	
9	1168	1274.26	91.66	86.5 - 97.1	(low: p<0.005)
10	754	905.35	83.28	77.4 - 89.4	(low: p<0.005)



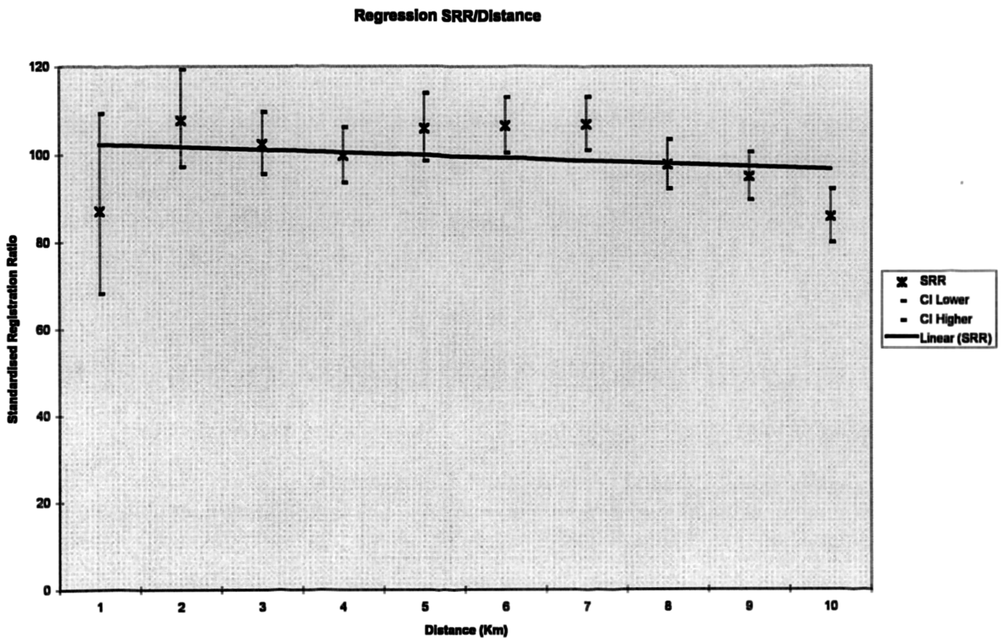
Slope = -0.018799 **p = 0.065**

Max. O/E (Stone) at ring 7.

Table 86

ASTHMA, POPULATION 0 TO 24 YEARS OF AGE. DISCHARGES.
OBSERVED AND EXPECTED SMR1 REGISTRATIONS (1981-91) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS, 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	73	83.89	87.02	68.2 - 109.4	
2	373	346.19	107.74	97.1 - 119.3	
3	814	795.13	102.37	95.5 - 109.7	
4	962	965.20	99.67	93.5 - 106.2	
5	730	689.29	105.91	98.4 - 113.9	
6	1097	1029.97	106.51	100.3 - 113.0	(high: p< 0.02)
7	1206	1128.54	106.86	100.9 - 113.1	(high: p< 0.015)
8	1167	1195.45	97.62	92.1 - 103.4	
9	1168	1230.28	94.94	89.6 - 100.5	
10	754	880.06	85.68	79.7 - 92.0	(low: p< 0.005)



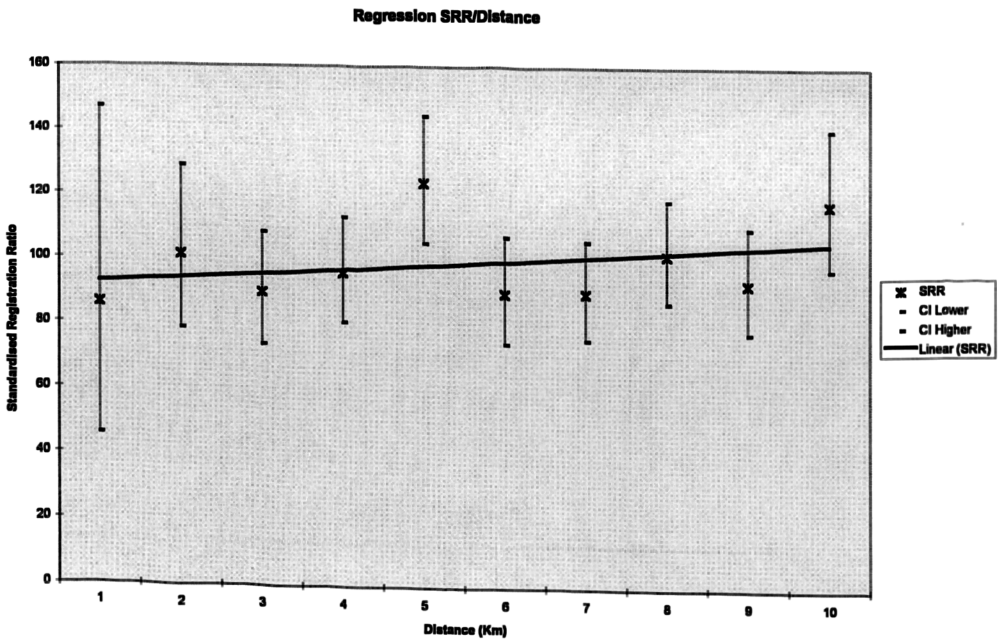
Slope = -0.013359 **p = 0.149**

Max. O/E (Stone) at ring 7.

Table 87

LEUKAEMIA, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	13	15.13	85.90	45.7 - 146.9	
2	67	66.07	101.40	78.6 - 128.8	
3	110	122.20	90.02	74.0 - 108.5	
4	143	148.60	96.23	81.1 - 113.4	
5	164	132.01	124.23	105.9 - 144.8	(high: p< 0.005)
6	123	135.73	90.62	75.3 - 108.1	
7	144	158.38	90.92	76.7 - 107.0	
8	175	169.85	103.03	88.3 - 119.5	
9	140	148.61	94.21	79.2 - 111.2	
10	126	106.22	118.63	98.8 - 141.2	



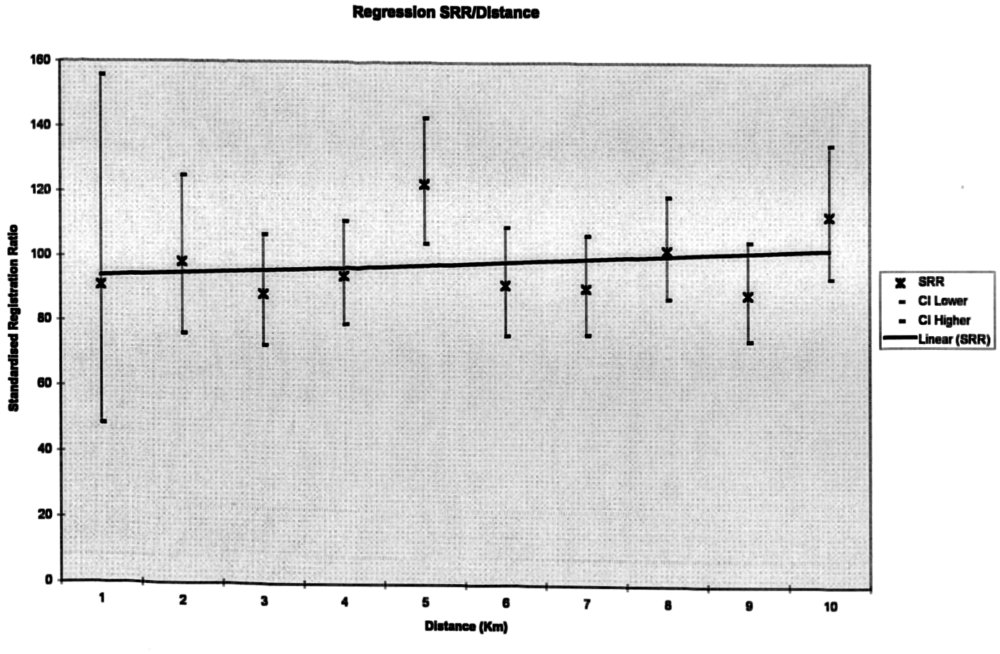
Slope = 0.01206 **p = 0.447**

Max. O/E (Stone) at ring 5.

Table 88

LEUKAEMIA, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND BY DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	13	14.28	91.04	48.4 - 155.7	
2	67	68.13	98.34	76.2 - 124.9	
3	110	123.81	88.85	73.0 - 107.1	
4	143	151.05	94.67	79.8 - 111.5	
5	164	133.33	123.01	104.9 - 143.3	(high: p< 0.005)
6	123	133.49	92.14	76.6 - 109.9	
7	144	157.77	91.27	77.0 - 107.5	
8	175	169.89	103.00	88.3 - 119.4	
9	140	156.35	89.54	75.3 - 105.7	
10	126	110.97	113.55	94.6 - 135.2	



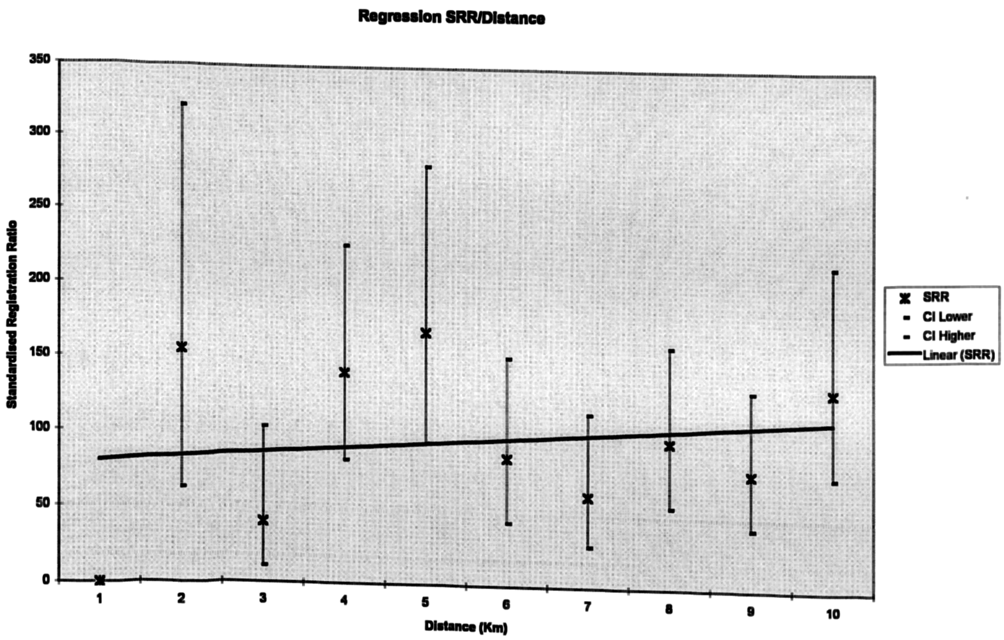
Slope = 0.00799 **p = 0.592**

Max. O/E (Stone) at ring 5.

Table 89

LEUKAEMIA, TOTAL POPULATION 0 TO 14 YEARS OF AGE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI
1	0	1.03	0.00	0.0 - 0.0 (no cases)
2	7	4.49	156.05	62.6 - 321.5
3	4	9.77	40.95	11.1 - 104.8
4	17	11.88	143.11	83.4 - 229.0
5	15	8.73	171.76	96.2 - 283.4
6	11	12.63	87.11	43.5 - 155.9
7	9	14.42	62.40	28.6 - 118.6
8	15	14.97	100.21	56.1 - 165.3
9	13	16.36	79.44	42.3 - 135.8
10	16	11.75	136.14	77.9 - 220.6



Slope = 0.00138 **p = 0.983**

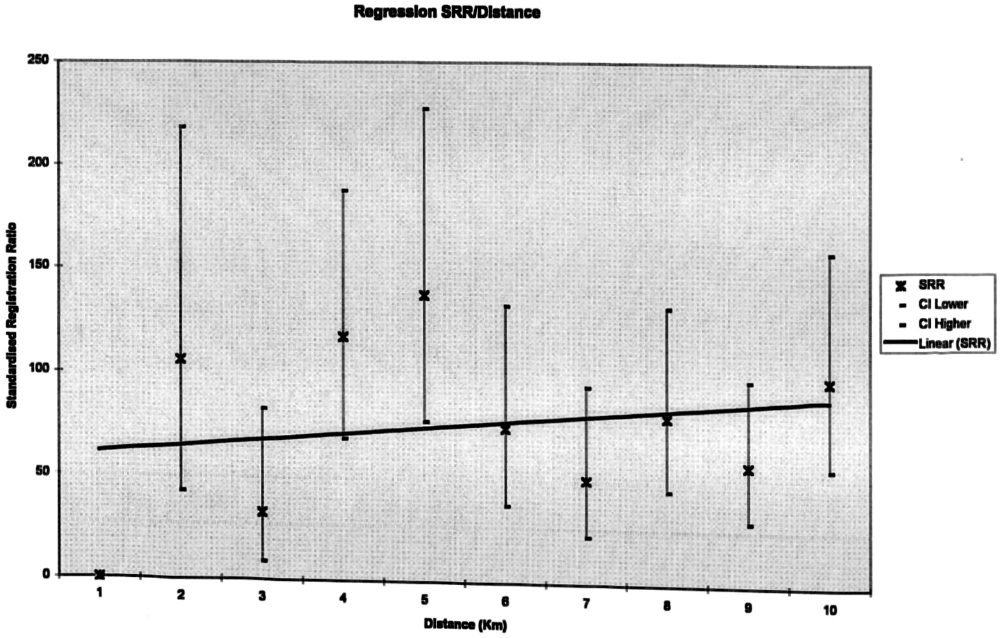
Max. O/E (Stone) at ring 2.

Table 90

LEUKAEMIA, TOTAL POPULATION 0 TO 14 YEARS OF AGE.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	0	1.12	0.00	0.0 - 0.0	(no cases)
2	7	6.61	105.98	42.5 - 218.3	
3	4	12.39	32.29	8.8 - 82.7	(low: p<0.005)*
4	17	14.46	117.58	68.6 - 188.1	
5	15	10.87	138.03	77.3 - 227.8	
6	11	14.78	74.41	37.1 - 133.2	
7	9	18.02	49.93	22.9 - 94.9	(low: p<0.015)*
8	15	18.63	80.52	45.1 - 132.9	
9	13	22.56	57.62	30.7 - 98.5	(low: p<0.021)*
10	16	16.20	98.75	56.5 - 160.0	

* - Exact Poisson.



Slope = 0.00332 p = 0.946

Max. O/E (Stone) at ring 5.

Table 89 B

LEUKAEMIA, TOTAL POPULATION 0 TO 14 YEARS OF AGE.
AGE STANDARDIZED, BUT IGNORING FIRST RING (NO REGISTRATIONS).

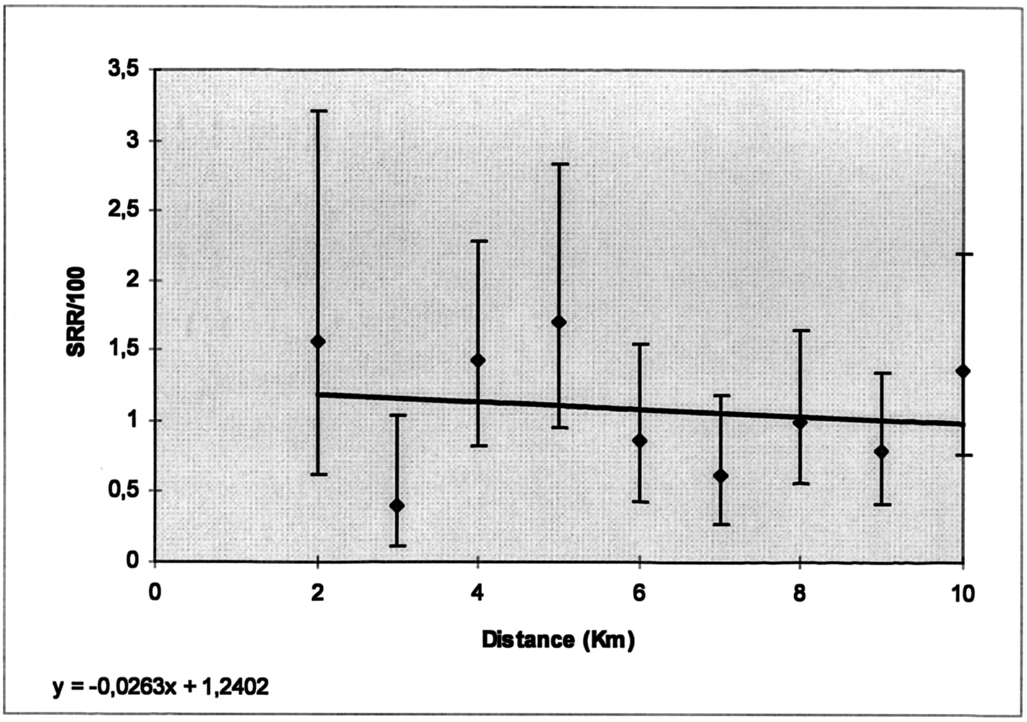


Table 90 B

LEUKAEMIA, TOTAL POPULATION 0 TO 14 YEARS OF AGE.
AGE AND DEPRIVATION STANDARDIZED, BUT IGNORING FIRST RING (NO REGISTRATIONS).

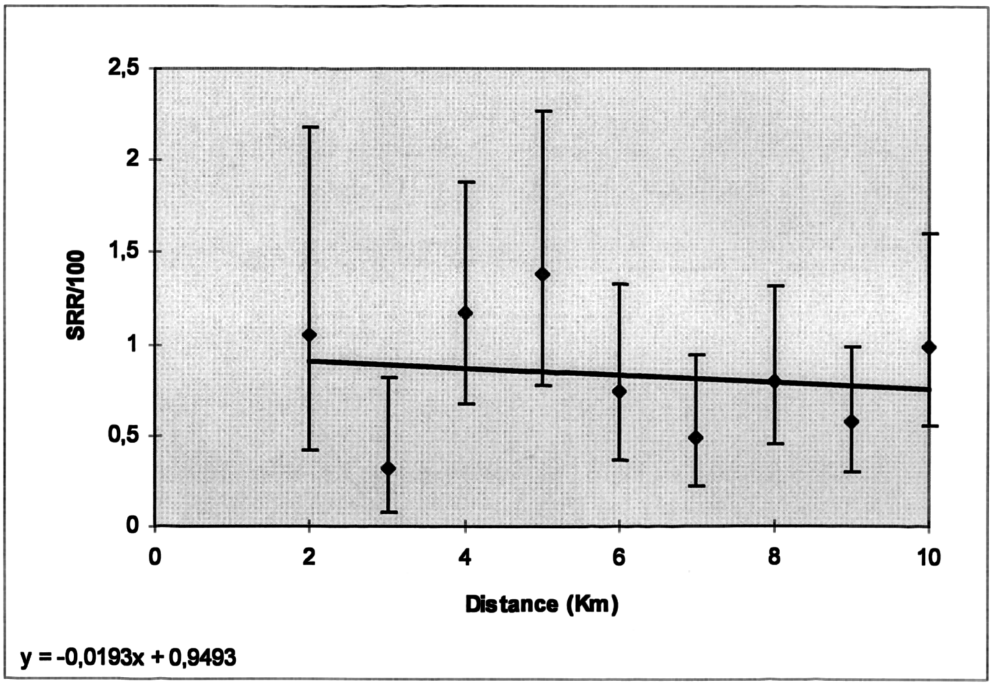
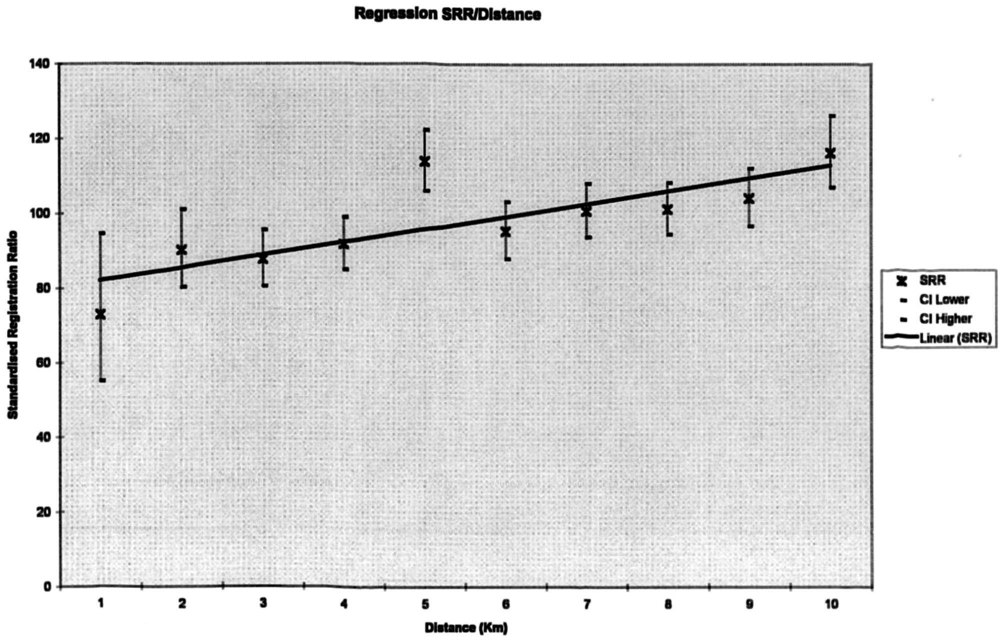


Table 91

SKIN CANCER, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS). STANDARD RATES : ARITHMETIC MEANS (1975-89) OF REGISTRATIONS BY AGE GROUP FOR THE WHOLE 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	56	76.92	72.81	55.0 - 94.5	(low: p< 0.007)*
2	301	333.79	90.18	80.3 - 101.0	
3	528	602.14	87.69	80.4 - 95.5	(low: p< 0.005)
4	671	731.82	91.69	84.9 - 98.9	(low: p< 0.015)
5	767	673.71	113.85	105.9 - 122.2	(high: p< 0.005)
6	624	654.19	95.39	88.0 - 103.2	
7	770	764.11	100.77	93.8 - 108.1	
8	835	824.92	101.22	94.5 - 108.3	
9	722	693.63	104.09	96.6 - 112.0	
10	578	497.33	116.22	106.9 - 126.1	(high: p< 0.005)

*** - Exact Poisson.**



Slope = 0.030169 **p = 0.011**

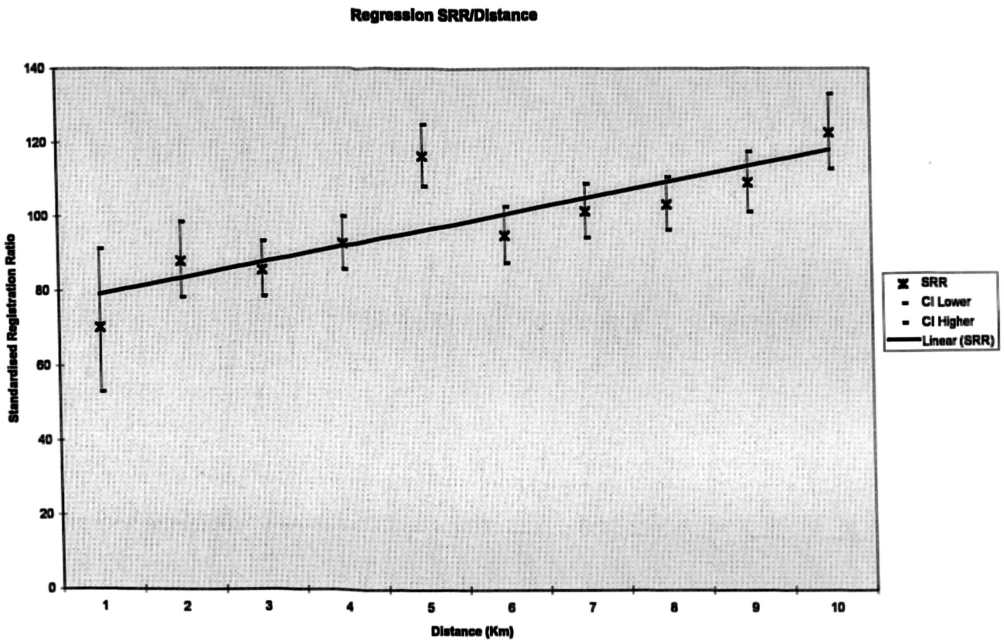
Max. O/E (Stone) at ring 10.

