THE CAUSE OF CANCER

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FOREWORD

In presenting this book in the hope that it will assist in determining the cause of cancer, it must be made clear that the possibility of the disease resulting from the presence of certain poisonous organic substances in manufactured towns gas and in other carbonization and most combustion gases, and in certain smoked foods, is offered as a theory based on rational grounds justifying the fullest possible research.

The fact is well established that compounds of the type described in this book are responsible for the cancer-causing properties of certain classes of tar, and if even a small percentage of these compounds is conveyed to foodstuffs, by whatever means, it may well be that such substances are responsible for the increasing death rate from cancer.

To avoid unnecessary alarm, it must be emphasised that the case presented by the author is at present based on a theory which has not yet been proved. Clearly the necessary research would have to be conducted on a scale and with resources beyond those of any ordinary individual. The author's contribution is limited to analysis of the possibilities from the standpoint of one who has had many years of experience in matters relating to combustion and carbonization.

Particularly it must be emphasised that should research confirm the author's theory, no blame can be attached to the owners of manufactured towns gas and coke oven establishments and to producers of smoked foods, for the presence of small quantities of poisonous substances which have not hitherto been recognised as detrimental. If it now be proved that they are injurious, the industries concerned will no doubt take immediate steps to effect their elimination.

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CHAPTER I

INTRODUCTION AND SUMMARY

DURING about the past 15 years I have formed the definite opinion that the primary cause of cancer in human beings is the action of poisonous organic products that are complex high boiling point benzene ring or aromatic hydrocarbons resulting from the decomposition under high temperature conditions of carbonaceous materials, especially bituminous coal and petroleum.

One of the main sources of these poisonous cancer-causing products is the high temperature carbonization at over say 1472°F. (800°C.) and particularly at 1832-2012°F. (1000-1100°C.) of bituminous coal in manufactured towns gas retorts and by-product recovery metallurgical coke ovens.

From the latter they pass out in the gases and vapours and remain partly in the condensed coal tar, which is well known to be strongly cancer-causing, and, according to my theory, partly in the coal gas after the latter has been subjected to the usual methods of purification, forming one of the chief constituents of average manufactured towns gas supply.

Another of the main sources of these cancer-causing poisons is the drastic heat decomposition (cracking) of petroleum fractions (gas oil) under high temperature conditions in the manufacture of semi-carburetted and carburetted water gas, also a main constituent of a large proportion of manufactured towns gas. Most varieties of petroleum and their distillation fractions are non-cancerous, whilst others are only slightly so, but the cancer-causing products develop after subjection to high temperature.

Throughout this book it is necessary to use the term "manufactured towns gas" because in a number of countries, such as Canada, Soviet Russia, and the United States, towns gas supplied for general domestic and industrial use is often natural gas only, from petroleum oil areas, which is non-poisonous and could not cause cancer.

Manufactured towns gas is almost always coal gas, obtained by the high temperature carbonization of coal in externally heated retorts, including the use of a blast of steam in many vertical retorts, and coke ovens, either alone or mixed with total gasification water gas, made separately from part of the coke. This water gas can be used direct, being then known as "blue" gas, or it may be carburetted, that is enriched with cracked petroleum oil fractions, forming semi-carburetted or carburetted water gas, according to the amount of oil used.

In a number of countries natural gas and various petroleum gases are added. Nearly all the manufactured towns gas of the world also, whatever may be its constituents, has a high heating value, within the range of 400-600 B.Th.U. per cubic foot (calculated at normal atmospheric pressure and temperature).

The same type of cancer-causing hydrocarbons are apparently also formed by the high temperature carbonization of lignite, oil shale, cannel, torbanite, peat, wood, general vegetable matter, bitumen saturated rock strata, oil sand, and general organic refuse. In practice, however, high temperature carbonization of such materials is only carried out to a limited extent.

Under low temperature carbonization and general heat treatment conditions, say at 900-1200°F. (482-649°C.) of all carbonacous materials, including bituminous coal and petroleum, no cancer-causing products result, and the degree of formation seems to be very slight below say 1292°F. (700°C.), although dependent partly on the operating conditions as well as the temperature.

To a very limited extent the same action takes place in the total gasification of bituminous coal and other fuels in producer gas and water gas generators, and in the operation of blast furnaces with splint coal instead of coke. The resulting tars are either non-cancerous or cancerous only to a slight degree because during the total gasification a certain degree of carbonization has also taken place, mostly under low temperature conditions.

Another general and widespread source of complex high boiling point cancer-causing hydrocarbons and their derivatives is the combustion of organic materials in general, because under these conditions local carbonization often results.

Thus in the case of a fire with a deep layer of coal, or other fuel, or a slow rate of air admission, an appreciable portion is first carbonized and the solid residue then burnt. Some of the gases and vapours evolved may escape complete combustion and consequently the waste gases will contain small amounts of carbonization products. For this reason soot from bituminous coal, that is unburnt or partly burnt solid products deposited in the flues and chimneys, is strongly cancerous.

I suggest these high boiling point hydrocarbon poisons cause cancer mainly by entering the human body in food. Although 60,000 people now die of cancer every year in England and Wales alone, and the number has increased steadily every year for over half a century, while the world death rate reaches terrible dimensions, the cause of almost all the cases that have been known, millions in number, has hitherto been a mystery.

There are, however, three known definite and important causes of a relatively small percentage only of the total cases of cancer, that is (1) soot; (2) coal tar and its fractions, particularly the residual pitch from the high temperature carbonization of coal in manufactured towns gas retorts and by-product coke ovens; and (3) a small proportion of lubricating oil from petroleum, together with shale oil, causing mule spinners' cancer. Coal tar for example has long been used in experimental and research work to cause cancer in mice by painting on the desired spot. This takes usually about 8-12 months, although mice differ greatly in resistance to cancer and as a mouse lives for 3 years the period corresponds to 16-24 years in a human being.

Some other sources of a negligible amount of cancer are known, such as oil shale carbonization, lignite carbonization, and constant irritation of one part of the body, of which an example is cancer of the tongue from smoking a clay pipe.

In all these cases cancer results from direct and long repeated contact of the body with the cancer-causing poisons, as in the case of chimney sweeps, workers in briquette making and other factories using coal tar, and fractions from it, such as creosote and coal tar pitch, and the men who attend to the spinning mules in the Lancashire cotton industry.

Only a very small percentage, however, of the population, even of industrial countries, such as Great Britain, follow such occupations.

In my opinion a large proportion of cancer cases are due to eating contaminated food resulting from the widespread use of manufactured towns gas for cooking under the conditions, as in most designs of gas cookers (ovens), that both the gas to some extent and all the waste combustion products are in direct contact with meat, bread, pies, cakes, biscuits, milk puddings, and other products.

These gas cookers usually have inside, at the bottom, rows of small gas burners, on the "bunsen" principle, and the food is placed in the oven space directly above the burners, being surrounded and "scrubbed" by the very hot gaseous combustion products as they pass upwards, discharging from the upper part of the oven.

Apparently about 7,000,000-8,000,000 gas cookers, mostly of this type, are in use in Great Britain alone, probably in more than 70% of all the houses in the country. Hundreds of thousands are also operating in restaurants, hotels, clubs, and similar establishments, and throughout the world many millions are at work, while the same principle is used for large scale commercial baking, especially bread, cakes, pies, and biscuits.

During recent years also there has been a rapid increase, quite apart from gas cookers, in the drying, cooking, and general heat treatment of food by means of gas under such conditions that the gas flames are in direct contact.

Examples are drying cereals, flour, breadcrumbs, cocoa powder, and hops for beer. In the latter case each portion of hops is exposed continuously for 9-12 hours at a temperature of about 140°F. (60°C.) obtained by means of gas flames fixed in the current of air passing upwards. Bunches of bananas also are ripened in England by exposing them for a long period to warm temperature utilising gas burners. Some other examples are toasting caramels, stripping the skins from small onions for making pickles, and roasting coffee beans, the latter being in contact with gas flames for about 20 minutes.

In general a very large proportion, probably over 80%, of the cooked food of Great Britain would seem now to be brought into contact with manufactured towns gas and its combustion products.

Under the conditions of ordinary domestic and industrial practice it is absolutely impossible to operate the numerous small bunsen gas flames in a gas cooker or internally heated oven at 100% efficiency, that is with complete combustion of the gas to say carbon dioxide (CO_2), water, and a small amount of sulphur dioxide (SO_2), without also using a large excess of air. Because of hot spluttering fat and the evolution of steam, gases and organic products from the food, some of the burners in many cases will not operate efficiently, and part of the gas will escape unburnt, or only partly burnt, and come into direct contact with the food.

As already stated in my opinion most manufactured towns gas contains the same general types of cancer-causing hydrocarbon poisons from two sources, that is carbonization of bituminous coal and heat decomposition of petroleum fractions (gas oil) in making carburetted water gas.

Also these complex poisonous hydrocarbons and their associated hydrocarbons have an extremely high boiling point, nearly always over 650-700°F. (343-371°C.) and often with a melting point over 400°F. (204°C.) being found largely, so far as concerns coal tar, in the anthracene oil fraction, boiling within the range of 518-680°F. (270-360°C.) and the pitch, which is the heavy residue left when the latter temperature 680°F. (360°C.) has been reached.

Most striking of the poisonous hydrocarbons which have been isolated from the coal tar pitch and definitely proved to be strongly cancer-causing by means of mice is 1 : 2 benzpyrene $C_{20}H_{12}$, a derivative of the hydrocarbon pyrene $C_{16}H_{10}$, and associated with phenanthrene $C_{14}H_{10}$, always found in coal tar along with anthracene $C_{14}H_{10}$, of which it is an isomer. Other similar cancer-causing hydrocarbons are probably present, whilst analagous hydrocarbons have been synthesized and proved to be strongly cancer-causing, such as 1 : 2 benzanthracene, 1 : 2 : 5 : 6 dibenzanthracene, and 5 : 10 dimethyl 1 : 2 benzanthracene.

Since the temperature range required for cooking food in an oven is within about 349-500°F. (176-260°C.) cancer-causing products that may escape unburnt from the small gas flames will not be decomposed by contact with the food and can therefore readily be absorbed.

It is possible also that well-known poisonous products almost always present in manufactured towns gas, as delivered to the consumer after the usual commerical purification, such as organic sulphur compounds, especially carbon disulphide, and unsaturated hydrocarbons that are normal constituents, especially ethylene, may play an important secondary part in the matter.

I would suggest further these cancer-causing poisons enter the human body in smoked food, such as fish and animal flesh, consumed in large amount by many civilized and savage races, that has been suspended for a long period in dense smoke from slow burning fuel, often wood. Many food products also, such as malt and hops, are dried very slowly, usually for a considerable number of days, in the combustion products from an anthracite, coke, or charcoal fire, which do not cause smoke, like bituminous coal, although, as already mentioned, manufactured towns gas is now being used to some extent in this field.

These are what may be termed the primary methods by means of which cancer poisons in gases from high temperature carbonization and combustion can be passed to the body, in food with which they have been in direct contact. Such food can be eaten for many years, over half a century, constituting a special variety of extremely slow and continuous poisoning before cancer develops, which almost invariably does not happen until middle and old age.

It is possible also that the cancer-causing poisons present to such a pronounced degree in high temperature carbonization coal tar and coal tar pitch, and probably in manufactured towns gas and its waste combustion gases, can be conveyed to the body in other ways than by direct contact with food.

For example, vast amounts of coal tar, mostly strongly cancer-causing, are spread at intervals over the surface of many thousands of miles of roads, and used in making tar macadam instead of the non-poisonous and non-cancerous natural bitumen and asphaltic bitumen (petroleum residues).

This is bound to result in the presence of cancer poisons in the small amount of dust formed, even with the latest modern roads, because of the enormous motor traffic, and is perhaps the explanation of the increase in lung cancer amongst the drivers of motor vehicles.

Another point is that cancer may be caused to some extent because of the widespread pollution of the atmosphere by escaping manufactured towns gas, coke oven gas, and the waste products of combustion from them, by breathing the poisons and by absorption in liquid food, such as milk. Thus any gaseous fuel, whether poisonous or otherwise, is always liable to leak at joints, taps, and valves, and when burners are turned on before lighting and re-lit because of "burning at the bottom", which causes a luminous flame. Gas rings, grillers, and toasters, as well as incandescent gas lights, discharge the whole of the combustion products direct into the atmosphere of kitchens, bedrooms, and other living-rooms. A very large proportion of gas cookers (ovens) also contribute to the pollution, and the same applies to an appreciable percentage of gas fires, provided with no outlet flue. Many gas fires also are fixed in front of empty open grates intended for solid fuel so that the degree of ventilation obtained is almost non-existent.

Gaseous fuel, however, is not the only source of pollution of the atmosphere in houses and other buildings. The population of the world is about 2,000,000,000 and making full allowance for nomadic races, presumably this means at least 300,000,000 homes that are more or less a fixture, and use fuel, if only for cooking.

In a huge proportion of these homes some type of slow-burning closed stove, clay or mud oven, or similar contrivance is used, very liable to pollute the atmosphere with combustion products, which may be slightly cancerous. Another factor of great importance is the motor vehicle, which to the extent of many millions in number is discharging to the atmosphere waste combustion products from the internal combustion engines, using petrol, benzol, and alcohol.

Carbon monoxide also in waste combustion gases burning any type of fuel, gaseous, liquid, or solid, is another possible secondary cause of cancer, quite distinct from the high boiling point hydrocarbons.

A further possibility, in view of the remarkable research work that has been undertaken recently on cancer-causing hydrocarbons, especially since 1932, is that these various harmful influences in the atmosphere, such as from the manufactured towns gas industry, motor vehicles, and closed stoves, may affect the liver and cause the secretion of cancer-causing hydrocarbons in the bile. Thus methylcholanthrene, a phenanthrene derivative, made in the laboratory by breaking down bile, is strongly cancer-causing.

In general, however, I contend that carbonization under high temperature conditions and general decomposition by heat of carbonaceous materials are the main causes of human cancer throughout the world, both by direct contact with the body, as in the case of soot and coal tar pitch, and by eating food that has been in contact with the gases, as represented particularly by the use of the average gas cooker (oven), and by the smoking of meat and fish.

With regard to mule spinners' cancer, apart from the admixture of shale oil in the lubricating oil, I suggest that certain varieties of petroleum oil are slightly cancerous because of the fact that the oil has been formed in the earth's crust at some such temperature as 932-1292°F. (500-700°C.) or over, higher than the average, since most petroleum oil is non-cancerous.

There is still no cure for cancer, although drastic surgery and analogous methods, such as the use of "X"-rays and radium, are partial remedies. Until the cause, or the main cause, of cancer is discovered it will be almost impossible to find a cure, except by a lucky accident. Once however the cause is known a tremendous advance will have been achieved since effective steps can then be taken to prevent people being attacked by cancer and there is much more possibility of a complete cure being discovered for those who have already contracted the disease.

This first chapter of the book, which throughout I have tried to write in non-technical language, not easy in some sections, is an attempt, regardless of a certain amount of repetition, to summarize the new theory in advance so that understanding of the following chapters will be easier. These will deal, in the following order, with a definition of cancer, statistics, the present methods of attempting to cure cancer, and some previous theories as to the cause.

Following this is a more detailed consideration of the known causes of individual cases of cancer, especially soot, coal tar and coal tar pitch, and lubricating oil in connection with mule spinners'. Next is a discussion on changing factors in national life, say during the past 50 years, that might cause cancer, such as increased speed, physical and mental, black smoke, motor vehicle exhaust, the wholesale scientific faking of food, the huge increase in the consumption of refrigerated meat, fish, and other products, and also tinned food, tobacco smoking, and the use of aluminium cooking vessels.

All these, however, do not seem to offer much encouragement in the search for the cause of cancer, but very striking is the position with regard to manufactured towns gas, which comes from a strongly cancerous source. The total number of consumers, in practice also corresponding very largely to the domestic consumer and the use of gas cookers, shows a steady and relatively rapid rise for many years, while Great Britain is not only one of the countries worst afflicted with cancer but also uses more towns gas per head of the population than any other.

I have then explained the circumstances under which the new theory originated, and followed it up with a description of the manufactured towns gas industry, historical, technical, and statistical, and the composition and properties of the gas, considered primarily in relation to cancer.

Also there is discussed the complicated and interesting subject of the possible relation between cancer and continuous slight carbon monoxide poisoning to which a considerable proportion of the human race is liable from motor car exhausts, manufactured towns gas, and incomplete combustion, especially with the solid fuel closed stove type of apparatus.

A brief description is given of a new method now being developed in Germany for the "detoxification" of towns gas, that is to convert the highly poisonous carbon monoxide, averaging about 15-20% in most gas, to hydrogen without reduction in the heating value. This method may be of great interest also in connection with the removal of any cancer-causing hydrocarbons.

Two other chapters deal with the composition and properties of coal tar and coal tar fractions and particularly the cancer-causing hydrocarbons, and of other carbonization and gasification tars and crude oils and of petroleum.

A separate chapter is devoted to a subject, which if this cancer theory is correct, becomes of primary national importance; that is efficient and healthy methods of lighting, heating, and cooking.

The concluding chapter is concerned more particularly with suggestions as to what should be done to prove or disprove the theory, both experimentally and in the way of obtaining much more statistical information, together with the methods that should be adopted immediately in regard to controlling the use of the highly cancerous coal tar and coal tar pitch.

It may be stated also that the first and preliminary description of this theory was described in an article "The Cause of Cancer" I wrote in the September 1937 issue of the *Engineer of India* (London, Vol. XXXI, pp. 139-142).

CHAPTER II

DEFINITION OF CANCER

EXPRESSED in simple language, cancer is a peculiar variety of malignant tumour, growth, or swelling. The human body may be afflicted with various types of growth, some of which are not dangerous, such as rashes, skin eruptions and local roughness, pimples, blisters, warts, wens, moles, ulcers, boils, carbuncles, and non-malignant tumours. These, however, are not cancer, although a number have relationship and common source of origin, such as direct skin contact with high temperature carbonization coal tar and coal tar pitch and breathing the atmosphere of tar and petroleum refineries.

Further, cancer is a malignant tumour, of different types and forms, that may occur in almost any part of the body, although often near the surface and in various inner parts such as the tongue, throat, and bowel, with a tendency to spread by secondary growths towards the end of the development. Undoubtedly cancer is the most ghastly of all diseases, causing as a rule terrible agony, often spread over a number of years.

Cancer also is a group of cells of the human body, more or less extensive in number, that have ceased to carry out their normal or original function in relation to the rest of the body, and develop independently and often rapidly in arbitrary fashion, with disastrous results. That is the human body, like most other forms of animal and vegetable life, is composed of millions of cells sub-divided into hundreds of types, each of which undertakes a specific function or duty essential to the body, and therefore to all the other types of cells, under some form of centralized or co-ordinated control from the brain. For example, very many different types of cell are concerned with primary functions such as sight, hearing, breathing, digestion, reproduction, and excretion. If all the types of cells, or even one type, connected with one primary function, such as breathing, cease to function or to carry out their share of the vital work of the whole body, then life ceases.

