STUDIES IN TOXICOLOGY.

1. Cyanide Poisonings
11. The Toxicology of Petrol.

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A CONTRIBUTION TO THE TOXICOLOGY OF HYDROCYANIC

ACID AND THE -(CN) RADICLE.

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HYDROCYANIC ACID POISONING

1. Place in Nature.

Hydrocyanic Acid is present in various members of the vegetable kingdom, being especially met with in the parenchymatous tissse of the fleshy cotyledons of the seeds of various members of the order Rosaceae particularly of the genus Prunus, the plum (P.domestica), apricot, peach, cherry, etc, and very especially the well known Prunus amygdalus (var. amara) the bitter almond. It is present in the seeds of Gynocardia odorata of Assam and Bengal, from which the Gynocardia oil sometimes used in the treatment of leprosy is expressed. When these seeds are crushed and mixed with water a strong odour of HCN is developed; they yield no less than 5% by weight of the cyanogenetic glucoside gynocardin, equal to .44% of HCN in the entire seed or .663% for the kernel (as 25 grammes of the seeds when divested of their shells weigh 17.7gm). Along with the glucoside in the Gynocardia seeds there is an enzyme gynocardase (a protein substance) in quantity corresponding to 2% of the weight of the seed; this enzyme is able to hydrolyse either gynocardin or amygdalin readily on the addition of water.

The Phaseolus lunatus (a leguminous plant- the common Scarlet Runner Bean is a Phaseolus) contains in its ripe seeds a quantity of Prussic Acid varying in different samples of the beans between .006% to .102% or over (8), the quantity differing with the degree of ripeness of the seeds and with their colour, differently tinted beans having widely different quantities of the glucoside present, those beans that are of a white colour containing practically nil.

Hydrocyanic Acid is present in the form of amygdalin in the bark of the Prunus serotina, another of the Rosaceae. It is obtainable from the fresh leaves of Prunus laurocerasus, the cherry laurel, the

glucoside of which Laurocerasin is identical with amygdalin. It is present in a considerably higher relative proportion in the young leaves and shoots in spring and early summer than it is in the larger and older leaves. It is to be found in the young twigs and the tender leaves of the Hawthorn (Crataegus oxyacanthus) and to a certain extent also in the green leaves and stems of the common Flax (Linum usitatissimum). The Bitter Cassava or Manoic (Manihot utilissima and M. aipi) though used as a staple article of farinaceous food in those countries where it is grown (Central and tropical South America and also, to a certain extent, in Bengal) is yet absolutely lethal if taken in a fresh and unprepared state, killing by the formation of free Hydrocyanic Acid. In fact it was not unknown in the days of slavery for negro slaves on the plantations to commit suicide by eating the raw cassava root, the fatal issue being almost as speedy as if induced by the prussic acid of commerce (1). The roots, which contain the nutriment, require to be submitted to a process of washing and fermenting before use, and this is carried out in various (25) ways. The roots may simply be bruised and then left for a period in a stream of running water; or the fresh roots may be grated, the poisonous juice expressed off and the remaining pulp washed and dried. These processes lead in the first place to the formation of Hydrocyanic Acid by hydrolysis due to the action on the glucoside present by a special ferment, and then to its removal, leaving behind a residue of woody fibre and starch, this crude product going by the name of "farinha" in Brazil. The result of the various processes is here so successful in freeing the Cassava of its poisonous properties that the prepared article is used not merely by the native South American tribes and the inhabitants of

the Southern American republics but largely also in this and other countries to which it is exported under the name of Tapioca.

Towards the close of 1905, a cattle food was introduced to the market for the purpose of acting as a substitute for Bean Meal as a food for farm cattle. This meal, which was imported in all good faith, seems to have been produced from a small bean, the Phaseolus lunatus, said to have been obtained from Burmah, although its distribution is in reality very much wider. The bean, samples of which I procured at the time, is of a small size and bright colour; the seeds being black, white, lilac, or ochraceous flecked with a darker brown, and all agreeing in having a white spot at the hilus. This meal, known commercially as "Java Meal", proved almost uniformly fatal when given as a feeding stuff, and having been introduced simultaneously to a large number of places throughout the country, gave rise to a costly and widespread epidemic of poisoning among the farm stock. In one instance, indeed, of which I heard 25 cows were fed with this meal before being let out in the morning and of these the entire number died within the space of about an hour. Similarly when given made up as a paste with water to some fowls, as occurred at the time on the south side of Glasgow, it killed them, and dogs obtaining access to it were fatally poisoned; fortunately so far as I am aware no cases were reported of human beings having been poisoned during this epidemic.

I examined some of the meal in question. It was a coarse dry powder of a light brownish colour and when dry without evident odour; in fact, in appearance it was considerably like oatmeal. On making a stiff paste of it with water however, in a short time it began to exhibit a very strong and unmistakable odour of prussic acid which the paste retained quite strongly and distinctly for several days if kept covered. A short time (the latent

period of the enzyme action) seems to be necessary before the odour begins to make itself apparent- this is obviously the reason why in some of the cases of poisoning that occurred some of the animals were found to refuse the food, while others to which it had been given a few moments before had taken it with fatal results(2).

On submitting the evolved vapour to chemical analysis - the details of which need not be entered into here, there could be little doubt that we were dealing with hydrocyanic acid, thus verifying the belief as to its nature which had already been raised by a consideration of its physical characters and by (as will be explained later) the remarkable absence of definite post-mortem features in the cases where it had acted as a poison. I may state that this conclusion as to the nature of the active constituent in the meal was confirmed by the results arrived at by investigators who had been working simultaneously at the subject in the various European countries where an attempt had been made to use this bean as a food. There is no evolution of the Hydrocyanic vapour if the meal is mixed with fluids such as ether , absolute alcohol, or oil, none of which contains H_2O.

It is perfectly evident, therefore, that this meal, which in itself contains no Hydrocyanic Acid as such, and evolves none so long as it is kept dry, evolves considerable quantities of the gas in the presence of water. From this it was evident that the Hydrocyanic Acid was present in the vegetable cells in organic combination with some glucoside, and that along with it there was an organic enzyme capable of acting on the latter with the aid of water, with the result that the Hydrocyanic Acid was set free as a bye-product in the formation of sugar and a volatile oil. The reaction therefore is comparable to that which occurs by the hydrolytic action of the enzyme Myrosin on a glucoside on the addition of water to a meal made of the Black

Mustard seeds of the B.P.; when an essential oil consisting of a compound of Sulphur and Cyanogen is evolved; and with what occurs on adding water to powdered Bitter Almonds, which are a recognised poisonous substance, as although an innocuous essential oil is liberated, yet, as in the case in question, quantities of free prussic acid are formed and may lead to a fatal issue.

It is evident therefore that such a meal could easily be rendered perfectly innocuous, and that in more ways than one:

(a) by prolonged steeping and washing in water, in which case the prussic acid evolved as the bye-product of the hydrolytic process induced by the enzyme would be removed and an innocuous mass having a comparatively high physiological value as a food-stuff remain. This could easily be practised on a large scale by mixing the food with water in large vats, leaving it exposed to the open air for two or three days, changing the supernatant fluid several times in the interval, finally decanting off the remaining fluid, and drying the paste either slowly in the open air or rapidly by the action of a current of hot air, or over pipes heated with superheated steam. The objection to this process on the score of danger to those employed in mixing the meal with the water in the vats could be met either by having the mixture performed mechanically or by conducting this part of the process in the open air and in a constant stream of water.

(b) by mixing the meal with water and boiling it to destroy the enzyme by the action of heat. In this case the cyanogenetic glucoside would remain unaltered, but without the presence of the requisite ferment would be innocuous, being unable to liberate the Cyanogen radicle either within the animal body or outside it (compare with Gynocardin,

which "has been ascertained to be devoid of any appreciable physiological action "when administered per se (4), and is unacted on by ferments of digestion such as diastase, ptyalin, pepsin, or pancreatin, although HCN is promptly liberated by the appropriate enzyme on contact with water). There seems to be every reason for believing that this food could have been administered to cattle without ill effects so long as it were efficiently cooked before use.

There is no reason why the proper preparation of this Bean Meal should not be just as successful as is the preparation of Tapioca for commercial purposes, nor why it should not acquire a permanent place among the foodstuffs in use amongst agriculturists, as it certainly contains a large amount of valuable protein material in a readily available form.

In the vegetable kingdom Prussic Acid is to be met with, in addition to the above mentioned sources, in the pips of the pear and apple, and in the seeds of the hawthorn. In tobacco smoke also Hydrocyanic Acid has been found in small quantities, existing probably combined with one or more of the many basic substances present in the smoke (5), but being here devoid of any physiological effect.

One of the most remarkable facts in connection with the distribution of Hydrocyanic Acid in nature is that it is found (uncombined) in the glandular secretions of certain of the Myriapoda, the cells secreting this poison being immune to its poisonous effect (6). The function of these glands is the production of odour and their secretion is probably an intermittent one .