Table 92

SKIN CANCER, TOTAL POPULATION.
OBSERVED AND EXPECTED REGISTRATIONS (1975-89) AND STANDARDIZED REGISTRATION RATIOS IN 10 RINGS , 1 KM. WIDE, CENTRED ON THE SOURCE OF CHROMIUM POLLUTION. STANDARDIZED BY AGE (1981 CENSUS) AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	56	79.67	70.29	53.1 - 91.3	(low: p< 0.006)*
2	301	341.72	88.08	78.4 - 98.6	(low: p< 0.015)
3	528	615.77	85.75	78.6 - 93.4	(low: p< 0.005)
4	671	722.80	92.83	85.9 - 100.1	
5	767	658.89	116.41	108.3 - 124.9	(high: p< 0.005)
6	624	655.88	95.14	87.8 - 102.9	
7	770	758.05	101.58	94.5 - 109.0	
8	835	807.03	103.47	96.6 - 110.7	
9	722	660.21	109.36	101.5 - 117.6	(high: p< 0.01)
10	578	470.73	122.79	113.0 - 133.2	(high: p< 0.005)

*** - Exact Poisson.**



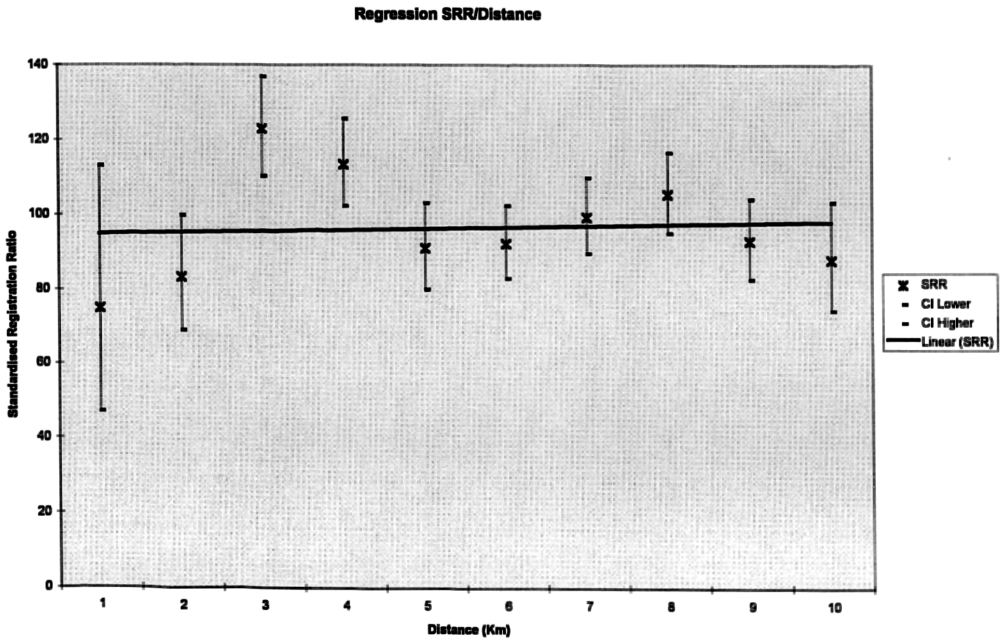
Slope = 0.03931 **p = 0.005**

Max. O/E (Stone) at ring 10.

Table 93

CONGENITAL ANOMALIES (1982-89) IN LIVE AND STILL BIRTHS AND INDUCED ABORTIONS.
OBSERVED AND EXPECTED NUMBERS OF REGISTRATIONS IN EACH OF 10 RINGS, 1 KM WIDE,
CENTRED ON SOURCE OF POLLUTION, INSIDE GREATER GLASGOW HEALTH BOARD.
STANDARDIZED BY OVERALL PREVALENCE (1982-89) IN 10 KM. CIRCLE.

Rings	Obs.	Exp.	SRR	95% CI	
1	22	29.40	74.82	46.9 - 113.0	
2	117	140.60	83.21	68.8 - 99.7	(low: p< 0.025)
3	342	278.03	123.01	110.3 - 136.8	(high: p< 0.005)
4	375	330.09	113.61	102.4 - 125.7	(high: p< 0.01)
5	251	275.28	91.18	80.2 - 103.2	
6	357	386.25	92.43	83.1 - 102.5	
7	388	390.12	99.46	89.8 - 109.9	
8	380	359.96	105.57	95.2 - 116.7	
9	300	322.22	93.11	82.9 - 104.3	
10	149	169.01	88.16	74.6 - 103.5	



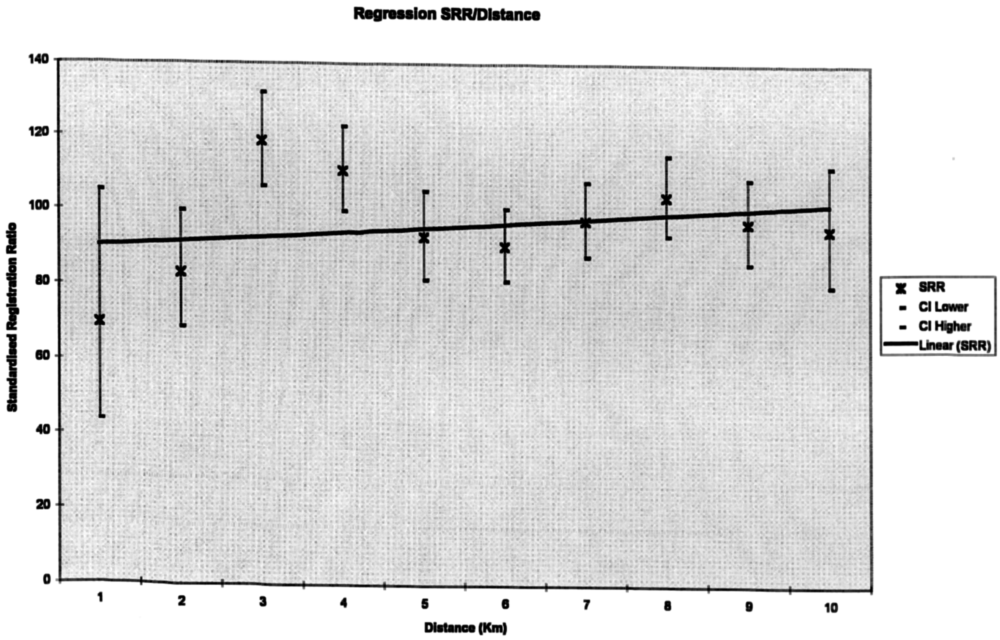
Slope = 0.00554 **p = 0.748**

Max. O/E (Stone) at ring 4.

Table 94

CONGENITAL ANOMALIES (1982-89) IN LIVE AND STILL BIRTHS AND INDUCED ABORTIONS.
OBSERVED AND EXPECTED NUMBERS OF REGISTRATIONS IN EACH OF 10 RINGS, 1 KM WIDE,
CENTRED ON SOURCE OF POLLUTION, INSIDE GREATER GLASGOW HEALTH BOARD.
STANDARDIZED BY OVERALL PREVALENCE (1982-89) IN 10 KM. CIRCLE AND DEPRIVATION CATEGORY (CARSTAIRS).

Rings	Obs.	Exp.	SRR	95% CI	
1	22	31.67	69.46	43.6 - 104.9	
2	117	140.71	83.15	68.8 - 99.7	(low: p< 0.025)
3	342	288.06	118.73	106.5 - 132.0	(high: p< 0.005)
4	375	337.97	110.96	100.0 - 122.8	(high: p< 0.025)
5	251	268.94	93.33	82.1 - 105.6	
6	357	391.77	91.13	81.9 - 101.1	
7	388	395.53	98.10	88.6 - 108.4	
8	380	363.67	104.49	94.2 - 115.5	
9	300	307.25	97.64	86.9 - 109.3	
10	149	155.40	95.88	81.1 - 112.6	



Slope = 0.00449 **p = 0.777**

Max. O/E (Stone) at ring 4.

Table 7 - 1: Synopsis of Results

Lung Cancer (Different areas)						
	Standardized by age			Standardized by age and deprivation		
Area and Population	Number of signif. high SRRs in 5 inner rings- 5 outer.	Regression slope's sign and significance	Stone value: ring with max. ratio O/E (cumulat.)	Number of signif. high SRRs in 5 inner rings - 5 outer.	Regression slope's sign and significance	Stone value: ring with max. ratio O/E (cumulat.)
Whole 10 km circle						
Total pop.	3 - 1	(-) Signif.	1	2 - 0	(-) Signif.	2
Total males	3 - 0	(-) Signif.	1	2 - 0	(-) Signif.	2
Total fem.	0 - 2	(-) No Sign.	3	0 - 1	(+)No Sign.	3
South of the Clyde						
Males	2 - 1	(-) No Sign.	1	1 - 0	(-) No Sign.	2
Males < 65	2 - 0	(-) No Sign.	1	1 - 0	(-) No Sign.	2
Males 65+	0 - 1	(-) No Sign.	1	0 - 1	(+)No Sign.	2
Males <55	1 - 0	(-) No Sign.	1	0 - 0	(-) No Sign.	1
Males 55+	2 - 0	(-) No Sign.	1	1 - 0	(-) No Sign.	2
Females	0 - 1	(-) No Sign.	1	0 - 1	(+)No Sign.	7
North of the Clyde						
Total males	4 - 1	(-) Signif.	1	4 - 0	(-) No Sign.	1
Males <65	3 - 1	(-) Signif.	2	3 - 0	(-) Signif.	1
Males 65+	3 - 1	(-) Signif.	1	3 - 0	(-) No Sign.	1
Males <55	3 - 0	(-) Signif.	2	1 - 0	(-) Signif.	2
Males 55+	4 - 1	(-) Signif.	1	3 - 0	(-) No Sign.	1
Females	2 - 1	(-) Signif.	3	1 - 0	(-) No Sign.	3

Incidence of male Lung Cancer (1975-89) decreased with distance to the centre of the study area, with the exception of those aged 65 years and over, after standardization by deprivation. This trend was particularly marked North of the river Clyde, where Lung Cancer also appeared to be more prevalent at later ages than it did South of the river. For females in the whole study area and South of the Clyde, a not too marked decrease of SRRs with distance was actually reversed after standardization by deprivation. In general, decrease with distance became less marked after standardization by deprivation category.

Table 7 - 1: Synopsis of Results (continuation).

Pharyngeal Cancer (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total pop.	0 - 0	(-) No Sign.	7	0 - 0	(-) No Sign.	7

Low numbers of cases, not showing excess of disease. SRRs peaking 3 to 7 kms. from centre of study area.

Nasal Cancer (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total pop.	0 - 0	(-) No Sign.	2	0 - 0	(-) No Sign.	2

Low numbers of cases, not showing evident excess of disease. SRRs peaking in second ring.

Chronic Obstructive Pulmonary Disease (COPD) (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total Cases	0 - 3	(+)No Sign	8	0 - 4	(+) Signif.	9
Total Disch.	0 - 3	(+)No Sign.	8	0 - 4	(+)No Sign.	9
Male Cases	0 - 3	(-) No Sign.	8	0 - 2	(+)No Sign.	8
Male Disch.	1 - 3	(-) No Sign.	1	0 - 3	(+)No Sign.	9
Female Cas.	0 - 2	(-) No Sign.	8	0 - 2	(+)No Sign.	9
Female Dis.	0 - 3	(+)No Sign.	8	0 - 5	(+)No Sign.	9

Irregular trends, generally increasing with distance to the centre of study area. SRRs peaking between rings 6 - 8.

Table 7 - 1: Synopsis of Results (cont.)

Upper Respiratory Irritation (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total Cases	0 - 1	(-) No Sign.	1	0 - 0	(-) No Sign.	8
Total Disch.	0 - 2	(-) No Sign.	8	0 - 2	(-) No Sign.	8

Little variation with distance. SRRs generally higher in outer rings.

Skin Irritation (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs	Regression slope.	Stone value.
Total Cases	0 - 3	(+) Signif.	10	0 - 3	(+) Signif.	10
Total Disch.	0 - 3	(+) Signif.	10	0 - 3	(+) Signif.	10
Total C.<19	0 - 2	(+) Signif.	10	0 - 2	(+) Signif.	10
Total D.<19	0 - 1	(+) Signif.	10	0 - 2	(+) Signif.	10

Strong trend to increase with distance.

Eye Irritation (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total Cases	1 - 0	(-) No Sign.	1	1 - 0	(-) No Sign.	1
Total Disch.	1 - 0	(-) No Sign.	3	1 - 0	(-) No Sign.	3
Total C <19	0 - 0	(-) No Sign.	1	0 - 0	(-) No Sign.	2
Total D<19	0 - 0	(-) No Sign.	1	0 - 0	(-) No Sign.	5

Irregular trends, generally decreasing with distance. Higher SRRs in inner rings for total population, but not for those under 20 years of age.

Table 7 - 1: Synopsis of Results (cont.)

Upper Digestive Tract Irritation (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total Cases	0 - 4	(+) Signif.	10	0 - 3	(+) Signif.	10
Total Disch.	0 - 5	(+) Signif.	10	0 - 3	(+) Signif.	10
Total C. < 9	0 - 0	(+)No Sign.	7	0 - 0	(+)No Sign.	7
Total D.< 9	1 - 1	(+)No Sign.	9	1 - 1	(+)No Sign.	9

Strong trend to increase with distance in total population. Also increasing, but more irregular, in those under 10 years of age.

Kidney Dysfunction (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total Cases	0 - 0	(+)No Sign.	10	0 - 1	(+) Signif.	10
Total Disch.	0 - 2	(+) Signif.	8	0 - 3	(+) Signif.	10

Strong trend to increase with distance.

Asthma (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total Cases	1 - 2	(-) No Sign.	7	1 - 0	(-) No Sign.	7
Total Disch.	1 - 2	(-) No Sign.	7	1 - 2	(+)No Sign.	7
Total C.<24	0 - 0	(-) No Sign.	6	0 - 0	(-) No Sign.	4
Total D.<24	0 - 2	(-) No Sign.	7	0 - 2	(-) No Sign.	7

Higher incidence in rings 4 to 7 for total population, in rings 2 to 7 for those under 25 years of age.

Table 7 - 1: Synopsis of Results (cont.)

Leukaemia (Whole 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total pop.	1 - 0	(+)No Sign.	5	1 - 0	(+)No Sign.	5
Total < 14	0 - 0	(+)No Sign.	2	0 - 0	(+)No Sign.	5

Irregular trend, generally increasing with distance for both total population and those under 15 years of age. Highest SRRs in fifth rings in all cases.

Skin Cancer (Whole 10 km. circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
Total pop.	1 - 1	(+) Signif.	10	1 - 2	(+) Signif.	10

Strong trend to increase with distance, similar to Skin Irritation.

Congenital Abnormalities (Part of GGHB inside 10 km circle)						
	Standardized by age			Standardized by age and deprivation		
Population	Number of sign. SRRs.	Regression slope.	Stone value.	Number of sign. SRRs.	Regression slope.	Stone value.
All births	2 - 0	(+)No Sign.	4	2 - 0	(+)No Sign.	4

Irregular trend, low in central rings and peaking at rings 3 - 4.

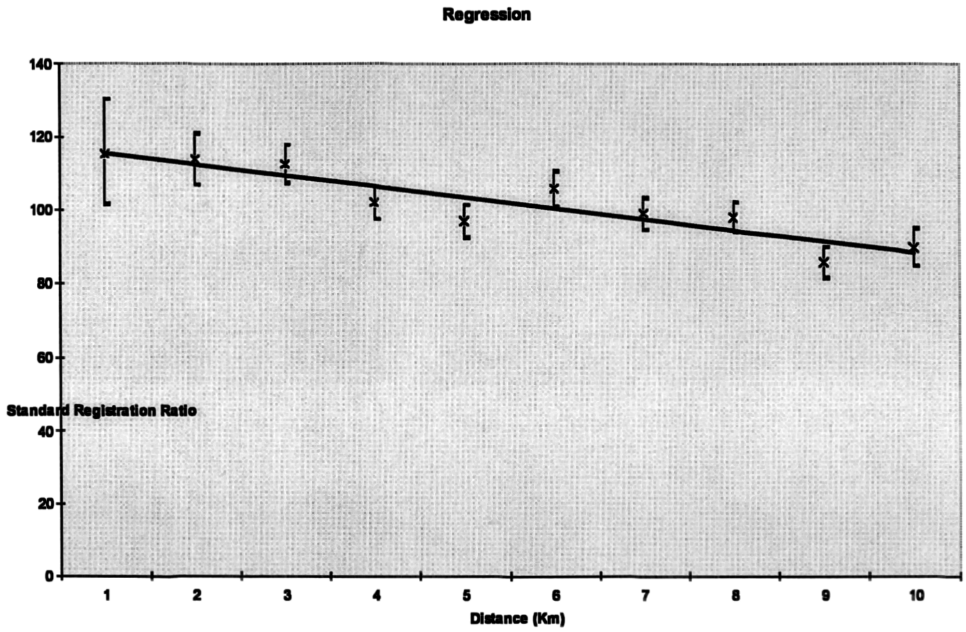
7.3 - Testing the method's sensitivity: results using false centres of pollution

Some of the analyses were repeated using different ('dummy') centres of pollution, in order to discard a possible methodological artefact and to check the method's sensitivity. To this effect, four new centres were chosen, each five kilometres from the real one, to the North, South, West and East of it. Since the set of data on Enumeration Districts and their populations available for analyses corresponded to a ring 10 km. in diameter, these new analyses were always done inside this ring, with the result that for them the first five rings are complete, but not so the outermost five, although these are large enough in area, population and numbers of observed cases, as it can be seen in the tables below. Analyses were carried out for Lung Cancer (total population). Results were as follows:

Table A - Lung Cancer (total population). Actual pollution centre (Ordnance Survey coordinates: East 608, North 622)

This table is identical to **Table 1,** already commented earlier in this Chapter. SRRs are high towards the central rings. This was mainly due to high SRRs in the central rings North of the Clyde.

Ring	Obs.	Exp.	SRR	95% CI	
1	254	220.06	115.42	101.7 - 130.5	(high: $p < 0.03$)
2	1030	903.05	114.06	107.2 - 121.2	(high: $p < 0.01$)
3	1823	1616.61	112.77	107.6 - 118.1	(high: $p < 0.01$)
4	2002	1960.90	102.10	97.7 - 106.7	
5	1778	1832.84	97.01	92.6 - 101.6	
6	1906	1797.40	106.04	101.3 - 110.9	(high: $p < 0.02$)
7	2075	2092.85	99.15	94.9 - 103.5	
8	2192	2231.40	98.23	94.2 - 102.4	
9	1632	1901.17	85.84	81.7 - 90.1	(low: $p < 0.001$)
10	1225	1361.37	89.98	85.0 - 95.2	(low: $p < 0.01$)



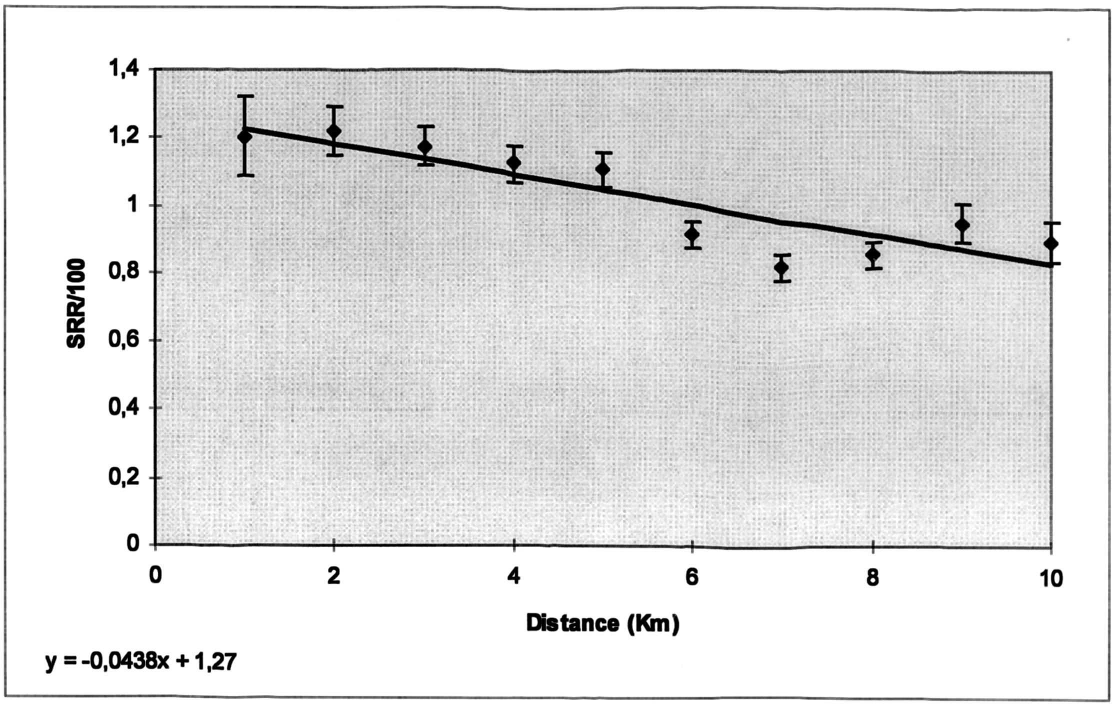
Slope = -0.030005

<u>Table B - Lung Cancer (total population).</u> <u>Centre five kilometres</u> **<u>North</u>** <u>from actual one</u> (Ordnance Survey coordinates: East 608, North 672)

A dummy centre of pollution was sited in the Cowlairs area of Springburn, exactly five kilometres North from the real one. In spite of this change, SRRs in the central rings appear, again, high, which might indicate a methodological artefact. Nevertheless, these central rings cover much of the area inside the central rings in Table A, above (just across the Clyde from the actual centre of pollution, where SRRs were highest), which can explain the apparent coincidence.

Ring	Obs.	Exp.	SRR	95% CI	
1	422	350.36	120.45	109.2 - 132.5	(high: p<0.005)
2	1080	883.31	122.27	115.1 - 129.8	(high: p<0.0005)
3	1661	1413.07	117.55	112.0 - 123.3	(high: p<0.0005)
4	1763	1558.07	113.15	107.9 - 118.6	(high: p<0.005)
5	1793	1611.45	111.27	106.2 - 116.5	(high: p<0.005)
6	1925	2078.65	92.61	88.5 - 96.8	(low: p<0.005)
7	1654	1992.67	83.00	79.1 - 87.1	(low: p<0.0005)
8	1665	1927.03	86.40	82.3 - 90.7	(low: p<0.0005)
9	1323	1382.81	95.67	90.6 - 101.0	
10	856	945.65	90.52	84.6 - 96.8	(low: p<0.005)

Regression of SRR on distance (rings)

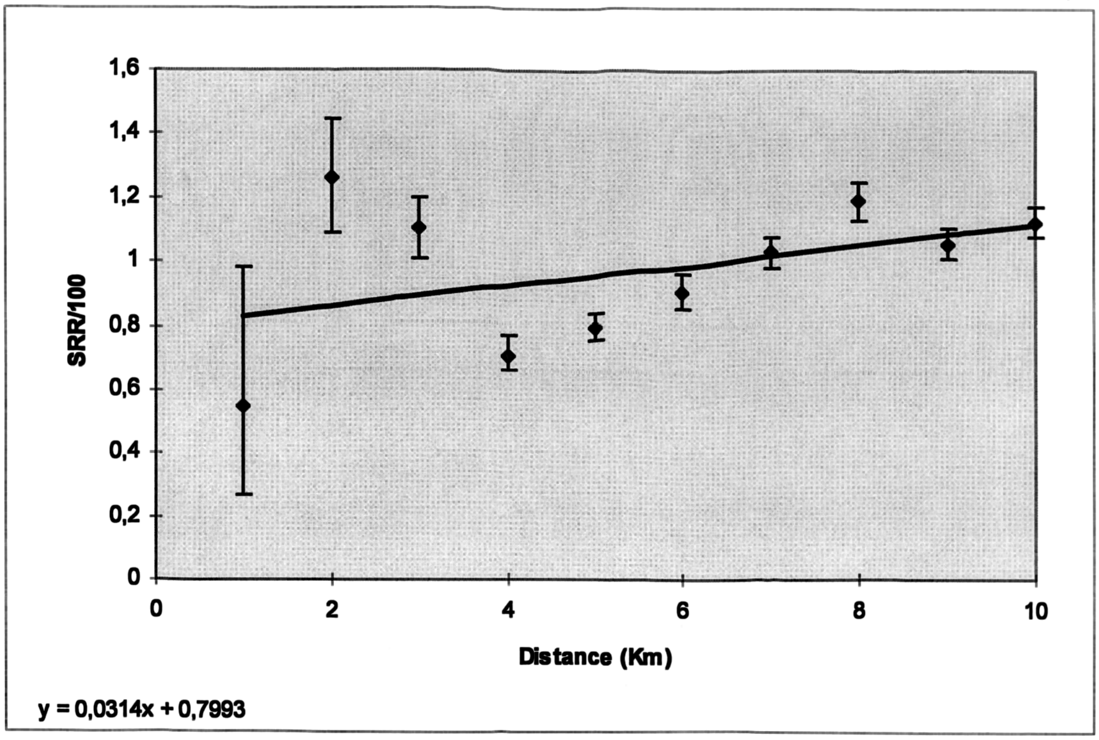


<u>Table C - Lung Cancer (total population).</u> <u>Centre five kilometres **South** from actual one</u> (Ordnance Survey coordinates: East 608, North 572)

The centre is now sited half a mile to the SE of Carmunnock. Areas North of the Clyde are included only in the last five rings, and constitute a substantial part of the last three only. Therefore, and as expected, high SRRs have moved down the table to these rings, with the notable exceptions of rings 2 and 3, one explanation for which would be the inclusion in these of the industrial area of East Kilbride. The existence of high lung cancer rates North of the Clyde appears now as more likely than a possible methodological artefact.