Cancer is essentially this action of uncontrolled growth or refusal of cells to continue with their normal specialized duties in a portion, or portions, of the body, and on such a scale that the latter cannot cope with the trouble. The body has many active and complicated systems of defence, such as for example the white corpuscles of the blood and the ability to develop anti-toxins and therefore partial or complete immunity against many diseases.

It is familiar knowledge that the bodies of many races have gradually developed over a long period a strong natural resistance against certain diseases, such as measles which will almost wipe out other races to whom such diseases have hitherto been unknown.

Probably given unlimited time, say very many centuries, the human body would build up a defence against many kinds of poisons and diseases at present fatal. Thus arsenic workers are stated not to be affected by doses that would kill normal people, and many such examples are known in the chemical and allied industries.

In the case of a non-malignant tumour what may be termed an internal wall of defence is developed by the body so as to isolate the abnormal portion. With cancer, however, the body has not yet been able to evolve an effective defence, and more and more serious disorganization results, with eventually death. But the body almost certainly fights to the utmost against cancer and slows up the action, apparently in some cases with such success as to effect a cure, although this is rare. Thus most natural fats have a protective action against skin troubles and this may also be the case with cancer.

CHAPTER III

CANCER STATISTICS

THE statistics of cancer, past and present, in the human race are lamentably incomplete and have almost no existence so far as most non-industrial and semi-industrial countries are concerned. How many people die of cancer every year throughout the world is not known definitely, but the number must be enormous.

There is no question, however, that in modern industrial countries deaths from cancer have increased in regular and relentless fashion for many years past, and this tendency still continues, although another complication is the increase in the average life of human beings. At the present time 60,000 people, a terrible total, die every year from cancer in England and Wales alone, which is about 12% of the deaths due to all causes, approximately 500,000 per annum, including old age. At any one time also there are at least 150,000 people in England and Wales suffering from cancer.

The death rate from cancer has, according to the available statistics, increased steadily in England and Wales for at least 80 years, as follows:—

DEATHS PER 1,000,000 FROM CANCER (ENGLAND AND WALES).

Year or Period of Average Years.	Deaths.
1847–1850	274
1861–1865	367
1876–1880	494
1886–1890	632
1901–1905	867
1911–1915	1055
1921 —	1229
1925 —	1336
1928 —	1425
1934 —	1563

The same tendency is shown in most civilized countries. For example in the United States the cancer death rate of 50 of the chief cities in 1906 was 716 per 1,000,000 and in 1929 the figure was 1178, somewhat less than in England and Wales but advancing at the same rate. Approximately New York at the present time has a cancer death rate of about 1100-1200 per 1,000,000 as against 1500-1600 for England and Wales, while in Switzerland the figure seems to be about 1400-1450. Some countries are stated to be much lower, such as 900-1000 for Australia and 600-650 for Italy, whilst South American countries are given as only 125-150 per 1,000,000.

One of the great difficulties, however, is the possible lack of accuracy, as well as the incompleteness, of cancer statistics. Also even in such advanced countries as Germany, Great Britain, and the United

States, the earlier statistics may be incorrect, with many deaths diagnosed wrongly.

Nothing very definite is known concerning the statistics of cancer amongst savage and semi-civilized races, or when cancer first appeared. The general opinion, however, is that almost all races are subject to cancer to a more or less degree, and if this is the case, cancer may have occurred for ages past. It is believed also, apparently on somewhat scanty evidence, that animals, birds, reptiles, fishes, and even plants may have cancer or some equivalent nodular irregular tumours or growths and derangement of normal cell functions. Many animals can of course be given cancer, say by the continual application of high temperature carbonization gas works tar or coke oven tar, and as stated the standard method used in cancer research is to utilize mice in this way. Whether cancer develops to any appreciable extent in many forms of animal life in the natural wild state is not known with certainty.

A detailed study of the statistics seems to show, in spite of their incomplete character, that cancer is to a considerable extent a disease of civilization, although there are many exceptions. Also that Great Britain, although far ahead of the average in sanitation, cleanliness, and general good health, is one of the worst countries for cancer.

Cancer also is essentially, with individual exceptions, a disease of middle and old age, and of slow and gradual growth. Most deaths from cancer take place within the range of about 35-65 years of age, and death is very rare from this cause below 25 years.

Little difference exists between men and women as regards the percentage of deaths from cancer compared with total deaths, but the location is remarkable. Cancer in women very largely occurs, to the extent of about 40%, in the generative organs, the breasts and the womb, but in men the chief areas are the tongue, mouth, throat, and small and large bowel, and rectum.

Statistics of cancer, say as regards Great Britain, also show all kinds of tendencies and possibilities, which on close study are however mostly found to be vague and indefinite, and lead nowhere. For example, cancer is more prevalent in large towns than in country districts, although the latter also suffer severely. Some counties also, such as Devon, suffer more from cancer than others. The number of deaths in ordinary trades and occupations conveys no information of any value, as quite distinct from the special cases where contact takes place with soot, high temperature carbonization towns gas and coke oven gas, coal tar and coal tar pitch, shale oil, and to a limited extent petroleum oil.

Thus agricultural labourers tend to have a low cancer death rate and the same applies to doctors and clergymen, whereas butchers, sailors, and lawyers are above the average. Jews seem to be just as liable to cancer as Christians, while in Great Britain cancer attacks the tongue and the digestive tract more than in Germany and Holland. Many similar observations can be made.

The vital subject of statistics is rendered all the more difficult because of the secrecy being maintained, presumably with the laudable intention of not alarming the community. For this reason the cause of death is almost never published in Great Britain when cancer is concerned and no reference to the subject is made in the present campaign for national fitness. I think such a policy of official secrecy, as in most other matters, is wrong both from the moral and the practical point of view, and it would be much more in the true interests of everyone to give the fullest publicity to cancer.

CHAPTER IV

PRESENT METHODS OF ATTEMPTING TO CURE CANCER

In spite of the tremendous efforts that are being made throughout the world by a whole host of devoted workers, including surgeons, X-ray and radium experts, and organic chemists, as well as many public-spirited people who are not scientists, there is still no cure for cancer.

The only partial remedy is to destroy, in drastic and elementary fashion, the malignant tumour or growth, that is to cut it out of the body with knives or equivalent electric apparatus, or to bring into action very high voltage X-rays or radium in such a manner as not to damage to any extent the healthy flesh.

There seems to be no conclusive evidence that either X-rays or radium is a definite cure, and no guarantee exists that if the cancer is removed by the above methods it will not return. In thousands of cases also, depending upon the locality, the damage that would have to be done by the operation would itself be fatal.

One important point, however, is to deal with the cancer at the earliest possible stage of development, when complete cures can often be effected by operation, and apparently also by X-rays and radium.

When the cancer is at or near the surface of the body there is obviously much better chance of success, and modern surgery has now reached such a high stage of development that about 80% of operations for cancer of the breast are a success. According to some statements also, up to 90% of lip and skin cancer can be cured by radium.

It is obvious, however, that to "cure" say a bad leg by the desperate remedy of cutting it off by a major surgical operation to save the rest of the body is not a real cure, either in the scientific or the popular sense of the term.

Cancer is still to-day in a much worse position, because deep-seated internal cancers cannot even be cut out, and on present knowledge (September 1937) there is no drug, chemical, serum, vaccine, or injection that seems to have any even partially beneficial effect. In this connection, however, new developments are the claims that snake venom and mustard gas will kill cancerous growths. Also literally hundreds of different cancer "cures" have been proved to be of no value.

CHAPTER V

PREVIOUS THEORIES OF THE CAUSE OF CANCER

THE cause of cancer and of this abnormal action of groups of cells forming part of the body has long been to use the term of the Royal Cancer Hospital (London) a "tragic mystery". All kinds of theories have been brought forward, one group of which is concerned with the action of specific bacteria. Until the present time, however, whatever may be the case in the future, no such bacteria has ever been isolated or proved to exist. Also cancer is not infectious, contagious, or hereditary, although many opinions to the contrary have been held.

In this connection it is often stated that various old houses, almost always in country districts and rarely in a large town, have caused cancer in a number of people, and are—or were—popularly called "cancer houses". The evidence for this is conflicting and inconclusive, although possibly continual slight leakage of manufactured towns gas, sewer gas or fermentation gas from decaying vegetable matter may play some part.

Similarly in various parts of England the opinion is held that certain villages, generally low lying and with bad drainage, or situated near swamps or other water, either stagnant or running, tend to cause cancer much more than other villages situated high up in the hills.

Definite inorganic poisons have also been supposed to be the cause of cancer. For a long period traces of arsenic were suspected, and for example cancer was stated to be prevalent to an unusual extent amongst tin and copper miners, the ores of which generally contained compounds of arsenic. Similarly miners in Germany dealing with copper, bismuth, and arsenic ores were stated to be liable to ordinary tumours and to cancer, while arsenic was also regarded as the cause of the cancer-causing properties of soot.

There is, however, no evidence that arsenic causes cancer, and for example miners in other arsenic mines, such as in Styria, do not suffer from cancer to any unusual degree. As already indicated also, many chemical workers are apt to take relatively large doses of arsenic, fatal to an ordinary man, and no cancer results.

Many theories of cancer have very naturally been concerned with food. For example, it is claimed the cause is deficiency of potassium salts in the blood. Roughly potassium is present in vegetables and salt (sodium chloride) in meat, and the two salts seem to be antagonistic in some way. The theory is that cancer results from too much salt (sodium chloride) both eaten direct, and added to food, and not sufficient potassium salts. This lack of potassium also results from eating insufficient vegetables, especially in the raw state, and tends to increase during old age. Similiarly deficiency of magnesium salts is another theory.

No real evidence appears to exist that sodium, potassium, or magnesium salts have anything to do with cancer, and the whole complicated subject of eating different types of fresh animal and vegetable food, and of different special diets, seems to play a negligible part in the matter. In fact vegetable foods have been much more blamed for cancer than flesh foods. For example tomatoes were once regarded as the cause, as well as beet sugar, supposed to be much more injurious than cane sugar.

There is no evidence also that either an excessive or deficient amount of food is a factor of importance, and a fat, wealthy, well-fed man seems to be just as liable to cancer as one who is thin, poor and half-starved.

Even in Great Britain, a relatively well-fed country, at least 25,000,000 people are living upon unsatisfactory and uninteresting food, and of these probably 5,000,000 are on the verge of actual starvation. A large part of the human race, certainly well over 1,000,000,000 people, have insufficient food to a chronic degree, and for example the Final Report (August/1937) of the Mixed Committee of the League of Nations (Geneva) appointed to investigate the relation of nutrition to health, states that millions of people are suffering from inadequate physical development or from disease due to insufficient nutrition, or are living in sub-normal health that would be improved if more or different food was consumed.

The world could very easily produce enough food not only to provide an ample supply for every human being, but to feed twice the present total population.

Starvation, however, any more than over-feeding, cannot be proved to result in an increased tendency to cancer, and the same applies to good or bad housing, lack of warmth, bodily weight in proportion to height, lack of physical exercise, and worry.

There also appears to be no connection between cancer and many other diseases, although theories of this type have been evolved. People suffering, or that have suffered, from say chest and nasal troubles, hay fever, asthma, rheumatism, constipation, and syphilis, do not—on present knowledge—take cancer more than those who have always been free from such troubles.

Drunkards, excessive tea drinkers, heavy tobacco smokers, and drug takers are not afflicted with cancer to any more appreciable degree than those who live abstemious and reasonable lives, even to the extent of being teetotallers and non-smokers.

It is obvious therefore that cancer results from some subtle and widespread cause that bears no relation to a whole host of factors and conditions in human life.

CHAPTER VI

KNOWN CAUSES OF INDIVIDUAL CASES OF CANCER

Obviously in endeavouring to find the cause, or causes, of cancer in general, that is all human cancer, it is necessary to consider in full detail the facts concerning any causes known to be responsible for even a small portion of the cases.

On studying cancer statistics it is abundantly clear that the only definite causes of importance, about which there is no possible dispute, are (1) soot; (2) high temperature carbonization coal tar from manufactured towns gas retorts and by-product recovery coke ovens, and, to a lesser extent, other carbonization tars and crude oils, especially shale oil, and (3) certain varieties of lubricating oil that result in mule spinners' cancer.

It has been known in Great Britain for 150 years that chimney sweeps suffer severely from cancer, and especially in the scrotum, which is still called "chimney sweep's cancer". Because of the crude hand methods long adopted in cleaning chimneys the sweep was brought into thoroughly effective contact with soot, which proved in unmistakable fashion the presence in the latter of active cancer-causing poisons. Thus at one time over 20% of the total deaths amongst sweeps in Great Britain were due to cancer and even at the present day, with modern relatively small and straight chimneys, sweeps are very liable to cancer, although the number of deaths has been much reduced.

A remarkable fact also is that chimney sweep's cancer seems to be almost peculiar to Great Britain. This may be partly due to the use of the characteristic English open fire, different from the closed stove of Canada, France, Germany, the United States, and many other countries. Apart from this, however, it is also another indication of the fact, to be discussed, that many varieties of British bituminous coal seem to be particularly liable to the formation of cancer poisons.

The soot in the domestic chimneys of Great Britain is, with rare exceptions, due to bituminous coal, and it is not known definitely whether soot from the burning of other solid fuels, such as lignite, peat, and wood, is cancer-causing to an equal extent. Apart from the practical proof that the soot from bituminous coal in British chimneys causes cancer by direct continuous contact with the human body, it has been proved experimentally that soot causes cancer in mice. In this connection, for example, reference can be made to a contribution "Experimental Soot Cancer", by Dr. R. D. Passey of Guy's Hospital in the *British Medical Journal*, 9th December, 1922, pp. 1112-1113.

Soot, therefore, largely composed of carbon and of complicated high carbon content hydrocarbons, some of which are fatty or greasy in character, contains a small amount of very active poisons that cause death from cancer in human beings.

Much the most serious and important definite cause of cancer in Great Britain, however, is coal tar obtained in the manufactured towns gas and metallurgical coke oven industries, and especially the residual pitch from the tar. The worst sufferers are workers in the briquette (patent fuel) industry, in which more or less finely divided coal, especially anthracite "smalls", is mixed with 8-10% by weight of hard coal tar pitch and compressed under very high pressure, about 1-2 tons per sq. in., in briquette presses. Pitch used in this way acts as a plastic binder and forms more or less hard and resistant briquettes or shapes, such as ovoids, tablets, and rectangular blocks.

Coal tar pitch used for briquetting causes more than 50% of all the notifiable cases of cancer in Great Britain, that is definitely caused by industrial employment and therefore have to be notified by the employer to the Home Office, as in the case of other dangerous diseases. For example, according to Sir Thomas Oliver in a contribution in the *British Medical Journal* (London, 1930), pitch from gas works and coke ovens used for briquetting was responsible for 66 cases of notified cancer out of a total of 95 cases in England and Wales during the period January 1920 to June 1922.

Workers in briquette plants in Great Britain also suffer severely not only from cancer but from rashes, warts, boils, ulcers in the stomach, and general skin troubles, as well as a swarthy appearance, loss of appetite, drowsiness after food, and vomiting. In the old days also, due to grotesque ignorance and inefficient Government regulations, the working conditions in briquette plants were almost incredible, with the hard solid pitch broken up by hand with picks and the grinding carried out without the slightest precautions against the cancer-poisoning dust.

All workers, however, connected with coal tar and coal tar pitch from high temperature carbonization towns gas and coke oven plants suffer much more than the average from cancer and from the associated troubles of warts, boils, ulcers, and skin troubles. This applies, for example, to tar distilling, the manufacture of tar-macadam (mixing broken stone with coal tar), cable making, ship repairing, net fixing, and felt proofing. Unhealthy jobs also in manufactured towns gas and coke oven plants are those in which contact is made with leaking hot gases and vapours, tar, and pitch, such as from hydraulic mains, tar sumps and traps, and tar stills.

Similarly the use of coal tar fractions, such as creosote, gives rise to much general skin trouble and an amount of cancer much above the average. Examples are creosoting timber and brick, tile, and sanitary pipe pressing, in which the clay shapes have an outer film of creosote.

One of the most interesting papers on the subject is that by Dr. S. A. Henry (H.M. Medical Inspector of Factories) entitled "Cancer in Relation to Occupation", read 14th November, 1929, at Bradford (Yorkshire), before the Society of Dyers and Colourists, West Riding Section (*Journal*, March 1930, pp. 61-69). He gives the following list of occupations relating to 439 cases of skin cancer investigated that were caused in England and Wales by pitch, tar, and tar products during the years 1920-1928 inclusive:—

Patent Fuel Manufacture (Briquetting)	183
Tar distilling	118
Coal gas manufacture	65
Pitch loading (as at wharfs)	22
Coke ovens	8
Brick, tile and pipe manufacture ..	6
Cable manufacture	6
Creosoting timber	6
Anthracene manufacture	5
Net fixing	4
Barge repairing	3
Felt proofing	2
Other industries	11
Total ..	439

Coal tar distilling, therefore, is another particularly dangerous operation, and the same applies to towns gas manufacture, although curiously enough by-product coke ovens show only a few cases.

The general recognition of the cancer-causing and other unhealthy and dangerous properties of gas works and coke oven tar and pitch is well indicated by the clauses of the Workmen's Compensation Act which refers to:—

> "Epitheliomatous cancer or ulceration of the skin . . . due to tar, pitch, bitumen, mineral oil, paraffin or other compound product or residue of any of these substances."

Originally the Workmen's Compensation Act of 1906 was intended to apply mainly to briquette workers because of the serious extent to which they suffered from cancer and all kinds of skin troubles. The Act was shortly afterwards altered to include the workers in the Scottish oil shale industry because of the prevalence of cancer and skin diseases in the latter connection.

A striking state of affairs obtains with regard to the workers in the briquette industry in the United States, who suffer no more from cancer or skin troubles than the rest of the population, entirely different from the position in Great Britain. The reason is that the binder almost entirely used in the briquette works of the United States is "asphaltic pitch" or "asphalt", that is the heavy bituminous residue from the distillation of petroleum oil. As already mentioned, most petroleum is non-cancerous, and poisonous high temperature carbonization coal tar now finds little use in the United States for briquetting because the asphaltic pitch is often cheaper and just as efficient.

A considerable portion of the coke oven and gas tar is merely burnt as a fuel for iron and steel furnaces, but there is also extensive distillation of the tar for the production of light oils, phenols, creosote, naphthalene, anthracene, and other products. The resulting pitch is mostly used for roofing felt, painting, insulating dry batteries, coating pipes, and manufacturing carbon black.