In the case of the plants in which Prussic Acid is found, it is in no case present uncombined as in the MYRIAPODA, but exists potentially only, in the form of a cyanogenetic glucoside, inert un-

unless decomposed by an appropriate ferment. There are no less than five of these cyanogenetic glucosides known. Amygdalin was the first to be isolated, and is the commonest and most widely distributed, it also goes by the name of Laurocerasin, $C_{20}H_{27}O_{11}N$, the maltose ether of benzaldehyde cyanhydrin — $C_{12}H_{21}O_{10}.O.CH(C_6H_5).CN$; Lotusin, $C_{28}H_{31}O_{16}N$, is the lotoflavin ether of maltose cyanhydrin (7); Dhurrin, $C_{14}H_{17}O_7N$ is the dextrose ether of p-hydroxybenzaldehyde cyanhydrin (8); $C_6H_{11}O_5.O.CH(CN).C_6H_4.OH$; Phaseolunatin is the dextrose ether of acetone cyanhydrin $C_{10}H_{17}O_6N$, and has (9) the composition $C_6H_{11}O_5.O.C(CH_3)_2.CN$; Gynocardin, $(C_{13}H_{19}O_9N)_2.3H_2O$ is the d-glucose ether of the cyanhydrin of either (there is some doubt about the matter as this glucoside has been difficult to obtain and to analyse) a trihydroxyaldehyde $C_5H_4(OH)_3.CHO$, or else a Trihydroxyketone $C_5H_5(OH)_3:CO$. "Since it has been impossible to isolate this substance, and as the quinine salt of its corresponding carboxylic acid was not obtained in an amount sufficient for the further investigation of the latter, its actual constitution could not be determined"(10). The constitutional formulae for gynocardyn is thus either

$C_5H_4(OH)_3.CH(CN).O.C_6H_{11}O_5$ or else

$C_5H_5(OH)_3:C(CN).O.C_6H_{11}O_5$. Gynocardin, unlike the other cyanogenetic glucosides which are relatively unstable, is only slowly hydrolysed and that with partial decomposition by prolonged boiling with 5% HCl or H_2SO_4; it is readily attacked either by gynocardase or by emulsin with liberation of HCN, but is not hydrolysed either by diastese or by the animal enzymes, ptyalin,

pepsin, or pancreatin . Whereas on the one hand amygdlin , dhurrin, phaseolunatin and gynocardin constitutionally are sugar ethers of the cyanhydrins of substances other than sugars, lotusin on the contrary is an aromatic ether (possessing three benzene rings) of a sugar cyanhydrin.

Action on the Blood.

It is well known that Hydrocyanic Acid is able to unite with the haemoglobin of the red cells to form a compound known as Cyanhaemoglobin which presents special features to spectrum analysis. This is only mentioned here in passing in order to emphasise the fact that this is an *in vitro* reaction and does not occur in the body (11) .

It has been shown (12) that when animals are slowly poisoned by Prussic Acid all the cells of the organism lose the power of fixing and of utilising oxygen even in the presence of an excess of this gas. This is the reason why immediately after death by hydrocanysic Acid poisoning the blood may be found of a bright red colour : the oxyhaemoglobin has not been reduced by the tissues although the reduction and re-formation of the oxyhaemoglobin itself is apparently in no way impaired by even a large amount of hydrocyanic acid , and the amounts of oxygen obtained from defibrinated blood by an air pump are the same as from blood which has been treated with hydrocyanic acid (13) . Though the exchange of oxygen between the blood- and tissue-cells is destroyed, yet this does not at the same time impair either the fixation or the liberation of oxygen by the red blood cell.

If blood in which HCN is present be tested with "guaiconic ether "(a mixture of hydrogen peroxide and ether) and guaiacum or guaiaconic acid the

usual blue colour-reaction does not occur. Where much prussic acid has been exhibited, glucose may be found in the blood as in cases of asphyxia (14).

Schläpfer of Zurich working on the Photo-activities of the blood has shown that - firstly, the fresh blood of the rabbit is photo-active, and that though this property disappears after some days, yet it may be restored again by an exposure to light; secondly, blood from animals which have been killed by poisons (such as chlorate of potassium) which produce corpuscular disintegration is "always active"; Thirdly, "blood treated with prussic acid is invariably inactive" (15).

The blood to be tested for its photo-activity requires, while this is being done, to be contained in some receptacle which is in itself inactive. Schläpfer achieved his purpose by using capsules of paraffin wax to hold the blood and these could then be placed directly upon the sensitive plate until it was sufficiently acted on by the radiations which the blood is found to give off. It is obvious that if this test were being applied, a control experiment with normal blood would have to be performed at the same time, in order to have some standard of comparison by which to check the result, and it is doubtful whether such a test can ever become of more than a merely academic interest, as other easier and more rapid methods for the identification of the Cyanogen radicle are at our disposal for chemical and medico-legal purposes (16).

While the blood reactions in the toxicology of the cyanides are being discussed it should be remarked that it would appear that fatal poisoning of the mother by the Cyanogen radicle may not necessarily affect the foetus in utero. This was established by direct observation by Sauer in the case

of a "bitch which could not be delivered, and was (therefore) poisoned with cyanide of potassium. Eight minutes after death the foetuses were observed to move in its abdomen, and this and the uterus being opened, they were extracted alive"(17). If one be prepared to accept this observation as correct - and on first sight it would certainly seem advisable to reject it wholly unless accompanied by some amount of experimental verification - extreme difficulty will be experienced to find an explanation for an occurrence so outside of what might have been expected on a priori grounds.

It hardly appears possible that it could have been due to the poison being inhibited in the uterine sinuses from diffusing through into the foetal circulation, as potassium cyanide and hydrogen cyanide (HCN) are both rapidly diffusible in solution, and are not of colloidal nature to be prevented from diffussion through an animal membrane. It is also difficult to believe that the immunity of the foetus could be due to the fact that, as the cyanides kill by medullary paralysis of the respiratory centre, they were unaffected owing to their lungs being non-functionating; For in such a case the inhibition would surely have prevented respiratory movements when they were born, and so have led to an asphyxia neonatorum. Unfortunately the details supplied by the reference are so vague that this may really have been the case; We are only informed that the foetuses were extracted alive, the inference being that they began to breathe naturally and remained alive, though the direct contrary may have really occurred.

Again, postulating the fatal effects of cyanide poisoning to be Asphyxia in a merely technical sense owing to the -(CN) Radicle preventing the continuance of blood- and tissue -respiration; it is difficult to believe that the blood cells of the foetus or early infant can be so different from those of the adult as to be incapable of

entering into chemical combination with the hydrocyanic acid. Such an explanation as the foregoing would seem the most feasable from a purely clinical point of view, but there is every possibility that it will be found to be incorrect.

As, however, it is an indisputable fact that the red blood cells of the young chicken are (apparently from absence of suitable Receptors) refractory to the action of certain Haemolysins, such for example as Arachnolysine, which rapidly act on the blood of the adult fowl, and that between the time of first hatching and the age of about a month the degree of haemolysis which can occur is almost directly in proportion to the age of the bird, the question of a possible increase of susceptibility to the action of the Cyanides as poisons during the early months of life would seem to be one well worth a critical investigation.

The question of the selective action, or "barrier-action" as it is called, of the placenta must not however be lost sight of in a discussion of the points raised by a consideration of this phenomenon; and it is only because of the high importance of the subject, and also for the purpose of indicating fresh lines for possible research on this matter, that I have devoted so much space to its theoretical discussion. There are two routes by which materials may be transferred from the maternal organism to the foetus. If the maternal lymphatics are charged with the substance in question, it may, as has been shown by Ferrari (18), pass from them into the amniotic fluid and thence enter the alimentary canal of the child by being swallowed, or may reach its tissues by some other way. The more common method, that by which food-substances, bacteria, and toxic materials usually pass, is by way of the blood stream and via the placenta. The placenta in health

exercises to some extent, a "barrier-action" which is weakened, but not altogether destroyed in disease. Some organisms are found to pass readily through the placenta to the foetus, while others only pass after the placenta has been saturated with an abundance of the organisms which have become entangled in its tissues. This action also extends, it has been found, to chemical substances over which the placenta can apparently exert some power of selection; that is to say, whereas some elements and compounds pass from the mother to the foetus with comparative ease, others do so with much less readiness. Porak (19) performed a considerable number of experiments upon guinea-pigs in this connection; and he found, for example, that whereas copper and lead were easily transmitted to the foetal tissues, arsenic passed across with greater difficulty, whilst mercury, though it reached the placenta and accumulated there, was inhibited from passing any further. It is just within the bounds of possibility that the cyanide in Sauer's case was checked in a similar way by the placenta from passing into the foetal circulation, and that here we have an explanation of an otherwise anomalous though immensely important observation. I regret that I am unable, at present at all events, to conduct any enquiry upon the points raised by this isolated observation by Sauer.

Important

Important Chemical Reactions.

Kobert pointed out so long ago as 1891 that Hydrocyanic Acid and peroxide of hydrogen unite together when brought into contact and form oxamide, according to the formula $2HCN + H_2O_2 = C_2H_4N_2O_2$

This is perhaps one of the most valuable contributions that has been made to our knowledge of the means of combating the poisonous effects of Prussic Acid before its absorbtion into the general circulation, as oxamide is practically without toxic effects (20); and so, if hydrogen peroxide solution or one of the substances containing it (such as ozonic ether, Sanitas Fluid or old turpentine) can be given in a case of prussic acid poisoning without any delay, it is possible that a fatal issue may be averted.

Seventy or eighty years ago Liebig and Wöhler prepared Allophanic Acid, or as they termed it "Cyan-aether", by the passage of the vapour of hydrocyanic acid through alcohol. This substance, in common with its salts, is absolutely without any physiological action, and on being absorbed either in the free state or in combination, the allophanic acid, $C_2H_4N_2O_3$, is decomposed in the blood and is excreted as urea and carbonic acid (21).