Ring	Obs.	Exp.	SRR	95% CI	
1	11	19.91	55.26	27.6 - 98.9	(low: p<0.022) Exact Poisson
2	193	152.53	126.53	109.3 - 145.7	(high: p<0.005)
3	563	507.91	110.85	101.9 - 120.4	(high: p<0.01)
4	746	1037.70	71.89	66.8 - 77.2	(low: p<0.0005)
5	1363	1693.83	80.47	76.3 - 84.9	(low: p<0.0005)
6	1107	1211.00	91.41	86.1 - 97.0	(low: p<0.005)
7	1494	1444.48	103.43	98.2 - 108.8	
8	1467	1230.91	119.18	113.2 - 125.4	(high: p<0.0005)
9	1796	1697.49	105.80	101.0 - 110.8	(high: p<0.01)
10	2246	1989.30	112.90	108.3 - 117.7	(high: p<0.0005)

Regression of SRR on distance (rings)



<u>Table D - Lung Cancer (total population).</u> <u>Centre five kilometres</u> **<u>West</u>** <u>from actual one</u> (Ordnance Survey coordinates: East 558, North 622).

The centre is now in the Pollok area. Again, areas North of the Clyde will appear substantially only in the second half of the table, which also shows the highest SRRs.

Ring	Obs.	Exp.	SRR	95% CI	
1	127	148.76	85.37	71.2 - 101.6	
2	618	837.84	73.76	68.1 - 79.8	(low: $p<0.0005$)
3	1691	1729.03	97.80	93.2 - 102.6	
4	1897	1773.91	106.94	102.2 - 111.9	(high: $p<0.005$)
5	1867	1897.34	98.40	94.0 - 103.0	
6	1910	1850.35	103.22	98.6 - 108.0	
7	2217	2090.62	106.05	101.7 - 110.6	(high: $p<0.005$)
8	1464	1374.51	106.51	101.1 - 112.1	(high: $p<0.01$)
9	1224	1132.64	108.07	102.1 - 114.3	(high: $p<0.005$)
10	816	792.34	102.99	96.0 - 110.3	

Regression of SRR on distance.

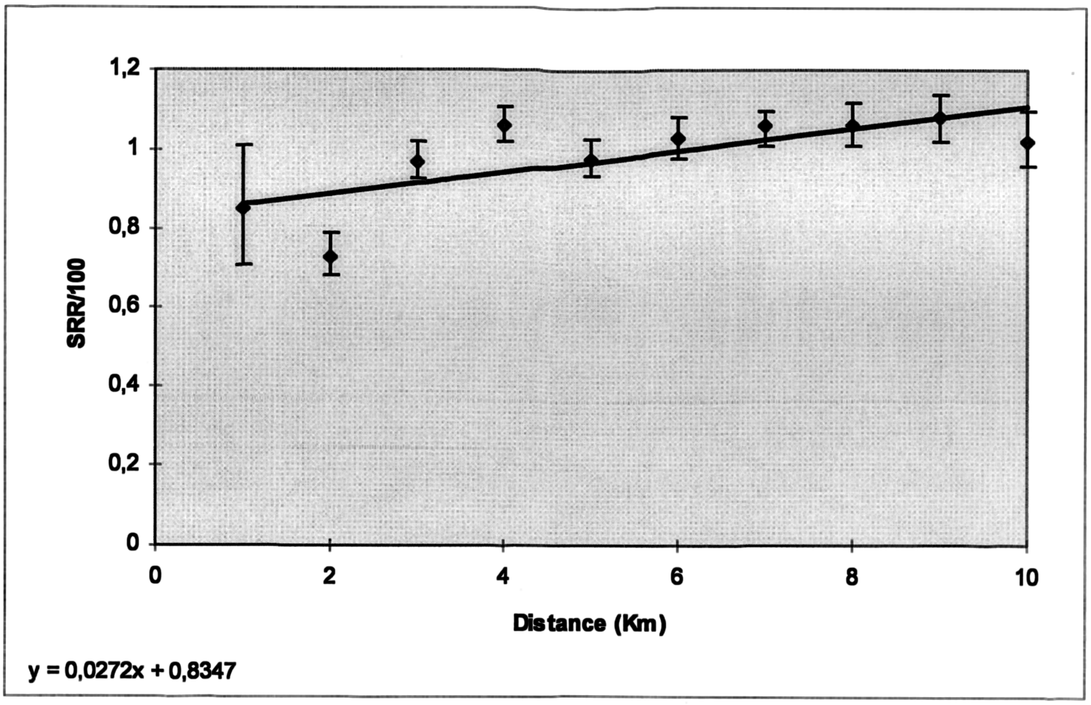
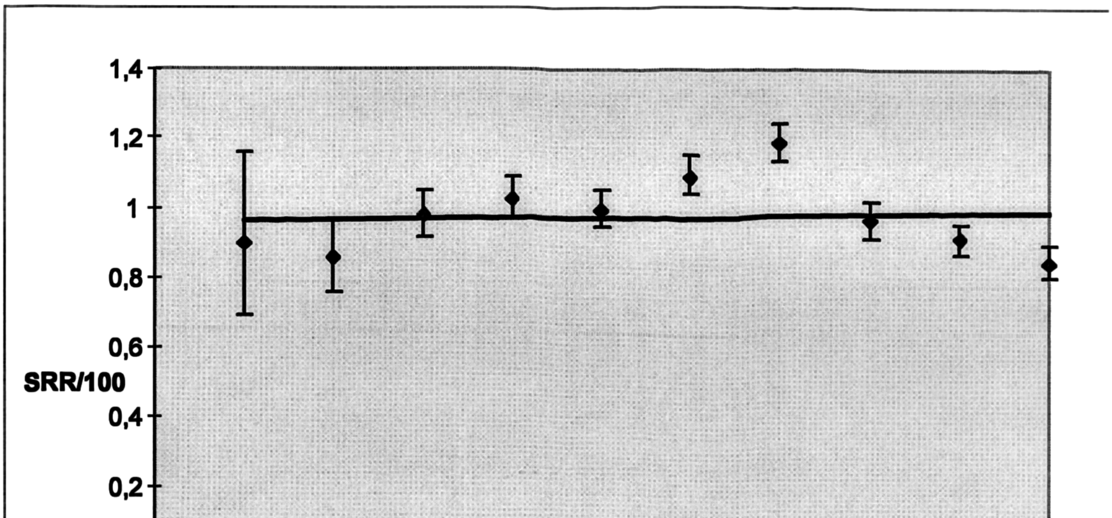


Table E - Lung Cancer (total population). Centre five kilometres **East** from actual one (Ordnance Survey coordinates: East 658, North 622).

The centre is next to Carmyle, just North of the Clyde. No SRR gradient seems to exist in Glasgow in the East-West direction, at difference with results from Tables 1, 2 and 3, which showed a South-North one. Nevertheless, Table 5 differs from Table 4, mainly in that high SRRs have moved to the middle. It would appear as surprising that, although the dummy centre for Table 5 is North of the Clyde, the central rings are non-significant. This could be explained if lung cancer tended to be higher towards the main urban area of Glasgow, i.e., centre-North (and perhaps the NW also) as seen from the actual centre of pollution, and not so much towards the much less populated NE. Results from the five tables shown here seem to give some support to this hypothesis, do support a South-North gradient for cancer and are diverse enough as to reject the possibility of a methodological artefact which would cause inner SRRs to appear high.

Ring	Obs.	Exp.	SRR	95% CI	
1	61	67.16	90.82	69.5 - 116.7	
2	252	291.60	86.42	76.1 - 97.8	(low: $p<0.015$)
3	822	833.28	98.65	92.0 - 105.6	
4	1043	1011.14	103.15	97.0 - 109.6	
5	1364	1351.18	100.95	95.7 - 106.5	
6	1374	1239.77	110.83	105.0 - 116.8	(high: $p<0.005$)
7	1755	1465.90	119.72	114.2 - 125.5	(high: $p<0.0005$)
8	1533	1572.85	97.47	92.6 - 102.5	
9	1566	1700.00	92.12	87.6 - 96.8	(low: $p<0.005$)
10	1411	1647.29	85.66	81.2 - 90.2	(low: $p<0.0005$)

Regression of SRR on distance.



7.4 - An alternative form of regression: Logistic regression

In order to check the reliability of simple linear regression as a measure of trends of diseases with distance, an alternative form of regression, Logistic regression, was tried out as a control. The set of data chosen for analysis was that for Lung Cancer for males and females, i.e., entering data separately for each sex, not as total population. Taking incidence in the innermost ring as reference (i.e., =1), the Logistic regression assessed possible trends of increase or decrease of Lung Cancer incidence for both sexes along the rings.

Variables were entered by ring and for each sex separately. These were:

- Independent variables: Sex (m=1,f=0) and Ring number.
- Dependent variable: Incidence of disease (innermost ring=1), expressed as the ratio: Numbers of cases / Risk-years population (i.e., population multiplicated by the number of years of the study period: 15 in this case).

The variable Ring (i.e., distance) was treated in two alternative ways: as a continuous variable (i.e., 1 to 10), which produced a first set of results, and as a discrete variable (i.e., 1,2,3...,10), which produced a second set of results comparable to the first one. Analyses were carried out using the STATA package, on a Personal Computer, at the Euskal Herriko Unibertsitatea Osasun Publikoa Saila (Department of Public Health of the University of the Basque Country, Bilbao). Results were as follows:

1 - Ring as a continuous variable:

Incidence = B0 + B1 sex +B2 ring+E. (1).

```
logistic case Sex Ring [fw=pob2]

Logit Estimates                               Number of obs =13158617
                                              chi2(2)       =3628.07
                                              Prob > chi2   = 0.0000
Log Likelihood =  -121014.9                   Pseudo R2     = 0.0148

---------------------------------------------------------------------------
 case |  Odds Ratio   Std. Err.       z      P>|z|       [95% Conf. Interval]
------+--------------------------------------------------------------------
 Sex  |    2.528245    .043652     53.721    0.000      2.44412    2.615266
 Ring |     .931576   .0030052    -21.971    0.000     .9257045    .9374848
---------------------------------------------------------------------------
```

The upper figure in the box indicates overall relative risk for males taking female incidence as 1 (although the programme calls it Odds Ratio, it is actually a relative risk, since total populations are taken into consideration). The figure below indicates overall diminution of incidence (Males and Females) along the rings (since it is <1). Its confidence interval (bottom right) indicates that this diminution is significant.

```
Logit Estimates                                      Number of obs =13158617
                                                     chi2(2)       =3628.07
                                                     Prob > chi2   = 0.0000
Log Likelihood =  -121014.9                          Pseudo R2     = 0.0148

----------------------------------------------------------------------------
 case |       Coef.   Std. Err.         z     P>|z|       [95% Conf. Interval]
------+---------------------------------------------------------------------
 Sex  |   .9275254   .0172657     53.721    0.000        .8936853    .9613656
 Ring | -.0708775    .003226    -21.971    0.000       -.0772002   -.0645547
 cons | -6.825581   .0240259   -284.093    0.000       -6.872671   -6.778491
----------------------------------------------------------------------------
```

Figures in the first column, above are coefficients for the regression equation (1). The one for ring would be the equivalent of a slope. It is negative, and the decrease significant, as seen above. This agrees with the previous simple regression analysis (see Table 1).

2 - Ring as a discrete variable:

Incidence = B0 + B1 sex +B2 ring1+ .... +B11 ring10+E. (2).

```
. xi: logistic case Sex i.Ring [fw=pob2]
i.Ring              IRing_1-10   (naturally coded; IRing_1 omitted)

Logit Estimates                                      Number of obs =13158617
                                                     chi2(10)      =3716.07
                                                     Prob > chi2   = 0.0000
Log Likelihood =  -120970.9                          Pseudo R2     = 0.0151

----------------------------------------------------------------------------
   case | Odds Ratio  Std. Err.       z     P>|z|       [95% Conf. Interval]
------+---------------------------------------------------------------------
   Sex  | 2.529874   .0436826     53.755   0.000         2.44569    2.616956
IRing_2 | .9687964   .0679395     -0.452   0.651        .8443834    1.111541
IRing_3 | .8388083   .0562352     -2.622   0.009        .7355236    .9565965
IRing_4 | .7783256   .0518939     -3.759   0.000        .6829807    .8869807
IRing_5 | .8346008   .0560395     -2.693   0.007        .7316858    .9519914
IRing_6 | .7300688   .048814      -4.705   0.000        .6403989    .8322945
IRing_7 | .6623712   .0440748     -6.191   0.000        .5813821    .7546424
IRing_8 | .6937891    .046031     -5.510   0.000        .6091898    .7901369
IRing_9 | .4994275   .0337196    -10.283   0.000        .4375244    .570089
IRing_10| .5374353   .0370882     -8.998   0.000        .4694454    .6152723
----------------------------------------------------------------------------
```

Logically, relative risk males/females is virtually the same as with equation (1). The figures below it indicate diminution of incidence from one ring to the next. All, except that for ring 2, are significant.

```
Logit Estimates                                   Number of obs =13158617
                                                  chi2(10)      =3716.07
                                                  Prob > chi2   = 0.0000
Log Likelihood =   -120970.9                      Pseudo R2     = 0.0151
```

case	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Sex	.9281696	.0172667	53.755	0.000	.8943274	.9620117
IRing_2	-.0317008	.0701278	-0.452	0.651	-.1691487	.1057471
IRing_3	-.1757731	.0670418	-2.622	0.009	-.3071726	-.0443736
IRing_4	-.2506104	.0666738	-3.759	0.000	-.3812887	-.1199321
IRing_5	-.1808017	.0671453	-2.693	0.007	-.3124041	-.0491993
IRing_6	-.3146165	.0668622	-4.705	0.000	-.4456639	-.183569
IRing_7	-.4119292	.0665409	-6.191	0.000	-.542347	-.2815113
IRing_8	-.3655872	.0663472	-5.510	0.000	-.4956254	-.2355491
IRing_9	-.6942927	.0675166	-10.283	0.000	-.8266228	-.5619627
IRing_10	-.6209468	.0690097	-8.998	0.000	-.7562034	-.4856903
_cons	-6.912211	.0639471	-108.093	0.000	-7.037545	-6.786877

Figures in the first column are coefficients for equation (2). All those for rings are negative.

Both sets of results, either considering distance as a continuous or a discrete variable, agree with previous analyses using simple linear regression: in general, the incidence of Lung Cancer for males+females (total population) diminishes with distance from the centre of the study area.

8 - DISCUSSION

Summary: Bearing in mind the possibility of false positive and false negative findings, these data provide no substantial evidence to reject the null hypothesis of no increases in the incidence of chromium-related health effects in the most contaminated areas. The possible impact of the minor contaminated areas in the results are considered. The different aspects of the methodology are discussed, and also some problems encountered during its planning and application. Usefulness of the methodology is discussed in connection with the case-studies reviewed in the first chapter of this thesis, as well as its possible implementation by local researchers wishing to carry out assessment analyses of sources of pollution. The application of the methodology in the circumstances already seen of a particular case study, the 1984 morbidity review near the Bonnybridge incinerator, is also presented. Finally, weaknesses and strengths of the method are listed, having in mind possible future uses of it.

8.1 - Discussion of results:

8.1.1 - Evidence against the null hypothesis:

The null hypothesis of the study is that no excess of diseases supposedly connected with chromium, or suspected of connection with it, is to be found in the rings containing, or near to, the chromium polluted areas. The strongest evidence against this assumption comes from Lung Cancer. It is evident that a significant incidence of this disease occurs in the inner rings. That this excess is due to soil pollution by chromium or not can be discussed as follows.

- In the rings containing the Main Polluted Area, South of the Clyde, SRRs for Lung Cancer are far higher among men than among women. Smoking alone can not account for this difference, since Lung Cancer in males does not follow a pattern similar to Chronic Obstructive Pulmonary Disease, which Lung Cancer in Females does. If the cause was purely environmental, non-occupational, the disease should be more evenly distributed between the sexes.

- In at least one of the rings next to the main Polluted Area, South of the Clyde, Lung cancer is significantly high among those aged over 54 years, but not for those older than 65. There is an indication of a peak of the disease among the 55 to 65 year-old. Part of the excess in this age group is likely to have occurred among ex-employees at the chromium processing factory in the area, i.e., those who could have been working there a minimum of between 20 to 30 years on average. The excess incidence was higher than what had been predicted based on the known levels of the pollutant in air (see **4.2.3**)

- In the inner rings North of the Clyde, the incidences of Lung Cancer are high for both males and females, which points to an environmental factor. But if chromium was this environmental factor, these high incidences occurred in the most unlikely of the two sides of the river, the one without known polluted areas. Even admitting that dust containing chromium could be blown over by winds from the Southern, polluted side, it would be very unlikely that it would reach far into the North side in concentrations high enough to cause a significant incidence of the disease.

Besides Lung Cancer, occupational studies point also towards a connection (see **4.2.1**) between airborne chromium and Nasal Cancer and Asthma. Nasal Cancer appears relatively high in the second ring, with an excess of 3 or 4 cases over fifteen years. Occupational concentrations in air of chromium are known to cause lesion of the nasal septum (Lindbergh and Hedenstierna, 1983) and cancer (Alderson et al., 1981), and it could be that these extra cases occurred among ex-workers in chromium processing. Since the numbers involved are so low (8 cases in this inner ring between 1975-89), no reliable statistical analyses can be conducted by side of the Clyde, sex or age. As for Asthma, the second ring had the highest incidence of hospital discharges for the condition in those under 25 years old.

A further condition which could be due to either airborne chromium or to direct contact with its waste (or rather contact with contaminated hands) is Eye Irritation, which was relatively high in the inner ring and highest in the third, pointing towards direct contact in the former (although the excess is very small) and possible airborne contact in the latter. Against this airborne contact is the fact that levels of the condition in the second ring are lower.

As for ingestion of chromium waste, there is a very slight indication of this having taken place through geophagia among those under 10 years, as it was already pointed out in **4.2.3**. Ring 4, next to the contaminated Duke's Road playground, as well as ring 2, not far from the Main Polluted Area, have slightly raised figures for Upper Digestive Tract Irritation in this age group, which could be due to geophagia. Nevertheless, incidence in the fifth ring, far from the Main Polluted Area, is higher than in either of those rings, while the possibility of children from that ring frequenting the playground, more than a kilometre away, is low.

There is no evidence in the literature of a possible connection between chromium and leukaemia. But in the five rings closer to the polluted areas, Childhood Leukaemia (under 15 years olds) showed excesses in rings 2, 4 and 5. After standardization, the excess in ring 2 (next to the Main Polluted Area) disappeared and that for ring 4 became very small, but that for ring 5 stayed much the same and relatively high. Ring 5 is too far away from the polluted areas for the excess to be connected with chromium. This excess of childhood leukaemia appears to coincide with the one detected in the Cambuslang area of Glasgow by previous studies (Hole et al., 1994).

8.1.2 - The possibility of false results:

Statistically, there is always the possibility of accepting as true differences which are not real. The significance test for SRRs was based on a Poisson distribution (one-tailed test) for numbers of observed cases under 100, and on a Normal approximation to a Poisson distribution (two-tailed test) when observed cases were equal or over 100. The percentage of possible false positive tests, i.e., those assumed to be significant when they appear to be so just by chance, is equal to the significance level set for the test, and tests in this study were set at the 5% significance level. Therefore, even in the case of a total absence of health effects (and assuming there are no confounders) up to 5% of all SRRs in the results could be significant only apparently, i.e., no real deviation from normality exists. To consider them as real means incurring in the Type I ,or Alfa, error (Mausner and Kramer, 1985).

In both Poisson and Normal approximation tests, significant excesses and significant defects have the same statistical probability to appear just by chance. Only statistically high SRRs (indicating a significant excess of disease) were taken into account, since the study was set out to look for possible negative effects of chromium pollution. In consequence, a total 2.5% of SRRs could appear as significantly high just by chance, one in every 40. Therefore, of the 940 SRRs in the study, between 23 and 24 could appear as statistically high just by chance. Since there are 184 significantly high SRRs in the study, 12-13% of these could be false positives. Taking into account that some results correspond to one-sided (0.05), exact Poisson results (due to low figures of cases), the number of false positives could be some 30, or 16% of the total.

The percentage of false negatives, i.e., SRRs far above 100, but undetected by the test, is more difficult to determine (Type II, or Beta, error). The power of the study, at the two-tailed significance level (SL) of 5%, was determined as 0.8 (see **6.2.3**), but only as an estimate, following the rule of thumb which determines that power = 1-(4 x SL), when SL is about 5% (Mausner and Kramer, 1985). This means that 8 out of 10 SRRs far removed from 100 would be detected, although how far is variable. By considering significant only high SRRs, and effectively lowering the significance level to 2.5%, the power of the study declines too, and it can be assumed that the power of the study (one-sided) is here 0.7 (Mausner and Kramer, 1985). This would mean that the 184 significantly high SRRs are only 70% of the total of those far from 100, and that between 70 and 80 high SRRs could be expected not to have been detected as significant and be false negatives. A total of 54 SRRs above 110, and 116 above 105 were non-significant.

As seen in **5.2.3**, the size of a significant difference depends, among other things, on the incidence of the disease and on population under study (i.e., inside each ring in this case). Therefore, those non-detected SRRs are to be found among those diseases with a very low incidence, such as Pharyngeal Cancer, Eye Irritation (under 19), Upper Digestive Tract Irritation (under 9, geophagia), Childhood Leukaemia and Nasal Cancer, as well as SRRs for rings with low population, notably the first ring North of the Clyde. High SRRs for these rings and diseases have been taken into account in this chapter, irrespective of their statistical significance. Although SRRs were high, the actual numbers of excess cases were minimal, such as a new case of Nasal Cancer in a population of 41,500 every 5 to 7 years, or 4-5 cases and 10-11 discharges of Upper Digestive Tract Irritation over 11 years in 11,727 children under the age of 10. Of the 54 SRRs above 110, forty-nine occurred either in the first ring (13) or in rings with fewer than 100 cases (47), or in both (11).

From all the above, it can be concluded that seven out of every eight statistically significant excesses of disease can be expected to be real, and that a majority of possibly undetected high excesses can be expected to have been taken into account. The ability of the study to detect real differences seems reasonable.

As it turns out, the estimate of minimum detectable excesses (see **Tables 5-1** to **5-4**) was conservative. A 15.4% (34 cases) excess in Lung Cancer in total population in the first ring was detected as significant, with a $p < 0.015$ (**Table 1**), against an estimated minimum 20% (37 cases) (**Table 6-3**).