It should be pointed out also that the briquette plants in the United States, as in Germany, appear to be in general more up-to-date and hygienic than in Great Britain. Thus the binder is melted separately in closed steam jacketted pans and the liquid blown by compressed air direct to the mechanical mixers, also closed, followed by discharge to the briquette presses so that practically no dust escapes into the air.

Apart from this, however, the briquette industry seems to confirm that the average bituminous coal of Great Britain, of particularly high-grade quality both for combustion and coking, produces cancer-causing poisons under the conditions of high temperature carbonization to a degree much above the average.

A remarkable confirmation is given by Dr. Imre Heller in the *Journal of Industrial Hygiene* (Baltimore, May 1930). In a plant in Cleveland (U.S.A.) carbons for dry batteries were made by compressing a mixture of lampblack, pulverized coke, light coal tar oil, and medium soft coal tar pitch, and heating in a furnace. The workers also were exposed to the pitch fumes and to pitch dust from the grinders. Until 1906 a large amount of English coal tar pitch from gas works was imported and much trouble had always been caused, not only by cancer but also warts and general skin troubles, including roughness, thickening, and local irritations.

In 1906 this English gas works pitch was replaced by home-produced high temperature carbonization coke oven pitch, and most of the skin troubles began to decline, and eventually vanished. At the same time some modifications were made in the process which resulted in a certain degree of improvement, such as mechanical ventilation and dust collection, and the use of hydraulic moulding machines for making carbon plates instead of moulding by hand.

The management of the factory, however, were positive the almost sudden great improvement in the general health condition of their workers was due to the replacement of the English pitch, and there is no reason to doubt this contention. Dr. Heller states also that in the 10 years 1920-1930 a total of 21 cases of cancer developed amongst the staff, 19 being from the pitch workers. Of the latter 15 had used the English pitch up to 1906, and it will be remembered that cancer is generally of very slow growth.

Mule spinners' cancer, long known in the Lancashire cotton industry, has now been proved to be due to the constant close contact of the human body with lubricating oil containing cancer-causing poisons. An attendant of a spinning mule has to walk backwards and forwards, and lean over a bar to attend to the threads. In the hot and high moisture content atmosphere of the mill the spinners wear little clothing, and often have bare feet. Everything also is saturated with lubricating oil. Under these conditions the body is subjected to continual slight friction whilst in constant contact with the oil, and the result is a serious amount of cancer, chiefly of the scrotum. Sometimes, however, mule spinners take cancer in other parts of the body, but never in the feet, walking on the oily floor, because the skin at this point is always thick and tough.

Mule spinning was long the third most dangerous occupation in Great Britain as regards cancer, inferior only to briquette workers (pitch) and chimney sweeps (soot). The other workers in the cotton industry, such as the weavers, are no more subject to cancer than those in average industrial employment.

A notable publication in this field is the *Report of the Departmental Committee Appointed to Consider Evidence as to the Occurrence of Epitheliomatous Ulceration Amongst Mule Spinners* (British Government, H.M. Stationery Office, London, 1926), which gives a record of 539 cases of skin cancer in mule spinners since 1876. Also Dr. S. A. Henry in his paper (1929), already mentioned, states that out of 546 cases of skin cancer due to mineral oil in Great Britain in the period 1920-1928 inclusive, 462 were mule spinners and 30 represent shale oil refining.

The Manchester Committee on Cancer have concentrated upon mule spinners' cancer and proved in the first place that some of the lubricating oil used caused cancer in mice. It was found also that the qualities made from shale oil were more dangerous than any petroleum oil, whilst all animal, fish, and vegetable oils, such as neatsfoot, sperm, and olive, are completely free from any trace of cancer-causing poisons.

After detailed and laborious work with mice, qualities of mineral oil from petroleum that caused cancer could be identified, and recently a new and rapid method of detection has been discovered, depending upon the refractivity and to some extent the viscosity. Consequently to-day cancer-free petroleum lubricating oil for mule spinning frames is available, having been treated chemically in simple fashion or obtained from crude petroleum oil containing no poisonous material, which applies to most of the varieties available.

Mule spinners' cancer also is almost unknown in United States cotton mills, although the same machinery and process is used. In many cases the spinners actually belong to the same race, that is men from Lancashire who have gone out to work in the States. Obviously the only difference between British and United States mills is the lubricating oil.

Because of the high scientific development of lubricating oil blending that has been achieved to-day, it is extremely difficult to determine the composition of any given oil, which may contain petroleum from a number of different oil-fields and of countries, as well as animal, fish, or vegetable oil and shale oil.

Not only may the average lubricating oil in the United States used for mule spinning contain, on the average, much more non-cancer causing petroleum oil and non-petroleum oil, but also the chemical treatment may be different, tending to destroy any cancer-causing products. Thus much of the petroleum lubricating oil used in the United States is treated with concentrated sulphuric acid, which decomposes the unsaturated constituents, such as higher olefines, by polymerization. The same general result is obtained by the use of sulphur dioxide or bromine.

However, the cause of mule spinners' cancer in Lancashire has definitely been determined, so that it is to be hoped this limited though definite source of cancer will now be removed for ever, although the matter still seems to be complicated and differences of opinion exist.

With regard to various minor causes, it is well known that cancer has sometimes resulted from long-continued irritation or damage of some part of the body, such as a blow, a jagged tooth, gall stones, syphylitic ulcers, continually drinking very hot liquid, use of metal body warmers containing burning charcoal, and X-rays. Many of the early pioneers of X-ray work suffered terrible injuries, necessitating repeated local amputations, from "X-ray cancer", although whether this was cancer in the ordinary sense of the term does not seem clear.

There has been also a certain amount of cancer of the tongue, popularly supposed to be due to irritation from smoking clay pipes. The theory is that the clay has a strong attraction for moisture, which is taken from the tongue at the point of contact and eventually causes a sore that sometimes developed into cancer. For this reason the mouthpiece part of the pipe stem generally received a protective coat of paint. However, this is of no direct interest to-day since the clay pipe has almost vanished in Great Britain, because of cigarettes and the cheap wooden briar pipe. As will be discussed, there is no evidence that tobacco smoking in general causes cancer. There is also a small amount of cancer of the bladder from aniline oil and other intermediates, known as aniline cancer, but this may be due to impurities.

The facts are therefore, which had already impressed me strongly a considerable number of years ago, that the only definite known causes of cancer are soot, coal tar and coal tar pitch obtained by the high temperature carbonization of bituminous coal in towns gas retorts and coke ovens, and lubricating oil from petroleum oil and from shale oil under the special conditions of mule spinning, especially in the cotton industry of Lancashire. Added to this, to a very limited extent, is accidental damage to the body.

These definite causes, however, are only responsible for an extremely small proportion of the huge number of deaths from cancer, amounting—as stated—to 60,000 per annum in England and Wales alone, and what is responsible for the rest has hitherto been unexplained.

CHAPTER VII

CHANGING FACTORS IN NATIONAL LIFE THAT MIGHT CAUSE CANCER

SINCE cancer has continued to increase steadily every year in Great Britain for at least 50 years, and especially during the last 30 years, and afflicts middle-aged and old people in every section of the community in town and country, the cause must be some fundamental change in the national life.

In the first place it is necessary to emphasize that during recent years enormous improvements in general health and sanitation have been effected in Great Britain. Thus the water supply has reached such a stage of average purity because of scientific control, including chlorine gas sterilization, that water-borne diseases such as cholera have almost vanished. Sewage treatment and drainage have improved, there is less vermin, and housing accommodation and ventilation are better. Personal cleanliness also has been completely revolutionized during the past half century.

In 1880, for example, there was a fixed bath in very few middle-class or upper-class houses, and none at all in working-class houses. A considerable proportion of the community regarded it as a species of sin to wash the body regularly all over in one operation. For many years past, however, almost every new house or flat in Great Britain, large and small, has been provided with a fixed bath, which is justly regarded as essential as a water closet. Public swimming baths and bathing pools now exist literally in thousands. More people keep their teeth in a healthy condition and fresh air exercise, especially golf, tennis, walking and cycling, as well as exposure of the body to the sun, have made giant strides.

The position of women has also been completely revolutionized in the past 25 years, especially as regards short hair kept thoroughly cleaned and groomed, the playing of games, motoring, and the scrapping of voluminous, heavy, and dirty clothes. Obviously girls of to-day, say 15-17 years of age, are on the average taller, heavier, quicker in action, and much more healthy, than the corresponding girls even of the pre-War (1914) period. Many dangerous diseases also, such as smallpox, bubonic plague, and hydrophobia have been almost eliminated, and a large number of others, such as diphtheria and scarlet fever, are kept in check, whilst deaths from tuberculosis have been reduced enormously. During the past 50 years also the death rate has come down from 18.7 per 1,000 to 9.2 and the infantile mortality from 138 to 59 per 1,000 while the average expectation of life has risen by nearly 20 years.

It is all the more extraordinary, therefore, that under these beneficial and improving circumstances such a terrible disease as cancer should continue to advance.

During the past 30 years a considerable number of changes have taken place in the national life of Great Britain which might possibly play a part in causing cancer. For example, life has quickened up enormously in speed, physically and mentally, with telephones, wireless, cinemas, multiplicity of newspapers and periodicals, motor vehicles, speedboats, and aeroplanes.

It is not easy to realize the vast difference in this respect between say the years 1937 and 1887, especially in large towns. There is, however, no shred of evidence that as a result the human body is less able to resist cancer, or has deteriorated in any way. All the facts show the reverse. Thus one of the most striking indications is the manner in which not only has the average length of life increased but also the mental activity. In 1887 a large proportion of men and women of say 65 years of age were haggard old people, largely bed-ridden or otherwise physically helpless, and more or less of feeble and rapidly decaying intelligence. To-day most men and women of 65 years and over are just as mentally active and alert as they were in youth and middle age, while even the actual physical difference as compared with middle age, say 40-50, is often surprisingly small.

In the World War of 1914-1918 millions of men withstood long continued heavy shelling with high explosives and exposure to hardships in trenches of a character far beyond anything previously experienced in the world's history, which shows there has been no deterioration.

Many major diseases of the human race come from air, water, and a large proportion of liquid and solid food, that is, are taken through the mouth (or nose) and down into the body. Almost certainly also various minor diseases and much of the general "out-of-sorts" feeling come from the same source, including the common cold, costing hundreds of millions of pounds per annum, including £400,000,000 per annum in the United States for wages alone. Thus in Great Britain, in any given day in winter, about 10,000,000 people have colds.

It seems obvious that cancer is not a water-borne disease, and general pollution of the atmosphere with smoke, dust, and acid sulphur compounds (from the combustion of the considerable amount of sulphur in coal) hardly appears to be a primary cause. A large number of people, including sailors and farmers for example, not exposed to general atmospheric pollution from combustion, die of cancer.

Black smoke is highly objectionable, and often dangerous, for many reasons, and it may contain a trace of the cancer-causing poisons in the soot, which is deposited almost entirely in the flues before reaching the chimney exit. Direct connection of atmospheric pollution with some cases of cancer, such as of the lung is therefore a possibility.

A great change in the life of Great Britain, especially since about 1900, is represented by the motor vehicle, of which to-day over 1,000,000 are in service. These are almost entirely operated by the internal combustion engine using petrol (very low boiling point petroleum fractions) and to some extent benzole (from the carbonization of coal and other solid products), and also alcohol. Since the question of internal combustion engine exhausts is largely concerned with carbon monoxide poisoning I will discuss the subject later, but it seems doubtful if motor vehicles are responsible for any large amount of cancer from hydrocarbons.

That the cause is connected with food, and especially solid food, appears to be much more likely. During the past 50 years a number of pronounced general changes have taken place in connection with food in Great Britain. First there is the question of the quality and freshness, which on the average has improved. Increased stringency in the general inspection of meat, fish, milk, and other products is now in vogue, and the more impudent and reckless methods of wholesale food adulteration have been largely prevented.

Thus a large number of countries now have a complicated collection of laws and regulations relating to food, along with public analysts and many different types of food inspectors and other officials to fight food producers, and undoubtedly this has prevented a considerable portion of the human race from being wiped out by poisoning and disease. Probably also the average cleanliness of kitchens and storerooms in shops, hotels, restaurants, and other establishments, although still deplorable, has improved to some extent.

The present position, however, in Great Britain, with regard to food faking, especially from the legal point of view, is scandalous, and a considerable proportion of the total ill-health of the country is probably due to this cause. We have now reached the stage when the terms for scores of standard articles of diet, such as "jam", "cream", "custard", "pork sausages", "potted lobster", and "ox-tail" soup, to mention a few examples at random, have no longer any specific meaning.

The law in general refuses to compel the food producer to state what is the exact composition of the food he sells, and except in rare cases to prosecute him either as a swindler for obtaining money by fraud, or as a serious criminal affecting the health of hundreds of thousands of people. Consequently instead of all raspberry jam being made, as the name indicates, of fresh raspberries and cane or beet sugar only, much of it may contain other cheap fruit, such as apples and commercial "pulp", glucose, gelatinous substances, and artificially prepared colouring and flavouring materials, which are synthetic organic compounds. Cream buns to-day we understand in most cases contain no cream, and much commercial custard, which should be made of fresh eggs and fresh milk, appears to be largely starch paste dyed and flavoured with triumphs of the aniline dye industry.

Some Devonshire cream also is made from low-grade imported butter and dried milk made into a homogeneous mixture in the latest designs of colloid mill, and the percentage of pork, even if fresh, in a pork sausage, like the chicken in chicken and ham paste, is mostly an indefinitely low figure. Cheap herrings and other white fish dyed and flavoured are obviously the main constituent of much lobster paste, and if any ox-tail is present in some qualities of factory-produced ox-tail soup it is not the main constituent.

Practically all white bread also is faked with "improvers", just as the sweetening and colouring of confectionery is still another triumph of applied organic chemistry.

Again, for example, the red rash on the top of boiled hams may not always be breadcrumbs fried in lard but has been known to be low quality rice dyed reddish brown with an aniline dye proof against decolorization by hot fat. Almost needless to state also is that butter has been largely replaced by imitation butter or margarine, some of which to me tastes "dead", like dyed candle grease, and contains also the catalyst used for fat hardening. Hundreds of other examples could be given.

A serious aspect is the cumulative effect of all the many different complicated organic products, preservatives, dyestuffs, and flavourings being taken into the body in food. It might be possible to believe that the materials used to adulterate say bread are, by themselves, harmless in view of the small amount taken, but what is the result when the makers of 50 other primary foods also have their own little methods of adulteration, equally claimed to be entirely harmless. As an organic chemist I refuse to be convinced, without most complete and independent evidence, that many of these chemical products, whether taken alone or together, have no ill-effect upon the human body.

The fact that almost everyone in Great Britain is compelled, to a more or less degree, to eat some faked and fraudulent food, does not however seem to be responsible for cancer.

Another drastic alteration in British national life is the wholesale consumption of meat, and to a less extent of poultry, game, and fish, that has been prevented from putrefying by lowering the temperature, that is freezing or chilling. To-day a large proportion of the population of Great Britain hardly ever taste fresh meat, and nearly everyone who eats in an hotel, restaurant, dining-car, or similar establishment, consumes some refrigerated flesh food. About 50 years ago the amount of such food consumed in Great Britain was negligible, but to-day over £80,000,000 per annum is spent on refrigerated meat alone.

The question is does meat, that is a portion of a dead body, prevented for weeks or months from putrefying by lowering the temperature, cause cancer when eaten, in view of the complicated and extensive chemical changes that still go on taking place? Thus refrigerated meat has largely lost its fresh flavour and smell, and has altered in texture and colour, although a considerable proportion of human beings seem to be deficient in palate and unable to tell the difference, for example, between delicious fresh English lamb and refrigerated lamb killed many months previously.

In Soviet Russia a number of mammoth carcases, thousands of years old, have been found from time to time completely preserved by the ice, and the meat has been eaten by human beings and animals. Would mice, for example, fed exclusively for months on such frozen mammoth meat contract cancer more easily than mice fed on fresh meat, say that of a similar animal such as an elephant?

This is another obvious field for detailed investigation, but it would seem there is no evidence that refrigerated beef, mutton, fish, and other food causes cancer.

An equally outstanding alteration is the consumption of tinned food, as developed upon a gigantic scale in the United States and now being rapidly extended in Great Britain and many other countries. By this method animal and fish food is prevented from putrefying by heating to cause sterilization and sealing up hermetically in a container such as a sheet metal "tin" or glass jar or bottle so that a partial vacuum results. Food treated in this way will keep indefinitely but in most cases the original fresh taste and the flavour is largely destroyed and the texture and colour altered. It is stated that in Great Britain the present consumption is about 1,600,000,000 tins per annum, of which about 60% are imported.

Whether human beings or animals, such as mice, fed exclusively for many years on tinned meat and fish would take cancer to a greater extent than men or mice fed on the corresponding fresh meat and fish is not known, but it certainly seems unlikely. This applies even more to tinned fruit and vegetables.

Tobacco smoking, especially cigarettes, has increased to an enormous extent in recent years, and one would naturally imagine the result would be an increase in cancer. Thus hot combustion products are being taken into the mouth continuously.

It is impossible, however, on the knowledge available, to pin down tobacco smoking as even one of the probable minor causes of the increase in cancer, although obviously the matter requires investigation. Until comparatively recent years women did not smoke to any extent in Great Britain but they always suffered as much, or even slightly more, than men, who smoked. Some races are heavier smokers than others, but this does not seem to affect cancer to any particular degree, and the same applies to men who are non-smokers.

One of the standard methods of low temperature carbonization for coal, oil shale, and other products, is to use a vertical intermittent retort which is ignited at the top and a regulated and restricted current of air pulled down at a uniform rate through the charge by an exhauster. The result is a progressive partial gasification of the charge from the top, with gradual advancing low temperature carbonization by the hot gases and vapours as they pass downwards. Alternatively the amount of air can be increased to allow of total gasification of the charge, leaving only ash and clinker.

A tobacco pipe is a small retort of this type operated so as to give more or less total gasification but with intermittent air admission. Possibly, therefore, one of the main actions in a pipe is low temperature carbonization of the tobacco, with not much formation of high temperature carbonization cancer-causing compounds. Tarry products, popularly called "nicotine", are also produced in considerable amount, which causes a "foul" pipe. The action of a cigarette or a cigar is somewhat of the same character, with the production of finely-divided tarry products, but excess air is generally present. Cases of cancer of the tongue due to smoking a clay pipe were perhaps caused by the constant irritation and eventual fracture of the skin of the tongue which allowed any very small amount of cancer-causing poisons in the combustion products from the burning tobacco to enter the system.

Work on the cancer-causing properties (if any) of smoke and tar from tobacco-smoking, pipes, cigars, and cigarettes, is another field for research.