Now as all authorities are in practical unanimity in stating that it is necessary to administer stimulants in cases of poisoning by hydrocyanic acid, if they can be got in time, and as the two stimulants specially recommended are ammonia and alcohol, it would certainly seem in view of the above-mentioned observations, that there are strong reasons why alcohol should be preferred, and in fact why it should be given in every case of poisoning by this substance. The value of alcohol in this respect is enhanced, when it is remembered that it can follow the absorbed poison into the circulation and deal

with it in the bloodstream, in a way that the other antidote that has been indicated is obviously unable to do .

The hope might also have been entertained that Adrenalin would have been of great value as a therapeutic agent in combating the poisonous effect of administration of one or other of the Cyanides, especially as Exner had found (22) that injections locally of adrenalin were able to protect the animal experimented on against a dose of Cyanide of Potash which was uniformly fatal in control animals. His work was severely criticised by Wells and Mendel (23) , and by Meltzer and Auer (24) because of various inaccuracies , but it seems evident that the protection afforded against this substance in these experiments is indisputably in favour of a certain protective influence of the injections, in spite of any technical and quantitative errors that there may have been in the original experiments . Presumably, as the rapidity of poisoning by the cyanides depends entirely upon their rate of absorbtion into the general circulation, other vasc-constrictors might also have been found to exercise to some extent a similar effect in liberating the poison slowly for absorbtion at a rate at no time in excess of the quantity the system is able to effectively dispose of. This knowledge, though possibly useful in other ways, is unfortunately entirely outside the sphere of practical therapeutics, for the reason that when dealing with adrenalin it has been found necessary to make the administration of the antidote antedate the exhibition of the poisonous substance. Exner, for instance, found it necessary to administer the adrenalin nine and three-quarter minutes before introducing the poison into the peritoneal cavity to secure a successful result.

Post-mortem Lesions

I have at different times made many thousands of observations on the poisoning by Hydrocyanic Acid of various insects belonging to many different natural orders, but these observations, however interesting in themselves (and some of the variations in the powers of resistance were very remarkable), could have no possible bearing on the subject of Forensic Medicine and so I have omitted altogether any further reference to them.

In no case of poisoning by Hydrocyanic Acid that has come under my notice have I heard of the animal having uttered the classical "cry" which is described in so many of the textbooks.

The post-mortem appearances in death from a considerable dose of the poison may be briefly described as follows:-

Shortly after death the body is found generally stiffened . There is no foam about the mouth and the tongue is not bitten between the teeth. There is a quantity of fluid secretion in the nose the mucous membrane of which is markedly injected and hyperaemic. The eyes are open and the pupils considerably dilated . In summer the body may retain its heat for several days.

The blood is dark and is semi-fluid in consistence, clotting being very imperfect. The great veins of the limbs are engorged with blood, and on cutting into them it slowly oozes out and a well-marked odour of the poison is distinguishable even as long as $2\frac{1}{2}$ days after death has occurred. A favourite method with Veterinarians of destroying dogs with Prussic Acid is to fill a hypodermic syringe with Scheele's acid, and then using a long needle to pierce an intercostal space and , pushing

the piston home in the barrel, throw the poison directly into the lung itself. In the case of animals killed by this speedy and effacious method, emphysematous bullae may on dissection be observed in the intermuscular planes of the thorax, and if these are ruptured the hydrocyanic odour is at once noticeable.

A few hours after death, the odour may be observed about the mouth and nose on disturbing the body and moving it from one place to another, even in cases where the poison has not been ingested per os and where vomiting has not occurred.

Three days after death, on opening the skull, incising the brain substance and opening into the lateral ventricles etc., the "almond" odour is unmistakably to be recognised. Three and a half days after death, the odour is equivocally present on opening the abdominal cavity, but on opening the chest it is again well-recognisable.

The peritoneum, bladder, and gastro-intestinal tract, the cerebro-spinal membranes and the pericardial sac appear normal and are not to any degree hyperaemic. The conjunctivae are normal and so is the tympanic membrane.

The lungs and nasal cavities are of a bright red colour and show very distinctly a general capillary injection.

In some cases there is a remarkable red line of hypostasis along the edge of the gums, the position of this line being influenced by gravity. In one of the subjects which I examined post mortem - a dog with scanty hair and a very delicate skin - the entire body surface was suffused with a pale pinkish flush and presented a rather peculiar appearance in consequence.

In death from a marked overdose of the poison, there may be no relaxation of the sphincters of either rectum or bladder, and the bladder may be found at post-mortem either distended with urine or empty, being in fact in the same state as it happens to be at the time of the exhibition of the poison. Exceptions to this are extremely rare.

The arteries are generally empty, the systemic veins distended and full of blood, as also are the pulmonary arteries, - the pulmonary veins being empty. The spleen and liver are engorged with blood, and the liver may be very friable.

There is paralysis of the right side of the heart, which stops in a state of diastole, both the auricle and the right ventricle being enormously distended with semi-fluid blood. The left side of the heart is in a state of contraction, the left ventricle containing neither blood nor blood-clot. The heart condition in fatal poisoning by hydrocyanic Acid as may be seen from the foregoing, is typical of Asphyxia in general. It shows an acute dilation of the chambers of the right side, and this possibly culminates after the cessation of consciousness and of respiratory effort. On removing the heart from the body and laying it on a plate, it shows the characteristic quadrilateral form of right heart dilation.

If on opening the peritoneal cavity an odour suggestive of hydrocyanic acid makes itself apparent, this is probably due to rupture of some of the mesenteric or retroperitoneal vessels engorged with venous blood from which the hydrocyanic acid then volatilises. In such a case the odour may linger for a comparatively long period

if it sufficiently strong at first, as the imperfectly clotted blood slowly oozes out, and for a long time allows the vapour to escape from fresh quantities on exposure to the air.

Example; notes of post-mortem on a dog:

"Dog: Odour of HCN about mouth 19 hours after " death; quite evident from brain-matter and lateral " ventricles 21 hours after death. The choroidal " plexuses were red and injected, the vertebral plexus " of veins within the spinal canal - between the " bone and the dura mater - was engorged with fluid " blood; and as these veins ruptured on stripping " up the dura they presented an appearance almost " as though a diffuse haemorrhage had occurred be- " tween that membrane and the bone. The oesophagus, " pharynx, and entire gastrointestinal tract were " pale in colour, presenting no abnormal features of " any sort. The tongue showed a red patch towards " its tip owing to the action of gravity (i.e. post- " mortem hypostasis). (W.J.R.)."

The fore-going observations were made upon animals that had died from the exhibition of marked overdoses of prussic acid, which had been administered to them for the primary purpose of destroying them, and which, therefore, was present probably greatly in excess of anything that would be met with other than very exceptionally indeed in the course of medicalegal practice. A description of the post-mortem signs of hydrocyanic poisoning would of necessity, therefore, be incomplete were no reference made to the lesions met with in those cases where the lethal dose has been of miminum amount sufficient to cause death, such as would more likely be met with in practice where the possibility of criminal administration of the poison (usually associated as it is with the administration of an overdose) does not always require to be considered seriously. Fortunately

I was able to remedy the deficiency owing to the epidemic of poisoning that occurred among cattle during the winter 1905-06.

On the evening of Jan: 11, 1906 a dog was given a meal of the food that had caused the poisoning, mixed with water. It soon began to exhibit signs of muscular weakness, fainted several times, vomited its stomach-contents (which smelt strongly of bitter almonds), appeared greatly nauseated, and finally died in about three hours after it had taken the poison: its temperature falling in the interval about eight degrees below the normal (which is about 101.8° F. for the dog) - this being a fall of about one degree Fahr. for every 25 minutes during which it remained alive. Its heart is said to have continued beating irregularly for some time after it finally fell asphyxiated. Some of the same food was given to another dog, which, however, vomited it in a short time and appeared none the worse.

I had the opportunity of examining the body of the first of these two animals the next day with the following results:

Twenty-one hours after death I found slight muscular rigidity present, fixation of the jaws, tongue between the teeth, vomited material about the mouth and lips, pupils both widely dilated, no froth or mucus about the mouth or external nares.

The arteries of the body were generally empty, the veins full and engorged. The blood was dark and semifluid. Stomach and intestines appeared normal and were in no way injected or ecchymosed. The bladder was empty and contracted, and it presented several patches of reddened and hyperaemic mucous membrane. The liver was dark red and friable, and was engorged with blood. The lungs were bright red and hyperaemic. The kidneys also were of a red colour from venous injection, and appeared some-

what enlarged. The Cyanide did not interfere with the postmortem staining of the abdominal organs by the development of haemosiderin. The right heart was enlarged and full of blood , the right auricular appendage contained a large ante-mortem thrombus, and the pulmonary artery also was occupied by a long branching ante-mortem clot several inches in length. The left ventricle was contracted, and contained no blood or thrombi. The heart -muscle was pale and avascular , showing no red streaks or puncta on section.

The aorta was practically empty: The venae cavae (anterior and posterior) were distended with dark-coloured blood.

On opening the Skull , the superior longitudinal sinus was found full of dark fluid blood, as were also the cavernous and other sinuses at the base. The veins of the arachnoid and pia mater were thick and dilated with dark blood. The arteries were collapsed and empty.

When the lateral ventricles were opened (21 hours after death) no odour of hydrocyanic acid was noticeable, but on mashing a quantity of brain-substance , an equivocal odour which might possibly have been due to HCN was to be noticed.

On Jan.16th 1906 a quantity of a mash made of the "Java Meal" with water was given to a cow , This mixture, which at first was odourless, soon began to exhibit the unmistakable cyanide odour, and the cow refused to touch it. It would not take the mash even when mixed with treacle, and finally forced feeding had to be resorted to. Within a few minutes after taking the food, I am told, it began to exhibit muscular tremors with weakness and unsteadiness of its legs, finally falling over on its side and pawing the ground feebly. In something less than an hour it was dead.