8.1.3 - <u>Impact of the secondary contaminated areas in the results (Groups B and C)</u>:

The centre of the rings was set in Group A since this was, by far, the most polluted area. Nevertheless, the presence of two smaller polluted areas South of the Clyde, Groups B and C has to be taken into account (see **5.2.2**). Group C, the smallest of the two, is situated about 1 mile from the centre of pollution, in ring 2. This ring had twelve SRRs above 100 for Lung Cancer South of the Clyde, six of them significant, which are higher than the eleven and four, respectively, for ring 1, the most polluted area. Nevertheless, ring 1 had seven SRRs above 100 for Eye Irritation, against four in ring 2. If the excess Lung Cancer in ring 2 was caused by high levels of chromium in the air, Eye Irritation inside the ring would also be high, at least as much as in ring 1, but this is not the case. In any case, it is very unlikely that Lung Cancer in the area is due to chromium in air in a non-occupational setting, since concentrations of Cr(total) measured in ring 2 were 0.0000048 microg/m3 air, one hundredth thousandth (1/100,000) of the UK's occupational limit for Cr(III) of 0.5 microg/m3. Therefore, as already discussed, this excess Lung Cancer in rings 2 and 1 is probably of occupational origin.

A possible indication of a chromium-related problem in ring 2 is a non-significant excess of Leukaemia among the under-15: 2-3 extra cases over fifteen years (7 observed against 4.49 expected). This excess was found in an analysis for both sides of the river, and disappeared after standardization by depcat. Another indication would be a very small excess in the number of cases of Upper Digestive Tract Irritation among the under 10. Group C was in a grassy area, next to a park, which could have led to some chromium-polluted geophagia. The excess (both SRRs for cases) was not significant, with an extra 1-2 cases over eleven years after standardization by deprivation, and it was also found in an analysis for both sides of the Clyde.

Group B, smaller and with about half the chromium levels of A, lies at the boundary between rings 3 and 4. In the Southern side of these rings there are five SRRs for Lung Cancer higher than 100 in each of them, none significant. The chromium waste is covered in grass, but since the polluted area is mainly made up by a park-playground and school grounds, there was concern as to possible effects on children, possibly through geophagia. A possible indication of geophagia could be that in ring 4 all four SRRs for Upper Digestive Tract Irritation in the under 10 are higher than 100, with an extra 4-5 cases (of 88 observed) and 10-11 discharges (of 135) between 1981-91, both after standardization by deprivation, but no SRR is significant. Also standardized by deprivation, a small excess of Childhood Leukaemia remains in ring 4, with 2-3 extra cases (of 17 observed between 1975-89). The excess of Eye Irritation in ring 3 is unlikely to be due to chromium, since levels are low in ring 4, where the playground is.

8.2 - Discussion of the methodology:

8.2.1 - Overview:

The aim of this thesis has been accomplished: a health study on a source of pollution has been carried out. The methodology followed owes to earlier studies in the field, while using this previous expertise in new ways. This methodology made use of readily available data: small areas (Enumeration Districts) and their population statistics as the basis for the study area, its population and subdivisions, as well as routinely collected health data, also at the small area level. Data editing and analyses were carried out in Personal Computers, using standard commercial programmes or short, simple ones.

Previous sections show that the results of the study are within reason, i.e., distribution of levels of the different diseases in the study area can, in general, be explained by factors (previously accounted for or not), such as sex, age, deprivation, subdivisions of the study area, or (speculative) levels of pollution and occupation. Nevertheless, there have been some surprises, such as the distribution of a particular disease (Chronic Obstructive Pulmonary Disease) for some analyses, totally different from that of another one (Lung Cancer), while both were expected to behave in similar ways (as they do for some other analyses). A similar surprise came from another disease (Skin Irritation). But, in general, it can be said that no methodological (or data) artifact could be perceived as having a disabling effect on the analysis and its results. Besides that, interpretation of results using a 'dummy' centre of pollution (see **7.3**) proved the method to be sensitive, as did the detection of a relative excess (for Leukaemia) previously explored by other researchers (see **8.1.1**).

There was a main reason why distance to the Main Polluted Area (or rather to its centre, the former site of the chromium processing factory) was adopted as proxy for exposure: the lack of data on actual exposure. The assumption that exposure was inversely proportional to distance was the best guess, short of procedures far more complicated and computer-power demanding, such as wind modelling (which, nevertheless, can not be ruled out for future studies). The choice of the Main Polluted Area as centre seems right, since other areas known to be polluted do not appear to have had much impact on the results.

The methodology allows the division of the study area into smaller ones. Analyses on both sides of a geographical barrier (the river Clyde in this case) can show the effect such a barrier may have on the incidence of disease. This division can be based on previous tagging of the data (as it was in the study), but the methodology permits also the division of a circular study area into halves and quadrants, by selecting (through SPSS commands or any similar package) Enumeration Districts West or East, North or South from the pollution centre. This can be useful if prevailing winds spreading pollution are taken into account, factor which was not explored in the present study.

Actual levels of detection appeared slightly lower than previously estimated (see Tables in **5.2.3** and **Tables 1** and **3**). This, besides a higher definition of the study area's boundary, confirms the superiority of the use of small areas, instead of relatively large ones such as Post Code Sectors.

The main reasons for the use of routinely collected data is that, being the methodology destined for rapid, exploratory studies, the conduction of a survey would much delay any analyses, and that this survey could not possibly cover such extense and populated study areas as the ones in studies like this. Also, questionnaire collected data are not necessarily more accurate than readily available ones, since they are less objective and more open to reflecting respondents′ bias. In any case, and besides its methodology, an study is as good as its data, and quality of routinely collected data differs according to their sources. Registries appear to offer the most reliable data. Registries of Congenital Malformations exist all over Europe and their data are know to be accurate, due to their following of the EUROCAT (European EUROCAT network of registries) criteria. Cancer registries also are known to offer reliable figures, product of coverage and level of histological verification, but caveats exist, as discussed in the next section. Hospital discharges (SMR1 in this study) are a less reliable source of data, and more on this is also discussed in the following section (**8.2.2**).

Some factors go unaccounted, either because they are usually unavailable (length of residence and, therefore, of exposure to the pollutant) or sketchy (exposure to other pollutants), or just unavailable at Enumeration District level (smoking, prevalence of risky lifestyles). The way the methodology tried to account for them, at least partially, was through standardization by Carstairs' Deprivation Category (Depcat). Residence near industrial areas is related to social deprivation, and residents in those areas often just can not afford to move outside them (Jolley et al., 1992). High correlation coefficients exist between Depcat and mortality for several common diseases. For Lung Cancer it is 0.81 for all ages, and 0.87 for Chronic Obstructive Respiratory Disease (Carstairs and Morris, 1991). Depcat can also be used as proxy for smoking prevalence, and it has been so (De Voss, 1991), since its correlation coefficient with mortality linked to smoking is highest than for any other group of diseases: 0.91 (Carstairs and Morris, 1991). Results standardized by Depcat generally showed lower levels of disease than those standardized by age only (see **Tables 1** to **94**), corroborating the above. The Small Areas and Rings methodology proved that Standardization by Depcat can be conducted through routine command files.

Standardization for each disease by deprivation category and age required the editing of population files in the following way: a) total population inside each ring was divided into partial populations, with the same deprivation category and age group; b) overall (all rings grouped) incidence rates for each age group in each deprivation category were obtained; c) overall incidence rates for each age group were also obtained; d) for each age group, overall rates by age group and deprivation were divided by overall rates by age group only; e) the ratios obtained were multiplied by the partial populations obtained in the first place, both matched by age group and deprivation category, inside each ring; f) partial results inside each ring were summed by age group to obtain an edited population file by rings; g) overall age-group incidence rates were then applied to this population to obtain SRRs standardized by age and deprivation (see files

CANCERS.PAD and SMR1S.PAD in **Appendix 4**). An alternative to this would have been a Multiple Regression of the type:

Incidence rate = a + b1 (ring 1 to 10) + b2(deprivation category) + b3(cases by age group) + b4(population by age group) + b5(standard deviation of cases) + b6(standard deviation of population) + E

by which incidence rates adjusted by deprivation and by age group would have been worked out for each particular disease (Armitage, 1971).

Some doubts were raised as to the usefulness of simple linear regression in assessing trends of health with distance from the centre of pollution. It can not be denied that the method appears as too simplistic, and that the pattern of Standardized Registration Ratios for some diseases, being too scattered, appears ill-fitted into an straight line. As an alternative, another form of regression, Logistic regression, was also tried out for limited sets of data, confirming previous results. Although admitting possible limitations with the use of simple linear regression with the methodology, it must be taken into account that an independent parameter, the Stone statistic, agreed with it in nearly 80% of the analyses.

8.2.2 - Some problems encountered:

There were some doubts as to the suitability to this case study of a methodology inspired on previous experience on punctual sources of pollution. The Main Polluted Area, acting here as such a source, covers a relative large expanse. Also, the problem existed of two secondary polluted areas, away from the main one. Nevertheless, when compared to the area of the first ring (ring), the size of the source was small, and, therefore, it was decided to apply the methodology to the case. Results were examined for possible effects due to the secondary sources.

Since distance had been adopted as a proxy for exposure, the width of the rings was kept constant in order to have proportionally diminishing levels, and in consequence populations inside the rings differed (see **Table 6-1**). The main problem with unequal populations consisted in that these were relatively low for the innermost two rings, from which, in consequence, comparatively low levels of detection would be expected.

Nevertheless, this would also be expected to be partially compensated by the higher incidence rates supposedly prevailing in these rings, resulting in higher numbers of cases and therefore in higher SRRs (see **5.2.3**). In the event, the first two rings frequently turned out to be significant, but also all their SRRs higher than 100 were taken into account when examining the results.

Some worries existed about data reliability. In Scotland (1981-91) Register data for Lung Cancer had an overall histological verification of only 58.9% and of 51.9% among those over 65 years of age, some of the lowest (Muir, 1993). In consequence, careful interpretation of some results is needed, since these could be based on overestimated data. These data were the only available, and this kind of problem is bound to appear in any environmental study, both in the UK and abroad. On the other hand, Leukaemia had a 75.9% verification (89.9% in the under 35) (Sharp et al., 1993), and verification was also high for Skin Nasal and Pharyngeal cancers.

The less reliable source of the data analysed is SMR1. Although this registration system is the main one for clinical conditions outside the Registers, there is scepticism amongst clinicians about its completeness and accuracy (Pears et al, 1992). Therefore, SMR1 data are inaccurate, to a degree as yet not fully known, and so will be the results drawn from them. But at the same time they are the only readily available source for studies covering long time periods, since no GP or outpatient system existed before 1991 for less serious conditions (it does now, SMR0). Results from SMR1 data appear as useful indicators, but should not be taken at face value.

Linkage of SMR1 hospital discharges to obtain numbers of patients, carried out on demand, delayed the arrival of data. Both SMR1 and cancer data needed editing at source, to allocate them to the different Enumeration Districts and this, too, demanded time and computer resources. These factors have a bearing on one of the main advantages this kind of methodology should have, rapidity of response. On the other hand, such editing was not available for, at least, one of the health parameters (Congenital Malformations), for which allocation to EDs had to be conducted manually. This would have been a forbidding task for larger sets of data.

Besides other possible shortcomings, levels of data misrecording were detected during the study. Although all Enumeration Districts in the study area were supposed to appear in the available data files, whether they had had any cases during the time-periods or not, some were missing, which meant that their populations could not be included in the study and entailed further ascertainments and delays. Also, deprivation categories for some EDs for which there were data, were missing. After obtaining most of the missing data, the overall (and for each ring) loss of population was judged to be low enough not to have a noticeable influence on the results. Most Enumeration Districts with missing deprivation categories turned out to be too small to have one, and they were grouped during the analysis under an extra category.

The 1981 Census was the most appropriate for some analyses, since it nearly corresponded to their time-period midpoint. This was not the case with these diseases whose time-period started in or near 1981. At some point, the use of population estimates was considered, but finally it was discarded, and the same population data were used for the analyses of both types of data.

Available computer power was good enough to conduct editing and analyses. Nevertheless, the full Stone test required computing environments more powerful than those of the personal computers. It could have been carried out using a mainframe, but the aim of the study was to apply the methodology using readily available means and, in the end, just the Stone statistic was calculated, but not their significance levels.

8.2.3 - Comparison with other methodologies reviewed:

The methodology of Small Areas and Rings could substitute advantageously those used in conventional descriptive studies reviewed in Chapter **3** (see also **3.6.1** and **3.6.2**). Study areas would have been better defined, a proxy for exposure (distance) routinely used, the effects of deprivation would have been taken into account, and comparable results would have been obtained from separate studies. The advantage is not so clear with those studies covering very large areas because of the rarity of the conditions studied, such as the ones on congenital malformations. Although their study areas are subject to the constraints attached to preset administrative divisions, the very fact of covering such large zones allows for a broad picture of the problem. Nevertheless, the local health problems at the origin of these studies may disappear against these backgrounds, and these problems had a suspected punctual cause (incinerators in both cases), around which descriptive local studies could be conducted through the Small Areas and Rings methodology, without detriment to other methods.

What the methodology does not aspire to is to replace analytic studies. Case-controls or follow-ups, like those conducted around several nuclear plants in England, Scotland and France look for a possible connection between the pollutant and disease. The Small Areas and Rings methodology is just a descriptive one, assessing the distribution of disease. But as an exploratory tool, the method can justify whether more lengthy and time-consuming analytic research, like those studies, is needed.

In descriptive geographical studies, and in those analytical looking for a possible relationship between parental doses and cases of disease in children, the methodology could be of support by treating multiples of the lowest doses considered as numbers of cases at the small area level, standardizing reproductive age groups by overall incidence and comparing the pattern of the results along the rings to those for the real disease in children. Also, comparisons between different groups (e.g., natives and outsiders) can be carried out, as long as data on these groups are available at the small area level.

The methodology also compares favourably with more advanced studies. It surpasses that of pioneer research, such as the use of rings in Armadale (no need for control disease by using wider rings), and the use of Enumeration Districts in Bonnybridge (see **8.2.5**) and Dounreay, all novel in their time. The method is indebted to the SAHSU methodology, and its advantage over it is its use in an independent, non-centralized context. It must be admitted, though, that SAHSU's area definition is better, because of high computing power, which also allows to carry out more sophisticated analyses of trends with distance.

The Spatial Point Process method and the Geographical Analysis machine are both exciting developments. But, although much less ambitious, Small Areas and Rings has the advantage over the former of a well defined population, and over the latter of investigating known sources of pollution, thus avoiding the risks a of 'post hoc' search for one.

8.2.4 - A general implementation of the methodology:

As it has been said already, this method can not be intended as a substitute for analytic studies. It is good as an exploratory tool, which may lead to further research in case some results point towards the convenience of doing so. An area of application is that of answering population concerns, without the inconveniences associated with surveys, and allowing the exploration of health parameters which may not seem to warrant research (such as congenital malformations in the present study). But even without external pressures, it can be used as a discreet way of assessing suspected sources of environmental hazards.

Prior to the study, a risk assessment of the hazard will help decide which main diseases should be analysed, as well as providing information on the dose-response factor and ways of exposure, which must be taken into account for the interpretation of results.

Routinely collected health data at the Enumeration District level can be requested in computerized form from regional Registries and Health Authorities. Researchers should be aware of the limitations of these data, and of such figures on their completeness and accuracy as there may exist, to help interpret the results. Population figures (Census or estimates) and deprivation indexes are usually available from the same sources. Standard incidence rates external to the study area may be used. But once data for the area have been obtained, there is always the option of using its overall rates as standards, by which the study would show distribution of disease inside the area by rings (as in the present study), rather than comparing it to average incidence in other areas.

Distance to the source of pollution as a proxy for exposure is implicit with this methodology and always available. Nevertheless, it should not be taken literally. Depending on the kind of source, inner rings will not necessarily be those with the highest levels of pollution, as in the case of incinerators, whose plumes reach the ground at varying distances from the stack, i.e., towards the outer rings. Basic meteorological data (local wind rose) should be available and will help with the interpretation. Based on this or, if available, on more detailed information on levels and spread of pollution (monitoring), the circular study area can also be divided into halves or quarters, depending on prevailing winds and varying levels, for separate analyses (see **8.2.1**).

If actual contact with the source is revealed as important by the risk assessment, geographical barriers hindering this contact must be taken into account. In this study, such a barrier for contact was the river Clyde. Data could be obtained separately for both sides of a barrier, or separated once obtained, since such accidents usually determine the limits of larger administrative areas, of which the Enumeration Districts are approximate subdivisions.

To have similar levels of detection (not taking incidence into account), equal populations can be obtained for each ring, in a simple way by previously deciding on their size and tentatively varying the width of each successive ring (see **create RING** commands in SPSS-PC+ file **CENDEP10.SYS**, in **Appendix 4**). The convenience of having equal populations should be considered against the effect that varying ring widths can have on distance as proxy for exposure. It should be remembered also that Ordnance Survey coordinates are currently accurate to 100 metres, with the impact this can have on the correct allocation of Enumeration District's centroids to narrow rings. Nevertheless, this accuracy is expected to improve.

Personal Computers and commercial packages are easyly available. Programmes for the calculation of Standardized Registration Ratios and for the Stone statistic can usually be obtained from Cancer Registers, or written on purpose. Standardization by Deprivation Category using the SPSS-PC+ package may look complicated, since the command files appear as long (see **Appendix 4**), but it is within anybody's reach, and more advanced environments (e.g., Windows) can simplify it. Linear regression and the Stone statistic combined, help analysing health trends linked to distance from the source of pollution. More sophisticated forms of regression are also commercially available.

Although the methodology is standard, and the results comparable, interpretation of the results must take into account all the above points, which may differ depending on local factors.

8.2.5 - An example: application of the methodology to the Bonnybridge incinerator:

The Lenihan study on health on the Bonnybridge/Denny area (Lenihan, 1985) could be improved by using the Small Areas and Rings methodology. In the first place, the original investigation followed perhaps too literally its remit and took as centre for its study area the midpoint between the localities of Bonnybridge and Denny, somehow ignoring the main factor behind the study: an industrial incinerator to the NE of Bonnybridge, putative source of the pollution giving rise to popular concern.

With the incinerator as centre for the study, an area made up of Enumeration Districts and 5 kilometres in radius, similar to the one originally used, would still include

Bonnybridge and Denny, and by further division into rings have the advantage of considering distance as a surrogate for (unknown) varying levels of pollution.

There are, nevertheless, several drawbacks to the above. One is that by displacing the centre to the NE, part of a major urban centre, the town of Falkirk, would be included inside the outer rings, with possibly distorting effects on the analyses. Another one is the size of Enumeration Districts in a semi-rural environment, as a big portion of the study area would be, which could lead to poor ring definition. These drawbacks could be overcome by halving the overall ring and studying only its Western half, still including the whole of Bonnybridge/Denny. This half is also approximately downwind from the incinerator, being the NE winds those more likely to spread pollution in the region (see: Lloyd, 1982; Williams et al., 1987). Not risking the inclusion of urban centres, the Eastern half could widen its radius (to perhaps 10 km), and their rings be wider (1.5 to 2 km), by which raggedness of edges could be balanced.

The study area could still be compared to similar ones, as in the original study. The Small Areas and Rings method would therefore be applied to each of these control areas (the analysis files would be the same, using different sets of data). Distributions of diseases along the rings could be compared, with centres for the control areas (none known to have major pollution sources) left to the researcher criteria. Another advantage would be that all the areas would be standardized by deprivation categories, which they were not in the previous study, making comparisons between the areas more accurate.

Of course, the above methodology would be applied to the analysis of major sets of data, such as mortality for different causes in the 1985 study. The original methodology would be retained for the study of particular conditions, like microphthalmos, with very low numbers of cases and requiring a case by case ascertainment.

8.2.6 - Final discussion: methodology's weaknesses and strengths:

Weaknesses:

- The methodology seems more appropriate for punctual, or near punctual sources of pollution, than for extended ones.

- Other sources of pollution in the area are not taken into account.

- Distance as a surrogate for levels of exposure, while useful, appears as too simplistic.

- In its most elemental application, differing populations along the rings can lead to problems of detection and interpretation.

- Quality of results depends on, frequently unknown, quality of routinely collected data.

- Routine data may need lengthy editing prior to analyses.

- Census-based population is not always the most adequate as denominator.

- All unaccounted factors are summarized into a single one: deprivation category.

- The methodology is not too good for the analysis of diseases with small numbers of cases.

- Linear regression appears as a simplistic approximation to assessing trends with distance.

- Based on British small areas, it remains to see how the methodology would behave outside the United Kingdom.

Strengths:

- The methodology is simple and within anybody's reach. It can be used through Personal Computers and makes use of standard programmes and routine commands, allowing independence to researchers and facilitating rapid answers to local problems.

- Results from different studies are comparable among them.

- Similar sources of pollution can be pooled into a single study, increasing the statistical power.

- Sensitivity of the methodology has been proven through analyses using false centres of pollution. Also, a known cluster of disease (leukaemia in Cambuslang) was detected by the present study.

- Although simple, distance as proxy for levels of pollution is always available in the absence of better data.

- Boundaries of study areas are adequately defined through the use of Enumeration Districts.

- The methodology allows for the subdivision of the study area into halves and quadrants, to take into account data on winds and spread of pollution.

- In spite of limitations in accuracy and completeness, routinely collected data are relatively easy to obtain, are less likely to reflecting bias than survey data. Pooled routine data, collected over the years allow for more statistical power.

- Deprivation is easily taken into account.

- The methodology is open to future developments, such as the use of even smaller units (Post Code Units), through improvements in population statistics and in Personal Computers' power.

9 - CONCLUSIONS AND RECOMMENDATIONS.

Summary: This final Chapter is divided into Conclusions and Recommendations regarding the case of chromium-polluted soil in Glasgow and the general methodology followed in the study. On the former, it is concluded that for most of the diseases studied chromium is not a factor, or it is a very minor one. Only for Nasal Cancer and Lung Cancer may have been an occupational factor, particularly South of the Clyde. North of the river, other undetermined environmental factors seem to exist, and further studies are suggested to elucidate this. On methodology it is concluded that the method is sensitive and easy to use by local researchers in the assessment of pollution sources, although careful interpretation of the results is necessary, as well as further development of this methodology. Improvements are recommended regarding the routine collection of data, particularly those for hospital discharges and minor conditions, as well as further research on the long term effects of low-level pollution, and reliable measurements of levels and distribution of pollution, among others.

9.1 - Conclusions and recommendations on the case of chromium pollution:

9.1.1 - Conclusions:

Pharyngeal Cancer, Chronic Obstructive Pulmonary Disease, Upper Respiratory Irritation, Kidney Dysfunction, Skin Cancer and, contrary to prior expectations, **Skin Irritation** appeared no higher in the polluted areas than in the non-polluted ones.

The only detected significant increase in **Eye Irritation** is unlikely to be due to chromium, since it occurs relatively far away from the Main Polluted Area (ring 3). If airborne chromium (carried by winds) had been responsible, the first two rings should have shown higher levels of the condition than were observed.

Congenital Abnormalities are significantly high in rings 3 and 4, possibly in relation to a secondary polluted area (Group B). But much higher levels of chromium than those in this secondary area exist in ring 1 (Main Polluted Area), and since the incidence of Congenital Abnormalities is not elevated in this ring and lower than expected in ring 2, it appears unlikely that rings 3 and 4, further away from the Main Polluted Area, would be more affected. Therefore, it is concluded that the excess in Congenital Abnormalities in rings 3 and 4 is not due to chromium pollution.

Even if the slight increase in **Upper Digestive Tract Irritation** in children is due to chromium-related geophagia, it is very small in magnitude: one new case every 2-3 years in ring 4 in a population (North and South of the Clyde) of 11,727 children under 10 years; one new case a year in ring 5 in a population (N and S) of 8,633 under 10 years.

There is a small increase in hospital discharges of **Juvenile Asthma** (under 25 years of age) near the Main Polluted Area: 2-3 extra discharges a year in ring 2, between some 15 patients (of 14,339 under 25 in the ring, North and South of the Clyde), each requiring clinical attention 2-3 times a year on average. This increase could be due to airborne dust from the adjacent Main Polluted Area (contaminated by chromium or not) blown by winds.

Although there is no known link between chromium and **Leukaemia**, the increase in Childhood Leukaemia in the second ring, near the Main Polluted Area, deserves a particular description. This increase (between 1975-89) was of one extra case for every 3,000 people under 15 years of age (North and South of the Clyde). After standardization by deprivation category, the increase reduced to one extra case for every 19,000 (0.39 extra cases in 15 years). The overall rate of Childhood Leukaemia in the whole study area between 1975-89 was one case for every 1,700 under 15 years of age. The increase is small in absolute terms, and smaller than those in the fourth and, particularly, fifth rings. But these increases can not be connected to chromium, since both ring 4 and 5 are far away from the Main Polluted Area (ring 4 is on Group B, but chromium there is much lower and covered by soil). Therefore, causes other than chromium seem to be behind these increases. The view supported in a study by the Scottish Health Service is that they are random excesses (Wilkie, 1994), other hypotheses being inheritance (Hole et al., 1994) or an infectious agent (Alexander, 1994). Chromium is unlikely to be the cause of the small increase of Childhood Leukaemia in the second ring.