Aluminium for cooking vessels is a change that may prove to be of great importance from the point of view of national health. One of the main objections to aluminium for this purpose is its much higher degree of chemical reactivity as compared with say cast-iron, copper, stainless steel, and ceramic ware. Thus aluminium tends to pass into solution to some extent in alkaline water (forming aluminates) and also in salt (sodium chloride) solution, whilst traces appear to be dissolved by acetic acid (vinegar) and acids found in fruit, such as tartaric, citric, and malic. As an example of the extent to which aluminium is affected, I might mention I have used for a number of years a large reading glass with an aluminium frame and handle. The latter is now almost completely black because of the heat and perspiration from the hand, which contains organic sulphur compounds.

Whether traces of soluble aluminium salts in food have an ill-effect does not seem to be known definitely, and much difference of opinion exists on the subject. The aluminium interests state the amount of aluminium that passes into solution is extremely small and the action is harmless. As against this it has been alleged that various British people living on the Continent of Europe, where aluminium cooking vessels are not yet used to any great extent, become ill with skin rashes, eczema, and boils when they return to Great Britain because of food cooked in contact with aluminium. The whole subject is complicated, but any definite damage to health does not seem to have been proved.

There is one other great fundamental change that has taken place in British national life during the past 50 years, that is the huge increase in the use of manufactured towns gas for cooking, especially under the conditions that the gas and the products of combustion from the gas are in direct contact with the food.

Most unfortunately there are no statistics for the number of externally heated coal-fired cooking ovens, internally heated gas-fired ovens (cookers) and electric cooking ovens in Great Britain, or in any other country, or for the different main uses of gas. In the first place, however, there has been during the past half century a great increase in the number of individual British gas consumers, which are very largely domestic so far as the number is concerned.

The following are the official British Government figures for each year since 1882 for the total number of consumers (all authorized undertakings), being about 96% of the total. It may be pointed out that until the year 1920 these figures are given in irritating and confusing fashion, divided into two entirely separate groups for "Local Authorities" and "Other than Local Authority Undertakings" (that is companies given a monopoly to sell gas over their area).

From 1882 to 1920 the figures relate to complete years, (1st January—31st December), in the case of the "Other than Local Authority Undertakings". But with "Local Authority" undertakings this obtains for two years only, 1882 and 1883, and then suddenly until 1920-1921 the year is switched over to mean in each case a 12 month period taken from within the corresponding years, expressed therefore as 1882-1883, and so on which adds to the confusion. Consequently in the totals from 1883 to 1920 there is a minor discrepancy for each year until the method was suddenly altered again to give one total only for each complete year.

MANUFACTURED TOWNS GAS INDUSTRY
Authorized Undertakings. Great Britain.

Year	Number of of Consumers	Year	Number of of Consumers
1882	1,971,971	1910	6,417,849
1883	2,019,846	1911	6,649,904
1884	2,058,356	1912	6,876,149
1885	2,095,025	1913	7,103,113
1886	2,130,377	1914	No record because of the World War.
1887	2,163,258	1915	
1888	2,192,946	1916	
1889	2,244,105	1917	
1890	2,297,278	1918	
1891	2,353,037	1919	7,540,133
1892	2,416,896	1920	7,448,332
1893	2,451,585	1921	7,559,310
1894	2,524,217	1922	7,672,146
1895	2,659,771	1923	7,810,350
1896	2,845,728	1924	7,993,786
1897	3,025,376	1925	8,200,455
1898	3,249,140	1926	8,404,561
1899	3,485,557	1927	8,686,339
1900	3,713,289	1928	8,901,271
1901	3,920,992	1929	9,137,581
1902	4,168,725	1930	9,343,834
1903	4,431,125	1931	9,558,229
1904	4,737,177	1932	9,773,015
1905	5,064,075	1933	10,012,379
1906	5,363,533	1934	10,277,010
1907	5,664,176	1935	10,516,759
1908	5,916,120	1936	10,775,444
1909	6,164,066		

Curiously enough gas cooking, which had been suggested and tried experimentally before 1850, started in Great Britain as a serious proposition about 1884, about the time when accurate statistics became available, largely because the gas industry, then depending chiefly upon the lighting load, became panic stricken because of the development of electric lighting. It will be noted there has been a steady and relatively rapid rise since 1882 of the total number of gas consumers in Great Britain, which as stated means very largely domestic consumers and gas cookers (internally heated ovens).

These developed very quickly after 1918, and representatives of the manufactured towns gas industry boast that 90% of the whole of the cooking of Great Britain is now carried out by gas whenever a supply is available. It is also stated that over 6,000,000 gas "cookers", that is presumably ovens internally heated by gas as usual, are let out on hire alone to domestic users, without including those purchased. There are about 9,000,000 houses in Great Britain and if the above figures are correct well over 75% of the whole of the food of the country cooked in ovens in private houses comes into direct contact with manufactured towns gas and the products of combustion of the latter. In view of the huge development also in cooking in restaurants, hotels, clubs, and other establishments, and in the food industries, including the baking of bread, biscuits, pies, and cakes, nearly all the food of the country is now liable to be contaminated by gas.

Whilst full statistical details are not obtainable, as stated, half a century ago hardly any food cooked in

Great Britain came into direct contact with gas or its combustion products, and before the World War (1914-1918) the figure was probably not over 25-30%. The increase in the number of gas consumers, however, has been steady and rapid, and particularly since about 1900, like cancer.

More or less the same general considerations apply to many of the world's chief countries. Great Britain, however, which suffers severely from cancer, uses per head of the population very much more manufactured towns gas than any other country, that is made by the high temperature carbonization of coal and by carburetting water gas, involving the high temperature decomposition of petroleum oil fractions, although some blue water gas is included. The following are the approximate average figures over a few years past for the population, the total sale of manufactured towns gas, allowing 6% loss for leakage on the production figures, and the consumption per head of the population per annum of Germany, Great Britain, and the United States.

Country	Population	Annual Sale of Manufactured Towns Gas (Cubic Feet)	Use of Manufactured towns gas per head of the population per annum (cubic feet)
Germany	65,000,000	115,000,000,000,000	1770
Great Britain	45,000,000	290,000,000,000,000	6440
United States	130,000,000	350,000,000,000,000	2690

It will be understood that according to my theory there may not be a direct relationship in any given country between manufactured towns gas used in the domestic and similar field and cancer, because the consumption of smoked food plays a part in the matter, and perhaps also poisoning due to closed stoves and other methods of combustion. Great Britain, however, so far as can be ascertained without statistics, does not seem to show a much increased consumption of smoked food over a considerable number of years past.

CHAPTER VIII

ORIGINATION OF THE NEW THEORY OF CANCER

About 15 years ago (1922) in the early stages of writing a treatise on carbonization I realized the rapidly-increasing rise in Great Britain of manufactured towns gas for cooking, and formed the tentative opinion this might offer a clue to the mystery of the cause of cancer, or at least one of the primary causes.

It will be necessary to explain the circumstances of the origination and development of my theory that cancer is largely caused by continuous very slow poisoning by the products from high temperature carbonization, general heat decomposition and combustion of bituminous coal, and other carbonaceous products, including petroleum in carburetted gas oil.

Originally I was an organic chemist employed in the British aniline dye industry in both research and technical work, and later I became a technical manager and chemist in the dyeing, calico-printing and allied industries, where the dyes are used. Because of the purely accidental circumstance that some firm sent us a well-written catalogue of one of the early combustion recorders (automatic flue gas analysing machines) I became interested in the efficient burning of coal in steam boiler and other furnaces. As a result I reorganized some of the boiler plants of the firm with whom I was engaged and effected a substantial annual saving in coal by applying scientific methods, both as regards plant and equipment and control of the operations, using combustion recorders, feed water meters, pryometers, and other apparatus.

Next I started a firm (Brownlie & Green Ltd., Manchester) of consulting boiler plant specialists, and during about 15 years we investigated in full detail the performance of 400 steam boiler plants in more than 50 industries and reorganized also over 100 plants.

Meanwhile I had also always been much interested in the intensified production of food from the soil and the complete scientific revolution of the existing general methods of agriculture, fundamentally not much improved since the days of prehistoric man, that will constitute one of the next great advances of civilization. For several centuries the people of Great Britain have been led to believe that it is impossible to grow enough food at home to feed the population. At the present time, for example, Great Britain, with a population of about 45,000,000 people, eats about £800,000,000 worth of food per annum, of which about £450,000,000-£500,000,000 worth is imported, that is with 37-44% produced at home, a dangerous and fantastic state of affairs. Even with the present crude methods of agriculture Great Britain could easily produce enough food to feed 75% of the population, whilst remaining an industrial country, and if the latest scientific principles now available were adopted 100% production would represent no difficulty.

When I first became interested in the subject, before the days of the synthetic nitrogen industry, one of the problems was sufficient sulphate of ammonia for use as a fertilizer. Because of this I began to study the low temperature carbonization of bituminous coal, representing a method of producing ammonia additional to the high temperature carbonization of the manufactured towns gas and by-product coke oven industries and of total gasification.

As a result I became involved in carbonization, and for about 17 years past have been writing an encyclopædic treatise on the subject. This will comprise, when completed, a description of 700-800 different processes, including also more than 2000 individual patents, that have been operated or considered actively for the carbonization, especially under low and medium temperature conditions, as well as gasification, of all carbonaceous material. Included are anthracite, bituminous and sub-bituminous coal, lignite, woody lignite, cannel, torbanite, oil shale, peat, wood, general vegetable and animal material, and bitumen and oil impregnated rock and sand.

Special attention also will be given to the chemical reactions concerned with carbonization and the composition, chemistry, and properties of the large number of tars and crude oils concerned, low, medium, and high temperature; and of the products contained in them. During the same time I have been preparing another lengthy book, being a world statistical survey of fuel and energy, a co-related subject.

It is because of this knowledge and experience of carbonization and of the continuous study of the subject over a considerable number of years that I am of the opinion cancer in human beings is largely due to poisonous high boiling point benzene ring hydrocarbon products.

As already indicated, it has long been known, if only because of the briquette industry, that towns gas retort and coke oven tar obtained by the high temperature carbonization of bituminous coal, and especially the pitch or heavy residue, is a highly dangerous cancer-causing product.

Obviously, however, actual direct contact of coal tar and coal tar pitch only occurs with an extremely small proportion of the population and could therefore only be responsible for a small proportion of the total cases of cancer in the world. The rate of increase also, up to the present figure of 60,000 deaths per annum in Great Britian, cannot have any relation to the relatively negligible increase in the consumption of tar and pitch, such as for briquetting and the manufacture of tar-macadam for road material.

It is not possible also to burn manufactured towns gas in any type of burner at theoretical (100%) efficiency, that is with complete combustion and without excess air. Such results cannot be obtained with any fuel, gaseous, liquid, or solid, even in large power station and steam boiler plants with the most up-to-date equipment and elaborate scientific methods of control.

All combustion in practice is less than 100% efficiency for two reasons. The first is excess air, which under special conditions of accuracy is at least 15-25% above the theoretical, while 50-70% represents good practice. As a result there is a loss of heat. In addition a certain degree of unburnt or partially burnt material escapes in the waste combustion gases, even when considerable excess air is used, although the amount is much more when there is deficiency of air.

For example, with manufactured towns gas part of the combustible saturated and unsaturated hydrocarbons may burn only to carbon monoxide (CO) in place of carbon dioxide (CO_2), and part may escape unburnt. Similarly in the burning of bituminous coal, carbon monoxide and other combustible gases and vapours are a normal constituent of the waste combustion gases.

Thus one of the most valuable instruments for the scientific control of boiler plant and other furnaces is a duplex automatic gas analysing machine, which determines continuously not only the percentage of carbon dioxide (CO_2) in the waste combustion gases but also the carbon monoxide (CO) and other unburnt products.

With oil fuel a considerable amount of unburnt oil may be present in the exhaust gases. A familiar example is the motor vehicle, with an average of 6% poisonous carbon monoxide and also "smoke", that is unburnt and partly burnt hydrocarbons in the exhaust of the internal combustion engine, which burns liquid fuel.

Since cancer-causing products are formed by the high temperature carbonization of coal and are present to a dangerous degree in the tar, and in the fractions of the latter, it is only reasonable to assume a proportion of the poisons, in spite of their high boiling point, may be carried over in the purified gas. Further, the standard purification methods used in the manufactured towns gas industry consist mostly of cooling and scrubbing the gas with water, forming ammonia liquor, which contains a considerable number of products in solution in addition to ammonia, and depositing tar, removing every trace of sulphuretted hydrogen by oxide of iron, and sometimes carrying out additional treatment, such as scrubbing for naphthalene and light oil.

In no case however (except in several new plants in Germany, to be described) is any heat treatment or other special method of purification involved, and there is a strong possibility therefore that traces of the cancer-causing hydrocarbon poisons are present in the towns gas as sold to the consumer.

Contrary to the popular opinion, combustible gases are difficult fuels with which to obtain high thermal efficiency at a reasonable rate of combustion because of the difficult problem of mixing the air and the gas intimately with sufficient rapidity. Modern "turbulent" burners of relatively large size and good design operate at say 85-90% efficiency, but most gas burners, large and small, probably do not average over say 75% burner efficiency.

Whilst excess (unburnt) air is the main cause of the fall of the efficiency below 100% unburnt or partially burnt gas is bound to be present in many cases in the waste combustion products from gas burners as normally operated. That is even under relatively good conditions the food in a typical internally heated gas cooker (oven) is in continual contact, not only with waste combustion products but also some unburnt or partially burnt gas.

A large proportion of the burners in domestic and other gas cookers are almost certainly not in good condition, since they are directly exposed close to hot fat and other products and the nozzles easily become stopped up to a partial extent. Under such conditions it is impossible to keep the burners clean, except by constant thorough attention of a character which only a small proportion of the users can be expected to give. I have seen gas cookers in an almost incredibly filthy state, literally caked inside with ancient layers of carbonized fat. A considerable proportion of people are of course lazy, dirty, and slipshod, and many coal-fired and electric cooking ranges will be found in the same condition.

When a gas burner is not kept perfectly clean partial combustion only of the gas takes place, with a luminous flame, and highly obnoxious products are formed, quite apart from unburnt gas, which also come into contact with the food. What happens is well illustrated when a burner, such as a boiling ring or a laboratory burner, "burns at the bottom", that is the flame jumps back and combustion results with insufficient air admission. The foul products resulting, generally supposed to be due to the formation of acetylene, are of a peculiarly toxic and obnoxious character. In addition some unburnt gas passes into the oven space when the burners are turned on just before lighting.

These average conditions are quite different from the case of an entirely new and clean gas cooker or one that is being used under the best possible, and therefore abnormal, conditions by experts in a laboratory, such as obtains in the case of much experimental work carried out by people associated with the manufactured towns gas industry.

There is every possibility, therefore, that a very large proportion of the millions of gas cookers (ovens) or internally heated gas ovens are being operated under such conditions that unburnt or partly burnt gas is almost always brought into continuous direct contact with the food.

The temperature used for cooking in an oven, that is roasting or baking, is within the range of about 320-500°F. (160-260°C.). Thus beef may require 450-500°F. (232-260°C.) and the same applies to roast potatoes, the figures for lamb or mutton are 350-450°F. (177-232°C.) and poultry is about the same. Similarly bread, pies, cakes, and biscuits are usually cooked at say 350-450°F. (177-232°C.) and milk puddings at 320-350°F. (160-178°C.).

The higher benzene ring hydrocarbons constituting the main cancer poisons obtained by the high temperature carbonization of coal, and present particularly in the coal tar and the coal tar pitch, are not decomposed at these temperatures, since they have a boiling point very much above 500°F. (260°C.) and would remain therefore in contact with the food.

Apart from the gas cooker, the use of manufactured towns gas in kitchens for boiling rings, toasters and grillers, and hot plates, means on the average an almost continuous slight direct leakage of unburnt gas and the discharge direct to the atmosphere of a large volume of waste products of combustion, which may also contain unburnt as well as partially burnt gas. It is possible therefore that cancer-causing poisons may be absorbed from a gas-contaminated atmosphere to some very slight extent by food, solid and liquid, and that the widespread use of cancerous coal tar in roadmaking may be another supplementary cause.

While in my opinion a large proportion of cancer in human beings is caused by the contact of unburnt or partly burnt manufactured towns gas, made by the high temperature carbonization of coal, with food cooked in gas ovens, many facts were still puzzling. Large numbers of human beings who cannot possibly come near manufactured towns gas die of cancer. Also the disease was known in Great Britain, although only to a limited extent, before the towns gas industry came into existence (1805-1810), while mule spinners' cancer has obviously no connection with gas.

In 1930 I read for the first time a highly interesting and important little book entitled *Combustion and Atmosphere and their Relation to Disease*, by Dr. W. Vernor Sinclair (John Bale Sons and Danielsson, Ltd., London, 1925). This describes in lucid language a theory that a large proportion of diseases, including cancer, are caused by breathing products of incomplete combustion of gaseous, liquid, and solid fuels, without however making any specific reference to food and gas cookers, and the poisonous action of higher hydrocarbons.

In the struggle to piece together all the complicated and incomplete fragments of information available to form even a partially complete figure of the gigantic jig-saw puzzle constituting the cause of cancer, this book by W. Vernor Sinclair was of great help.

New and important pieces for the puzzle were suggested at once, especially the fact that in the combustion of coal or any other solid fuel a certain slight degree of high temperature carbonization instead of combustion takes place in the furnace setting. Consequently the cancer-causing hydrocarbon poisons resulting from high temperature carbonization towns gas retorts and coke ovens may also be present in the waste combustion products from the burning of all solid fuels of a bituminous character, such as coal, lignite, peat, and wood, and probably liquid fuels as well.

Such carbonization takes place to a considerable extent in any type of fire, large or small, especially at the outer portion of the fuel layer and when the latter is thick and the draught insufficient for rapid combustion. Every race uses fire and hundreds of millions of human beings are therefore exposed to waste combustion products, and probably to cancer-causing poisons, when the fire is within a building, hut, tent, cave, or other confined space.

It may be remembered also that in the case of mechanical stokers of the coking type for steam boiler and other furnaces the basic operating principle is gradual carbonization of the bituminous coal, followed by combustion of the coke, with the gases and vapours burnt over the top of the fire.

One would expect also that non-bituminous or only slightly bituminous fuels, such as coke and anthracite, would not result in cancer-causing hydrocarbons in the waste combustion gases because carbonization, that is heat decomposition of bituminous material, is essential for such action to take place.

Although, as in the case of manufactured towns gas, it is not very likely that cancer can be caused to any great extent by absorption of these poisons from the atmosphere, whether by way of food or otherwise, this train of thought very soon suggested another primary cause of cancer, the eating of smoked meat, fish, and other food.