P.-M. Appearances: Eyes open and pupils dilated. No retinal haemorrhages. Blood very dark in colour but clotting when allowed to stand exposed to the air. No injection of peritoneum or intestine. The walls of the stomachs show no injection or hyperaemia of their villi or mucous membranes. It is difficult to say whether the stomach-contents have any odour suggestive of bitter almonds, owing to the large quantity of wet and altered grass etc. which is present in that organ. The blood and the peritoneul cavity give also a very doubtful and indefinite odour of the acid.

CONCLUSIONS.

I have arrived at the following conclusions from a consideration of the results of my dissections, the majority of which have been performed on dogs, while one or two were made on animals so diverse as the cat and the cow. From this it will be seen that the danger resulting from working with a limited horizon is reduced to a miminum . I have purposely avoided making any use of cases recorded by various authors where examinations were made post mortem in cases of suicide etc. as by so doing I might have been led unconsciously to echo the ideas of others, reading their views into the cases I examined.

1. THERE is no single characteristic post mortem appearance in Hydrocyanic poisoning such as might be visible to examination by unaided vision.

2. THE appearances are in the main those of death by Asphyxia but without those petechial appearances on pleural surfaces and in the oesophagus, which this presents.

Signs of irritant poisoning in gastrointestinal tract or elsewhere (and such have been described) are probably more often fancied than observed.

3. UNLESS death has been the result of a gigantic dose such as would not commonly be met with in the general run of medico-legal practice, the diagnosis by recognition of the special odour is most fallacious. Again; no inference should be drawn from the absence of this odour .

4. IN all cases the result of chemical examination is more trustworthy than that of mere observation of the postmortem lesions.

5. THE examination by chemical analysis of stomach contents and of articles of food may afford information of extreme value.

6. CONSIDERATION of the history of the case should never be neglected.

7. OWING to the brain being contained within a continuous bony envelope and so being in great measure protected from external conditions, it is advisable in all cases where the body has not been examined at once, to secure portions of the cerebral substance, as recommended by Casper, for chemical examination. It might also be advisable to secure at the same time some of the cerebrospinal fluid, and of the blood from the larger cerebral sinuses. If seen at an earlier period, the blood from the right heart or vena cava or even from the femoral, brachial or jugular vein may suffice to reveal on analysis the presence of Hydrocyanic Acid.

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Studies in Toxicology, part ij.

THE TOXICOLOGY OF PETROL.

The Toxicology of Petrol.

Petrol is a variable mixture (boiling at 50°C, having a specific gravity ranging within wide limits but which may roughly be taken as between .68 and .8 of that of water, and with a vapour inflammable at all temperatures over -17°C) of low flash-point hydrocarbons with a common chemical formula of $C_n H_{2n+2}$, and is produced by the fractional distillation of crude mineral oil. By the nature of things, the action of different samples of such a commercial product must vary immensely, and for the proper understanding of the toxicology of this substance it is essential to take a wide view of the subject and ascertain the toxic action, if any, of its congeners, a few of the synonyms of which are contained in the following list: natural gas, essence de petrole, motor spirit, gasolene spirit, deodorised benzolene, paraffin spirit, naphtha, petroleum, paraffin oil, gasolene, low flashpoint illuminating oils, kerosene, rock oil, rock naphtha, heavy lubricating oils, petroleum jelly, petrolatum, soft paraffin, vaseline, vasol, minerolin, fossiline, hard paraffin, paraffin wax.

It will also be found necessary to touch on the subject of poisoning by carbon monoxide, one of the most important of all the various products of the incomplete combustion of the hydrocarbon substances.

This subject of the toxicological action of Petrol and its combustion products is one that apparently no attempt has ever been made to elucidate; and that petrol can cause any toxic symptoms at all I have heard denied again and again while engaged in my investigation on the subject. I have met men who amongst other things stated that they washed their hands daily in petrol to cleanse them from the

stains of grease and tar: one man told me that he cleansed and rejuveniated his outer coat by steeping it in a bucket of petrol and put it on his back whilst still reeking with the petrol it had absorbed. ... that they had even swallowed petrol by the mouthful while cleaning the machinery of motor cars and emptying the tubing by sucking through to clear the pipes - all without the least suggestion of either local or systemic re-action. Sir Thomas Oliver, also, appears to be highly sceptical as to the reality of ill effects from inhalation of the vapour of naphtha (vide postea). Indeed from some of the accounts received one might almost be led to infer that petrol was an absolutely innocuous substance, and as bland and unirritating as water in both local and general effect.

I induced a cycle agent of wide experience to send a letter to a trades' Journal inviting a correspondence among those in the Cycle and Motor trades as to their personal experiences with regard to the local effects of petrol upon the skin, and the dangers if such existed - attendant upon breathing an atmosphere charged with petrol vapour. That letter was never published, but some time afterwards a typewritten letter was received from the Editor of the Journal in question, and his communication merits quotation in full as an example of a biassed document:

"The inhalation of Petrol vapour in moderate "quantities is not injurious, but a man who spends "many hours at a stretch in an atmosphere highly " charged with Petrol would probably suffer from " sickness, and might find that his digestion was " affected. Pure Petrol gas is, of course, poison " in that it contains no oxygen, and any animal " in an atmosphere of pure Petrol vapour would be " unable to breathe, and would, therefore die.

"Petrol affects the skin by removing all grease " from it, that is to say, it has a drying and roughen-

" ing effect. Washing the hands in Petrol re-
" moves all grease from the pores of the skin,
" and if the hands are dirtied shortly afterwards,
" the dirt is liable to work right into the skin
" and be subsequently difficult to dislodge. It
" is also liable to cause the skin to become loose
" round the nails.

"However, in a general way Petrol is quite innocuous, and no one need be afraid of breathing the vapour or touching the fluid in moderation". It is significant that here the only condition admitted in which petrol would exert a poisonous effect (and then only in a passive manner, by oxygen deprivation) is one which is absolute inconceivable to the ordinary mind, "an atmosphere of pure Petrol vapour", i.e. petrol vapourised in vacuo as in the Torricellian vacuum above the mercury column of a barometer tube.

We shall now endeavour to see what light may be thrown upon the subject by a consideration of its literature.

In the early part of 1908, Gowers (1) recorded a case of nervous disease due, he considered, to chronic poisoning by petrol fumes. This case was commented on in editorials in both the Lancet (2) and the British Medical Journal (3) shortly afterwards, and the remarkable paucity of literature on the subject pointed out. The result of such marked attention being directed in this way to the subject was that for some time thereafter a series of cases were recorded by contributors to the latter journal (4, 5, 6, 7), and the following points then especially brought out may be summarised as follow.

Exposure to inhalation of the fumes of vapourised petrol has caused in various persons the following train of symptoms; ashen-grey pallor, a slight degree of cyanosis of lips; a thready collapsible pulse running at (e.g.) 90 to the minute or, it may be, quite imper-

ceptible : a sensation of great faintness or of actual nausea, with headache and giddiness, a sense of suffocation; an impaired mental condition exemplified by inability to fix the attention, by irritability, semidelirium, or actual transient mania , by coma if the inhaled vapour be sufficiently concentrated, and by subsequent insomnia (4) ; by ocular phenonema which in various cases occurred as pupillary dilitation, as conjugate deviation of the eyes (vertical), and as proptosis, while , probably arising out of the latter, a staring and terrified expression has also been noted. Finally there may occur slight suffusion of the conjunctivae as the direct result of the irritant action of the petrol in the air.

The combustion products of petrol vary with the completeness of the oxidation , and in the case of motor engines it is entirely a matter of the efficiency of the carburettor as to what the end-products of the combustion may be. Carbon di-oxide and water vapour are the ideal end-products, and should be found alone if the maximum of efficiency is to be attained, but working with too rich a mixture there may appear in the gases from the exhaust of a petrol engine carbon monoxide, methane, acetylene, a variable quantity of soot, hydrogen gas, and even unoxidised petrol itself. In my opinion, judging from the physiological action of these fumes, a certain amount of formic aldehyde is formed also and escapes in the exhaust.

The effects which may occur from inhalation of the petrol vapour mixed with the products of imperfect combustion are pallor, cyanosis, vertigo and a sense of constriction of the head, a small rapid pulse, syncope or coma, clonic spasm of the limbs and "shivering", temporary amnesia, and in some cases, also, a pricking sensation of the conjunctivae.

The combustion products free from admixture with unoxidised petrol produce effects which are essentially those of chronic poisioning by carbon monoxide, viz., anaemia, breathlessness on slight

exertion, loss of flesh, headaches, cramps and numbness in the limbs. Pain in the front of the chest may be complained of, with neuralgic pains and perversion of taste; actual peripheral neuritis has been noted, and transient idiocy, or hemiplegia of a temporary character. In the case recorded by Sir Wm. Gowers there were symptoms of a typical myasthenia with both dysphagia and dysphonia, while Massanek, a continental observer, has recorded actual death from poisoning by carbon-monoxide as the result of being shut up all night in a room in which there was a smoking petroleum lamp.

Finally the scanty literature here analysed gives the direct effects on the skin of contact with motor spirit. The local effects of petrol as recorded by various observers are a sensation of burning pain, tenderness, erythema and blistering, oedema locally, and, where it has been in contact with the hair, a harsh dry sensation to touch after the petrol has evaporated.