Nasal Cancer is relatively high next to the Main Polluted Area (ring 2), with 3-4 extra cases out of a total of 8 observed over a period of 15 years in a total population of 41,482 (North and South of the Clyde). The most probable cause appears as occupational, and possibly part of the cases occurred among former employees at the chromium-processing factory.

Lung Cancer. For registrations between 1975 and 1979, standardized by age group and deprivation category, the study showed statistically (0.05 significance level, two-tailed) increases in Lung Cancer on both sides of the Clyde near the Main Polluted Area. The increases were markedly different according to sex, area and age.

South of the Clyde there is a minimum of 22-23 extra cases of male Lung Cancer (14-15 aged 55 and over) inside two kilometres from the site of the former chromium-processing factory in the Main Polluted Area. There is no apparent excess among females. These extra cases are more than what was estimated from a lifetime exposure to air levels of chromium in the area: one case among those aged over 55 (see **4.2.3**).

North of the Clyde there is a minimum of 68-71 extra cases of male Lung Cancer within 4 km. from the factory's site, of which 56-59 are older than 54 years and 8-10 older than 64 years. There is also a minimum 3-4 extra female cases. With levels of chromium in air similar to those measured near the Main Polluted Area, South of the Clyde, 1 or 2 extra cases could have been expected among the over 55 and none in those younger.

The conclusion is that most, if not all, extra cases of male Lung Cancer South of the Clyde are due to present or former occupational causes and/or male lifestyles. North of the river, a further environmental factor may be present since:

a) Females are, to a lesser degree, also affected, which is unlikely to be due to their sharing male risk factors to a higher degree than in the South, particularly after standardization by deprivation-social class.

b) Numbers and levels of extra cases among males are higher than in the South, even after standardizations by deprivation account for different types of occupation.

Environmental chromium is very unlikely to be the cause of these numbers of extra cases.

Routes of exposure

From the lack of positive results in **Skin Irritation**, direct contact with the pollutant seems to be limited.

The very small increase in **Upper Digestive Tract Irritation** also suggests that ingestion by children of chromium-polluted soil is rare.

Negative results for **Eye irritation**, and very little evidence of an effect on **Asthma**, confirm previous monitoring indicating very low levels of air pollution by chromium near the polluted areas.

Final conclusion:

- There was little evidence to support a causal relationship between chromium contaminated soil and excess disease, including lung cancer.

9.1.2 - Recommendations:

Since the main conclusion is that, within the limitations of the study, the chromium-polluted areas are not a cause of ill-health, both the health professionals and the public should be informed of this conclusion and the study leading to it, in order to allay possible existing fears to the contrary and, at the same time, open a discussion as to the reliability of the study and its methodology. Consequently, the first recommendation would be:

- To publish the results of the study, informing the population living near the polluted areas that possible ill-health is unlikely to be due to chromium, and on the reasons for this conclusion. A full version of the study should also be made available to health professionals and to the public on request.

Although it was concluded that Childhood Leukaemia South of the Clyde was not related to chromium, the causes of its relatively high incidence, particularly in the fifth ring, are still unknown, which warrants that:

- It should be confirmed whether excesses of Child Leukaemia occur South of the river, as previous studies suggested (Hole et al., 1994), and further studies of these excesses should be undertaken to determine their causes.

Regarding Nasal Cancer:

- The small number of cases (5-6 new cases per year in the whole of Glasgow), permits to conduct a case-by-case study, including the use of questionnaires or interviews with patients and the review of their employment record. This could help elucidate whether the cases in Glasgow occurred among those employed in chromium processing, thus supporting or challenging previous studies (Alderson et al., 1981).

Lung Cancer, due to its proven higher incidence near the polluted areas, as well as North of the Clyde, should be the object of detailed studies. Therefore:

- It would be advisable to conduct a case-control study of male Lung Cancer South of the Clyde, in the area inside four kilometres from the former chromium-processing factory. This study could include as cases all persons diagnosed with lung cancer during a year. From cancer incidence during 1975-89, the number of cases would be in the order of 150, of which some 15 would be under 55 years of age, 45 between 55 and 64, and 90 would be 65 years and over. Ideally, for each case, his control should be drawn from inside the same one-kilometre ring, from an Enumeration District with the same Carstairs deprivation category and be of approximately the same age. Since some of those aged 65 and over now could have worked up to 15-20 years in the chromium-processing factory, a review of the employment records of cases and controls in that age group, as well as their possible exposure, can help elucidate the extent to which, if any, chromium contributes to Lung Cancer in the area. Since individual lifestyles could be assessed, the role of smoking could be sorted out from that of occupational and environmental causes.

- It would also be convenient to conduct a similar case-control study in the equivalent area North of the Clyde. This study should include females as well. Due to smaller populations, the number of cases and controls would be about 130 each, about 40 of which females. Matching of cases and controls should be conducted as indicated for the study South of the Clyde, with the addition of matching by sex. Since causes other than occupational could have a particular impact in the area, lifestyle and individual perception of environmental pollution should be assessed with particular care.

9.2 - Conclusions and recommendations on the methodology of this and future studies.

9.2.1 - Conclusions:

As far as the author is aware, this is the most comprehensive desk study of its type ever carried out in the United Kingdom. A thesis can be seen as a long and cumbersome task, unsuited to provide a rapid answer to a situation of pollution creating public concern. Nevertheless, the thesis may be seen as an exploratory exercise, rather than one based on a previously existent methodology, the creation and testing of one being, precisely, its aim. Therefore, besides being a thesis, this study may be seen as the prototype of a low-cost and efficient method of health assessment. It combines the simplicity of previous desk studies with the more appropriate definition of the study area achieved by, for example, the Small Area Health Statistics Unit. Regardless of the difficulties encountered during its creation and testing, the main conclusions regarding the study's methodology are:

- The objective of developing a standard, simple methodology for the health assessment of areas near sources of pollution has been met. This methodology is appropriate for the assessment of the health effects of localized pollution, particularly in those cases where a reasonably rapid study and easy to interpret results are demanded.

- Besides its potential use as an answer to public concern, the methodology provides local researchers, with limited means of analysis but with access to Registries and routinely collected data, with a proactive, flexible exploratory tool in the assessment of such possible situations.

The quality of the data used differs according to diseases and sources, with those from Registries (cancer, congenital malformations) being accepted as reliable in terms of completeness and accuracy of diagnoses. The main difficulty with data for less serious conditions is that their principal source is hospital discharges records (SMR1 in Scotland), and these are known to be more inaccurate than records from Registries, although their quality is expected to improve as a consequence of their use as indicators for fund-holding practices and Health Boards in the purchase of services (Kohli and Knill-Jones, 1992 ; Pears et al., 1992). A first step in the improvement of non-Registry data, also as a consequence of the new division between purchasers and providers, has been the set up in Scotland of the SMR0 system, collecting data on outpatients at consultant clinics (Information and Statistics Division-ISD, 1991).

A two-sided significance level of 0.05 is appropriate in the detection of increases (and if necessary, defects) of disease. A one-sided 0.05 significance level would make significant increases smaller than those encountered in the study, but it seems advisable to keep a conservative approach as to what is significant, particularly in studies which, like the present one, cover a controversial subject. Nevertheless, in the interpretation of the results, it is also necessary to remember that with a given significance the levels of detection for different conditions differ depending on the incidence rates of the diseases, and for a single condition depending on the population at risk in the area studied, higher rates and populations causing lower SRRs to be significant. As an example of the former, both Lung Cancer and Eye Irritation appear as significant for the total population in the third ring with the same probability ($p<0.005$, see **Tables 1** and **59**), but their SRRs differ by about 6%, although the incidence of Lung Cancer during 1975-79 in the ring was about eight times higher than that of Eye Irritation. As an example of the effect of differing populations, equal probability significant SRRs for Lung Cancer for total population are different in rings 2 and 3, with similar incidence rates, because the population of ring 3 is nearly twice that of ring 2 (see **Table 1**). Differing incidence rates should not be a problem as long as attention is drawn to this point when circulating the results. The problem of differing populations could be avoided by using rings with equal populations, keeping in mind that this can have a negative effect on the assumption of distance as a proxy for exposure.

The choice of standard rates has a bearing on the results in that more (or less) rings can appear as significant, depending on how different the study area is on average from the area from where the standard rates are drawn. In this study, the study area approximately covers Glasgow, a conurbation quite different in morbidity from Scotland as a whole, its rates for Lung Cancer, for instance, nearly double the Scottish ones. If the Scottish rates had been used, virtually all rings would have been significantly high, but by using internal, overall rates, a picture of the distribution of disease inside the study area appears, with only those rings in which incidence is higher likely to appear as significant (not taking into account, that is, the problem of differing populations inside the rings).

Definition of the rings is finer in the study by the Small Area Health Statistics Unit, since Post Code Units are taken into account in those Enumeration Districts straddling the rings when defining the population (Kleinschmidt, 1992). The present study made use of over 3,000 EDs (2,780 of which were finally included in the study area). Since each ED has, on average, 14 PCUs, had the study been done at PCU level, over 40,000 of these would have been used. This is within Personal Computer power, but, as SAHSU itself admitted, the definition of rings is not greatly improved (Kleinschmidt, 1992). On the other hand, individual data entries are always postcoded at PCU level. Using population data at PCU level and raw registrations at PCU level too could, if more cumbersome, save the time devoted to allocating cases to Enumeration Districts. Since the 1991 Census, there are detailed population data at the PCU level. Nevertheless, there are no deprivation indicators at levels smaller than ED, and a PCU is perhaps too small to have one allocated. In balance, the use of Enumeration Districts, particularly inside densely populated areas (as in this case), where they are small enough to give good ring definition, is appropriate for the moment.

As already discussed, radial distance to the source of pollution is a reasonable proxy for actual exposure in the absence of better environmental measurements. The Stone calculation of highest ratio between cumulative numbers of observed and expected cases and a regression line (linear or not) are useful indicators of trends with distance.

The use of proxy parameters, distance for exposure, deprivation category for smoking and general state of health, is unavoidable in the absence of exact figures. In the type of studies which may make use of the methodology of Small Areas and Rings, these proxies constitute a useful tool. Only if a first, exploratory study of this type revealed an excess of disease, would more exact, 'ad hoc' measurements of exposure and lifestyle not routinely available be justified with a view to further studies, now focused on the disease, or diseases, whose incidence was found to be increased. As an example, a detailed collection of data on smoking prior to an exploratory study would prove futile in case the health parameter found to be increased was one for which smoking is not a confounder, such as leukaemia or skin conditions, even if the study includes health parameters for which smoking is a confounder.

As explained in **6.3.2**, **6.3.3** and **8.2.1**, indirect standardization for each disease by deprivation category and age required editing of population files by routine commands. An alternative would have been the use of Multiple Regression. Nevertheless, files containing population, cases and deprivation categories would still need editing prior to multiple regression. As it has been shown in the study, the editing of these files through routine commands in a simple commercial package (SPSS-PC+, or equivalent) was relatively easy, yielding good results. Therefore, as long as only one extra factor (deprivation in this case) is taken into account for standardization, the methodology followed will suffice.

From the above, further conclusions on the methodology of the study are:

- Routinely collected data are appropriate for studies of this kind, with data from registries still being more reliable than those from sources like SMR1, whose completeness and accuracy are, however, expected to improve.

- Due to the different sizes of population in the rings, particular care has to be taken in the interpretation of significant results.

- Urban areas usually differ notably in health status from surrounding, more rural areas. In these cases, as in the one object of this study, the use of incidence rates for the whole study area as the standard rates is preferable to the use of regional or national rates.

- Enumeration Districts as building blocks provide for the moment adequate definition for the study area and its rings. Additional definition by using Post Code Units would greatly increase the size of the data and require more powerful Personal Computers.

- In exploratory studies such as those the method is intended for, proxy parameters like distance for levels of exposure and deprivation for smoking and general health status, are adequate substitutes for more adequate measurements routinely unavailable.

- Standardization through the use of simple programmes and routine commands appears as good enough. Nevertheless, other methods such as Multiple Regression are not to be ruled out in future developments of the methodology.

9.2.2 - Recommendations for future studies:

1 - On background information of pollutants' effects:

- More research is needed as to the long term effects of very low or low concentrations of toxic waste and pollutants in general. So far, most literature comes from occupational studies.

- Databases on the health effects of the different classes of toxic wastes and pollutants should be kept up to date, and be easily accessible to researchers.

2 - On exposure and area of study:

- Interpretation of results would be easier if based on data from routine monitoring of levels of pollution.

- A better model of exposure than the simplistic one based on rings is needed. This future model has to be able to accurately map the spread of pollution and the varying levels of exposure, taking winds and geographical features into account.

- The use of Geographical Information Systems for the mapping of irregular study areas and their subdivisions should be included in future studies, based on more advanced models, using better data on pollution and its distribution.

3 - <u>On data and methods</u>:

- There is a need for the improvement of the quality of health data, particularly SMR1. Misregistrations and misallocations of data should also be corrected and avoided.

- Data for minor conditions should also be collected on regular bases. Use should be made of GP and outpatient data (such as SMR0). Although major health effects may be absent from an area, minor conditions can have a major impact on the well-being of the local population.

- Although currently the procedures are acceptable, extraction and obtention of the data requested for a study should be made easier and faster.

- Rings could contain populations of similar size, as long as their widths are not too dissimilar and the assumption of a relationship distance-exposure is still seen as valid.

- It would be advisable if data on smoking prevalence were added to those making up deprivation scores and their categories at the Enumeration District level. There should also be a regular reassessment of these deprivation scores. Data on lengths of residence in an area are also desirable, preferably as percentages for small area units.

4 - <u>On general application of the methodology</u>:

- In a more general context, the Small Areas and Rings method should be used in the health assessment of all cases where the origin of pollution or the polluted area (single or principal) are small or compact, as a way to obviate the current relative lack of knowledge and practice in the area. These assessments can be carried out in either a reactive or proactive way.

- Local studies making use of regional data, should be exchanged between researchers, with a view to coordinating and pooling of results.

- The results from these studies should be used in the assessment of health needs by local, regional and national health authorities, which should also be in charge of disseminating the findings to the public. These results should also inform environmental policies.

- If appropriate, these exploratory, descriptive studies should be followed by analytical studies, of the case-control and cohort types, focusing on the conditions found to be statistically raised.

- The Small Areas and Rings methodology should be considered as the basis for the future development of more advanced methods, taking into account, when available, more accurate data on levels and spread of pollution, as well as on distribution of the population.

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APPENDIX 1 - TOXIC WASTE AND SPECIAL WASTE: DEFINITION, HEALTH EFFECTS AND ESTIMATE OF AMOUNTS.

A1.1 - Definition of Toxic Waste:

To define Toxic Waste as any waste product potentially harmful to human health seems easy and commonsensical. Nevertheless, having made this definition, how much harm is harm?. Fulminant death by acute poisoning?. A cancer allegedly caused by exposure to waste over a lifetime?. A transitory skin rash, or permanent brain damage?. Furthermore, virtually any product, waste or not, can damage human health given adequate doses and circumstances, from pure water or salt to cyanide or pesticides. To approach the Toxic Waste problem in a realistic way, it is necessary to focus on a limited list of products while defining their possible effects on human health.

The multiple generic names under which toxic wastes are grouped, often constitute a source for confusion.

The Deposit of Poisonous Waste Act, 1972 defined NOTIFIABLE WASTE as: 'Those wastes which subject persons or animals to material risk of death, injury or impairment of health' (House of Commons, 1972). No lists of specific substances or definitions of health effects were given.

The same definition, applying to HAZARDOUS WASTE, reappeared in the Control of Pollution Act, 1974, again with no mention of specific substances (House of Commons, 1974).

A first list of substances, and their health effects, appeared in the European Community's Directive (1978) 778. The generic name for these substances was TOXIC AND DANGEROUS WASTE, and twenty-seven were listed (Conseil des Communautes Europeenes, 1978). The list was enlarged to fifty-one substances in the European Community Directive (1988) 339. In this same Directive, HAZARDOUS WASTE is defined as any compound having as constituent one or more of the substances in the list and/or deriving from a certain source or process (as defined in the Directive, such as sewage sludges) and/or having certain physical properties such as flammability or corrosiveness (Conseil des Communautes Europeenes, 1988).

The current British list of waste substances potentially harmful to human health derives from EC Directive (78) 778. These substances are known as SPECIAL WASTE. The Control of Pollution (Special Waste) Regulations 1980 define Special Wastes as those:

'consisting of or containing any of the substances listed in Part I of Schedule 1 and by reason of the presence of such substance, dangerous to life within the meaning of Part II of Schedule 1' (Department of the Environment, 1980).

This list, virtually the same as that in the EC Directive (78) 778, contains thirty-one substances, listed below in **A1.2**. The Regulations (Schedule 1, Part I), define a waste as dangerous to life if:

(*a*) 'a single dose of not more than five cubic centimetres would be likely to cause death or serious damage to tissue if ingested by a child of 20 kilograms body weight or:

(*b*) exposure to it for fifteen minutes or less would be likely to cause serious damage to human tissue by inhalation, skin contact or eye contact.'

The EC Directive (78) 778 originated both the term TOXIC WASTE and the list of substances from which all subsequent lists derive in Europe and Britain. Therefore, any substance or substances included in the Control of Pollution (Special Waste) Regulations (1980) are referred to in this thesis as TOXIC WASTE, in preference to the exclusively British denomination of SPECIAL WASTE.

A1.2 - Review of health effects of toxic wastes.

As indicated, the British list of Toxic Wastes (Special Wastes), consists of thirty-one substances. In the following brief review of their respective health effects, two types of waste are not taken into account. One is asbestos, due to its ubiquity after having been extensively used in house insulation and in shipbuilding (Parmeggiani, 1983), which makes almost impossible to distinguish its possible effects on health due to disposal from those due to its previous uses. The other is the group of pharmaceutical and veterinary compounds, since these, usually, are not considered as industrial waste.

The remaining twenty-nine substances or groups are listed below. In order to give an overall idea of the health hazards of toxic waste, a brief list of these is given for each particular substance or group of substances, as well as industrial activities from which these arise in the United Kingdom (Department of the Environment, 1981; Parmeggiani, 1983).

1. Acids and alkalis. (Inorganic mineral acids, aliphatic and aromatic organic acids, inorganic alkalis, several inorganic acid and alkaline salts). Health effects: corrosivity. Main sources in the UK: sulphuric acid waste from titanium dioxide manufacture.

2. Antimony and antimony compounds. Health effects: skin irritants (solids), haemolytic poison (gas produced from contact acid-antimony compound, e. g. in landfills). Main sources in the UK: batteries.

3. Arsenic compounds. Health effects: gastrointestinal damage (acute), eczema, skin cancer (chronic exposure). Main sources in the UK: wood preservatives and semiconductors wastes.

4. Barium compounds. Health effects: mild pneumoconiosis, mucose irritation. Main sources in the UK: glass, ceramic and paint industries wastes.

5. Beryllium and beryllium compounds. Health effects: lung disease by inhalation, dermatitis by contact.

6. Biocides and phytopharmaceutical substances. Health effects: oral and dermal toxicity, irritation, inflammation. Main sources in the UK: agricultural and horticultural uses.

7. Boron compounds. Health effects: mucose and skin irritation. Main sources in the UK: wastes from nylon industry.

8. Cadmium and cadmium compounds. Health effects: Acute: pneumonitis (inhalation), food poisoning-like symptoms (ingestion). Chronic: kidney dysfunction. Main sources in the UK: electroplating industry.

9. Cooper compounds. Health effects: skin irritation. Main sources in the UK: electrolysis wastes.

10. Heterocyclic organic compounds containing oxygen, nitrogen and/or sulphur. Health effects: carcinogens, teratogens. Main sources in the UK: oil, tar and coal refining wastes, emissions from industrial incinerators.

11. Hexavalent chromium compounds. Health effects: skin and respiratory irritant, lung carcinogen. Main sources in the UK: waste from metal finishing industry.

12. Hydrocarbons and their oxygen, nitrogen and/or sulphur compounds. Health effects: different ones depending on the kind of hydrocarbon and its derivatives: carcinogenesis, skin dermatitis and irritation, lung disease, etc. Main sources in the UK: fuel and chemical waste.

13. Inorganic cyanides. Health effects: highly poisonous orally. Main sources in the UK: waste oxide from coal-gas purification.

14. Inorganic halogen containing compounds. Health effects: corrosive, irritant. Main sources in the UK: chemical industry and laboratories.

15. Inorganic sulphur-containing compounds. Health effects: corrosive, irritant. Main sources in the UK: industry in general (e. g. sulphuric acid).

16. Laboratory chemicals. Health effects: many, depending on the kind of chemical. Main sources in the UK: laboratories.

17. Lead compounds. Health effects: central nervous system (CNS) damage, gastrointestinal damage. Main sources in the UK: lead smelting slag, paint and glass industries wastes.

18. Mercury compounds. Health effects: CNS and renal damage. Main sources in the UK: wastes from battery and fine metal treatment industries.

19. Nickel and nickel compounds. Health effects: dermatitis, cancer. Main sources in the UK: electroplating wastes.

20. Organic halogen compounds, excluding inert polymeric materials (plastic monomers, pesticide wastes, etc.). In 90% the halogen is chlorine. Health effects: skin and mucose irritants. Main sources in the UK: chemical and plastics industries.

21. Peroxides, chlorates, perchlorates and azydes. Health effects: most of them of low toxicity, the main risk is posed by spontaneous fire or explosion. Main sources in the UK: pharmaceutical industry and laboratory wastes.

22. Phosphorus and its compounds. Health effects: toxicity (even through intact skin), carcinogenity. Main sources in the UK: clothing, ammunition and detergents industries.

23. Selenium and selenium compounds. Health effects: skin and mucoses irritation, dermatitis. Main sources in the UK: electrical and xerocopy industries.

24. Silver compounds. Health effects: corrosive to skin and mucoses. Main sources in the UK: photographical and electrical industries.

25. Tarry materials from refining and tar residues from distilling. Health effects: irritants, carcinogenic. Main sources in the UK: chemical and allied industries.

26. Tellurium and tellurium compounds. Health effects: minor, depending on the substances along which tellurium wastes occur. Main sources in the UK: rubber industry.

27. Thallium and thallium compounds. Health effects: acute or chronic poisoning (often fatal). Main sources in the UK: very small scale, from some precision instruments manufacture.

28. Vanadium compounds. Health effects: fumes readily absorbed, irritant, death if prolonged exposure. Main sources in the UK: catalysts and dye industries.

29. Zinc compounds. Health effects: in aqueous solution, corrosive, serious irritation. Main sources in the UK: wastes from metal finishing, batteries and pigments industries.

A1.3 - Amounts of toxic wastes in the United Kingdom :

Most Toxic Waste (Special waste) in Britain is originated by the industry, with some from household and commercial waste. The amounts of toxic waste annually produced in the United Kingdom are known only with relative accuracy since the creation of the Hazardous Waste Inspectorate in 1983. This body, and its successor since 1987, Her Majesty's Inspectorate of Pollution (British Medical Association, 1991) have been in charge of preparing and publishing estimates of arisings based on the figures provided to them by the waste disposal bodies (Waste Disposal Authorities). Yearly estimates of the arisings between 1984 and 1990 appear in **Table A1 - 1**, from the figures published by the Inspectorates (Hazardous Waste Inspectorate, 1985, 1986, 1988 ; Her Majesty's Inspectorate of Pollution, 1988, 1989, 1990).

TABLE A1-1: Arisings of Toxic Waste (Special Waste) and Hazardous Waste in the UK

	Hazardous	Special
1984	4.5 Mill. Tonnes.	1.8 Mill. Tonnes.
1985	3.7 ‘	1.5 ‘
1986	3.9 ‘	1.6 ‘
87-88	4.8 ‘	1.9 ‘
88-89	-	1.8 ‘
89-90	-	2.2 ‘

There is no official British definition of Hazardous Waste, except in the Transfrontier Shipment of Hazardous Waste Regulations 1988, which makes them analogous to Special Wastes (British Medical Association, 1991). Nevertheless, the Hazardous Waste Inspectorate took into account those wastes contaminated by, or partially composed of Special Waste, in the same way as the later EC Directive (88) 399 defined Hazardous Waste in an European context. As an estimate, the Inspectorate calculated the amount of Hazardous Waste by multiplying the figure for Special Waste by 2.5, being Special Waste included in Hazardous Waste (Hazardous Waste Inspectorate, 1985).