In this process the meat or fish is hung up for many hours in the thick dense smoke of a smouldering fire, generally of wood. Under such conditions a certain amount of carbonization almost certainly takes place with, I suggest, the presence of cancer-causing hydrocarbon poisons in the smoke, deposited on and absorbed by the food, on the same lines as if, for example, the latter had been brought into direct contact with cancer-causing soot. In this connection some savage races living largely on smoked fish are stated to suffer severely from cancer, although savages in general—on present knowledge—are less subject to cancer than civilized races.

The cause of mule spinners' cancer was another puzzle for a long time, especially as most varieties of petroleum oil, and the fractions from them, such as lubricating oil, are non-cancerous. However, I suggest, as stated, the reason is that certain qualities of petroleum oil have been heated in the earth's crust to a medium or high temperature, say 1292-1652°F. (700-900°C.) with consequent formation to a slight extent of the cancer-causing benzene ring hydrocarbons found in coal tar.

The claim that, if cancer-causing poisons are present in the combustion gases from manufactured towns gas and many solid fuels, they can only be in small and harmless amount is not a valid argument against the new theory, although at one time I was inclined to think so myself.

It is well known that extraordinarily minute traces of substances have a pronounced effect upon an appreciable proportion of human beings. One of the best examples is, of course, what the medical profession calls "idiosyncrasies". Thus many people are affected in extraordinary and abnormal fashion say by perfumes, drugs, saccharine, strawberries, tomatoes, mussels, crabs, and lobsters, which often cause an extensive skin rash, for which there is so far no explanation, chemical or physiological.

There is also the remarkable example of asthma, with about 50,000 sufferers in Great Britain alone, in which air over or near the sea (containing a minute trace of salt) as against inland air, and in the latter connection, towns air or country air, represents the difference between good health and serious illness.

Analogous is the case of hay fever in which sufferers are affected by minute traces of dust in the air, especially the pollen liberated from grasses during the early autumn, so that life in or near agricultural districts becomes a misery.

Most striking of all is the important part now known to be played by vitamins in food. However, the latest work since 1930 at the London Cancer Hospital Research Institute on actual cancer-causing hydrocarbons alike when extracted from coal tar and made synthetically, has now proved conclusively that the minutest amount of such substances will cause the damage.

As will be discussed, only 0·003% of 1 : 2 benzpyrene is present in coal tar pitch and this appears to be responsible for almost all the strongly cancer-causing properties. Similarly less than 0·001 of a gram of 1 : 2 : 5 : 6 dibenzanthracene will cause cancer in a mouse.

So far as I am aware no one has hitherto published the theory that most human cancer, and not only a very small portion of it, is due to complex poisonous products from high temperature carbonization and general heat decomposition, and combustion of coal and other carbonaceous material, which largely enter the body in food, with manufactured towns gas and the smoking of meat, fish, and other products playing a primary part. Or in other words that cancer is essentially a carbonization and combustion disease.

This theory may prove to be wrong or to offer only a partial and incomplete explanation, and in any case I do not suggest it explains every known case of cancer. But, whether right or wrong, it is published herewith, although from a fuel technologist and not a medical man, because I feel that it is the duty, in common humanity, of any one of whatever race, colour, creed, political opinion, occupation or social position, who has definite ideas that may help in killing the foul devil of cancer, to make them known.

In this connection also it is an incredible disgrace that cancer hospitals and research centres in some countries, including Great Britain, have—in their own words—to appeal pathetically for money to carry on the work.

CHAPTER IX

THE MANUFACTURED TOWNS GAS INDUSTRY: HISTORICAL, TECHNICAL AND STATISTICAL

THE manufactured towns gas industry originated in Great Britain about the period 1805-1810, and the gas was made by the low temperature carbonization of bituminous coal, sometimes mixed with cannel, using horizontal, intermittent, externally heated, cast iron retorts.

The temperature of carbonization was at first only about 900-1000°F. (482-536°C.) giving an average of 4000-5000 cubic feet of gas per ton, but as no profit could be earned this was gradually raised to increase the yield of gas., At 1000-1200°F. (536°-649C.) for example 5000-7000 cubic feet of rich carbonization gas, 650-850 B.Th.U. per cubic foot, were obtained per ton of average bituminous coal, along with low temperature carbonization tar or crude oil and coke, which was a free burning smokeless fuel. Eventually the temperature reached about 1400°F. (760°C.) a bright red heat, with a yield of say 8000 cubic feet of gas per ton of coal, but this played havoc with the cast iron retorts.

About 1845-1850 horizontal fireclay retorts came into use in Great Britain, originally introduced in

1824 by John Grafton at the Cambridge gas works. This enabled the carbonizing temperature to be raised immediately to about 1750°F. (955°C.) with an average yield of say 10,000 cubic feet of straight gas per ton, and afterwards to 1832-2012°F. (1000-1100°C. or over, giving about 12,000 cubic feet of gas per ton of lower heating value, about 550-600 B.Th.U. per cubic foot.

It was not until the period 1840-1850 therefore that the manufactured towns gas industry began to produce any cancer-causing poisons, because the average temperature of carbonization did not exceed about 1292-1472°F. (700-800°C.). At this period the deaths from cancer in Great Britain were only say about 250 per 1,000,000, one-seventh of the present figure, in my opinion largely due, to such causes as soot, lubricating oil, (mule spinners' cancer), the eating of smoked fish and meat, and perhaps the products of combustion from closed stoves and slow burning coal fires in kitchen ranges.

Vertical fireclay retorts also began to come into general use after about 1905 although often tried previously, with simple external heating and high temperature carbonization at 2000°F. (1093°C.) or over.

The vertical carbonization setting in modern practice is now either a retort or a "chamber oven" essentially a retort of larger cross section, while it should be stated also the inclined retort, a compromise between the horizontal and the vertical retort, has never been much used. Retorts and chamber ovens also can be "intermittent", "continuous", or "mechanically continuous" in operation.

In an intermittent retort, horizontal or vertical, the charge of coal is carbonized and then the coke removed completely at the end of the operation, the retort being opened for the purpose. A "continuous" vertical retort or oven is not opened for discharging the coke, part of which only is taken out at intervals from the bottom and a corresponding amount of fresh coal added at the top, without stopping the operation.

With a mechanically continuous vertical retort the coke is discharged from the bottom continuously by mechanically operated gear and the coal passes in continuously at the top.

Then about 1880 the principle began to be widely adopted, first used in the United States, of gasifying part of the residual gas coke in separate total gasification generators on the water gas principle. That is the coke is gasified by an alternate "blow" with air to maintain the charge at an incandescent heat, with discharge of the "blow" gas, mostly carbon dioxide (CO_2) to waste, and "run" with steam to form "blue" water gas, carbon monoxide and hydrogen, ($C+H_2O=CO+H_2$). This gas is 300 B.Th.U. per cubic foot and can also be increased in heating value by "carburetting", that is mixing with the rich vapours from the complete heat decomposition of medium petroleum oil fractions in a red hot firebrick chamber well over 1472 F.(800C.), forming part of the plant. The blue water gas, or the carburetted gas, is then mixed in any desired amount with the straight retort carbonization or coal gas to form towns gas.

Another development also, especially during the past 25 years, is "steaming" of vertical high evaporative carbonization retorts, that is blowing in steam continuously at the bottom of the charge to gasify direct part of the red hot coke charge giving essentially water gas ($CO+H_2$) and a higher yield of mixed carbonization and total gasification gas lower in heating value, say 450 B.Th.U. per cubic foot, than the straight carbonization gas.

The manufactured towns gas industry also, and especially in the United States and Germany, purchases an enormous amount of metallurgical coke oven gas, which is straight high temperature carbonization coal gas, made in large, externally heated, coke ovens with a narrow charge, usually within the range of say 10-20 ins., at a carbonizing temperature of 1832-2012°F. (1000-1100°C.) similar to horizontal retort gas.

This coke oven gas is mixed with the towns gas and in some countries also, notably the United States, a considerable volume of natural gas and of petroleum gas, such as refinery and cracking gas and oil gas, is used in the same way.

Manufactured towns gas therefore varies greatly in composition but, with rare exceptions a relatively costly rich gas only is almost always sold, within the range of say 400-600 B.Th.U. per cubic foot, although a cheap low grade gas of say 200 B.Th.U. per cubic foot will do equally well. However, because of the notable pioneer work of Mr. George Helps one manufactured towns gas undertaking in the world, the Nuneaton (Warwickshire) Gas Company, is selling cheap gas of this type, obtained by low temperature carbonization of coal and partial gasification, entirely different in quality from ordinary manufactured towns gas.

In the course of the preparation of my book dealing with world statistics of fuel and energy I have estimated the world is carbonizing under high temperature conditions in towns gas retorts an average of about 41,000,000 metric tons (2205 lbs.) of coal per annum (during the 12 year period 1924-1935). This is 3·5% of the total world production and consumption of coal (not lignite) per annum, which for the above period is 1,162,000,000 metric tons per annum.

Also in the same period 160,000,000 metric tons of coal per annum, or 13·8% of the world production and consumption, are carbonized under high temperature conditions in metallurgical coke ovens, both by-product recovery and non-recovery ovens. Mostly the latter are of the "beehive" and analagous types, operating on the principle of internal heating by partial gasification of the charge, obtained by regulated air admission.

The amount of coal carbonized in by-product recovery ovens averages 152,000,000 metric tons per annum, that is 95% of metallurgical coke is of the by-product type. Only about 8,000,000 metric tons of coal per annum are carbonized in non-recovery beehive and similar ovens, of which 7,000,000 metric tons are in the United States.

Accordingly the total amount of coal carbonized per annum throughout the world during the 12 year period 1924-1935 is 193,000,000 metric tons (41,000,000 tons in gas works retorts and 152,000,000 tons in coke ovens).

It is not generally realized that Great Britain carbonizes very much more coal in high temperature carbonization towns gas retorts than any other country. Thus the average total annual amount of coal carbonized per annum in retorts during the 12 year 1924-1935 period is approximately as follows (metric tons).

Great Britain	18,300,000
Germany	6,500,000
France	3,300,000
United States	3,200,000
Australia	1,200,000
Japan	1,150,000
Holland	1,100,000

Great Britain, therefore, carbonizes in towns gas retorts 44·6% of the world total (41,000,000 tons) and Germany comes second but far behind, with 6,500,000 tons. The United States produces a small amount of manufactured towns gas in retorts, carbonizing slightly over 3,000,000 tons of coal per annum, like France. Only seven countries carbonize more than 1,000,000 tons of coal per annum in towns gas retorts, totalling 34,750,000 metric tons per annum, and more than 40 countries make up the balance (6,250,000 tons).

I have estimated that the sale of manufactured towns gas throughout the world, representing an average of the 12 year period 1924-1935, is approximately 1,100,000,000,000 cubic feet per annum, of say 475 B.Th.U. per cubic foot, equal to a production of 1,170,000,000 cubic feet, to allow for loss by leakage. If it be assumed that the average yield of the gas obtained by the carbonization of the 41,000,000 metric tons of coal per annum in all types of retorts and ovens in gas works including steaming, is 12,500 cubic feet per ton, the yield of carbonization coal gas is about 513,000,000,000 cft. per annum, or 43·8% of the total. The other 56·2% therefore is made up of water gas, largely obtained from the coke, purchased coke oven gas, a small amount of coke oven gas from ovens owned by gas works, and natural gas, along with the relatively small amounts of petroleum industry gas.

Including the purchased coke oven gas it is probable that very roughly about 60% of the manufactured towns gas of the world is high temperature carbonization gas, say 660,000,000,000 cubic feet sold per annum, that is made under conditions of the production of cancer-causing hydrocarbon poisons to a pronounced degree, and present largely in the coal tar and the coal tar pitch.

World statistics for the average composition of the manufactured towns gas are not available, but probably at least another 30% of the total manufactured towns gas consists of semi-carburetted or carburetted water gas, with the formation of cancer-causing poisons all added direct to the gas, because of the high temperature decomposition of cracking of the petroleum oil fractions used in carburetting. Also I estimate that 3,500,000-4,000,000 metric tons of gas oil are consumed per annum for carburetting water gas.

In addition a smaller amount of blue water gas is used in the world's manufactured towns gas industry, especially in the United States. That is, coke is converted to water gas and mixed direct with the coal carbonization and other gas without carburetting, being therefore non-cancerous. Mostly blue water gas can only be used to any considerable extent when very rich natural gas (about 1,000 B.Th.U. per cubic foot) is available since the manufactured towns gas industry insists on supplying only a rich gas (400-600 B.Th.U. per cubic foot).

No figures can be obtained concerning the total amount of blue water gas, as distinct from carburetted water gas, used by the manufactured towns gas industry.

Full statistics also are not published for the actual annual production or sale of manufactured towns gas of most countries over a considerable number of years, and statistics when given are often incomplete and misleading. For example, much confusion exists between "gas made" and "gas sold" to consumers. On the average at least 6% of the gas made, and often much more in individual cases, is lost before reaching the consumer's meters, chiefly by continual leakage from buried gas mains, nearly all made with obsolete rigid joints that will not stand the vibration from modern heavy motor traffic. The gas loss after the meters, for which of course the consumer has to pay, is also considerable.

Approximately, however, the annual manufactured towns gas production, taking averages for a few years (since 1929), of the more important countries is (cubic feet).

United States	376,000,000,000
Great Britain	310,000,000,000
Germany	125,000,000,000
France	60,000,000,000
Japan	27,000,000,000
Holland	23,000,000,000

About 995,000,000,000 cubic feet per annum also (85% of the total of 1,170,000,000,000) is made by 17 countries.

Detailed official statistics are available concerning the British manufactured towns gas industry, chiefly in the Board of Trade Annual Reports. The calculations given below are the essential figures (long tons, 2240 lbs.) for annual consumption and production being an average of the corresponding figures for 12 years period, 1924—1935 inclusive. This refers as before to authorized undertakings, that is manufactured towns gas establishments authorized by Parliament and given a monopoly of supply over a particular area of the country, producing about 96% of the total towns gas in Great Britain. There is not included in the Board of Trade statistics a number of small "non-authorized" gas undertakings not allowed a monopoly which however only produce about 4% of the total gas.

MANUFACTURED TOWNS GAS INDUSTRY, GREAT BRITAIN

Average Annual Figures. Period, 1924-1935

Coal carbonized in gas retorts (long tons)	17,227,000
Coke used for water gas (long tons)	907,000
Oil used for carburetting water gas (gallons)	55,854,000
Coal gas made (cubic feet)	247,339,000,000
Water gas made (cubic feet)	42,870,000,000

Other gas made (cubic feet)	4,644,000,000
Purchased coke oven gas (cubic feet)	10,998,000,000
Total gas made and purchased (cubic feet)	305,851,000,000
Total gas sold to consumers (cubic feet)	283,648,000,000
Tar produced (gallons)	207,409,000,000
Sulphate of Ammonia produced (long tons)	105,680
Coke and Coke Breeze produced (long tons)	11,591,000
Number of gas consumers	9,234,000

As showing the rate of increase of the manufactured towns gas industry in Great Britain the following are some comparative figures for typical years (12 months) from 1882 for the coal carbonized in high temperature carbonization retorts, the coke used for making water gas to mix with the coal gas, and the gas oil used for carburetting the water gas.

MANUFACTURED TOWNS GAS INDUSTRY, GREAT BRITAIN
Some Typical Figures. Coal Used and Water Gas Manufacture

Year	Coal Carbonized (Tons)	Coke Used for Water Gas (Tons)	Oil Used for Carburetting Water Gas (Gallons)
1882	7,280,757	None	None
1890–1	10,242,427	None	None
1900–1	13,906,288	Not stated	Not stated
1910–1	15,397,783	Not stated	Not stated
1913–4	16,771,664	Not stated	Not stated
1920	17,566,000	Not stated	Not stated
1925	17,031,000	1,153,000	61,383,000
1930	17,669,000	790,000	49,073,000
1935	17,294,000	640,000	41,679,000

In view of the great importance of carburetted water gas in connection with cancer, the following is the annual consumption of gas oil, in most cases medium petroleum fractions, by the authorized manufactured towns gas industry in Great Britain, 96% of the total production, for each of the years 1924-1935:—

1924	45,641,000	gallons
1925	61,383,000	,,
1926	97,703,000	,,
1927	61,001,000	,,
1928	56,377,000	,,
1929	58,083,000	,,
1930	49,073,000	,,
1931	53,124,000	,,
1932	51,749,000	,,
1933	54,139,000	,,
1934	40,296,000	,,
1935	41,679,000	,,
Average	55,854,000	,,

That is an average of about 55,854,000 gallons or 260,000 tons of petroleum oil are decomposed every year at very high temperature in water gas plant, and the cancer-causing poisonous hydrocarbons that must result in most cases are passed into the towns gas supply.

The corresponding figures also for the coal gas made and purchased coke oven gas (constituting the total high temperature carbonization gas) and the total mixed gas actually sold, the difference being chiefly water gas, are:—

Year	Coal Gas Made (cubic feet)	Purchased Coke Oven Gas (Cubic feet)	Total Gas Sold (Cubic feet)
1882	72,583,000,000	None	66,714,000,000
1890–1	103,010,000,000	None	94,646,000,000
1900–1	152,007,000,000	None	130,418,000,000
1910–1	175,276,000,000	None	182,834,000,000
1913–4	195,826,000,000	Not stated	206,474,000,000
1920	214,703,000 000	Not stated	235,403,000,000
1925	231,348,000,000	4,798,000,000	265,727,000,000
1930	255,336,000,000	13,201,000,000	289,991,000,000
1935	260,505,000,000	20,455,000,000	295,857,000,000

It should be emphasized that as regards "gas made" and "gas sold" the Board of Trade figures are incomplete and extremely misleading because no average figures are given for the heating value of the gas.

Thus the fact that in 1930 the towns gas industry sold say 290,000,000,000 cubic feet of gas and in 1935 this had become 296,000,000,000 is apt to give a wrong impression. What is required in each case for the statistics to be of full value is the average B.Th.U. per cubic foot of the gas. It would be a simple matter, for example, to pump a little air into the 290,000,000,000 cubic feet and make it into 296,000,000,000 with a corresponding reduced heating value, representing of course no real advance but merely a difference in volume.

The increase therefore in the annual sale of manufactured towns gas, that is on the volume basis, was relatively very rapid from 1882 to the commencement of the World War 1914, but after the latter period the rate of increase slowed down considerably. The rate from 1930 is extremely slow, only 2% in the

5 years 1930-1935. On page 53 there has already been given the "total consumers" of manufactured towns gas for each year since 1882, and it will be remembered that although the annual increase in the sale of gas in Great Britain is now extremely slow, almost negligible, and the actual amount of coal carbonized is stationary, the number of consumers, nearly all domestic, has increased rapidly for many years. That is, the use of gas continues to spread, which means in effect that more and more gas and its combustion products come into direct contact with food.