The American neurologist Starr gives an interesting account (8) of a man who suffered for two successive winters from a malady which he was inclined to attribute to chronic poisoning by "natural gas" which existed in that part of the country in which he lived, and which was used as an illuminant and also for heating purposes in both his house and his office, the gas fittings being imperfect and having allowed of such constant leakage that it was necessary to make special provision for ventilation, in spite of which both house and office were often pervaded by foul and nauseating gases when the ventilators were not acting properly. To make matters worse the combustion of the gas was found to have been imperfect also. The patient was

affected with tingling and a numbness of the arms and legs, first manifest in the latter, and later going on to ataxia with associated cutaneous anaesthesia . He also complained of suffering from a form of gastrointestinal catarrh with attacks of diarrhoea during the course of his illness. Residence in an open-air sanatorium - probably aided as it was by a course of tonic treatment - resulted in a speedy and satisfactory cure. The next year however, the patient relapsed as the result of a winter's exposure to the old conditions, but he again recovered quickly with removal from the toxic influence and a change of air. Similar natural gas has been found not merely in other parts of America but in various places in Britain also, and in Heathfield in Sussex it has been supplied to houses, etc. as an illuminant.

It appears that the persons liable to be affected in their health by petrol fumes are mainly those who have to work in confined air-spaces where this liquid fuel is being used, such, for example, as garages and in the interior of submarine vessels. Intoxication where petrol has been used as a hair wash has occurred on several occasions, the first case of the kind having been placed on record by Professor Mackendrick. It is claimed that even in the open air immunity is not secured (7), and that even policemen on point duty in busy thoroughfares have been injuriously affected in their health by the fumes that escape in the exhaust gases of the constantly passing motor cars, and so recently as the early part of February of the present year (1909) a London policeman was publicly rewarded for bravery in saving life from a burning house (occupied by a well-

known motorist), during which he had incurred considerable risks and had in the end been overcome and rendered unconscious by the fumes of the petrol. It may also be recollected that in the British international motor-boat race held at Huntingdom Bay, Long Island in 1908, one of the two members of the crew of the winning boat, Dixie II. (U.S.A.), was over-powered by the fumes of the motor spirit, though in the open and in the presence of a good air circulation, and became unconscious during the actual progress of the race.

Those engaged in workshops where the manufacture of rubber is carried on have a special risk of poisoning by naphtha, which is a similar substance to petrol although they are not identical. The india-rubber trade gives employment to a large number of men, women, and young persons; the rubber being used very widely for insulating electrical conductors, in the manufacture of surgical sheetings etc., water-proof clothing, soles and heels for foot-wear, toys, tobacco-pouches, tyres for cycles, motors and other vehicles, in machinery and for many other minor purposes.

Richard Whiteing from whom I shall quote largely, in a novel dealing with social questions, describes (6) one of the Rubber factories in London where, as in all the other branches of this industry, large quantities of naphtha were made use of as a solvent for the rubber. The cleansed rubber is dissolved in the naphtha and this solution is then spread in the form of a paste onto the various fabrics to be rendered water-proof, the seams of the articles being then fastened by painting them with a further solution of rubber in the same solvent; all this latter department of the work being in the hands of female workers. "Hundreds of girls and

women .. stand in the vast room, each with paint-box "of solution and brush in hand, and lay on the live- "long day." The vapour of the naphtha is powerful and all-pervading, and begins to be appreciable within a quarter of a mile away from the gate of the factory "and within that range the hardiest flowers "have a desperate struggle for existence. There is "not a flea in the factory ... The mephitic air grows "thicker as you near the buildings, and within them "it is a vapour that leaves no crany unvisited as it "mounts story to story to the roof".

The workers in a rubber factory, says Whiteing, come to get used to naphtha as one may get used to a pleasurable fragrance, the olfactory nerves being surfeited by the monotonous sameness of the sensory stimulus, and he goes the length of affirming that he has "known what it is to miss it when taking a "walk in the green fields". The work girl in the rubber factory carries her mid-day meal with her to her work, and eats it in the factory: "While wait- "ing to be eaten, it absorbs the vapours of the place. "Her midday meal is thus, to some extent, red herring "cured in naphtha, with bread and naphtha butter, or "pie and naphtha jam. But the really odd thing is "that the only way to get so much as a morsel of it "down is to serve it in the very room in which it "has received the taint. Try to eat it outside, "and the palate, revived by the fresher air, instant- "ly rejects the nauseating dose. To make it taste- "less in fact, you must first debauch the sense of "taste ... The poor child brings what she calls the "taste home to bed with her at night, and rises with "it in the morning. It comes between her palate "and all natural flavours, and gives her a loathing

"for the kindly fruits of the earth." (9).

The symptoms due to chronic poisoning by constant inhalation of naphtha vapour are found to be faintness and giddiness; anorexia, dyspepsia and headache; a greater or lesser degree of anaemia; general lassitude and premature ageing; an impaired mental condition exemplified by petulance and illtemper, or even by mania and paralysis * "or comsumption as a choice of evils - and, in due course, the end". The ocular and the psychical symptoms in this form of chronic intoxication Amongst workers in naphtha - which is a somewhat less volatile moiety of mineral oil distillation than is petrol - is well-marked. "Their eyes "smart and water (and) as they toil in the penetrat-"ing fumes, and they weep with the mechanical facil-"ity of experienced crocodiles. They see double "at times, and the vast barn-like room swims round "them as though its pots, brushes, garments, stuffs, "and furnace fires of gas jet were all but so much ruin in a whirlpool. Sometimes, as I learn in "answer to inquiries, they 'ketch it in the lungs'. "They invariably, as we have seen, 'ketch it in the 'knob'' in the form of bilious headache. The moral "effects are even more distressing. They lose their "temper for nothing, and will find scope and verge "enough for quarrel on a pin's point. Some have "been known to go 'right off their chump', and to "be exceedingly rude to the overseers".

Of course all this evidence is very much at variance with that of Sir Thomas Oliver, who almost appears in the light of an advocatus diaboli in the recently issued edition of Green's Encyclopaedia of Medicine and Surgery, where we are given to under-

* Osler catalogues naphtha among the causes of multiple neuritis(14)

stand (10) that the constant inhalation of naphtha vapour gives rise to but trifling dis-comfort of no very serious moment: "The pungent vapour of the naphtha is at first very irritating to the eyes and "the respiratory passages, but the workers soon get "accustomed to this . What the work-people complain of is that the taste of the naphtha lingers in the "mouth long after they have left the factory, so that "it prevents them taking food with any relish. Part-"ly owing to this circumstance, and to the fact that the work is carried on often in overheated and ill-"ventilated rooms, the girls become anaemic, and suffer "much from headache. Beyond these facts and the dis-"comfort which naphtha vapour sometimes causes, it "cannot be said that any serious illness has been "traced to its employment".

With the foregoing exceptions, literature on this important subject of the petrol poisonings seems to be almost entirely barren.

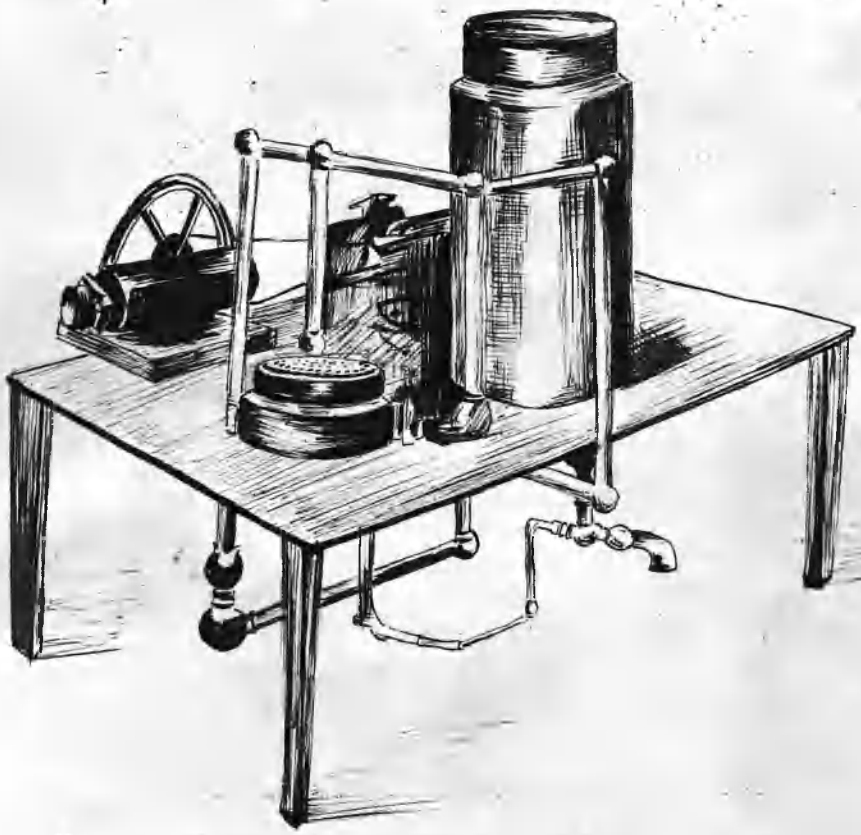
A cycle agent with whom I was once discussing the matter told me that some years ago he had worked for hours at a stretch every day in a naphtha-laden atmosphere in an un-ventilated building, and that neither he nor his assistant had at any time suffered the least inconvenience from it. They used to renovate the appearance of the tyre of the cycle, especially before a show, by sponging them over with a handful of cotton-waste soaked in the oil, and during the process were constantly inhaling its fumes. Perhaps the secret of their immunity lay in the fact that every afternoon they used to go for long spins out into the country, getting their blood thoroughly oxygenated, and returning to dinner with splendid appetites.