The arisings in Scotland are just a small portion of the British figures. Between the Spring of 1986 and the Spring of 1987, 80,000 Tonnes of Hazardous and 30,000 of Special Wastes were reported (Hazardous Waste Inspectorate, 1988).

APPENDIX 2 - UNIVERSITIES CONTACTED:

In order to have access to University research, between May and September 1990, the author contacted in writing those British Universities having at least one Department which could be carrying out work on this specific subject. In some cases a faculty, without specifying Department, offered during that year a course related to Environmental Studies. In others, even though the University offered such a course, it was not clear enough which Faculty or Department was doing so, in which case the author addressed his letter to the University's Registrar.

A few Departments were technical, non-medical ones, but offering Environment-related courses. These were approached as well, since they were judged likely to provide useful references. The Universities were asked about their possible research, past or current, on the relationship between industrial toxic waste disposal and the health of populations. Other Universities were directly approached through personal visits. Obviously, this was the case with Glasgow and Strathclyde. Dundee and Newcastle Universities were also visited, and further discussions were held in Glasgow with lecturers from both. At the suggestion of one of the Universities already approached two further institutions were added: The School of Environmental Sciences at Bradford and London's St. Mary's Hospital Medical School.

In all, thirty-eight Universities and Medical Schools were contacted. After reminders to some of them, all but one had sent written replies or, in some cases, phoned.

The Universities and Departments approached were in England, Scotland, Wales and Ulster, and appear in the following **Table A - 2**.

Table A - 2: Universities and Departments contacted.

University	Department or person contacted, environmental studies offered
ENGLAND	
Birmingham	Faculty of Medicine. MSc in Toxicology.
Bradford	School of Environmental Sciences.
Bristol	Epidemiology and Community Medicine.
Brunel (London)	Registrar. MSc in Environmental Sciences.
Cambridge	Community Medicine.
Cranfield	Registrar. MSc in Energy Conservation and the Environment.
East Anglia	Environmental Science.
Lancaster	Institute of Environmental and Biological Sciences.
Leeds	Community Medicine.
Leicester	Community Health.
Liverpool	Community Health.
London - British Postgraduate Medical Federation	Community Medicine.
London Hospital Medical College	Registrar (on advice).
London - King's College	Community Medicine.
London - Royal Postgraduate Medical School	Registrar. MSc in Toxicology.
London - St. Mary's Hospital School	Pharmacology and Toxicology.

London - School of Hygiene and Tropical Medicine	Departments of Community Health and Epidemiology
London - United Medical Schools of Guy's & St. Thomas Community Medicine Hospitals	Community Medicine.
Manchester - Institute of Science and Technology	Registrar. MSc in Pollution and Environmental Control.
Manchester - Victoria (Medicine)	Depts. of Environmental Biology and Community Medicine.
Newcastle	Family and Community Medicine.
Nottingham	Physiology and Environmental Science.
Oxford	Community Medicine.
Salford	Registrar. MSc in environmental Health.
Sheffield	Community Medicine.
Southampton	Community Medicine.
Surrey	Registrar. MSc in Environmental Protection.

SCOTLAND

Aberdeen	Environmental and Occupational Medicine.
Edinburgh	Community Medicine.
Dundee	Community Medicine.
Glasgow	Community Medicine.
Stirling	Environmental Science.

Strathclyde	Engineering. Degree in Environmental Health.

WALES

University College of Wales (Aberystwyth)	Depts. of Biology and Biochemistry
University of Wales' College of Medicine	Epidemiology and Community Medicine.

ULSTER

Belfast	Community Medicine.
Ulster	Environmental Studies.

APPENDIX 3 - SEARCH FOR A CASE STUDY: ZULOKO.

My first choice for a practical case study was that of the dump at Zuloko (literally 'of- the hole' in the Basque language), in the council of Barakaldo (pop. 110,000), province of Bizkaia (Biscay), in my native Spanish Basque Country. The area is some five miles NW from the provincial capital, Bilbao (pop. 400,000) and three miles S from the Bay of Biscay. Zuloko is part of a flat, low-lying valley centred on the Castaño river. The site is about one mile from the centre of Barakaldo and some 300 metres from its Zuazo-Arteagabeitia borough (pop. 15,000) with other three small population centres inside a radius of 500 metres. Part of the land around is taken by small market gardens and farms.

There is a dump of industrial waste in Zuloko which covers between 4,500 and 6,000 sq. metres. Its volume was estimated in late 1986 at between 15,000 and 20,000 cubic metres (Inicress, 1989). The dump contains an undetermined amount of the pesticide waste byproduct Hexachlorocyclohexane (HCH) (Cicna, 1987). The residual HCH was allegedly dumped by a factory, situated about one mile by road from the dump, which had been producing the pesticide Lindane, of which HCH is a waste product, since around 1950 (Bilbao Chemicals, 1985).

After complaints of bad smells by the residents of Zuazo-Arteagabeitia, nearly 1,500 tons of HCH were removed from Zuloko in 1987 and dumped in an abandoned mine shaft (Ayuntamiento de Barakaldo, 1987). New, stronger complaints occurred in 1989 when hitherto unknown dumps of HCH, shallowly buried, were revealed in the course of land removal works. These newly uncovered dumps held an undetermined amount of HCH, estimated at several thousand tons (El Correo Español, 1989).

Although the Press and many of Barakaldo Council's papers mention HCH as Lindane, only the HCH gamma isomer can properly be so called. All six possible isomers of HCH, of which the gamma is the most toxic, are classified as toxic and dangerous substances by the EEC Council Directive of March 30 1978 on waste (Conseil des Communautes Europeenes, 1978). In the United Kingdom HCH is classified as an Special Waste (Toxic Waste), dangerous to life, as a non-polymeric organic halogen compound. (Department of the Environment, 1980).

Although toxicity variates according to its different isomers, HCH has an adverse effect upon different systems and organs, with more evident effects on children, the elderly and the ill (Karel-Verschueren, 1983). The organs known to be affected by HCH are the central nervous system, causing muscle spasms and convulsions (WHO, 1982); the haematopoietic system, causing anaemia (West, 1967); the liver, causing fatty degeneration (West, 1967); the skin, eye, nose and throat, of which HCH is an irritant through contact or vapour (USEPA, 1990). The gamma isomer is classified as a carcinogen by the USA's Environmental Protection Agency, with the other isomers considered likely carcinogens (USEPA, 1990). Possible cancers are liver cancer and leukaemia. The gamma isomer appears as acutely toxic. Data on chronic effects are limited (West, 1967).

HCH can enter the body by inhalation, ingestion (including maternal milk) and skin absorption (Medical Panel of the Advisory Committee on Pesticides, 1983). It accumulates in fat tissue (Czegled-Janko and Avar, 1970).

In the Zuloko case, the possibility of inhalation was supported by the fact that the Northwest wind is prevailing in the region, blowing along the line Zuloko to Zuazo-Arteagabeitia (Inicress, 1989). Also, HCH or its derivates may have spread with the smoke that fires in the dump gave off, or as part of dense fogs in which sublimated HCH may enter (Cicna, 1987).

Direct contact would be made easy by the fact that the valley is the nearest open space in a highly populated area (there is even a football pitch in it) and is crossed by several footpaths and lanes.

Ingestion could have taken place through consumption of vegetables grown in the some fifty to sixty kitchen gardens close to the dump. These vegetables often had a bad taste and their consumption was occasionally banned. A 1989 study (Inicress, 1989) found HCH in leeks, lettuces and tomatoes grown in the Zuloko area, but at a level below the maximum permitted by the Spanish law. Also, there was some milk production in the area.

In July 1990, the Local and Regional Administrations were contacted, in order to obtain data on the case, as well as their permission to conduct a health study. The contacts were with Barakaldo's Local Council and the Basque Sub-Department for the Environment (Viceconsejeria de Medio Ambiente) and Basque Department of Public Health (Direccion General de Salud Publica) and took place in the course of two visits to the Basque Country (July-August 1990 and Nov. 1990 - Feb. 1991), during which appropriate background literature, both on HCH and on the Zuloko case, was gathered. Also, the Department of Pathological Anatomy in the main local hospital (Residencia de Cruces) was contacted, with a view to both its participation in the possible study and the provision of advice. The final decision on a permission for the study was subjected to the consideration of a study proposal.

The proposal was sent for consideration in late January 1991. The proposed study entailed the analysis of routinely collected health data. These data were on the main health outcomes which (according to the literature review) were expected from exposure to HCH, divided into morbidity data (of the central nervous system, skin, liver, respiratory system and haematopoiesis) and cancer (liver). Morbidity data were to be gathered from the then recent Health Survey of the Basque Country (Basque Department of Health, 1987), while cancer data would be provided by the Basque Cancer Register.

The study area would have been that covered by local administrative divisions (Distritos Municipales), up to a distance of two kilometres from the centre of the dump. Population data would have been provided by the Basque Institute of Statistics. As an indirect measure of exposure, anatomical samples of fat were to be taken from autopsies carried out in the local Hospital and analysed for HCH in the Provincial laboratory of the Basque Department of Public Health.

Standardized (by age group) incidence ratios for morbidity and cancer by District would have been obtained and compared, taking into account distances from the dump. A correlation would have been made between HCH levels in fat and distance (between the deceased's address and the centre of the dump).

The proposal, addressed to the Basque Department of Public Health was finally rejected in March 1991, on the basis that no study was judged to be necessary at the time.

APPENDIX 4: SPSSPC+ FILES USED IN THE ANALYSES

(NOTE: Actual files appear in **bold** characters, inserted text are explanatory notes)

A4.1 - FILE '**CENDEP10.PAD**'.

This file is essential in analysing the data. In both SMR1 and cancer analyses, populations are calculated from it. It also serves to allocate ring numbers and deprivation categories to Enumeration Districts, and to decide whether an ED is situated North or South of the Clyde, according to its. The file has the following variables:

-ED: Six digits code identifying each enumeration district

-DIST: Distance to the nearest 100 metres between ED centroids and the National Grid (Ordnance Survey) coordinates of the point deemed as the centre of pollution.

-CIRCLE: Number (1 to ten, outwards) of the one-kilometre wide ring,centred on the centre of pollution, on which an ED centroid lies.

-DEPCAT: Deprivation category (Carstairs') allocated to a given ED, ranging from 1 (less deprived) to 7 (most deprived).

-TAG: Location respect to the river Clyde of an ED: 1 = North, 2 = South.

-M4 to M85, F4 to F85: Eighteen five-year age groups for each of the sexes at ED level, from the 1981 Census.

The file 'Cendep10.sys' was created by combining two previously existing files, the population file 'Censusns.dat', and the deprivation score file 'Depriv.dat'.

'Censusns.dat' contained codes, age groups and East-North centroid coordinates of all EDs inside the National Grid NS 100,000 metre square, inside which the whole study area was contained. This file was obtained from ISD-Edinburgh. 'Depriv.dat' contained ED codes, tags and depcats for all EDs in Post Code Sectors totally or partially inside the study area. it was obtained from Dr. Vera Carstairs, at the University of Edinburgh.

STEPS IN THE CREATION OF 'CENDEP10.SYS'.

a) After converting CENSUSNS.DAT into CENSUSNS.SYS, create DIST and select EDs inside the 10 Km. circle.

```
get file = 'Censusns.sys'.
compute dist = sqrt(((east-608)**2)+((north-622)**2)).
select if(dist le 100.00).
save outfile = 'census10.sys'.
```

b) Create CIRCLE.

```
get file = 'census10.sys'.
compute circle = dist*1.
recode circle (0.00 thru 10.00=1) (10.00 thru 20.00=2) (20.00 thru 30.00=3)
(30.00 thru 40.00=4) (40.00 thru 50.00=5) (50.00 thru 60.00=6)
(60.00 thru 70.00=7) (70.00 thru 80.00=8) (80.00 thru 90.00=9)
(90.00 thru 100.00= 10).
save outfile = 'census10.sys'.
```

c) After converting 'DEPRIV.DAT' to DEPRIV.SYS', add DEPCAT and TAG.

```
get file = 'depriv.sys'.
sort cases by ed.
save outfile = 'depriv.sys'.

get file = 'census10.sys'.
sort cases by ed.
save outfile = 'census10.sys'.

join match file = 'depriv.sys'
/keep = ed, tag, depcat
/file = 'census10.sys'
/by = ed.
select if(circle ge 1 and circle le 10).
save outfile = 'cendep10.sys'.
```

Some EDs did not have depcat allocated and, therefore it did not appear on 'cendep10.sys' (209,i.e., 7% of all EDs under study). Their depcat was listed as missing, and their tag was allicated manually, by using correspondence lists ED-Post Code Sector for those inside the GGHB, and by locating their coordinates for the rest.

A4.2 - **CANCER.PAD**. SPSS FILE TO PROCESS CANCER DATA FILES FOR ANALYSES BY RING. STANDARDIZED BY AGE. TOTAL POPULATION

(In this particular case, the analysis is for skin cancer).

COPY ISD'S CANCER DATA (1975-89) TO SPSS.

```
data list file = 'a:\eds1.dat'
 / ed 1-6 (a) east 10-12 north 13-15 tag 17
 // m41 1-3 m91 4-6 m141 7-9 m191 10-12 m241 13-15 m291 16-18 m341 19-21
 m391 22-24 m441 25-27 m491 28-30 m541 31-33 m591 34-36 m641 37-39 m691 40-42
 m741 43-45 m791 46-48 m841 49-51 m851 52-54 f41 55-57 f91 58-60 f141 61-63
 f191 64-66 f241 67-69 f291 70-72 f341 73-75 f391 76-78 f441 79-81 f491 82-84
 f541 85-87 f591 88-90 f641 91-93 f691 94-96 f741 97-99 f791 100-102
 f841 103-105 f851 106-108
 ///// m42 1-3 m92 4-6 m142 7-9 m192 10-12 m242 13-15 m292 16-18 m342 19-21
 m392 22-24 m442 25-27 m492 28-30 m542 31-33 m592 34-36 m642 37-39 m692 40-42
 m742 43-45 m792 46-48 m842 49-51 m852 52-54 f42 55-57 f92 58-60 f142 61-63
 f192 64-66 f242 67-69 f292 70-72 f342 73-75 f392 76-78 f442 79-81 f492 82-84
 f542 85-87 f592 88-90 f642 91-93 f692 94-96 f742 97-99 f792 100-102
 f842 103-105 f852 106-108
 ///// m43 1-3 m93 4-6 m143 7-9 m193 10-12 m243 13-15 m293 16-18 m343 19-21
 m393 22-24 m443 25-27 m493 28-30 m543 31-33 m593 34-36 m643 37-39 m693 40-42
 m743 43-45 m793 46-48 m843 49-51 m853 52-54 f43 55-57 f93 58-60 f143 61-63
 f193 64-66 f243 67-69 f293 70-72 f343 73-75 f393 76-78 f443 79-81 f493 82-84
 f543 85-87 f593 88-90 f643 91-93 f693 94-96 f743 97-99 f793 100-102
 f843 103-105 f853 106-108
 ///.
save outfile = 'az1.sys'.
```

a) Do the same for each of five separate files. Select relevant Enumeration Districts (i.e., those whose centroids are less than 10 Kms. from the centre of pollution). Join the five resulting files into one.

```
get file = 'az1.sys'.
compute dist = sqrt (((east-608)**2)+((north-622)**2)).
select if (dist le 100.00).
save outfile = 'az1.sys'.

join add file = 'az1.sys'
/file = 'az2.sys'
/file = 'az3.sys'
/file = 'az4.sys'
/file = 'az5.sys'.
save outfile = 'skin.sys'.
```

1- OBSERVED REGISTRATIONS BY RING (MALE+FEMALE).

a) Group individual distances into ten circles. Compute total registrations by Enumeration District (males plus females, all periods together: 1=1975-79, 2=1980-84, 3=1985-89).

```
get file = 'skin.sys'/drop = ed to tag.
recode dist (0.00 thru 10.00 = 1) (10.00 thru 20.00 = 2) (20.00 thru 30.00=3)
 (30.00 thru 40.00 = 4) (40.00 thru 50.00 = 5) (50.00 thru 60.00 = 6)
 (60.00 thru 70.00 = 7) (70.00 thru 80.00 = 8) (80.00 thru 90.00 = 9)
 (90.00 thru 100.00 = 10).
compute t4 = m41+m42+m43+f41+f42+f43.
```

```
compute t9 = m91+m92+m93+f91+f92+f93.
compute t14 = m141+m142+m143+f141+f142+f143.
compute t19 = m191+m192+m193+f191+f192+f193.
compute t24 = m241+m242+m243+f241+f242+f243.
compute t29 = m291+m292+m293+f291+f292+f293.
compute t34 = m341+m342+m343+f341+f342+f343.
compute t39 = m391+m392+m393+f391+f392+f393.
compute t44 = m441+m442+m443+f441+f442+f443.
compute t49 = m491+m492+m493+f491+f492+f493.
compute t54 = m541+m542+m543+f541+f542+f543.
compute t59 = m591+m592+m593+f591+f592+f593.
compute t64 = m641+m642+m643+f641+f642+f643.
compute t69 = m691+m692+m693+f691+f692+f693.
compute t74 = m741+m742+m743+f741+f742+f743.
compute t79 = m791+m792+m793+f791+f792+f793.
compute t84 = m841+m842+m843+f841+f842+f843.
compute t85 = m851+m852+m853+f851+f852+f853.
save outfile = 'az6.sys'/drop = m41 to f853.
```

b) Compute total number of registrations by ring. Create document file of totals.

```
get file = 'az6.sys'.
compute t = t4+t9+t14+t19+t24+t29+t34+t39+t44+t49+t54+t59+t64+t69
 +t74+t79+t84+t85.
aggregate outfile = 'az7.sys'
/break = dist
/obs = sum (t).

get file = 'az7.sys'.
set listing = 'azobserv.doc'.
list variables = dist, obs.
```

2- RATES FOR THE WHOLE 10 KM. CIRCLE BY AGE GROUP (M + F).

a) Aggregate total registrations by age group by Enumeration District, for the whole 10 km. circle.

```
get file = 'az6.sys'.
recode dist (1 thru 10 = 1).
aggregate outfile = 'az8.sys'
/break = dist
/t4 = sum(t4)
/t9 = sum(t9)
/t14 = sum(t14)
/t19 = sum(t19)
/t24 = sum(t24)
/t29 = sum(t29)
/t34 = sum(t34)
/t39 = sum(t39)
/t44 = sum(t44)
/t49 = sum(t49)
/t54 = sum(t54)
/t59 = sum(t59)
/t64 = sum(t64)
/t69 = sum(t69)
/t74 = sum(t74)
/t79 = sum(t79)
/t84 = sum(t84)
/t85 = sum(t85).
```

b) Compute total population by age group by Enumeration District.

```
get file = 'a:\cendep10.sys'.
compute tp4 = m4+f4.
compute tp9 = m9+f9.
compute tp14 = m14+f14.
compute tp19 = m19+f19.
compute tp24 = m24+f24.
compute tp29 = m29+f29.
compute tp34 = m34+f34.
compute tp39 = m39+f39.
compute tp44 = m44+f44.
compute tp49 = m49+f49.
compute tp54 = m54+f54.
compute tp59 = m59+f59.
compute tp64 = m64+f64.
compute tp69 = m69+f69.
compute tp74 = m74+f74.
compute tp79 = m79+f79.
compute tp84 = m84+f84.
compute tp85 = m85+f85.
save outfile = 'az9.sys'/drop m4 to f85.
```

c) Aggregate total population by age group for the 10 km. circle.

```
get file = 'az9.sys'.
recode circle (1 thru 10 = 1).
aggregate outfile = 'az10.sys'
/break = circle
/tp4 = sum(tp4)
/tp9 = sum(tp9)
/tp14 = sum(tp14)
/tp19 = sum(tp19)
/tp24 = sum(tp24)
/tp29 = sum(tp29)
/tp34 = sum(tp34)
/tp39 = sum(tp39)
/tp44 = sum(tp44)
/tp49 = sum(tp49)
/tp54 = sum(tp54)
/tp59 = sum(tp59)
/tp64 = sum(tp64)
/tp69 = sum(tp69)
/tp74 = sum(tp74)
/tp79 = sum(tp79)
/tp84 = sum(tp84)
/tp85 = sum(tp85).
```

d) Match total numbers of registrations and total populations by age group. Compute mean rates (1975-89) by age group. Create document file of rates.

```
get file = 'az8.sys'.
join match file = 'az10.sys'
/file = *.
compute r4 = (t4/15)/(tp4/100000).
compute r9 = (t9/15)/(tp9/100000).
compute r14 = (t14/15)/(tp14/100000).
compute r19 = (t19/15)/(tp19/100000).
compute r24 = (t24/15)/(tp24/100000).
compute r29 = (t29/15)/(tp29/100000).
```

```
compute r34 = (t34/15)/(tp34/100000).
compute r39 = (t39/15)/(tp39/100000).
compute r44 = (t44/15)/(tp44/100000).
compute r49 = (t49/15)/(tp49/100000).
compute r54 = (t54/15)/(tp54/100000).
compute r59 = (t59/15)/(tp59/100000).
compute r64 = (t64/15)/(tp64/100000).
compute r69 = (t69/15)/(tp69/100000).
compute r74 = (t74/15)/(tp74/100000).
compute r79 = (t79/15)/(tp79/100000).
compute r84 = (t84/15)/(tp84/100000).
compute r85 = (t85/15)/(tp85/100000).
save outfile = 'az11.sys'.

get file = 'az11.sys'.
set listing = 'azrates.doc'.
list variables = r4 to r85.
```

3- TOTAL POPULATION BY RING AND AGE GROUP. Create its document file.

```
get file = 'az9.sys'.
aggregate outfile = 'az12.sys'
/break = circle
/tp4 = sum(tp4)
/tp9 = sum(tp9)
/tp14 = sum(tp14)
/tp19 = sum(tp19)
/tp24 = sum(tp24)
/tp29 = sum(tp29)
/tp34 = sum(tp34)
/tp39 = sum(tp39)
/tp44 = sum(tp44)
/tp49 = sum(tp49)
/tp54 = sum(tp54)
/tp59 = sum(tp59)
/tp64 = sum(tp64)
/tp69 = sum(tp69)
/tp74 = sum(tp74)
/tp79 = sum(tp79)
/tp84 = sum(tp84)
/tp85 = sum(tp85).

get file = 'az12.sys'.
join match file = 'cirdummy.sys'
/file = *.
set listing = 'azpopula.doc'/width = 132/eject = on.
list variables = all.
```

EDIT FILES FOR OBSERVED REGISTRATIONS AND FOR POPULATION ACCORDING TO THE FORMATS SPECIFIED IN THE FORTRAN FILE FOR OBTAINING SRRS.

FURTHER NOTES:

- If only one of the sexes is to be studied, do not include the rest in the 'data list file' command.

- If only certain age groups are to be studied, do not include the rest in the commands above.

- When studying only one bank of the Clyde, select using variable 'tag' (1 = North, 2 = South).

- The file 'cirdummy.sys' contains the circle identifiers G01.0 to G10.0, which the population files need, to be identified by the FORTRAN file.

- All notes and headings between commands do not appear in the actual working file.

A4.3 - **CANCERS.PAD**, SPSS FILE TO PROCESS CANCER DATA FILES FOR ANALYSIS BY RING STANDARDIZED BY AGE AND BY DEPRIVATION CATEGORY (CARSTAIRS'). TOTAL POPULATION.

(In this particular case, the analysis is for lung cancer).