In Great Britain the approximate average composition of the manufactured towns gas supplied by all the different undertaking, say during the 12 year period 1924-1935 is appreciably 80·1% high temperature carbonization retort gas, including steaming of the charge, 14·8% water gas made from coke, 3·7% purchased coke oven gas, and 1·4% other gas. Matters in this respect are very different in the United States where the average composition of the manufactured towns gas is approximately 49·7% water gas, 12·3% coke oven gas made in coke ovens belonging to towns gas works, 24·1% purchased coke oven gas, 8·7% high temperature carbonization retort gas, 2·8% purchased natural gas, and 2·4% other gas, (including petroleum gases).

The following are the detailed average annual production and composition figures for the gas manufactured and purchased by the manufactured towns gas industry in the United States, being an average for the 12 years 1924-1935, which I have calculated chiefly from the U.S. Bureau of the

Census, the U.S. Bureau of Mines, and the American Gas Association publications.

Nature of the Gas	Cubic Feet	Percentage of the Total Manufactured and Purchased
Manufactured Gas.		
Water Gas	206,000,000,000	49·7
Coke Oven Gas	51,000,000,000	12·3
Retort Gas	36,000,000,000	8·7
Oil Gas	4,000,000,000	1·0
Reformed Oil Refinery Gas	3,000,000,000	0·7
Reformed Natural Gas	150,000,000	0·1
Propane Gas & Butane Gas	350,000,000	0·1
Total Manufactured Gas	300,500,000,000	72·6
Purchased Gas		
Coke Oven Gas	100,000,000,000	24·1
Oil Refinery Gas	2,000,000,000	0·5
Natural Gas	11,500,000,000	2·8
Total Purchased Gas	113,500,000,000	27·4
Total Gas Manufactured and Purchased	414,000,000,000	100·0

Of this about 376,700,000,000 cubic feet or 91% of the total is sold, the rest being lost or used by the industry. Further the total amount of gas oil for carburetting also averages 560,000,000 U.S. gallons per annum.

The manufactured towns gas of the United States is therefore decidedly less cancerous in its origin than that of Great Britain. In the latter case practically the whole of the gas comes from cancerous sources, that is, towns gas retorts, coke ovens, and carburetted water gas, with very little blue water gas. Also 80% of the gas is made in towns gas retorts, which give rise to more cancer-causing poisons than by-product coke ovens, and in addition a large proportion of these retorts in Great Britain are of the horizontal type, which forms on the average the most dangerous tar of all.

In the United States, however, about 3% of the gas is derived from almost entirely non-cancerous sources, that is natural gas, and this may apply to the 2·4% direct from petroleum sources.

A considerable (though unknown) proportion of the water gas also is of the "blue" or uncarburetted variety, which is non-cancerous. Highly significant is that even in the case of high temperature carbonization coal gas 36·4% is from coke ovens, which are less cancer-producing than gas retorts, and only 8·7% of the gas is produced by the latter, as compared with 80% in Great Britain.

The approximately average yield obtained by the high temperature carbonization at say 1832-2012°F. (1000-1100°C.) of average bituminous coal (25-35% volatile matter) can be taken as below. By this is indicated the average of horizontal retorts, vertical retorts, and chamber ovens, intermittent, continuous, and mechanically continuous in operation, and by-product recovery ovens. The vertical retort with steaming of the charge gives a somewhat different result, with tendency to approach low temperature carbonization to a partial degree. However, as stated, no statistics are available for the amount of coal carbonized in steamed vertical retorts but the figure is a relatively small proportion of the total coal carbonized (193,000,000 metric tons per annum) in the world under high temperature conditions (retorts and ovens). For comparison average figures are given for low temperature carbonization in simple externally heated retorts at about 900-1,200°F. (482-649°C.) yield per ton of coal.

	High Temperature Carbonization	Low Temperature Carbonization
Gas (cubic feet)	12,000	5000
Light Oil (*a*) Scrubbed from gas	1·5	2·0
(Gallons) (*b*) Fractionated from tar	1·1	1·5
Tar. Total Crude (gallons)	11·0	18·0
Sulphate of Ammonia (lbs.)	25·0	10·0
Coke (total lbs.)	1658 (74%)	1680 (75%

The composition and properties of the gas, light oil and tar will be discussed in future pages, but it may be stated high temperature carbonization coke averages about 3% volatile matter, and is therefore a product of low combustibility, whereas typical low temperature carbonization fuel has 10-12% volatile matter and is very free burning.

The ammonia also from the gas liquor is recovered and sold, chiefly as sulphate of ammonia, because the manufactured towns gas industry is not allowed by law in any country to discharge gas liquor into sewers, rivers, and streams.

In most countries the price of ammonia, and of nitrogen products generally, has been reduced to such an extent by the gigantic developments of the synthetic nitrogen industry since 1914 that the manufactured towns gas industry can no longer make an appreciable profit on by-product ammonia, which is rapidly becoming a liability instead of an asset.

CHAPTER X

COMPOSITION AND PROPERTIES OF MANUFACTURED TOWNS GAS

Discussing now the composition and properties of manufactured towns gas, below is given the approximately average composition, as obtained by standard gas analysis methods, of carbonization gases made by simple external heating only in retorts or ovens under low temperature conditions, 900-1200°F. (482-649°C.), using cast iron or steel retorts (gas tight), and under high temperature conditions, 1832-2012°F. (1000-1100°C.) in fireclay intermittent horizontal, and vertical retorts without steaming, and by-product recovery coke ovens, using high-grade bituminous coal with say 25-35% volatile content. Average general figures of this kind must always vary considerably from those of many individual plants because of differences in the quality of the coal, the exact working conditions, and the operating efficiency, especially leakage of air into the retorts or ovens.

It should be pointed out also that the composition of the low temperature carbonization gas and the coke oven gas is after scrubbing for light oil with heavier oil fractions (gas oil). High temperature carbonization gas from towns gas retorts is generally not scrubbed because in most cases the manufactured towns gas industry will not recover the light oil, and the horizontal and vertical retort figures refer to gas of this type. A minor complication in this connection is that in some cases the gas is washed with gas oil to remove as much naphthalene as possible to reduce the troubles caused by stoppages in gas mains.

APPROXIMATE AVERAGE COMPOSITION OF SIMPLE CARBONIZATION GASES FROM BITUMINOUS COAL (25-35% VOLATILE)

	Low Temperature Carbonization %	High Temperature Carbonization		
		Horizontal Retorts %	Vertical Retorts Without steaming %	Coke Ovens By-product Recovery %
Carbon Monoxide (CO)	3·00	7·00	6·00	6·00
Hydrogen (H_2)	17·50	49·50	49·50	50·00
Hydrocarbons (Sat.)	70·50	34·00	33·75	27·00
Hydrocarbons (Unsat.)	7·50	3·50	4.00	3·00
Total Combustible	98·50	94·00	93·25	86·00
Carbon Dioxide (CO_2)	0·40	1·50	2·00	3·00
Oxygen (O_2)	0·20	0·50	0·00	0·20
Nitrogen (N_2 by difference)	0·90	4·00	4·75	10·80
Total	100·00	100·00	100·00	100·00
Heating Value B.Th.U. per cubic foot (gross)	850	600	550	520
Yield per ton of coal, (cubic feet)	5000	12,000	11,500	11,000

The corresponding approximate average figures for different types of total gasification gas, of direct interest in connection with the manufactured towns gas industry are also given herewith, that is, blue water gas from coke, semi-carburetted water gas and carburetted water gas, both made from the blue water gas (coke), and producer gas made from bituminous coal.

By semi-carburetted water gas is meant the use of ¾-1 gallon of gas oil cracked per 1000 cubic feet of blue water gas, whilst "carburetted" gas indicates the use of 2½-3 gallons of oil. Producer gas, sometimes used (but not in Great Britain) for adding to manufactured towns gas, is made from bituminous coal (or other solid fuel) by total gasification using a continuous blast of steam and air.

APPROXIMATE AVERAGE COMPOSITION OF TYPICAL TOTAL GASIFICATION GASES

	Blue water gas from coke %	Semi-carburetted water gas from coke %	Carburetted water gas from coke %	Producer gas from bituminous coal %
Carbon Monoxide (CO)	43·00	38·35	33·80	24·00
Hydrogen (H_2)	47·70	37·50	35·00	13·00
Hydrocarbons (Sat.)	0·35	8·00	12·00	1·75
Hydrocarbons (Unsat.)	0·00	6·50	10·00	0·25
Total Combustible	91.05	90·35	90·80	39·00
Carbon Dioxide (CO_2)	3·75	3·55	3·55	5·50
Oxygen (O_2)	0·35	0·40	0·50	0·35
Nitrogen (N_2 by difference)	4·85	5·70	5·15	55·15
Total	100·00	100·00	100·00	100·00
Heating Value, B.Th.U. per cubic foot, gross	300	475	525	165

The composition of typical varieties of manufactured towns gas, as sold, is as follows, being 70-75% straight coal gas and 20-25% semi-carburetted water gas, 70-75% straight coal gas and 20-25% carburetted water gas, and vertical retort gas with 20% and with 32·5% steaming of the charge respectively. All kinds of mixtures of retort, coke oven, and total gasification gas are of course supplied by the thousands of manufactured towns gas undertakings throughout the world, and the exact composition varies accordingly.

APPROXIMATE AVERAGE COMPOSITION OF TYPICAL MIXED MANUFACTURED TOWNS GAS

	70–75% straight coal gas and 20–25% semi-carburetted water gas %	70–75% straight coal gas and 20–25% carburetted water gas %	Vertical Retort Gas	
			20% steaming of the charge %	25% steaming of the charge %
Carbon Monoxide (CO)	22·00	18·80	16·40	17·40
Hydrogen (H_2)	42·00	40·00	48·90	48·80
Hydrocarbons (Sat.)	22·00	27·75	18·30	15·60
Hydrocarbons (Unsat.)	2·50	2·75	2·50	3·00
Total Combustible	88·50	89·30	86·10	84·80
Carbon dioxide (CO_2)	3·00	3·50	3·60	5·10
Oxygen (O_2)	0·20	0·20	0·90	0·90
Nitrogen (N_2 by difference)	8·30	7·00	9·40	9·20
Total	100·00	100·00	100·00	100.00
Heating value, B.Th.U. per cubic foot	450	475	445	435

These figures cover the average composition of most manufactured towns gas, and apply particularly to countries such as Great Britain, Germany, France, Czechoslovakia, Japan, Australia, Holland, Belgium, and South Africa.

In the United States, Canada, and Soviet Russia, as already indicated, a certain amount of natural gas and petroleum refinery and cracking gases are used, whilst the proportion of water gas is sometimes very high, but the average composition does not vary from the above to any great extent.

Approximately, therefore, manufactured towns gas chiefly made by high temperature carbonization of coal and total gasification of part of the coke on the water gas principle, with or without carburetting, contains 16-22% carbon monoxide (CO), 40-49% hydrogen, 15-22% saturated hydrocarbons, chiefly of the aliphatic or open chain series, especially methane (CH_4) and 2·5-3·0 aliphatic unsaturated hydrocarbons, largely of the ethylene series, that is 85-89% total combustible, the rest being carbon dioxide, oxygen, and other gases, chiefly nitrogen (by difference).

Apart from the carbon monoxide content the composition of towns gas, as determined by ordinary methods of standard gas analysis, gives no indication of the degree of poisoning that may be caused by the use of manufactured towns gas.

With regard to my theory that traces of dangerous cancer-causing higher hydrocarbon products are present largely from the high temperature carbonization of the coal at over 1292-1472°F. (700-800°C.), the higher the carbonizing temperature the more poisonous will become the gas, as well as the tar. High temperature carbonization also by external heating only from horizontal retorts and non-steaming vertical retorts and metallurgical coke ovens should give a more cancer-causing gas than one made by high temperature carbonization in vertical retorts with steaming of the charge. This would seem to be indicated, as will be described, by the fact that horizontal retort tar is more cancer-causing than steamed vertical retort tar.

In addition semi-carburetted and carburetted water gas is probably cancer-causing because the gas oil (medium petroleum fractions) generally used is decomposed or cracked at a very high temperature, well over 1472°F. (800°C.) and more in the nature of 1652-1832°F. (900-1000°C.) and forms the same general type of poisonous higher hydrocarbons found in high temperature carbonization coal tar. Assuming that manufactured towns gas contains cancer-causing constituents like the tar, it seems doubtful if they can be determined quantitatively by ordinary chemical methods, a point to be discussed in future pages.

Two other products usually present in manufactured towns gas as sold to the consumer, organic sulphur, an obnoxious impurity, and unsaturated hydrocarbons, such as ethylene, which are normal combustible constituents, may also play a part in causing disease generally, perhaps including cancer.

Gas obtained by the carbonization of bituminous coal contains an appreciable amount of organic sulphur, chiefly (70-80%) extremely poisonous carbon disulphide (CS_2), together with traces of higher organic sulphur compounds such as thiophenes and mercaptans. This is another of the evils of high temperature carbonization. Although naturally the figures depend to a considerable extent upon the sulphur content of the coal, very roughly low temperature carbonization of average coal at 900-1200°F (482—649°C.) gives say 10-12 grains of total organic sulphur per 100 cubic feet whereas high temperature carbonization at 1832-2012°F. (1000-1100°C.) results in about 35-50 grains organic sulphur, equivalent to 0.02% by volume of the gas. Partly the carbon disulphide is formed by the action of sulphuretted hydrogen (H_2S) upon coke under very high temperature conditions.

In Great Britain, and apparently in most other countries, there is no legal obligation upon the manufactured towns gas industry to remove organic sulphur compounds, that is distinct from sulphuretted hydrogen (H_2S). The latter has to be eliminated entirely, an operation carried out in a cheap and simple manner merely by passing over oxide of iron, forming iron sulphide. But to remove poisonous carbon disulphide and other organic sulphur compounds more or less completely is extremely difficult, and the manufactured towns gas industry is therefore allowed to pass these poisons on in the gas supplied for domestic and industrial use.

Originally in Great Britain, although the matter is complicated and difficult to explain in full, there was until 1860 no legal restriction in any part of the country upon the amount of carbon disulphide allowed in towns gas. In the above year a few areas of the country, including London, compelled towns gas companies to limit the carbon disulphide figure.

A consideration of the matter in a short space is rendered all the more troublesome because originally manufactured towns gas was purified by lime, which absorbs carbon disulphide (CS_2) to a considerable extent, as well as sulphuretted hydrogen (H_2S). For the removal of the latter impurity, oxide of iron is much cheaper and easier, and gradually, especially after 1880, the use of lime went out of existence and any compulsion then exerted upon gas companies in some parts of Great Britain to keep down the carbon disulphide figure was quietly allowed to lapse.

Hardly any manufactured towns gas supply in the world at the present time has had the poisonous carbon disulphide and the other organic sulphur compounds completely removed, although one British gas undertaking has long struggled with the problem.

Part of the organic sulphur is eliminated in the ammonia liquor as ammonium sulphide or polysulphide, but the rest remains in the gas as sold. The average amount present in manufactured towns gas is difficult to find out, but is probably within the range of say 10-20 grains per 100 cubic feet and in some cases may be higher. For more or less complete removal of organic sulphur, say to less than 1 grain per 100 cubic feet, various methods might be used. Examples are Activated Carbon, using an extra large amount of gas oil for scrubbing, or heating to a considerable temperature, such as 752°F. (400°C.) and passing over finely divided nickel or other catalyst. Under the latter conditions the carbon disulphide and other organic sulphur compounds interact to a considerable extent with the hydrogen present to form sulphuretted hydrogen, easily removed by oxide of iron. Iron catalysts at 392-572°F. (200-300°C.) could also be used. But such methods are costly and troublesome, and as the manufactured towns gas industry is under no legal compulsion in the matter they are naturally in nearly all cases not desirous of incurring the extra expenditure.

It is claimed that all the poisonous carbon disulphide left in towns gas is burnt to sulphur dioxide ($CS_2+3O_2=CO_2+2SO_2$), itself an obnoxious product. Since theoretically complete combustion of gas is almost always impossible, as stated, in my opinion the result is in a gas cooker that the food must often be brought into direct contact with traces of carbon disulphide, as well as thiophenes and mercaptans.

The great difficulty of removing carbon disulphide from any gas is well illustrated by the case of the well-known "Fischer-Tropsch" process for the production of liquid fuel, especially motor spirit. This consists in passing mixtures of carbon monoxide (CO) and hydrogen (H_2) over heated catalysts, such as nickel, at atmospheric pressure. For this operation, in addition to sulphuretted hydrogen almost every trace of organic sulphur, including carbon disulphide, must be removed from the gases to avoid "poisoning" the catalyst. The gases, therefore, have to be passed through tubes at a very high temperature, such as 1652°F. (900°C.), when most of the carbon disulphide is converted to sulphuretted hydrogen, removed by oxide of iron. By repeating the action nearly all the organic sulphur is removed, although a chemical equilibrium is established between the carbon dioxide (CO_2), hydrogen (H_2), carbon disulphide (CS_2), and water (H_2O), and to remove the final trace requires special catalysts.

In this connection it may be mentioned that another impurity in coal gas is the extremely poisonous hydrocyanic acid, popularly called prussic acid, and known in the manufactured towns gas industry as cyanogen. This is a still further disadvantage of high temperature carbonization, especially at over 1832°F. (1000°C.) which results in a much increased amount of cyanogen as compared with low temperature carbonization. In the British manufactured towns gas industry the cyanogen content of the gas is reduced to an extremely low figure. Part of it is absorbed in the ammonia liquor and part by the oxide of iron, whilst in addition special scrubbing methods can be employed, using for example such solutions as ferrous sulphate and ammonia, alkaline ferrous carbonate, or ammonium polysulphide.

The cyanogen is extracted from the oxide of iron, and by the different methods an amount of ferrocyanides up to 1-1½ lbs. (as cyanide) per ton of coal carbonized can be obtained.

The unsaturated hydrocarbon gases, especially ethylene C_2H_4, and the ethylene (C_nH_{2n}) series, present to a considerable extent in manufactured towns gas, sometimes as much as 6-7½% and nearly always not less than 2½-3%, and almost certainly also in the waste combustion products from the gas, are very poisonous substances. Their effect upon human life is therefore an extremely important field for research. It has been suggested on more than one occasion that unsaturated hydrocarbons are the cause of cancer. Certainly they have a particularly deadly effect upon plant life, as well known to many horticulturists, gardeners, and greenhouse attendants. A typical example is described in the interesting *Report on Investigations into the Damage Caused to Greenhouse Crops by Minute Quantities of Escaping Coal Gas*, by J. G. Murray, Horticultural Organizer of the Lindsey area, and H. T. Cranfield, Advisory Chemist of the Midland Agricultural College, published several years ago (after 1932, not dated) by the Horticultural Education Sub-Committee of the County Council of Lindsey (Lincolnshire).