Towards the close of the year 1907 I became

aware of an epidemic characterised by curious toxic symptoms, that had begun to manifest itself among workers employed in a certain laundry, and I had opportunities of observing the condition at intervals during the next year and into the early part of 1909. These toxic conditions were, I found, entirely due to the use that was made in this factory of a non-luminous gas, prepared by the partial saturation of air with the vapour of petrol, for the purposes of heating implements such as internal combustion hand irons (gas irons, as they are called), the iron of collar machines, and the rollers of mangles. Owing to the position of the laundry in a country place where town gas was not obtainable for heating and illuminating purposes, the proprietor had installed a plant for the manufacture on a small scale of this Petrol Gas, or "Air-gas" as it is called, and it was to his surprise and no small annoyance that he found it exert its unpleasant effects on his work people.

The gas prepared on the premises had a variable composition but was found to give the best results for the trade purpose when it was composed of about 98 volumes per cent. of air to 2% of petrol vapour, and it was conducted to the centre of the room through metal tubing from the corner of the workroom, where there was a small gasometer, and a hot-air engine which drew a regulated draft of air over the surface of petrol in a tank and by thus saturating it with the vapourised hydrocarbon produced an imflamable mixture

As petrol contains about 8000 available calories to the litre, such a gas as this proves very efficient



Plant for generation of Petrol Gas.

when used as a heating agent where complete combustion can be ensured. In conjunction with incandescent mantles of the inverted type it has also been made use of as an illumant, and for this purpose it has lately been adapted for use in motor head lamps, the gas being supplied from a small generating plant fixed to the dashboard of the car. It has been seriously suggested that such an illuminant may prove itself a distinct competitor to acetylene as an illuminant in the larger head-lights of motor cars in the future; in view of its possible extended use in these directions the dangers attendant on its toxic properties merit careful consideration.

There were in the factory a staff of seven

women, not including the proprietor and a vanman, both of whom had in addition to their other duties a good deal to do in the building itself, and soon after the plant had got into working order the poisoning ensued, and in a comparatively short time four of the workers were absolutely incapacitated by it, while all the others who were exposed to the toxic influence suffered from profuse lachrymation and other eye symptoms. At the outset, and before the necessity for increased ventilation had been seen, on more than one occasion the work of the laundry was absolutely disorganised owing to the illness of the work-people. On one day in particular, the proprietor had to carry out one by one every one of the women occupied in the ironing-room and lay them on a grassy bank at the back of the building, where they soon recovered in the fresh country air.

The first symptoms experienced by all those who are at any time affected were in connection with their eyes, which used to become puffed up, with smarting of the conjunctivae and excessive lachrymation so that, especially if they were working with the hand iron heated by internal combustion, tears streamed down their faces and fell on to the articles they were engaged in ironing so as - I was told - to make the material absolutely damp. The eyes appeared very much irritated and red, this hyperaemia lasting not merely while at work but being present the next morning also - after the workers had been to their homes for the night and had had to go and come considerable distances in the clear fresh air. The redness of the

eyes became constant with some of the women, but was only temporary in the case of others of the workers.

While in the work-room their noses felt nipped and they sneezed, but not excessively; experiencing also a curious lingering taste in their mouths, afterwards feeling this taste in their food while eating their meals - one of which, by the way, some of them took in the laundry at the middle of the day without troubling to go to their homes for it . In some of the sufferers it produced an absolute paralysis of appetite, and at the worst period of the poisoning some of the women became intensely stupid as the result of the exposure to the fumes of the burning petrol, and made such blunders at their work that, as their master told me, they became absolutely useless.

Two of the women suffered for many days from repeated syncopal attacks while at work in the factory, recovering if taken into the open air; and vomiting occasionally occurred, the vomited material being of a green colour particularly striking to the untrained observer. Others of the workpeople had at this time to be sent home owing to their helplessness induced by the toxic influence, and took ill with retching and vomiting there. A curious feature of the whole ~~thing~~ outbreak was that no medical man was at any time called in either by the workpeople themselves or by their employer, and it was only by the merest chance that I happened to become aware of the state of affairs.

At my request the manageress of the laundry wrote to me describing the way in which she had been

taken ill when at work: "The first effects I "felt from the petrol fumes were pains in my "head, afterwards I went verry (sic)dizzy, and "sick, I was sick for nearly two hours I then "laid down for a few hours sleep, when they "called me next morning I could hardly see, "my eyes ached so much, my face was swollen, "I had a positive distaste for anything to "eat, or drink, I worked for another three hours "in the same room and I began to be sick again, "I then went for a long walk and I felt much "better".

The young woman who wrote the foregoing described her headache, as did most of those whom I interrogated on the subject, as having been entirely frontal in distribution(Probably from irritation of the lining membrane of the frontal sinuses), and accompanied by a sensation as if her head were swelling and going to burst, and as though her scalp were "lifting up". The other women exposed to the petrol fumes also had headaches, and like her found relief almost at once from the pain and from some of the other symptoms on going out into the fresh air.

Illustrative cases of the Petrol poisoning.

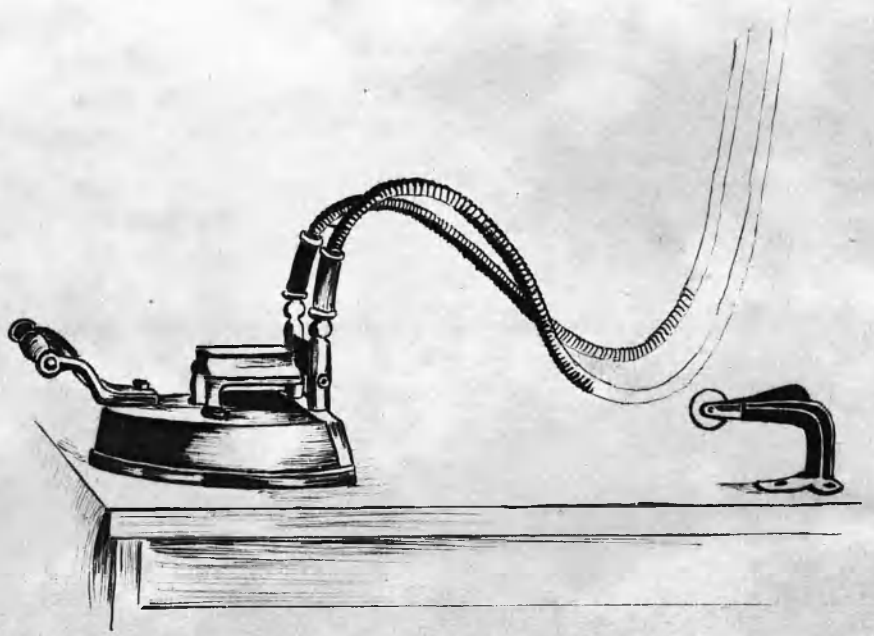
1. Mrs E.C.; age doubtful, but over 50; had worked in the laundry for a little over three months but is not now (9.4.09) employed there. States that when the gas-irons were in use she could not see, as her eyes smarted and were always running. Her eyes would smart at once whenever the gas jet in the iron was lit and profuse lachrymation would then

ensue . This smarting would disappear in a short time aftes ; cessation of work for the day , and indeed it would have passed off entirely before she had reached home. While working at ironing the water used to run from her eyes and would "fair drop on her work". In addition the fumes used to make her sneeze and made the inside of her nose smart. She felt "a right nasty taste"in her mouth ("Right "in Lancashire parlance signifies very), and it was "as bad as poison to her"and caused her to spit a lot. She could feel this taste afterwards when eating her food . Nearly as soon as she began to use a gas-iron a slight headache would ensue, frontal and bilateral in situation, and the longer she worked with the iron the worse the headache would become, but it never was really very severe. This pain, on ceasing to use the gas iron, always gradually, but on the whole fairly rapidly, wore away. She felt heavy but not dizzy, and never had any lapses of memory. Her appetite however improved markedly and her general health became better while at this work than it either was before or is now - probably owing to the extra nourishment and comforts she was able to get as the result of a steady wage as opposed to her previous condition of merely casual employment.

At the time she was working here a slight photophobia began and this has since become permanent. She has now, months after leaving the laundry, a mild degree of chronic congestion of the conjunctivae without however blepharospasm, secretion of sensory phenomena .