COPY ISD'S CANCER DATA (1975-89) TO SPSS.

```
data list file = 'a:\eds1.dat'
 / ed 1-6 (a) east 10-12 north 13-15 tag 17
 / m41 1-3 m91 4-6 m141 7-9 m191 10-12 m241 13-15 m291 16-18 m341 19-21
 m391 22-24 m441 25-27 m491 28-30 m541 31-33 m591 34-36 m641 37-39 m691 40-42
 m741 43-45 m791 46-48 m841 49-51 m851 52-54 f41 55-57 f91 58-60 f141 61-63
 f191 64-66 f241 67-69 f291 70-72 f341 73-75 f391 76-78 f441 79-81 f491 82-84
 f541 85-87 f591 88-90 f641 91-93 f691 94-96 f741 97-99 f791 100-102
 f841 103-105 f851 106-108
 ///// m42 1-3 m92 4-6 m142 7-9 m192 10-12 m242 13-15 m292 16-18 m342 19-21
 m392 22-24 m442 25-27 m492 28-30 m542 31-33 m592 34-36 m642 37-39 m692 40-42
 m742 43-45 m792 46-48 m842 49-51 m852 52-54 f42 55-57 f92 58-60 f142 61-63
 f192 64-66 f242 67-69 f292 70-72 f342 73-75 f392 76-78 f442 79-81 f492 82-84
 f542 85-87 f592 88-90 f642 91-93 f692 94-96 f742 97-99 f792 100-102
 f842 103-105 f852 106-108
 ///// m43 1-3 m93 4-6 m143 7-9 m193 10-12 m243 13-15 m293 16-18 m343 19-21
 m393 22-24 m443 25-27 m493 28-30 m543 31-33 m593 34-36 m643 37-39 m693 40-42
 m743 43-45 m793 46-48 m843 49-51 m853 52-54 f43 55-57 f93 58-60 f143 61-63
 f193 64-66 f243 67-69 f293 70-72 f343 73-75 f393 76-78 f443 79-81 f493 82-84
 f543 85-87 f593 88-90 f643 91-93 f693 94-96 f743 97-99 f793 100-102
 f843 103-105 f853 106-108
////.
save outfile = 'azs1.sys'.
```

a) Do the same for each of five separate files. Select relevant Enumeration Districts (i.e., those whose centroids are less than 10 kms. from the centre of pollution). Join the five resulting files into one.

```
get file = 'az1.sys'.
compute dist = sqrt (((east-608)**2)+((north-622)**2)).
select if (dist le 100.00).
save outfile = 'az1.sys'/drop = east, north.

join add file = 'azs1.sys'
/file = 'azs2.sys'
/file = 'azs3.sys'
/file = 'azs4.sys'
/file = 'azs5.sys'.
save outfile = 'azslung.sys'.
```

1-AGGREGATE REGISTRATIONS IN TEN KM. CIRCLE BY AGE GROUPS INSIDE EACH DEPCAT CATEGORY.

a) Compute total registrations by Enumeration District (males plus females, all periods together: 1=1975-79, 2=1980-84, 3= 1985-89).

```
get /file = 'azslung.sys'.
compute t4 = m41+m42+m43+f41+f42+f43.
compute t9 = m91+m92+m93+f91+f92+f93.
```

```
compute t14 = m141+m142+m143+f141+f142+f143.
compute t19 = m191+m192+m193+f191+f192+f193.
compute t24 = m241+m242+m243+f241+f242+f243.
compute t29 = m291+m292+m293+f291+f292+f293.
compute t34 = m341+m342+m343+f341+f342+f343.
compute t39 = m391+m392+m393+f391+f392+f393.
compute t44 = m441+m442+m443+f441+f442+f443.
compute t49 = m491+m492+m493+f491+f492+f493.
compute t54 = m541+m542+m543+f541+f542+f543.
compute t59 = m591+m592+m593+f591+f592+f593.
compute t64 = m641+m642+m643+f641+f642+f643.
compute t69 = m691+m692+m693+f691+f692+f693.
compute t74 = m741+m742+m743+f741+f742+f743.
compute t79 = m791+m792+m793+f791+f792+f793.
compute t84 = m841+m842+m843+f841+f842+f843.
compute t85 = m851+m852+m853+f851+f852+f853.
save outfile = 'azs6.sys'/ drop = m41 to f853.
```

b) Optional: calculate total numbers of registrations by ring.A similar file obtained in the standardization by age group can also be used.

```
get file = 'azs6.sys'.
recode dist (0.00 thru 10.00 = 1)(10.00 thru 20.00 = 2)(20.00 thru 30.00 = 3)
 (30.00 thru 40.00 = 4)(40.00 thru 50.00 = 5)(50.00 thru 60.00 = 6)
 (60.00 thru 70.00 = 7)(70.00 thru 80.00 = 8)(80.00 thru 90.00 = 9)
 (90.00 thru 100.00 = 10).
compute obs = t4+t9+t14+t19+t24+t29+t34+t39+t44+t49+t54+t59+t64+t69+t74
  +t79+t84+t85.
aggregate outfile = 'azs7.sys'
/break = dist
/obs = sum(obs).

get file = 'azs7.sys'.
set listing = 'azsobser.doc'.
list variables = all.
```

c) Add variable depcat from a preexisting file. Aggregate registrations by age group by deprivation category.

```
join match file = 'azs6.sys'
/file = 'a:\cendep10.sys'
/keep = ed, depcat
/by = ed.
save outfile = 'azs8.sys'.

get file = 'azs8.sys'.
aggregate outfile = 'azs9.sys'
/break = depcat
/t4 = sum (t4)
/t9 = sum (t9)
/t14 = sum (t14)
/t19 = sum (t19)
/t24 = sum (t24)
/t29 = sum (t29)
/t34 = sum (t34)
/t39 = sum (t39)
/t44 = sum (t44)
/t49 = sum (t49)
/t54 = sum (t54)
/t59 = sum (t59)
```

```
/t64 = sum (t64)
/t69 = sum (t69)
/t74 = sum (t74)
/t79 = sum (t79)
/t84 = sum (t84)
/t85 = sum (t85).
```

2-AGGREGATE TOTAL POPULATIONS BY AGE GROUP BY DEPCAT.

a) Compute total populations by age group by Enumeration District.

```
get file = 'a:\cendep10.sys'.
compute t4p = m4+f4.
compute t9p = m9+f9.
compute t14p = m14+f14.
compute t19p = m19+f19.
compute t24p = m24+f24.
compute t29p = m29+f29.
compute t34p = m34+f34.
compute t39p = m39+f39.
compute t44p = m44+f44.
compute t49p = m49+f49.
compute t54p = m54+f54.
compute t59p = m59+f59.
compute t64p = m64+f64.
compute t69p = m69+f69.
compute t74p = m74+f74.
compute t79p = m79+f79.
compute t84p = m84+f84.
compute t85p = m85+f85.
save outfile = 'azs10.sys'
/drop = ed to circle, m4 to dist.
```

b) Aggregate total populations by age group by depcat.

```
get file = 'azs10.sys'.
aggregate outfile = 'azs11.sys'
/break = depcat
/t4p = sum (t4p)
/t9p = sum (t9p)
/t14p = sum (t14p)
/t19p = sum (t19p)
/t24p = sum (t24p)
/t29p = sum (t29p)
/t34p = sum (t34p)
/t39p = sum (t39p)
/t44p = sum (t44p)
/t49p = sum (t49p)
/t54p = sum (t54p)
/t59p = sum (t59p)
/t64p = sum (t64p)
/t69p = sum (t69p)
/t74p = sum (t74p)
/t79p = sum (t79p)
/t84p = sum (t84p)
/t85p = sum (t85p).
```

3-WORK OUT RATES BY AGE GROUP AND DEPCAT, AND DIVIDE THEM BY OVERALL (10 KM.)
RATES BY AGE GROUP.

a) Match cases by depcat and age group to population by depcat and age group. Work out mean annual rates by depcat and age group (1975-89), inside the ten km. circle.

```
join match file = 'azs9.sys'
/file = 'azs11.sys'
/by depcat.
compute r4d = (t4/t4p)*(100000/15).
compute r9d = (t9/t9p)*(100000/15).
compute r14d = (t14/t14p)*(100000/15).
compute r19d = (t19/t19p)*(100000/15).
compute r24d = (t24/t24p)*(100000/15).
compute r29d = (t29/t29p)*(100000/15).
compute r34d = (t34/t34p)*(100000/15).
compute r39d = (t39/t39p)*(100000/15).
compute r44d = (t44/t44p)*(100000/15).
compute r49d = (t49/t49p)*(100000/15).
compute r54d = (t54/t54p)*(100000/15).
compute r59d = (t59/t59p)*(100000/15).
compute r64d = (t64/t64p)*(100000/15).
compute r69d = (t69/t69p)*(100000/15).
compute r74d = (t74/t74p)*(100000/15).
compute r79d = (t79/t79p)*(100000/15).
compute r84d = (t84/t84p)*(100000/15).
compute r85d = (t85/t85p)*(100000/15).
save outfile = 'azs12.sys'
/drop t4 to t85, t4p to t85p.
```

b) Optional: Compute mean annual rates (1975-89, overall 10 km), or use those from age-standardized analyses, if already obtained.

I-Total registrations by age group:

```
get file = 'azs6.sys'.
recode dist (0.00 thru 100.00 = 1).
aggregate outfile = 'azs13.sys'
/break = dist
/t4 = sum (t4)
/t9 = sum (t9)
/t14 = sum (t14)
/t19 = sum (t19)
/t24 = sum (t24)
/t29 = sum (t29)
/t34 = sum (t34)
/t39 = sum (t39)
/t44 = sum (t44)
/t49 = sum (t49)
/t54 = sum (t54)
/t59 = sum (t59)
/t64 = sum (t64)
/t69 = sum (t69)
/t74 = sum (t74)
/t79 = sum (t79)
/t84 = sum (t84)
/t85 = sum (t85).
```

II-Total populations by age group.

```
get /file = 'azs10.sys'.
recode dist (0.00 thru 100.00 = 1).
aggregate outfile = 'azs14.sys'
/break = dist
/t4p = sum (t4p)
/t9p = sum (t9p)
/t14p = sum (t14p)
/t19p = sum (t19p)
/t24p = sum (t24p)
/t29p = sum (t29p)
/t34p = sum (t34p)
/t39p = sum (t39p)
/t44p = sum (t44p)
/t49p = sum (t49p)
/t54p = sum (t54p)
/t59p = sum (t59p)
/t64p = sum (t64p)
/t69p = sum (t69p)
/t74p = sum (t74p)
/t79p = sum (t79p)
/t84p = sum (t84p)
/t85p = sum (t85p).
```

III-Match total registrations and populations, work out mean annual rates by age group (1975-89). List also their document file.

```
get file = 'azs13.sys'.
join match file = 'azs14.sys'
/file = *.
compute rt4 = (t4/t4p)*(100000/15).
compute rt9 = (t9/t9p)*(100000/15).
compute rt14 = (t14/t14p)*(100000/15).
compute rt19 = (t19/t19p)*(100000/15).
compute rt24 = (t24/t24p)*(100000/15).
compute rt29 = (t29/t29p)*(100000/15).
compute rt34 = (t34/t34p)*(100000/15).
compute rt39 = (t39/t39p)*(100000/15).
compute rt44 = (t44/t44p)*(100000/15).
compute rt49 = (t49/t49p)*(100000/15).
compute rt54 = (t54/t54p)*(100000/15).
compute rt59 = (t59/t59p)*(100000/15).
compute rt64 = (t64/t64p)*(100000/15).
compute rt69 = (t69/t69p)*(100000/15).
compute rt74 = (t74/t74p)*(100000/15).
compute rt79 = (t79/t79p)*(100000/15).
compute rt84 = (t84/t84p)*(100000/15).
compute rt85 = (t85/t85p)*(100000/15).
save outfile = 'azs15.sys'
/drop = t4 to t85, t4p to t85p.

get file = 'azs15.sys'.
set listing = 'azsrates.doc'.
list variables = all.
```

c) Expand overall mean rates by age group to 8 lines to match with mean rates by depcat and age group.

```
join add file = 'azs15.sys'
```

```
/file = 'azs15.sys'
/file = 'azs15.sys'
/file = 'azs15.sys'.
save outfile = 'azs16.sys'.

join add file = 'azs16.sys'
/file = 'azs16.sys'.
save outfile = 'azs17.sys'.
```

d) Match and compute ratio:
k = (rate by depcat and age group/overall rate by age group),
for each of the age groups.

```
get file = 'azs17.sys'.
join match file = 'azs12.sys'
/file = *.
compute kt1 = r4d/rt4.
compute kt2 = r9d/rt9.
compute kt3 = r14d/rt14.
compute kt4 = r19d/rt19.
compute kt5 = r24d/rt24.
compute kt6 = r29d/rt29.
compute kt7 = r34d/rt34.
compute kt8 = r39d/rt39.
compute kt9 = r44d/rt44.
compute kt10 = r49d/rt49.
compute kt11 = r54d/rt54.
compute kt12 = r59d/rt59.
compute kt13 = r64d/rt64.
compute kt14 = r69d/rt69.
compute kt15 = r74d/rt74.
compute kt16 = r79d/rt79.
compute kt17 = r84d/rt84.
compute kt18 = r85d/rt85.
save outfile = 'azs18.sys'
/drop = r4d to r85d, rt4 to rt85.
```

4-BY DEPCAT INSIDE EACH RING, MULTIPLY THE ABOVE RATIOS BY THEIR CORRESPONDING AGE GROUPS. WORK OUT POPULATION BY RING AND AGE GROUPS STANDARDIZED BY DEPRIVATION CATEGORY.

a) Work out total population by age group, by depcat, inside each ring.

```
get file = 'azs10.sys'.
aggregate outfile = 'azs19.sys'
/break = circle, depcat
/t1p = sum (t4p)
/t2p = sum (t9p)
/t3p = sum (t14p)
/t4p = sum (t19p)
/t5p = sum (t24p)
/t6p = sum (t29p)
/t7p = sum (t34p)
/t8p = sum (t39p)
/t9p = sum (t44p)
/t10p = sum (t49p)
/t11p = sum (t54p)
/t12p = sum (t59p)
/t13p = sum (t64p)
/t14p = sum (t69p)
```

```
/t15p = sum (t74p)
/t16p = sum (t79p)
/t17p = sum (t84p)
/t18p = sum (t85p).
```

b) Expand ten times the file containing ratios, to match it to each of the ten rings in the file containing population by ring and depcat.

```
join add file = 'azs18.sys'
/file = 'azs18.sys'
/file = 'azs18.sys'
/file = 'azs18.sys'.
save outfile = 'azs20.sys'.

join add file = 'azs20.sys'
/file = 'azs20.sys'
/file = 'azs18.sys'
/file = 'azs18.sys'.
save outfile = 'azs21.sys'.
```

c) Add the variable 'distance' to the expanded file, arranged in the same way as in the file with population aggregated by distance and depcat (i.e., 8x1, 8x2,...,8x10).

```
get file = 'azs19.sys'.
aggregate outfile = 'azs22.sys'
/break = dist
/dis = max(dist).

join add file = 'azs22.sys'
/file = 'azs22.sys'
/file = 'azs22.sys'
/file = 'azs22.sys'.
save outfile = 'azs23.sys'.

join add file = 'azs23.sys'
/file = 'azs23.sys'.
save outfile = 'azs24.sys'/drop = dis.

get file = 'azs24.sys'.
sort cases by dist.
save outfile = 'azs24.sys'.

get file = 'azs21.sys'.
join match file = 'azs24.sys'
/file = *.
save outfile = 'azs25.sys'.
```

d) Match ratios and population. Compute products of ratios by corresponding populations, by ring. Aggregate those products by ring and age group. Create document file of totals (population by ring and age group, standardized by deprivation category).

```
join match file = 'azs19.sys'
/file = 'azs25.sys'
/by = dist, depcat.
save outfile = 'azs26.sys'.

get file = 'azs26.sys'.
compute t4s = t1p*kt1.
```

```
compute t9s = t2p*kt2.
compute t14s = t3p*kt3.
compute t19s = t4p*kt4.
compute t24s = t5p*kt5.
compute t29s = t6p*kt6.
compute t34s = t7p*kt7.
compute t39s = t8p*kt8.
compute t44s = t9p*kt9.
compute t49s = t10p*kt10.
compute t54s = t11p*kt11.
compute t59s = t12p*kt12.
compute t64s = t13p*kt13.
compute t69s = t14p*kt14.
compute t74s = t15p*kt15.
compute t79s = t16p*kt16.
compute t84s = t17p*kt17.
compute t85s = t18p*kt18.
aggregate outfile = 'azs27.sys'
/break = dist
/t4s = sum (t4s)
/t9s = sum (t9s)
/t14s = sum (t14s)
/t19s = sum (t19s)
/t24s = sum (t24s)
/t29s = sum (t29s)
/t34s = sum (t34s)
/t39s = sum (t39s)
/t44s = sum (t44s)
/t49s = sum (t49s)
/t54s = sum (t54s)
/t59s = sum (t59s)
/t64s = sum (t64s)
/t69s = sum (t69s)
/t74s = sum (t74s)
/t79s = sum (t79s)
/t84s = sum (t84s)
/t85s = sum (t85s).

get file = 'azs27.sys'.
join match file = 'cirdummy.sys'
/file = *.
save outfile = 'azs27.sys'.

get file = 'azs27.sys'.
set listing = 'azspopul.doc'/width = 132 / eject = on.
list variables = all.
```

EDIT FILES FOR OBSERVED CASES AND FOR POPULATION, ACCORDING TO THE FORMATS SPECIFIED IN THE FORTRAN FILE FOR OBTAINING SRRs.

FURTHER NOTES: As in Cancer.pad

A4.4 - **SMR1.PAD**: SPSS FILE TO PROCESS SMR1 DATA FILES FOR ANALYSES BY RING STANDARDIZED BY AGE. TOTAL POPULATION.

(In this particular case, the analysis is for number of discharges of kidney dysfunction: D7NO).

COPY ISD'S SMR1 DATA (1981-91) TO SPSS.

m3120.arc
arc.exe

arc e m3120
m3120eds.exp

1- OBSERVED REGISTRATIONS BY RING (MALE + FEMALE).
a) Import data file, compress by Enumeration District.

```
import file = 'm3120eds.exp'
/drop = flag, ageed, sex, d1no to d6no, d1cs to d7cs.
aggregate outfile = 'az1.sys'
/break = ed
/d7not = sum (d7no).
```

b) Attach ring number to Enumeration Districts under study. Select them.

```
get file = 'a:\cendep10.sys'
/drop = depcat to f85.
save outfile = 'az2.sys'.

get file = 'az1.sys'.
sort by ed.
save outfile = 'az1.sys'.

get file = 'az2.sys'.
sort by ed.
save outfile = 'az2.sys'.

join match file = 'az2.sys'
/file = 'az1.sys'
/by = ed.
save outfile = 'az3.sys'.

get file = 'az3.sys'.
select if ( circle ge 1 and circle le 10).
save outfile = 'az3.sys'.
```

c) Aggregate registrations by ring. Create document file of totals.

```
get file = 'az3.sys'.
aggregate outfile = 'az4.sys'
/break = circle
/ocases = sum(d7not).
get file = 'az4.sys'.
set listing = 'azobserv.doc'.
list variables = circle, ocases.
```

2-RATES FOR THE WHOLE 10 KM CIRCLE BY AGE GROUP (M + F).

a) Aggregate male and female registrations by age group inside Enumeration Districts.

```
import file = 'm3120eds.exp'
/ drop = flag, sex, d1no to d6no, d1cs to d7cs.
save outfile = 'az5.sys'.

get file = 'az5.sys'.
aggregate outfile = 'az6.sys'
/break = ed, ageed
/d7nob = sum(d7no).
```

b) Add circle (i.e., ring number) from a preexisting file including this variable, create file with 18 times the Enumeration Districts under study. Match it to the data file with all Enumeration Districts provided, each with 18 age groups. Select EDs inside the ten km. distance.

```
join add file = 'az2.sys'
/file = 'az2.sys'
/file = 'az2.sys'
/file = 'az2.sys'.
save outfile = 'az7.sys'.

join add file = 'az7.sys'
/file = 'az7.sys'
/file = 'az7.sys'
/file = 'az7.sys'.
save outfile = 'az8.sys'.

join add file = 'az8.sys'
/file = 'az2.sys'
/file = 'az2.sys'.
save outfile = 'az9.sys'.

get file = 'az9.sys'.
sort by ed.
save outfile = 'az9.sys'.

get file = 'az6.sys'.
sort by ed.
save outfile = 'az6.sys'.

join match file = 'az9.sys'
/file = 'az6.sys'
/by ed.
select if (circle le 10 and circle ge 1 and d7noag ge 0).
save outfile = 'az10.sys'.
```

c) Aggregate total numbers of registrations by age group.

```
get file = 'az10.sys'.
aggregate outfile = 'az11.sys'
/break = ageed
/d7noag = sum(d7nob).
```

d) Calculate total populations by age group.

```
get file = 'a:\cendep10.sys'.
```

```
compute t4 = m4+f4.
compute t9 = m9+f9.
compute t14 = m14+f14.
compute t19 = m19+f19.
compute t24 = m24+f24.
compute t29 = m29+f29.
compute t34 = m34+f34.
compute t39 = m39+f39.
compute t44 = m44+f44.
compute t49 = m49+f49.
compute t54 = m54+f54.
compute t59 = m59+f59.
compute t64 = m64+f64.
compute t69 = m69+f69.
compute t74 = m74+f74.
compute t79 = m79+f79.
compute t84 = m84+f84.
compute t85 = m85+f85.
save outfile = 'az12.sys'
/drop = ed, tag,depcat to dist.

get file = 'az12.sys'.
recode circle (1 thru 10 = 1).
aggregate outfile = 'az13.sys'
/break = circle.
/t4 = sum(t4)
/t9 = sum(t9)
/t14 = sum(t14)
/t19 = sum(t19)
/t24 = sum(t24)
/t29 = sum(t29)
/t34 = sum(t34)
/t39 = sum(t39)
/t44 = sum(t44)
/t49 = sum(t49)
/t54 = sum(t54)
/t59 = sum(t59)
/t64 = sum(t64)
/t69 = sum(t69)
/t74 = sum(t74)
/t79 = sum(t79)
/t84 = sum(t84)
/t85 = sum(t85).
```

g) Match registrations and population files. Since registrations appear as a column, and age groups as a row, flip the latter. Compute mean annual rates (1981-91) by age group. Create document file of rates.

```
get file = 'az13.sys'.
flip variables = t4 to t85.
save outfile = 'az13.sys'

get file = 'az13.sys'.
join match file = 'az11.sys'
/file = *.
compute rates = ((d7noag/11)/(var001/100000)).
save outfile = 'az14.sys'.

get file = 'az14.sys'.
set listing = 'azrates.doc'.
```

```
list variables = rates.
```

3- TOTAL POPULATION BY RING & AGE GROUP. Create its document file.

```
get file = 'az12.sys'.
aggregate outfile = 'az15.sys'
/break = circle
/t4 = sum(t4)
/t9 = sum(t9)
/t14 = sum(t14)
/t19 = sum(t19)
/t24 = sum(t24)
/t29 = sum(t29)
/t34 = sum(t34)
/t39 = sum(t39)
/t44 = sum(t44)
/t49 = sum(t49)
/t54 = sum(t54)
/t59 = sum(t59)
/t64 = sum(t64)
/t69 = sum(t69)
/t74 = sum(t74)
/t79 = sum(t79)
/t84 = sum(t84)
/t85 = sum(t85).

get file = 'az15.sys'/drop = circle.
join match file = 'cirdummy.sys'
/file = *.
save outfile = 'az15.sys'.
get file = 'az15.sys'.
set listing = 'azpopula.doc' /width = 132 /eject = on.
list variables = all.
```

EDIT FILES FOR OBSERVED REGISTRATIONS AND FOR POPULATION ACCORDING TO THE FORMATS SPECIFIED IN THE FORTRAN FILE FOR OBTAINING SRRs.

FURTHER NOTES

-If only one of the sexes is to be studied, select it by variable 'sex' (1=male, 2=female).

-If only certain age groups are to be studied, do not include the rest in the commands above.

-When studying only one bank of the Clyde, select using variable 'tag' (1 = North, 2 = South).

-The file 'cirdummy.sys' contains the circle identifiers G01.0 to G10.0, which the population file needs, to be identified by the fortran file.

-All notes and headings between commands do not appear in the actual working file.

A4.5 - **SMR1S.PAD**, SPSS FILE TO PROCESS SMR1 DATA FILES FOR ANALYSES BY RING STANDARDIZED BY AGE GROUP AND BY DEPRIVATION CATEGORY (CARSTAIRS'). TOTAL POPULATION.

(In this particular case, the analysis is for number of discharges of eye irritation: D6NO).