This Report points out that in the spring of 1932 a nurseryman in Lindsey reported to the County Horticultural Organization that certain crops in a small lean-to greenhouse were failing, and that he suspected poisoning by fumes of some kind.

Up to 1932 this greenhouse had been running for seven years and always gave the most satisfactory results, being used for forcing early bulbs, followed by the growing of cucumbers and chrysanthemums. It had already been noticed that early in 1931 the bulb crop failed to develop flowering shoots, while later on the cucumbers also failed. In consequence tomato plants were grown but these gave very poor results, although when the house was afterwards filled with chrysanthemums there were no ill-effects and it was thought the trouble had finished.

However, the next year when bulbs were again placed in the house for early forcing they were all ruined for sale purposes, and expert advice was called in. No smell of any kind could be detected, and the heating apparatus was conclusively proved not to be to blame.

The matter became so mysterious that a detailed examination was made in the surrounding neighbourhood with the experimental growing of plants in bell jars, and finally the only conclusion was that the cause must be gas, either from sewers or towns gas mains. It was discovered that the town sewer traversed the path adjacent to the greenhouse and that a gas main was situated under the road about 16 feet from the boundary wall. There was, however, no trace of sewer gas, as proved conclusively by damped lead acetate papers, no indication of sulphuretted hydrogen being shown, even when holes were dug all over the ground.

Next the local gas works manager was consulted with regard to the possible leakage of towns gas, but according to his report the apparatus used by the gas works officials failed to detect any leak in the gas main, while there was no smell of coal gas even when holes were dug. However, it was suspected that the poisoning of the plants was caused by ethylene and similar products and finally the presence of leaking coal gas was conclusively proved by means of palladium chloride papers, which go grey or black in the presence of carbon monoxide. These palladium chloride papers were sealed up for 24 hours in different parts of the greenhouse, and showed decidedly the presence of carbon monoxide, and therefore towns gas.

The method of entry of the gas into the greenhouse was discovered by pure accident, which incidentally is only another of the many striking examples of the insidious character of manufactured towns gas in penetrating to all kinds of places. Some days after removing the bell jar over a hole in the floor of the greenhouse one of the nurserymen noticed that a spider had spun a web over the hole, which kept up a persistent fluttering. It was then discovered that a current of air was ascending through this hole, and on excavation there was unearthed a disused stone culvert or drain 2½ feet below the surface. Towns gas from a leak in the gas main was passing into the culvert and then gaining access to the greenhouse through the porous earth floor.

The authors of the paper quote another interesting paper by Mr. George E. Stone of Amherst (Mass) in the United States, which was read on the 8th July, 1916, before the Florists' Exchange, entitled *Damage Resulting to Greenhouse Crops and Soil by Escaping Illuminating Gas.* In this paper by Stone a case is reported where coal gas had travelled 2,000 feet under frozen soil in winter and gained access to a greenhouse. Further, in another case towns gas from a leaky gas main ¼ mile away penetrated a sewer, and travelled through a drain to a greenhouse, causing serious damage to plants, in spite of the fact that no trace of gas could be detected by smell.

As a result of this discovery of the entry of gas into the greenhouse in Lindsey the culvert was cemented over and a ventilating pipe inserted so that no trace of escaping gas could possibly penetrate into the greenhouse. The result was an immediate success, and tomato plants have now been grown without any ill-effects, while during the spring of 1933 the whole house was filled with bulbs for forcing, giving the most excellent results.

As a result much experimental work was carried on with the growing of young tomato plants under conditions of manufactured towns gas contamination, the most characteristic feature in this connection being the stunted growth of the plant, accompanied by a marked thickening of the main stem. The poisonous effect of towns gas also is extraordinarily rapid and deadly, and according to these researches boxes of young tomato plants in a gas-contaminated greenhouse with closed ventilators showed a droop of the leaves within 30 minutes. On opening the ventilators the plants recovered almost as rapidly and were quite normal when removed from the greenhouse. Prolonged exposure, however, to the gas-contaminated atmosphere resulted in permanent injury.

Another important paper also in the United States is that by Hervey and Rose entitled *The Effect of Coal Gas on Plants*, which appeared in the *Botanical Gazette*, Volume 60, No. I, 1915, giving detailed results of investigations upon the effect of Chiago towns gas on plants. They found that one part of gas in 400 parts of air caused a marked effect on the roots of plants, and after suspecting ethylene they proved that a concentration of only one part of ethylene in 250,000 parts of air was sufficient to poison plants to a degree similar to that given by traces of gas, that is, one part in 400. Further, they stated that tomato plants and etiolated sweet pea seedlings were more sensitive to ethylene poisoning than any ordinary common plants.

The deadly effect of ethylene was also shown in 1917 by an American botanist, Sarah L. Doubt, in her paper *The Effect of Coal Gas on Plants* (*Botanical Gazette*, Volume 63, No. III, 1917). This work has proved that a concentration of even one part of ethylene in 1,000,000 parts of air retards or prevents the opening of carnation buds, while other plants such as sweet pea, mimosa, castor oil, and tomato are extremely sensitive to traces of coal gas, the first symptoms being a falling off of the leaves, the older leaves going first. Many plants also react to diluted coal gas as low as one part in 20,000, and the shedding of the older leaves with certain plants is one of the best tests possible for the detection of traces of coal gas in the air.

In this connection William Crocker had an article in the American paper *Science Service* (Philadelphia, 23rd April, 1932), in which it is suggested that potted tomato plants should be carried in submarines to act as extremely sensitive detectors of traces of ethylene, which seems to be almost invariably produced when carbon monoxide is being formed. That is, the presence of ethylene is a sure indication of carbon monoxide. According to William Crocker, one part of ethylene in 10,000,000 parts of air, an almost incredible figure, can be detected by the fact that in many cases leaf stems show a curious bending. Certain plants also seem to be doped by ethylene and lose all their sense of direction in growing.

Familiar knowledge also is that not only towns gas but any combustion products from a gas or solid fuel fire, such as coke, coal, or wood, must not be allowed to enter greenhouses for fear of killing the plants, and all heating has to be "external" from outside, say by pipes.

The peculiar unhealthy and "toxic" smell of unburnt manufactured towns gas is another indication that traces of complicated organic substances are present, quite distinct from the ordinary simple hydrocarbon gases and other products that in the pure state have no smell, although organic sulphur compounds may be a part explanation.

Significant in this connection are the results of detailed experiments carried out by Yandall Henderson, Howard W. Haggard, and their associates at Harvard University on the amount of pure carbon monoxide and of manufactured towns gas that causes death in dogs. This work was mainly concerned with the subject of poisoning from the exhaust of motor vehicles, and the results are given in the contribution *Physiological Effects of Automobile Exhaust Gas and Standards of Ventilation for Brief Exposures* by Y. Henderson, H. W. Haggard, M. C. Teague, A. L. Prince, and R. M. Wunderlich in the *Journal of Industrial Hygiene* (Boston, July and August 1921, pp. 79-92 and 137-146 respectively).

In a first series of experiments pure carbon monoxide was mixed with air to give an atmosphere of 0·30-0·40% carbon monoxide, with which five dogs were killed. In each case they became unconscious with no more apparent discomfort than if anæsthetized with ether or chloroform. At the point of death also the carbon monoxide saturation in the blood was 87%, 82%, 84%, 79%, and 88% respectively, or 84% average.

Another set of experiments were then carried out by adding the manufactured towns gas to air in sufficient amount to give an atmosphere as before of 0·30-0·40% carbon monoxide, and in this case the effect was very different. The four dogs used, all vomited and were greatly distressed, while the collapse was more rapid. Also on the point of death the saturation of the blood was 74%, 67%, 76%, and 76%, or 73% average. Here, therefore, it is clearly shown that poisonous constituents are present in manufactured towns gas in addition to carbon monoxide, since death was caused with only 73% blood saturation instead of 84% as with pure carbon monoxide, and under different conditions. As Henderson and his colleagues express it:—

> "These observations and the fact that death ensued though a lower percentage of carbon monoxide existed in the blood indicate that illuminating gas contains some substance or substances which render it distinctly more toxic than an equal amount of pure carbon monoxide."

Unfortunately the composition of the manufactured towns gas is not stated in the contribution but presumably, according to the usual practice in the United States, was a mixture of a considerable proportion of carburetted water gas made from coke and of high temperature carbonization coal gas from coke ovens or gas retorts. Presumably also the latter gas by itself, without the water gas, would have had a still more drastic effect.

The well-known deadly character of manufactured towns gas so far as concerns sudden death is due to poisoning from carbon monoxide. As indicated on page 88, this is always present in high temperature carbonization (coal gas) to the extent of 6-7% approximately. With steaming of the charge the figure is 16-18%, whilst semi-carburetted and carburetted water gas contains 33-39%, with 43% for blue water gas. A large proportion of manufactured towns gas, therefore, contains 15-20% carbon monoxide, and death is caused often in a minute or two, by breathing the gas. Consequently the standard method of committing suicide is now to "put the head in a gas oven", that is, turn on the gas and breathe it.

CHAPTER XI

CARBON MONOXIDE POISONING IN RELATION TO CANCER

MANY suggestions have been made that cancer may be caused by carbon monoxide poisoning, particularly from the exhausts of the internal combustion engines of motor vehicles. It is quite possible that slight but more or less continuous carbon monoxide poisoning plays an important part in causing general ill health by reducing the natural resistance to many diseases, including cancer. Here again is another field in which much further investigation is urgently required.

There are four main sources of carbon monoxide in what may be termed bulk amount; (1) manufactured towns gas plants and by-product recovery coke ovens; (2) internal combustion engine exhausts; (3) slow burning fires, especially of the closed stove variety, and (4) total gasification, such as in the case of producer gas and suction gas and the operation of the blast furnace.

Great Britain, for example, produces, taking the 12 year average period 1924-1935, a total of approximately 305,851,000,000 cubic feet of manufactured towns gas per annum of which, as already indicated (page 80) 283,648,000,000 cubic feet are sold. These figures refer to authorized undertakings, that is

96% of the total, so that about 19,000,000,000 cubic feet of the gas (based on 100% total) are lost (discharged to the air) by leakages before reaching the consumers meters, penetrating especially into all available underground cavities, including cellars, basements, sewers, and conduits for electric cables, telephone and telegraph wires, and other services. No statistics are available as to the amount of towns gas lost by the consumers, that is past the meter, but the total amount must be very great.

Probably for 100% of the undertakings it is at least 5%, corresponding in Great Britain to 14,800,000,000 cubic feet per annum (5% of 295,500,000,000). Accurate statistical information as to the average chemical composition of the manufactured towns gas supplied in Great Britain is not known.

It will be remembered from pages 88-90 that three main types of gas are supplied, simple high temperature carbonization gas from retorts and coke ovens with 6-7% carbon monoxide, high temperature carbonization vertical retort gas with average steaming of the charge having 16·5-17·5% carbon monoxide, and carburetted water gas with 34% carbon monoxide. Obviously therefore if a given gas undertaking is supplying coal gas only the percentage of carbon monoxide is relatively low, although still dangerous, whilst in the case of steamed vertical retort gas the figure is much higher. The more carburetted water gas also that is added to coal gas the greater is the carbon monoxide content.

In my opinion there is an average of about 17·5% carbon monoxide in the manufactured towns gas supply of Great Britain. That is, the 33,000,000,000 cubic feet per annum of unburnt towns gas lost by leakage contains 5,915,000,000 cubic feet of carbon monoxide, discharged to the air. In addition a relatively large but unknown amount of unburnt carbon monoxide is contained in the waste products of combustion from the burning of towns gas under most conditions since combustion is not taking place at 100% efficiency.

It should be pointed out also that in Great Britain the manufactured towns gas industry is allowed by law an entirely free hand as to the percentage of poisonous carbon monoxide contained in the gas and also the methods of manufacturing the gas. That is, any towns gas undertaking can supply, if it so desires, say producer gas of 165 B.Th.U. per cubic foot, with 24% carbon monoxide or blue water gas of 300 B.Th.U. per cubic foot, with 43% carbon monoxide. Both these gasses, apart from carbon monoxide poisoning, would give results quite equal in every way to the present expensive rich gas of 450-500 B.Th.U. per cubic foot and 17·5% carbon monoxide.

The by-product coke oven industry of Great Britain carbonizes 14,813,000 long tons of coal per annum, (12 year average, 1924-1935,) and produces approximately 185,000,000,000 cubic feet of coal gas per annum, containing 6-7% carbon monoxide. From the point of view of national health this, however, is of comparatively minor importance.

The coke oven industry is prevented by law, in the interests of the manufactured towns gas industry, from selling this gas direct to the community.

Consequently, taking averages for the past few years, about 60% of the gas is used to heat the coke oven settings, although cheap low grade blast furnace gas and producer gas will do equally well, and 24% for other application in the coke oven plants, such as the firing of boilers. Also about 10% is sold to the manufactured towns gas industry, 3·5% sold to other establishments and 2·5% wasted by blowing into the air. Under these circumstances pollution by the 6-7% carbon monoxide in the gas is more or less local, at the coke oven plants themselves, and the 10% sold for mixing with manufactured towns gas is included in the latter so far as considerations of general carbon monoxide poisoning are concerned.

Many hundreds of people are killed throughout the world every year by the exhaust from the internal combustion engines of motor vehicles. The petrol, benzole, alcohol, Diesel oil, or other liquid hydrocarbon used, is burnt in the vapourized form with such rapidity as to cause an explosion. Since it is impossible for this combustion to be 100% efficiency either as regards unburnt products or excess air, the engine exhaust contains on the average about 6% carbon monoxide, although the figure varies considerably, depending upon the speed of revolution of the engine and the care exercised in obtaining the correct explosive mixture. It is therefore an extremely dangerous practice to allow the engine of a car to run when in a small closed garage.

The general idea, however, that the unhealthy effect of the exhaust of motor vehicle, or any other types of internal engine, is due only to carbon monoxide is not correct. Just as serious may be the

the presence of cancer-causing hydrocarbons in motor spirit because of the cracked gasoline in petrol, and decomposition by the very high temperature of the explosion, over 1472°F. (800°C.)

If combustion is not complete whilst running normally under the best conditions it is obvious that when the engine is "idling" or "ticking over" in traffic the exhaust must contain a greatly increased amount of hydrocarbon compounds, unburnt or partly burnt, as well as carbon monoxide.

Petrol and benzole contain a small percentage of higher hydrocarbons boiling at over say 302°F. (150°C.) and since petroleum products when heated to a high temperature become cancerous, this action probably takes place in an internal combustion engine and results in the exhaust containing cancer-causing constituents. These, however, should be much less liable to cause cancer by breathing the contaminated air than carbonization and combustion products brought into contact with food.

The closed stove also, burning any variety of solid fuel, such as charcoal, anthracite, coke, kitchen and similar refuse, and wood is extremely dangerous because the slow rate of combustion is apt to result in a high percentage of carbon monoxide. Here again many hundreds of people are killed every year throughout the world by what are usually called "fumes" from closed stoves. For some not very clear reason high temperature carbonization towns gas and metallurgical coke seems to be the most dangerous fuel to use in the closed stove. Coke of this type made from bituminous coal, as distinct from low temperature carbonization, is of poor combustibility and tends therefore to burn to carbon monoxide (CO) instead of the almost harmless carbon dioxide (CO_2). Charcoal however is almost as dangerous, but anthracite seems to be slightly less liable to carbon monoxide formation and wood is the safest.

The main reason would seem to be the ease with which the fuel will burn, that is the degree of combustibility, so that for example wood combines with all the oxygen available in a somewhat limited air supply, whereas coke or charcoal does not. It must be understood, however, that any solid combustible material will give a large amount of carbon monoxide in the waste combustion gases if the air supply is restricted sufficiently. The closed stove is a contrivance very favourable to the formation not only of carbon monoxide but also cancer-causing carbonization hydrocarbons, since it operates with a deep and narrow diameter bed of fuel and most of the air admitted at the bottom. There is no question that in a huge number (very many million) of domestic and other establishments throughout the world, human beings, because of closed stoves, are more or less constantly in an atmosphere containing small amounts of carbon monoxide.

Particularly dangerous also are closed water heaters, in this connection solid fuel, such as charcoal, anthracite, or coke, being almost as bad as gaseous fuel, because of the restricted combustion space and air admission.

Carbon monoxide, a colourless, tasteless, and combustible gas, is one of the most deadly poisons known. When breathed in the pure state it will kill a human being almost in a few seconds and even when relatively diluted the action is incredibly quick. Thus, manufactured towns gas containing about 17·5% carbon monoxide when breathed direct into the lungs causes unconsciousness say in less than 30 seconds, and death in a few minutes. Although motor car exhausts only contain, as stated, 6% carbon monoxide when discharged into the relatively large amount of air in a closed one-car garage they may cause dizziness very quickly, followed upon after by unconsciousness and death probably in some such time as 5-15 minutes, depending on the air-tight character of the garage.

A vivid example of the extreme rapidity of the action of carbon monoxide was a description published in connection with the operation of blast furnaces, which, it will be remembered, operate day and night continuously. A worker engaged in repairs liable to come into contact with the gas has a rope attached to his body so that another man, away from the danger zone, can pull him away while cylinders of oxygen are kept ready. In the description mentioned it is stated a workman was striking a series of slow steady blows with a heavy hammer. Between the period of these blows, a matter only of seconds, and while the hammer was in the air, he collapsed unconscious because of a whiff of the gas which contains about 25-30% carbon monoxide. As the narrator expressed it, no viper could have struck with such speed.

In the pure state carbon monoxide can be made in the laboratory in various ways such as the action of concentrated sulphuric acid on formates, exalates, or ferrocyanides. Also it is produced in huge amount, as already indicated, by the carbonization of conbonaceous material, that is in general the animal and vegetable products of the world, all of which contain carbon.

Expressed in simple language carbonization consists in heating carbonaceous material in a closed container, retort or oven in absence of air, so that the huge number of complicated organic compounds are decomposed and mostly broken down into less complicated organic compounds, including the simplest of all, such as carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), ethylene (C_2H_4), and acetylene (C_2H_2). Consequently it is a normal constituent not only of the gas from the high temperature carbonization of bituminous coal but of the gas from the low, medium, and high temperature carbonization of any carbonaceous material. Gasification may be described also as complete conversion of solid (or liquid) carbonaceous material, not including the mineral matter of the latter, into a combustible gas. Mostly this is carried out by air to give carbon monoxide ($2C+O_2=2CO$) or by steam to give carbon monoxide and hydrogen ($C+H_2O=CO+H_2$) under conditions that the carbonaceous material is at a very high temperature, such as 1652-1832°F. (900-1000°C.) which is obtained by burning part of the carbonaceous material to carbon dioxide (CO_2). In this connection carbon monoxide also results by passing carbon dioxide through a deep bed of incandescent fuel ($CO_2+C=2CO$). Combustion is direct and more or less complete combination of carbonaceous material, gaseous, liquid or solid, not including the mineral matter or ash, with the oxygen of the air, evolving heat and light to form carbon dioxide ($C+O_2=CO_2$).