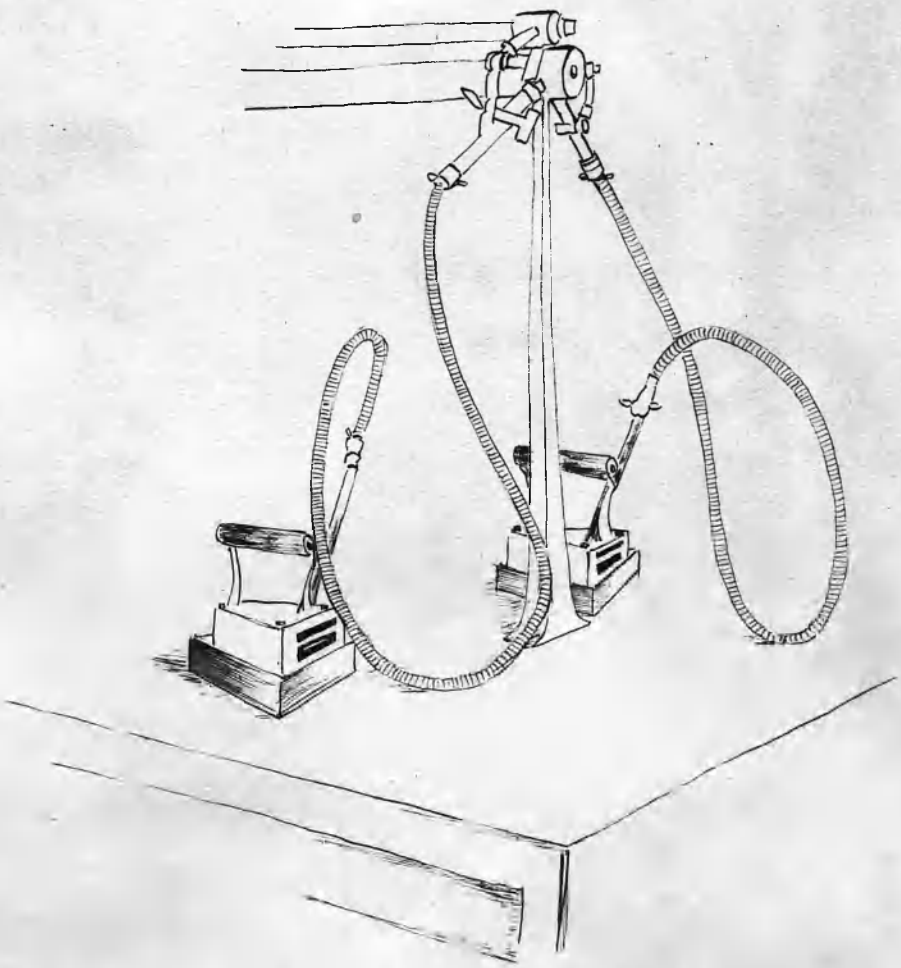
2. Mrs A. V. , annos aetatis 41, had worked

at the laundry for seven months. The petrol fumes in the workroom made her eyes red and watering and gave her frontal headaches, but at no time did she suffer from dizziness or forgetfulness. She had a biting sensation in her nose, with sneezing and a copious flow of clear serous secretion. A funny taste (indescribable) was constantly in her mouth and she always tasted it in any food she took in the laundry itself. It



Hand Iron as used for Petrol Gas in Laundries.

made her feel sickly and she had occasional loss of appetite. She has not worked at the laundry for the past four months and at present (15.4. 09)is perfectly well and free from organic disease. I tried the effects of the atmosphere of this laundry upon myself on more than one occasion and although I escaped the majority of the symptoms outlined above, I speedily experienced when the hand irons were in use a curious nipping sensation in the nasal passages with an inclination to sneeze, very similar to that experienced on inhaling the vapour of formic aldehyde



Gas Irons and connections.

as when handling a specimen that has been pickled in formalin, and also - although I habitually breathe with mouth closed - a distinct disagreeable formalin -like taste on the dorsum of the posterior half of the tongue. I am strongly of the opinion, indeed, that formic aldehyde, HCOH, was actually formed by incomplete oxidation of the petrol and that its presence accounts for much of the irritation of the nasal mucous membrane and of the conjunctivae that the workers experience. In Glasgow since the introduction of taxi-cabs (the inefficient and wasteful action of the carburettors of which is nothing short of astonishing) the pungent odour of formalin can often be recognised in the streets when one of these vehicles has just passed in a cloud of hazy smoke*.

* The process of the combustion of a hydrocarbon like petrol is not fully understood. The old idea, which I was taught and to which some still lean, is that there is a preliminary decomposition of the hydrocarbon, and that the more actively oxidisable hydrogen is burnt preferentially, the dissociated carbon particles being heated to incandescence by the burning hydrogen impart the glow to the flame and themselves are burnt later in the more luminous less central zones. Subsequently the theory that hydroxyl compounds are formed as an intermediate stage was advanced; and this idea has of late been revived.

In the Laundry All the gas-jets except those for illumination, which were practically never in use, I found to be acting most imperfectly and permitting the escape of a very considerable proportion of the gas unburnt. In the case of the hand-irons this was particularly noticeable, but it was even worse from the collar machines, where the gas was supplied from a half-inch pipe and where the vapour from the exhaust tube was practically as imflammable as the original gas in the burners had been, blazing away vigorously at the end of the tube with a flame nearly a foot high on the application of a light.

Not only was there the unburnt gas and the products of its incomplete oxidation constantly escaping in this way into the atmosphere when the burners were lit, but there was in this laundry yet another way in which petrol vapour escaped into the atmosphere of the workroom. The hand irons, which were hollow and were supplied inside with burners to keep them constantly hot by the combustion of the gas, were connected up with the gas-pipe running down the center of the ironing-table by lengths of flexible metalic tubing. This metalic tubing is formed by coiling in tubular form a long strip of stamped metal ribbon, and is made water-tight or air-tight by the interposition of a thin thread of soft rubber which is gripped between the coils (in the case of large-bore flexible pipes designed to withstand high temperatures a thread of asbestos is introduced instead). Whether it was owing to a spray of petrol from the petrol gas that was in use condensing on the inner surface of the cool tubing and dissolving the rubber thread - rubber being very readily soluble in petrol - or that the rubber had the power of absorb-

ing to itself some of the petrol from the semisaturated vapour with which it was constantly in contact and so assuming a semifluid character and in sonsequence gradually working down from the higher parts of the tubing under the influence of gravity, the rubber thread in course of time entirely dissappeared from the flexible tubing, which then became permeable to the gas and leaked along its whole length. When these hand-irons were in use the gas leaking from this tubing would occasionally, from its proximately to the jet burning inside the iron itself, catch alight and the flame would then run from one end to the other of the tubing before it died out.

On my recommendation the proprietor of the laundry largely increased the ventilation of the building whenever the gas was in use, and lowered the fittings of the gas jets that were used for heating metalic surfaces so that the upper part of the flame would not become unduly chilled by contact with the cold metal, so permitting escape of unburnt petrol into the atmosphere. He also avoided as much as possible the use of the gas continuously for prolonged periods at a time, and made a change in the supply of petrol he was using. He had at first been using petrol with a specified specific gravity of .690(as a matter of fact he had really been supplied with stuff of sp.gr.:700 and over), but he latterly obtained it at sp.gr..680, and tested the gravity of every consignment himself before accepting it. By these means the toxic effects were reduced to insignificant proportions, and the efficiency of the workers became greater than it had ever been before. Whether rightly or not, the proprietor was inclined to assign the chief credit for the cessation of the poisoning to the lighter petroleum spirit he was using to

make the gas; he said it was quite obvious that the heavier stuff had given the worse results as far as the health of the workers were concerned.

That to a great extent the poisonous effects noted among these work-people was due not so much to the petrol itself as to the carbon monoxide produced as the result of its inefficient combustion, is evident from a consideration of the similarity of the effects on the health of the workers of the waste gases sent out into the atmosphere in other cases where similar internal combustion hand-irons were used but where the heating agent was something other than petrol. Examples of such poisoning are therefore sub-joined.

In a laundry (of the internal arrangements of which I know nothing) in a large Lancashire town the town gas has been used for two years at least in connection with such gas-irons. All the girls engaged in the ironing used at one time to use these irons and suffered to some extent from toxic symptoms, but all except one of the irons got broken and the proprietor apparently has not thought it worth his while to get the fittings re-hewed in the circumstances. The gas used to leak from the burner inside the iron and flames would pop and flicker round about it when in use. The irons were fitted up to the gas-pipe by means of rubber tubing which to prevent kinking had wire coiled inside it. This tubing in process of time got dried became cracked and then flames would run all up the leaking tube from the iron; filling the room with a smell of burning rubber

L.R.; aetatis 17, was engaged in ironing

with the only remaining iron in working order in this laundry, but had to abandon its use owing to the illness it had caused her. She states that the girl who had worked with it before her also required to stop it as it had made her ill too. An "awful smell came from the iron and she used to go as sick as a dog", vomiting many a time and coming home day after day unable to eat her food. She tasted the gas in her mouth and used while working with this iron to bring the taste home with her in the evening, and it was this she says that made her unable to eat her meals. The fumes made her constantly so sleepy that she would involuntarily make all sorts of mistakes in the daily routine of her work. At present she is pale and suffering from chlorosis.

In the Excelsior Laundry in Colne although both gas and charcoal irons are used there is no poisoning among the workpeople so far as I can ascertain, but when these irons are in use the doors of the workroom are kept open and they have a fan working in the room to increase the ventilation and so avoid poisonous effects appearing.

The following is a case of poisoning by Carbon monoxide gas generated from glowing charcoal in the interior of such hand-irons

Mrs J., aet. 42 years, came to me on April 15th last, suffering from the effects of carbon monoxide poisoning. From the 6th to the 8th of the month, three days inclusive, she had put in each day a heavy day's work ironing for Easter, getting through the work with the use of two

charcoal irons. She worked in a small kitchen, the doors and windows being all shut. On the second of these days she began to feel ill, she sweated much, experiencing a loss of strength and appetite, and had a severe headache which was so bad that she had to go to bed in the afternoon with it. After an interval of four days (8th to 12th April), she again put in some work with the same irons on the 13th - that is to say, on the following week from first appearance of toxic symptoms - working from 8.30 a.m. to 12.20. While leaning over the ironing table at her work she suddenly became extremely dizzy and felt as if she were going to drop, she broke out into a profuse cold perspiration and began to tremble. Other symptoms were as before.