1-AGGREGATE REGISTRATIONS IN 10 KM. CIRCLE BY DEPCAT AND AGE GROUP.

a) Select discharges or cases. Aggregate male and female registrations by age group inside Enumeration Districts.

```
import file = 'm3120eds.exp'/ drop = flag, sex, d1no to d5no, d7no to d7cs.
save outfile = 'azs1.sys'.
get file = 'azs1.sys'.
aggregate outfile = 'azs2.sys'
/break = ed, ageed
/d6no = sum(d6no).
```

b) Add circle (i.e., ring number) and depcat. From a preexisting file including both variables, create file with 18 times the Enumeration Districts under study. Match it to the data file with all Enumeration Districts provided, each with 18 age groups. Select EDs inside any of the ten rings.

```
get file = 'a:\cendep10.sys'
/drop = tag, m4 to dist.
save outfile = 'azs3.sys'.

join add file = 'azs3.sys'
/file = 'azs3.sys'
/file = 'azs3.sys'
/file = 'azs3.sys'.
save outfile = 'azs4.sys'.

join add file = 'azs4.sys'
/file = 'azs4.sys'
/file = 'azs4.sys'
/file = 'azs4.sys'.
save outfile = 'azs5.sys'.

join add file = 'azs5.sys'
/file = 'azs3.sys'
/file = 'azs3.sys'.
save outfile = 'azs6.sys'.

get file = 'azs2.sys'.
sort by ed.
save outfile = 'azs2.sys'.

get file = 'azs6.sys'.
sort by ed.
save outfile = 'azs6.sys'.

join match file = 'azs6.sys'
/file = 'azs2.sys'
/by ed.
select if (circle ge 1 and ageed ge 1).
save outfile = 'azs7.sys'
```

```
/drop = ed.
```

c) Aggregate registrations by age group and depcat.

```
get file = 'azs7.sys'.
aggregate outfile = 'azs8.sys'
/break = depcat, ageed
/cases = sum(d6no).
```

Optional: To work out SRRs, calculate total registrations by ring, or use equivalent file from the age-standardized analysis .

```
get file = 'azs7.sys'.
aggregate outfile = 'azs9.sys'
/break = circle
/total = sum(d6no).

get file = 'azs9.sys'.
set listing = 'azsobser.doc'.
list variables = circle, total.
```

2-AGGREGATE TOTAL POPULATIONS BY AGE GROUPS BY DEPCAT.

a) Compute total populations by age group by Enumeration District.

```
get file = 'a:\cendep10.sys'.
compute t4 = m4+f4.
compute t9 = m9+f9.
compute t14 = m14+f14.
compute t19 = m19+f19.
compute t24 = m24+f24.
compute t29 = m29+f29.
compute t34 = m34+f34.
compute t39 = m39+f39.
compute t44 = m44+f44.
compute t49 = m49+f49.
compute t54 = m54+f54.
compute t59 = m59+f59.
compute t64 = m64+f64.
compute t69 = m69+f69.
compute t74 = m74+f74.
compute t79 = m79+f79.
compute t84 = m84+f84.
compute t85 = m85+f85.
save outfile = 'azs10.sys'/drop = ed, tag, m4 to dist.
```

b) Aggregate total populations by age group by depcat.

```
get file = 'azs10.sys'.
aggregate outfile = 'azs11.sys'
/break = depcat
/t4d=sum(t4)
/t9d=sum(t9)
/t14d=sum(t14)
/t19d=sum(t19)
/t24d=sum(t24)
/t29d=sum(t29)
/t34d=sum(t34)
/t39d=sum(t39)
/t44d=sum(t44)
```

```
/t49d=sum(t49)
/t54d=sum(t54)
/t59d=sum(t59)
/t64d=sum(t64)
/t69d=sum(t69)
/t74d=sum(t74)
/t79d=sum(t79)
/t84d=sum(t84)
/t85d=sum(t85).
```

3-WORK OUT RATES BY AGE GROUP & DEPCAT, AND DIVIDE THEM BY OVERALL (10 KM) RATES BY AGE GROUP.

a) Flip vertical totals for registrations by age group for each depcat, to horizontal (as in population). Join add the resulting files.

```
get file = 'azs8.sys'.
select if (sysmis(depcat)).
flip variables cases.
save outfile = 'azs12.sys'.

get file = 'azs8.sys'.
select if (depcat = 1).
flip variables cases.
save outfile = 'azs13.sys'.

get file = 'azs8.sys'.
select if (depcat = 2).
flip variables cases.
save outfile = 'azs14.sys'.

get file = 'azs8.sys'.
select if (depcat = 3).
flip variables cases.
save outfile = 'azs15.sys'.

get file = 'azs8.sys'.
select if (depcat = 4).
flip variables cases.
save outfile = 'azs16.sys'.

get file = 'azs8.sys'.
select if (depcat = 5).
flip variables cases.
save outfile = 'azs17.sys'.

get file = 'azs8.sys'.
select if (depcat = 6).
flip variables cases.
save outfile = 'azs18.sys'.

get file = 'azs8.sys'.
select if (depcat = 7).
flip variables cases.
save outfile = 'azs19.sys'.

join add file = 'azs12.sys'
/file = 'azs13.sys'
/file = 'azs14.sys'
/file = 'azs15.sys'.
```

```
save outfile = 'azs20.sys'.

join add file = 'azs16.sys'
/file = 'azs17.sys'
/file = 'azs18.sys'
/file = 'azs19.sys'.
save outfile = 'azs21.sys'.

join add file = 'azs20.sys'
/file = 'azs21.sys'.
save outfile = 'azs22.sys'.
```

b) Match registrations by depcat and age group to population by depcat and age group. Work out mean annual rates by depcat and age group (1981-91), inside the ten Km. circle.

```
get file = 'azs22.sys'.
join match file = 'azs11.sys'
/file = *.
compute r4d = (var001/t4d)*(100000/11).
compute r9d = (var002/t9d)*(100000/11).
compute r14d = (var003/t14d)*(100000/11).
compute r19d = (var004/t19d)*(100000/11).
compute r24d = (var005/t24d)*(100000/11).
compute r29d = (var006/t29d)*(100000/11).
compute r34d = (var007/t34d)*(100000/11).
compute r39d = (var008/t39d)*(100000/11).
compute r44d = (var009/t44d)*(100000/11).
compute r49d = (var010/t49d)*(100000/11).
compute r54d = (var011/t54d)*(100000/11).
compute r59d = (var012/t59d)*(100000/11).
compute r64d = (var013/t64d)*(100000/11).
compute r69d = (var014/t69d)*(100000/11).
compute r74d = (var015/t74d)*(100000/11).
compute r79d = (var016/t79d)*(100000/11).
compute r84d = (var017/t84d)*(100000/11).
compute r85d = (var018/t85d)*(100000/11).
save outfile = 'azs23.sys'
/drop t4d to var018.
```

c) Calculate mean annual rates (1975-89, 10 km. circle) by age group. Optionally, use those from the age-standardized analysis.

I-Total registrations by age group. Flip from column to line.

```
get file = 'azs8.sys'.
aggregate outfile = 'azs24.sys'
/break = ageed
/cases = sum(cases).

get file = 'azs24.sys'.
flip variables = cases.
save outfile = 'azs24.sys'.
```

II-Total population by age group.

```
get file = 'azs10.sys'.
recode circle (1 thru 10 = 1).
aggregate outfile = 'azs25.sys'
/break = circle
```

```
/t4 = sum(t4)
/t9 = sum(t9)
/t14 = sum(t14)
/t19 = sum(t19)
/t24 = sum(t24)
/t29 = sum(t29)
/t34 = sum(t34)
/t39 = sum(t39)
/t44 = sum(t44)
/t49 = sum(t49)
/t54 = sum(t54)
/t59 = sum(t59)
/t64 = sum(t64)
/t69 = sum(t69)
/t74 = sum(t74)
/t79 = sum(t79)
/t84 = sum(t84)
/t85 = sum(t85).

get file = 'azs24.sys'.
join match file = 'azs25.sys'
/file = *.
compute r4 = (var001/t4)*(100000/11).
compute r9 = (var002/t9)*(100000/11).
compute r14 = (var003/t14)*(100000/11).
compute r19 = (var004/t19)*(100000/11).
compute r24 = (var005/t24)*(100000/11).
compute r29 = (var006/t29)*(100000/11).
compute r34 = (var007/t34)*(100000/11).
compute r39 = (var008/t39)*(100000/11).
compute r44 = (var009/t44)*(100000/11).
compute r49 = (var010/t49)*(100000/11).
compute r54 = (var011/t54)*(100000/11).
compute r59 = (var012/t59)*(100000/11).
compute r64 = (var013/t64)*(100000/11).
compute r69 = (var014/t69)*(100000/11).
compute r74 = (var015/t74)*(100000/11).
compute r79 = (var016/t79)*(100000/11).
compute r84 = (var017/t84)*(100000/11).
compute r85 = (var018/t85)*(100000/11).
save outfile = 'azs26.sys'/drop = circle to t85, var001 to var 018.

get file = 'azs26.sys'.
set listing = 'azsrates.doc'.
list variables = r4 to r85.
```

d) Expand file with rates by age group to 8 lines to match with rates by depcat and age group.

```
join add file = 'azs26.sys'
/file = 'azs26.sys'
/file = 'azs26.sys'
/file = 'azs26.sys'.
save outfile = 'azs27.sys'.

join add file = 'azs27.sys'
/file = 'azs27.sys'.
save outfile = 'azs28.sys'.
```

e) Match overall rates by age group (expanded to 8 lines) with rates by depcat and age group. Work out ratio (rate by depcat and age group/ overall rate by age group).

```
get file = 'azs28.sys'.
join match file = 'azs23.sys'
/file = *.
compute k1 = r4d/r4.
compute k2 = r9d/r9.
compute k3 = r14d/r14.
compute k4 = r19d/r19.
compute k5 = r24d/r24.
compute k6 = r29d/r29.
compute k7 = r34d/r34.
compute k8 = r39d/r39.
compute k9 = r44d/r44.
compute k10 = r49d/r49.
compute k11 = r54d/r54.
compute k12 = r59d/r59.
compute k13 = r64d/r64.
compute k14 = r69d/r69.
compute k15 = r74d/r74.
compute k16 = r79d/r79.
compute k17 = r84d/r84.
compute k18 = r85d/r85.
save outfile = 'azs29.sys'
/drop r4d to r85.
```

4-BY DEPCAT INSIDE EACH RING, MULTIPLY THE ABOVE RATIOS BY THEIR CORRESPONDING AGE GROUPS. WORK OUT POPULATION BY RING AND AGE GROUPS, STANDARDIZED BY DEPRIVATION CATEGORY.

a) Work out total population by age group, by depcat, inside each ring.

```
get file = 'azs10.sys'.
aggregate outfile = 'azs30.sys'
/break = circle, depcat
/t4cd = sum(t4)
/t9cd = sum(t9)
/t14cd = sum(t14)
/t19cd = sum(t19)
/t24cd = sum(t24)
/t29cd = sum(t29)
/t34cd = sum(t34)
/t39cd = sum(t39)
/t44cd = sum(t44)
/t49cd = sum(t49)
/t54cd = sum(t54)
/t59cd = sum(t59)
/t64cd = sum(t64)
/t69cd = sum(t69)
/t74cd = sum(t74)
/t79cd = sum(t79)
/t84cd = sum(t84)
/t85cd = sum(t85).
```

b) Join add ratios file ten times, to match with file of population by ring and depcat.

```
join add file = 'azs29.sys'
```

```
/file = 'azs29.sys'
/file = 'azs29.sys'
/file = 'azs29.sys'.
save outfile = 'azs31.sys'.

join add file = 'az3s31.sys'
/file = 'azs31.sys'
/file = 'azs29.sys'
/file = 'azs29.sys'.
save outfile = 'azs32.sys'.
```

c) Join match age groups by ring and depcat with expanded ratios file. Multiply each ratio by its corresponding age group. Create document file of populations by ring and age group, standardized by deprivation category.

```
join match file = 'azs32.sys'
/file = 'azs30.sys'
/by = dist, depcat.
save outfile = 'azs33.sys'.

get file = 'azs33.sys'.
compute spop4 = t4cd*k1.
compute spop9 = t9cd*k2.
compute spop14 = t14cd*k3.
compute spop19 = t19cd*k4.
compute spop24 = t24cd*k5.
compute spop29 = t29cd*k6.
compute spop34 = t34cd*k7.
compute spop39 = t39cd*k8.
compute spop44 = t44cd*k9.
compute spop49 = t49cd*k10.
compute spop54 = t54cd*k11.
compute spop59 = t59cd*k12.
compute spop64 = t64cd*k13.
compute spop69 = t69cd*k14.
compute spop74 = t74cd*k15.
compute spop79 = t79cd*k16.
compute spop84 = t84cd*k17.
compute spop85 = t85cd*k18.
aggregate outfile = 'azs34.sys'
/break = circle
/pop4s = sum(spop4)
/pop9s = sum(spop9)
/pop14s = sum(spop14)
/pop19s = sum(spop19)
/pop24s = sum(spop24)
/pop29s = sum(spop29)
/pop34s = sum(spop34)
/pop39s = sum(spop39)
/pop44s = sum(spop44)
/pop49s = sum(spop49)
/pop54s = sum(spop54)
/pop59s = sum(spop59)
/pop64s = sum(spop64)
/pop69s = sum(spop69)
/pop74s = sum(spop74)
/pop79s = sum(spop79)
/pop84s = sum(spop84)
/pop85s = sum(spop85).
```

```
get file = 'azs34.sys'.
join match file = 'cirdummy.sys'
/file = *.
save outfile = 'azs34.sys'.
set listing = 'azspopul.doc'/width = 132 /eject = on.
list variables = all.
```

EDIT FILES FOR OBSERVED CASES AND FOR POPULATION, ACCORDING TO THE FORMATS SPECIFIED IN THE FORTRAN FILE FOR OBTAINING SRRs.

FURTHER NOTES: As in SMR1.PAD.

A4.6 - **CM.PAD**, SPSS FILE TO PROCESS CONGENITAL MALFORMATIONS (ALL) DATA FILE FOR ANALYSIS BY RING STANDARDIZED BY OVERALL INCIDENCE (1982-89).

Prior editing of the data (e.g.,manual allocation of ED code) is explained in the Methods chapter. The resulting file is 'cmpcode2.sys'.

1-OBSERVED REGISTRATIONS BY RING.

a) Add congenital malformations by Enumeration District using the sex code (1 = male, 2 = female, 3 = indetermined, 4 = not known).

```
get file = 'cmpcode2.sys'.
recode sex(2,3,9 = 1).
aggregate outfile = 'az1.sys'
/break = ed
/total = sum(sex).
```

b) Add the 'circle' (ring number) variable. Aggregate registrations by ring. Obtain .doc file of these registrations.

```
join match file = 'az1.sys'
/file = 'a:\cendep10.sys'
/keep = ed, circle
/by = ed.
save outfile = 'az2.sys'.

get file = 'az2.sys'.
aggregate outfile = 'az3.sys.sys'
/break = circle
/cmtot = sum(total).

get file = 'az3.sys'.
set listing = azobserv.doc'.
list variables = circle, cmtot.
```

2-TOTAL BIRTHS BY RING, 1982-89 (POPULATION).

a) Join files of yearly births data.

```
join add file = 'edbr82.sys'
/file = 'edbr83.sys'
/file = 'edbr84.sys'
/file = 'edbr85.sys'
/file = 'edbr86.sys'.
save outfile = 'edbr8286.sys'.

join add file = 'edbr8286.sys'
/file = 'edbr87.sys'
/file = 'edbr88.sys'
/file = 'edbr89.sys'.
save outfile = 'edbr8289.sys'.
```

b) Aggregate births by ED. Select EDs with centroids inside the ten Km. distance. Aggregate total births by ring.

```
get file = 'edbr8289.sys'.
recode sex(2,3,9 = 1).
aggregate outfile = 'az4.sys'
/break = ed
/births = sum(sex).

join match file = 'a:\cendep10.sys'
/keep = ed, circle
/file = 'az4.sys'
/by = ed
save outfile = 'az5.sys'.

get file = 'az5.sys'.
aggregate outfile = 'az6.sys'
/break = circle
/brtot = sum(births).

get file = 'az6.sys'.
set listing = 'azobserv.doc'.
list variables = circle, brtot.
```

3-OVERALL INCIDENCE RATE OF (ALL) CONGENITAL MALFORMATIONS PER 100,000 BIRTHS (1982-89).

```
get file = 'az3.sys'.
recode circle (1 thru 10 = 1).
aggregate outfile = 'az7.sys'
/break = circle
/cmtots = sum(cmtot).

get file = 'az6.sys'.
recode circle (1 thru 10 = 1)
aggregate outfile = 'az8.sys'
/break = circle
/brtots = sum(brtot).

join match file = 'az7.sys'
/file = 'az8.sys'
/by = circle.
compute rate = (cmtot/brtot)*100000.
save outfile = 'az9.sys'.

get file = 'az9.sys'.
set listing = 'azrates.doc'.
list variables = rate.
```

EDIT FILES FOR OBSERVED REGISTRATIONS BY CIRCLE AND FOR TOTAL BIRTHS BY CIRCLE ACCORDING TO THE FORMATS SPECIFIED IN THE FORTRAN FILE FOR OBTAINING SRRs.

Note: If only one of the banks of the Clyde is to be studied, select according to tags by ED included in file 'a:\cendep10.sys' (1 = North, 2 = South).

A4.7 - **CMS.PAD**, SPSS FILE TO PROCESS CONGENITAL MALFORMATIONS (ALL) DATA FILE FOR ANALYSIS BY RING STANDARDIZED BY OVERALL INCIDENCE (1982-89) AND BY DEPRIVATION CATEGORY (CARSTAIRS').

Prior editing of the data (e.g., manual allocation of ED code) is explained in the Methods chapter. The resulting file is 'cmpcode2.sys'.

1-AGGREGATE REGISTRATIONS IN TEN KM. CIRCLE BY DEPCAT (INSIDE GREATER GLASGOW HEALTH BOARD)

a) Add congenital malformations by Enumeration District using the sex code (1 = male, 2 = female, 3 = indetermined, 9 = not known). Preexisting files (from standardization by overall incidence) can be used.

```
get file = 'cmpcode2.sys'.
recode sex (2,3,9 = 1).
aggregate outfile = 'azs1.sys'
/break = ed
/total = sum(sex).
```

b) Calculate total registrations (1982-89) by depcat in 10 km. circle (inside Greater Glasgow Health Board).

```
join match file = 'azs1.sys'
/file = 'a:\cendep10.sys'
/keep = ed, circle, depcat
/by = ed.
save outfile = 'azs2.sys'.

get file = 'azs2.sys'.
select if(circle ge 1).
aggregate outfile = 'azs3.sys'
/break = depcat
/total = sum(total).
```

Optional: For SRRs calculation, obtain total numbers of registrations by ring. Create its .doc file. A similar file , obtained in the standardization by overall incidence can be used.

```
get file = 'azs2.sys'.
aggregate outfile = 'azs4.sys'
/break = circle
/total = sum(total).

get file = 'azs4.sys'.
set listing = 'azsobser.doc'.
list variables = circle, total.
```

2-AGGREGATE BIRTHS BY DEPCAT (as above, preexisting files can also be used).

a) Join add annual data files.

```
join add file = 'edbr82.sys'
/file = 'edbr83.sys'
/file = 'edbr84.sys'
/file = 'edbr85.sys'
/file = 'edbr86.sys'.
```

```
save outfile = 'edbr8286.sys'.

join add file = 'edbr8286.sys'
/file = 'edbr87.sys'
/file = 'edbr88.sys'
/file = 'edbr89.sys'.
save outfile = 'edbr8289.sys'.
```

b) Aggregate births inside 10 Km. circle, first by ed and then by depcat.

```
get file = 'edbr8289.sys'.
recode sex(2,3,9 = 1).
aggregate outfile = 'azs5.sys'
/break = ed
/births = sum(sex).

join match file = 'a:\cendep10.sys'
/keep = ed, circle, depcat
/file = 'azs5.sys'.
/by = ed.
save outfile = 'azs6.sys'.

get file = 'azs6.sys'.
select if (circle ge 1).
aggregate outfile = 'azs7.sys'
/break = depcat
/births = sum(births).
```

3-WORK OUT RATES BY DEPCAT. DIVIDE THEM BY OVERALL (10 KM. CIRCLE) RATES.

a)Join match registrations and births files. Work out rates by depcat.

```
join match file = 'azs3.sys'
/file = 'azs7.sys'
/by = depcat.
Compute deprate = (total/births)*100000.
save outfile = 'azs8.sys'.
```

b) Calculate overall incidence rate (1982-89, 10 km. circle inside GGHB, per 100,000 births). Alternatively, rate file from previous standardization by overall incidence can be used.

I- Total registrations.

```
get file = 'azs2.sys'.
select if(circle ge 1).
recode circle (1 thru 10 = 1).
aggregate outfile = 'azs9.sys'
/break = circle
/total = sum(total).
```

II-Total births.

```
get file = 'azs6.sys'
select if(circle ge 1).
recode circle (1 thru 10 = 1).
aggregate outfile = 'azs10.sys'
/break = circle
```

```
/births = sum(births).
```

III-Overall rate. Create its .doc file, or use an existing one, for the final SRRs analysis.

```
join match file = 'azs9.sys'
/file = 'azs10.sys'
/by = circle.
compute rate = (total/births)*100000.
save outfile = 'az1s11.sys'.

get file = 'azs11.sys'.
set listing = 'azsrate.doc'.
list variables = rate.
```

c) Expand overall rate file to eight lines. Match it to rates by depcat. Compute ratios: rate by depcat/overall rate.

```
join add file = 'azs11.sys'
/file = 'azs11.sys'
/file = 'azs11.sys'
/file = 'azs11.sys'.
save outfile = 'azs12.sys'.

join add file = 'azs12.sys'
/file = 'azs12.sys'.
save outfile = 'azs13.sys'.

get file = 'azs13.sys.
join match file = 'azs8.sys'
/file = *.
compute ratio = deprate/rate.
save outfile = 'azs14.sys'.
```

4-BY DEPCAT INSIDE EACH RING, MULTIPLY THE ABOVE RATIOS BY THEIR CORRESPONDING NUMBER OF BIRTHS. WORK OUT NUMBER OF BIRTHS BY RING STANDARDIZED BY DEPRIVATION CATEGORY.

a) Work out numbers of births by depcat inside each ring.

```
get file = 'azs6.sys'.
select if (circle ge 1).
aggregate outfile = 'azs15.sys'
/break = circle, depcat
/births = sum(births).
```

b) Expand ratios file ten times to match it to births by ring and depcat.

```
join add file = 'azs14.sys'
/file = 'azs14.sys'
/file = 'azs14.sys'
/file = 'azs14.sys'.
save outfile = 'azs15.sys'.

join add file = 'azs15.sys'
/file = 'azs15.sys'
/file = 'azs14.sys'
/file = 'azs14.sys'.
```

```
save outfile = 'azs16.sys'.
```

c) Add variable 'circle' to the latest file.

```
get file = 'a:\cendep10.sys'
/keep = circle.
aggregate outfile = 'azs17.sys'
/break = circle
/circ = max(circle).

join add file = 'azs17.sys'
/file = 'azs17.sys'
/file = 'azs17.sys'
/file = 'azs17.sys'.
save outfile = 'azs18.sys'.

join add file = 'azs18.sys'
/file = 'azs18.sys'.
save outfile = 'azs19.sys'/drop = circ.

get file = 'azs19.sys'.
sort cases by dist.
save outfile = 'azs19.sys'.

get file = 'azs16.sys'.
join match file = 'azs19.sys'
/file = *.
save outfile = 'azs20.sys'.
```

d) Match ratios and births. Compute products of ratios by corresponding numbers of births, by ring. Aggregate those products by ring. Create document file of total births by circle standardized by depcat.

```
join match file = 'azs15.sys'
/file = 'azs20.sys'
/by = circle, depcat.
save outfile = 'azs21.sys'.

get file = 'azs21.sys'.
compute bir = births*ratio.
aggregate outfile = 'azs22.sys'
/break = circle
/bir = sum(bir).

get file = 'azs22.sys'.
join match file = 'cirdummy.sys'
/file = *.
save outfile = 'azs22.sys'.

get file = 'azs22.sys'.
set listing = 'azsbirth.doc'.
list variables = all.
```

EDIT FILES FOR TOTAL REGISTRATIONS BY RING AND FOR DEPCAT STANDARDIZED NUMBERS OF BIRTHS, ACCORDING TO THE FORMATS SPECIFIED IN THE FORTRAN FILE FOR OBTAINING SRRs.

FURTHER NOTES: As in CM.PAD.