When she came for treatment two days later she was pale and listless and wore a heavy expression. Her appetite was absolutely gone; she had neither thirst, headache nor vomiting. She stated that she felt considerably relieved when she went into the open air, and at the time of the acute symptoms this had revived her considerably.

The foregoing two cases shewed a train of symptoms very comparable to those displayed in the cases of petrol poisoning, if the manifestations due to the irritation of the mucous membranes be left out of account.

The next question that falls to be considered in a discussion of the subject of poisoning by petrol is its dermatological effect.

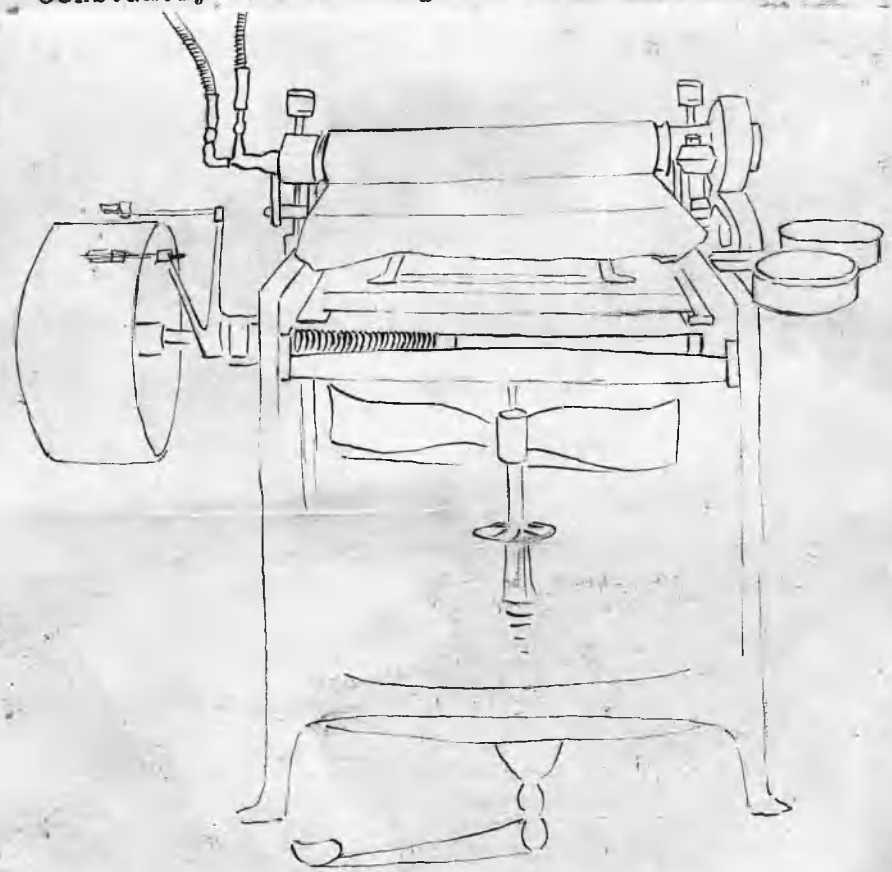
It has here also been completely denied that substances such as petrol and its allies have any irritant

action on the skin whatever (11), and the subject of the production of a dermatitis by the action of these bodies is entirely ignored in many of the standard textbooks on the subject of dermatology. "Petroleum products" are incidentally mentioned - and that is all - as the cause of dermatitis venenata by Stelwagon (12), Gemmell states that petroleum has been credited with the production of an erythema somewhat like that due to the toxic action of belladonna and quotes Love to the effect (13) that impure vaseline instead of being bland and soothing in its action may act "as a very efficient irritant, sometimes even producing pustules, especially on the skin of delicate "children".

A cycle agent has informed me that in his experience, if one gets a scratch or cut on the hand and happens to be using petrol at the time the wound will heal with unusual rapidity. A chauffeur told me that petrol has never had the slightest effect on his skin (or even on lips, tongue, or inside of cheeks when he has taken it into his mouth) but that two young men of his acquaintance have had a different experience, as they have found that petrol getting into the slightest crack or abrasion on their skin has always caused great irritation so that the wound has become septic and taken long to heal.

In the laundry which has already been mentioned no more than once, and where I was able to observe the poisonous action of petrol fumes on the system, there occurred a distinct case of petrol dermatitis in a girl who was employed feeding a mangle the hollow roller of which was kept hot by a row of

gas jets burning inside it. Through this cylinder there was a draft of air circulating and the worker constantly had to bring her hands across its open



mouth with the result that at times they would be exposed to a fine spray of unburnt petrol. The effect of this was the production of a crop of little opaque white blisters about the size of small pins' heads on the dorsa of her hands, and this was accompanied by considerable itching and smarting. In process of time however, her skin became acclimatised to the effects of the petrol so that she got to be able to

feed the tank of the gas generator with as much as six gallons of petrol at a time and set the engine working in the mornings with impunity, in spite of soiling her hands with the petrol in the tins and in the machinery. Curiously enough, illustrating the effect of personal suspectibility in the cases, this young woman experienced not the slightest cutaneous discomfort from the use of the turpentine which was mixed with the starch jelly to impart a glaze to the collars, while another worker whose skin was never affected in the least degree by the petrol was utterly unable to work with this starch glaze because of the state that it got her hands and forearms into with a most painful cracked and bleeding eczema.

The manageress of the laundry stated to me that occasionally she had received drops of petrol on her hands and this had had an astringent or desiccating effect on the skin making it feel tight and drawn, and causing the epidermis to feel harsh and dry for some appreciable time afterwards. When this feeling wore off the skin became quite normal, and there never was any after-effect in the way of erythematous reddening or vesication in her case.

Some time ago I learned in a casual way of a working man who had found himself unable even to get out of his bed to go to work one morning, owing to have put petrol on his back as a local application for the relief of muscular pains from which he had been suffering.

On inquiry the following facts were elicited. It seems that this man had had pains in his back, and as so many of his class do had been endeavouring to obtain advice as to treatment from an unprofessional source. A commercial traveller to whom

he applied determined to "take a rise out of him", and solemnly recommended him to go to the nearest motor garage, get some petrol and with it on retiring for the night to paint his back thoroughly where he felt the pain, informing him that for his purpose there was nothing better if he would only lay it on liberally. The victim, charmed with the idea of obtaining gratuitous advice as to treatment without requiring to interview his medical attendant, carried out this absurd recommendation to the letter. That night he was unable to sleep. The next day his back, to use his wife's description, "felt like fire and was all over blisters" and he was in consequence so ill that he had to miss going out to his work.

As this man was not a patient of mine and I had only heard of the incident from a lay source, I had unfortunately no opportunity of personal observation of the local effects of the petrol in this case, and I am unable to record how long the direct effects lasted. One of the most interesting features of the case is the rapidity with which the petrol exercised its irritant action on a susceptible subject.

On my own skin petrol experimentally applied has not the slightest effect apart from its action as a solvent.

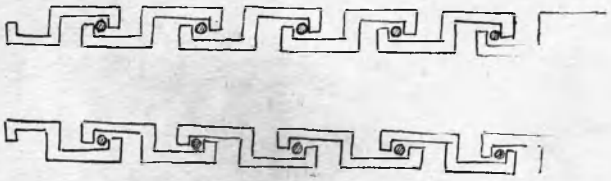
Applied to the conjunctiva petrol causes the most intent pain for a short time, but leaves no after-effects. It not infrequently happens that mechanics lying on their backs and working beneath a motor car receive a drop of this oil into the eye, but apart from the pain which is at the moment most severe there is not even a local reddening produced.

The only other question left for consideration

with respect to the toxicology of petrol and allied bodies is the subject of their internal action. The only person I have ever come across who had swallowed petrol, told me that it was tasteless and had had absolutely no effect on him although he had taken it repeatedly, but nevertheless there can be little doubt that it would be a most dangerous substance to take in any appreciable quantity. Purified petroleum (paraffinum liquidum of the B.P., which has a sp.gr. of .885 or over) is taken internally in the form of terraline and of the various petroleum emulsions and has never been known in these forms to exert any poisonous effect. Vaseline internally administered is also practically inert and is excreted unchanged. Paraffin oil has however, proved itself frankly poisonous in certain cases not merely to vermin but to man himself, and is recognised as such in the more modern works on toxicology . To give an instance; When I was a boy at school we had a maid at home whose little brother had been killed by drinking paraffin oil from a bottle that had been used previously to hold lime juice, and from which the old

Metallic Tubing with rubber thread exposed at one end.

shop label had not been removed - he had climbed up to the shelf in the cupboard where he knew the lime juice used to be kept and had taken a long drink from the neck of the bottle.



Ideal Section of metallic tubing shewing stamped metal ribbon and interposed rubber thread.

CONCLUSIONS:

From a consideration of the foregoing observations on the toxic influence of petrol in the various aspects in which the subject presents itself, two things are found to stand out clearly.

FIRSTLY, that the effect of petrol either as inhaled in the form of vapour, or by reason of its combustion products, or as a local irritant on the skin are absolutely dependent on the idiosyncracy of the person exposed to its influence - an eminently variable factor that can in no way be predicted for any individual.

SECONDLY, that in so far as petrol fumes act poisonously in virtue of the Carbon monoxide generated in combustion the poisonous symptoms can be warded off, or if they have already arisen can be effectually combated by plenty of fresh air. As a natural Se-

quent to this knowledge, the value of Inhalations of Oxygen in poisoning either by Petrol fumes or by Carbon monoxide hardly requires to be more than merely indicated in order to be accepted.

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