Under many conditions, however, the combustion is incomplete and carbon monoxide ($2C+O_2=2CO$) is present, along with carbon dioxide (CO_2) in the waste combustion gases. This happens also in the explosions, that is sudden very rapid combustion of carbonaceous material. In colliery explosions, for example, caused by ignition of methane (fire damp) (CH_4) and other hydrocarbon gases, and coal dust, the dangerous character of the "choke damp" or waste products of combustion is due to the presence of carbon monoxide in the carbon dioxide.

Carbon monoxide is poisonous because it combines directly with the hæmoglobin (red corpuscles) of the blood to form a loose addition product, termed carboxy-hæmoglobin, which is cherry red in colour, quite different from healthy ærated blood (oxy-hæmoglobin) and has a characteristic absorption spectrum. Hæmoglobin is a highly complicated organic compound, or mixture of compounds, of nitrogenous composition, which combines with oxygen to form another loose addition product, known as oxy-hæmoglobin. The blood circulates continuously, pumped by the heart through the whole body, including the fine capillaries of the chest or continuously operating breathing bag, where it comes into direct contact with the air, containing 21% oxygen and roughly 79% inert nitrogen, along with traces of other gases. The oxy-hæmoglobin formed is carried in the blood stream through to every part of the body and supplies oxygen necessary for the multitudinous and complicated oxidation reactions essential to life, which expressed in the simplest possible form consist of combustion of carbonaceous (organic) material ($C+O_2=CO_2$) with formation of carbon dioxide. The latter is discharged by the blood on its return to the lungs, and re-absorbs more oxygen, and so on.

In connection with breathing, death results rapidly (only a few minutes) from one of two causes. The first is prevention of air (oxygen) from entering the lungs, that is suffocation, since the blood can no longer obtain oxygen to form oxy-hæmoglobin. The second is prevention of the hæmoglobin from combining with oxygen to form oxy-hæmoglobin. This is what happens in the case of carbon monoxide poisoning. For some mysterious and unknown reason the extremely complicated organic compounds known as hæmoglobin will combine instantly, under the low temperature conditions of the body of 98-99°F. (36-37°C.) with carbon monoxide to form carboxy-hæmoglobin. It is extraordinary also that the affinity of hæmoglobin for carbon monoxide is 200-300 times as great as for oxygen. Therefore, if even the merest trace of carbon monoxide is in the air breathed, it will almost all be absorbed by the blood in preference to oxygen. As soon as carboxy-hæmoglobin is formed the corresponding amount of hæmoglobin can of course no longer supply oxygen to the body. For this reason breathing pure carbon monoxide causes death with even greater rapidity than say sudden drowning (displacement of all the air in the lungs by water) because in the last extremity life is sustained for a number of seconds by using up every trace of oxygen in the blood stream, which does not obtain in normal breathing.

The general idea that carbon monoxide causes "suffocation" is not correct because this means deprivation of oxygen, and not inability of the body to absorb oxygen. In almost every case carbon monoxide breathed into the body, whether from carbonization, gasification or combustion, is much diluted. Consequently the body goes on absorbing over a period of minutes or of hours, the carbon monoxide in the air as it is breathed into the lungs, and the amount of carboxy-hæmoglobin increases accordingly.

Death is caused approximately at 80% blood saturation, that is when 80% of the total hæmoglobin is converted to carboxy-hæmoglobin the remaining 20% of oxy-hæmoglobin being unable to support the last flicker of life.

When carbon monoxide is breathed in air, even in very small amounts, such as from towns gas or exhaust from a closed stove, the only symptoms which become evident at the stage of about 30-35% blood saturation, or formation of carboxy-hæmoglobin, are a slight dizziness, then headache and sometimes palpitations, followed rapidly by loss of sight, hearing, and intelligence, and unconsciousness, that is, collapse in a faint. Under these conditions breathing of course goes on, and the absorption of carbon monoxide continues unaltered until 80% blood saturation is reached, and death results.

Because of the avidity of hæmoglobin for carbon monoxide extremely small proportions of the latter in the air breathed will cause serious results. When less than 0·5% is present death follows in a short time. Continued breathing also of air containing such an extraordinarily small amount as 0·025%, which is often present in the atmosphere of garages, gas works, blast furnaces, and other establishments, will in a number of hours, convert the hæmoglobin into 30-35% carboxy-hæmoglobin, with perceptible symptons of poisoning.

For this reason the most elaborate precautions have to be taken with the ventilation of long main road tunnels which at any given time may be completely filled with motor cars, even for considerable periods.

Under these conditions the carbon monoxide in the atmosphere from all the exhausts would very soon reach the danger point if powerful mechanical ventilation was not in use. An atmosphere containing 0·10% carbon monoxide also will begin to cause unpleasant symptoms in about an hour, while in this time an atmosphere of 0·15% becomes dangerous.

The only method of saving life in case of acute carbon monoxide poisoning with less than 80% blood saturation, is to increase the oxygen supply to the lungs. On the ordinary principles of physical chemistry and solution of gases in liquids where no pronounced chemical action, as distinct from unstable addition products, is concerned, the relation between the amount of carboxy-hæmoglobin and oxy-hæmoglobin depends largely on the relative amount of oxygen and carbon monoxide in the lungs. Air, as already stated, is only 21% oxygen, and when carbon monoxide is added, say to the extent of 0·25%, the blood from this absorbs relatively dilute oxygen and extremely dilute carbon monoxide an enormous proportion of the latter.

But if air with 21% oxygen is replaced by 100% oxygen from a cylinder of liquid gas the position is altered entirely. Under these conditions of great difference in amount between oxygen and carbon monoxide the latter is rapidly displaced from the blood and oxy-hæmoglobin is formed again, with return to consciousness.

In treating severe carbon monoxide poisoning cases therefore one method is to drag the patient out into the fresh air and pass oxygen into the lungs. At the same time every effort must be made to keep the body warm, using blankets, hot bottles, or bricks, or any other method, to prevent pneumonia since the temperature is at a low ebb due to the heavy reduction in the normal degree of oxidation of the blood, that is internal heat formation.

It was then discovered that oxygen mixed with about 5% carbon dioxide (CO_2) gives better results than 100% oxygen, whilst the latest method is to use carbon dioxide only for a very short period, oxygen not being essential. Apparently, the brain control of the normal movement of the lungs regulates itself according to the amount of carbon dioxide present. Excess causes the lungs to work at a higher speed and take in an amount of air above the normal. Another of the new remedies also for carbon monoxide poisoning, in conjunction with oxygen, is the injection into the blood of methylene blue solution. Much further information, however, is required, the cause of the beneficial effect in this case not being known.

The body also endeavours to fight against carbon monoxide poisoning by making more red blood corpuscles (containing hæmoglobin) as fast as possible to replace those put out of action. According to the latest researches it would now appear that if the atmosphere contains less than 0·02% carbon monoxide the body is able for some time to make red corpuscles fast enough to prevent any appreciable decrease in the oxygen absorbed. The difficulty in acute carbon monoxide poisoning, as with many other types of poisoning, is that the body has not time to develop the antidote quickly enough.

The most important point in relation to cancer is the effect upon human health of a very small degree of long continued carbon monoxide poisoning, say for 15-20 years or over. It is stated that in the crowded streets of large towns there often is 0·001-0·026% of carbon monoxide in the atmosphere, due largely to internal combustion engine exhausts, although leakage of manufactured towns gas probably also contributes.

According to some authorities the air of living-rooms and kitchens often contains 0·01% carbon monoxide, and the average gas cooker, it will be remembered, is particularly dangerous in this respect, because in many cases no flue is fitted and the large volume of waste combustion gases is discharged direct into the air, including all carbon monoxide present after combustion, as well as that from the leakage of unburnt gas.

From one cause or another probably 50-75% of the population of Great Britain, or any similar industrial country, have their blood contaminated to a slight extent, say 1-5% saturation, by carbon monoxide. Workers in many industries also connected with the manufacture and use of carbonization and total gasification gases may be expected to have a higher percentage than the average, which will decrease again during the night or on holiday.

Much interest attaches to a series of investigations carried out in 1927 by the Australian Government Division of Industrial Hygiene, upon the health of the employees of a well-known towns gas works in Melbourne. A total of 370 men were examined and 15·4% of them had a considerable degree (over 4%) of carbon monoxide saturation. One man had no less than 15%, one man 10%, four men 8%, two men 6%, and forty-nine men 4%, that is a total of 57 or 15·4%, presumably the others having none or only a slight degree. According to this investigation there was no evidence that the general health of the employees, including liability to cancer, was inferior to the average.

Whether such more or less slight poisoning by carbon monoxide has any widespread ill effect is not known with certainty. It may be the result is in many cases a certain amount of decreased resistance to disease in general, part of a general "off-colour" feeling and slight dulling of the nervous system. Perhaps also the beneficial result of sea and mountain air after town life is that the blood for the first time for a long period contains no trace of carboxyhæmoglobin. This does not alter the fact that at the seaside and in the country the atmosphere of the living-rooms of many houses is often much worse than that of the average town house.

Since carbon monoxide poisoning means slightly less oxygen in the blood than normal it is interesting to note that according to some theories cancer is caused by oxygen deficiency. A variation is that the eating of food having less than the normal oxygen content, due to inadequate growth, results in cancer. The contention is that if many vegetables, such as potatoes, white turnips, and swede turnips, are deprived of a proper supply of oxygen, abnormal growths develop, resembling cancer. Much undeveloped or oxygen-deficient vegetable food therefore, according to this theory, is cancerous, of which other examples are unripe fruit and rhubarb "forced" in the dark, and when eaten will cause cancer in human beings. A further point claimed is that a bad year for crops, due to wet weather, is always followed by the increase of diseases such as influenza and sleepy sickness, and foot and mouth disease in cattle, due to eating oxygen-deficient food. Another theory, that of Dr. Vernor Sinclair, already mentioned, is that slight carbon monoxide poisoning impedes the natural flow of the mucuous membrane or "dries the mouth" which is well known to be one of the disadvantages of many types of gas fire.

This he regards as one of the chief causes of colds and influenza, but even more important is the claim that carbon monoxide interferes with the flow of other secretions of the body, and the whole internal lymphatic circulation. The result is constant irritation in various tissues and cells, which may cause cancer in addition to nervous and neurotic troubles.

As will be discussed on future pages the latest research work on cancer-causing hydrocarbons has shown that bile acids secreted by the liver may be decomposed to form very active cancer-causing products, such as methylcholanthrene, and it is possible this action may take place because of some type of poisoning such as from carbon monoxide, manufactured towns gas, and motor car exhausts.

The main question is would a human being living permanently in a state of partial carbon monoxide poisoning, with say 5-10% blood saturation, take cancer more easily than a similar human being living in pure air, completely devoid of any trace of carbon monoxide. No one knows definitely the answer to this question. Similarly it is not certain that one or several experiences of acute carbon monoxide poisoning, necessitating the use of oxygen or carbon dioxide leaves the system without a permanent injury, although no blood saturation may remain.

Some people also are much more badly affected by carbon monoxide poisoning than the average, and it would be extremely valuable to know if these same people are more liable to cancer.

So far as can be made out, however, on present knowledge, carbon monoxide poisoning does not seem to play a major part in causing cancer, whatever may be the case with regard to other diseases and general ill-health.

The matter is different with regard to motor vehicle exhausts because the high temperature decomposition of the petrol or benzole and the lubricating oil will result in the formation of cancer-causing hydrocarbons, which are almost certain to be to some extent in the exhaust.

This aspect of motor vehicle exhausts will be discussed at more length in connection with the composition and properties of coal tar fractions and petroleum.

CHAPTER XII

DE-TOXIFICATION OF MANUFACTURED TOWNS GAS

BECAUSE of the huge number of people killed every year (accidents and suicides) throughout the world by manufactured towns gas, many attempts have been made to devise some method of making what is termed a "non-toxic" gas.

This means in general the elimination of carbon monoxide, and to some extent organic sulphur, because the possibility of cancer-causing hydrocarbon poisons being also present in manufactured towns gas is a new idea.

Natural gas from petroleum wells, often used for towns supply, is absolutely non-poisonous, being composed chiefly of methane (CH_4) containing no carbon monoxide and no cancer-causing constituents. Further, in my opinion, all gas from the low temperature carbonization of bituminous coal or other carbonaceous material, and probably also from medium temperature carbonization up to about 1292°F. (700°C.) cannot cause cancer. This should apply, therefore, to the 200 B.Th.U. per cubic foot supply of the Nuneaton Gas Company, already referred to, made by low temperature carbonization and partial gasification of bituminous coal in mechanically continuous vertical retorts.

Great interest attaches to a new and important gas "de-toxification" process that has been developed since 1934 by the Non-Poisonous Gas Holding Co. of Lugano-Slazione. This is the invention of Dr. Wilhelm Bertelsmann, a gas works chemist of Berlin, and his associates, according to the patents of Bertelsmann, Schuster, and Becker, and the Gesellschaft für Gasentgiftung.

The first manufactured towns gas works in the world to be operated on "non-toxic" carbon monoxide and partly organic sulphur free principles, using this process, is that of the town of Hameln-am-Weser, made famous by the story of the Pied Piper and the rats. This is a small works with a capacity of 350,000 cubic feet per 24 hours, and the detoxification plant was started up in November 1934, whilst details of the process were published for the first time in 1935 by H. C. Gerdes, the manager at Hameln. Several other plants are now stated to be operating in Germany.

The process consists, in the main 1-stage modification, in mixing the manufactured towns gas with steam at atmospheric pressure, heating to 752°F. (400°C.), and passing over an iron oxide catalyst, contained in two chambers operating in series, so that the carbon monoxide interacts with the steam to give carbon dioxide and hydrogen ($CO+H_2O=CO_2+H_2$). The hydrogen formed has approximately the same heating value as the original carbon monoxide, so that the gas is not much altered in this connection, whilst the carbon dioxide is left in.

At Hameln the original manufactured towns gas was high temperature carbonization coal gas mixed with blue water gas. In order to make a gas of exactly the same heating value after de-toxification it is necessary to alter the proportions slightly by increasing the coal gas. There is now used at Hameln 73% coal gas and 27% blue water gas, 1·0 volume of which is mixed with 1·1 volume of steam (water vapour). Heating to 752°F. (400°C.) is carried out on the external principle in the two catalyst chambers, burning a small part of the gas as fuel for the purpose, and the gas is then cooled, being used to preheat the incoming cold gas in heat interchangers.

The following is the average composition of the manufactured towns gas at Hameln after mixing the coal gas and the water gas, and of the non-toxic gas (as now made) after passing over the iron catalyst:—

	Original Towns Gas at Hameln before treatment	Non-toxic Towns Gas at Hameln after treatment
	%	%
Carbon monoxide (CO)	21·4	1·0
Hydrogen (H_2)	53·8	63·3
Hydrocarbons (saturated)	14·7	17·5
Hydrocarbons (unsaturated)	1·7	1·8
Total Combustible	91·6	83·6
Carbon dioxide (CO_2)	2·8	13·3
Oxygen (O_2)	0·6	0·2
Nitrogen (N_2 by difference)	5·0	2·9
Total	100·0	100·0
B.Th.U. per cubic heating value foot gross	485	470
Specific Gravity (Air=1)	0·46	0.46

The 21·4% carbon monoxide has been reduced to 1·0%, an almost harmless figure, while the hydrogen has been raised from 53·8% to 63·3% and the carbon dioxide from 2·8% to 13·3%, which, however, makes no difference to the suitability of the gas for towns supply.

Apart from removing carbon monoxide, highly important is that the treatment of the gas at the relatively high temperature with an iron catalyst reduces to a pronounced degree the cyanide, naphthalene, and difficult and objectionable organic sulphur content. Thus at Hameln it is stated that the cyanogen is reduced from 5·29 grains per 100 cubic feet to 1·57 grains, the naphthalene from 6·00 grains to 2·76 grains, and the organic sulphur from 10·90 grains to 1·57 grains.

If my theory of the presence of dangerous cancer-causing hydrocarbons in average high temperature, carbonization gas, and also carburetted water gas, is correct, an important point is whether the above treatment for the removal of carbon monoxide also destroys these poisonous high boiling point hydrocarbons.

The serious practical objection from the point of view of the manufactured towns gas industry to any de-toxification process is the extra capital and operating costs involved, especially as regards deterioration of the catalyst by the organic sulphur compounds.

In addition the process can be operated on the 2-stage principle, according to which most of the carbon monoxide is removed by the above treatment, the carbon dioxide then eliminated by scrubbing with high pressure water sprays, and the remaining small amount of carbon monoxide removed in a second stage by using a nickel or other catalyst.

The general principles involved in the conversion of carbon monoxide by catalysts in the presence of steam, hydrogen, and other gases, into carbon dioxide, methane, and a whole range of complex alcohols, commencing with methyl alcohol or methanol (CH_3OH), have long been familiar knowledge in organic chemistry. The classic researches of Sabatier and Senderens in France in this field commenced shortly after 1900 and included the conversion of carbon monoxide in the presence of hydrogen to methane by the use of finely divided nickel as the catalyst ($CO+3H_2=CH_4+H_2O$). In 1902 Sabatier and Senderens had the intention of developing this new discovery for the de-toxification of manufactured towns gas. The process, however, made no progress, being much too costly, whilst an obvious difficulty is that the manufactured towns gas industry is not compelled by law to supply a non-poisonous gas, or in most cases even to reduce the carbon monoxide and organic sulphur content to below a certain limit.

Carbon monoxide could also be separated from towns gas by very high pressure and intense refrigeration methods on the "Linde" principle, converting the constituents into the liquid condition, such as used for making hydrogen from coke oven gas (coal gas) in the synthetic ammonia, hydrogenation, and synthetic liquid fuel industries. As before, the objection is the cost.

CHAPTER XIII

COMPOSITION AND PROPERTIES OF COAL TAR AND COAL TAR FRACTIONS, AND OF CANCER-CAUSING AND ANALOGOUS HYDROCARBONS

It is difficult for any one who is not an organic chemist to understand the extreme complexity of coal tar made by the carbonization of bituminous coal, or of any other variety of coal within the complete range from anthracite to semi-bituminous. The yield of tar from anthracite and semi-anthracitic coals is only small because of the low bituminous and high carbon content, and such coals are therefore not generally carbonized unless they are used in the form of blends.

With regard to bituminous coal a different tar is obtained from the same coal according to the temperature and duration of the carbonization and also the type and design of the retort or oven used. In addition each variety of bituminous coal probably gives its own variety of tar, different from any other, for each specific condition of temperature and duration of heating, and of retort or oven design. That is many hundred varieties of coal tar have already been produced, and theoretically the figure could be thousands.

Consequently all references to high temperature carbonization coal tar, as well as to low temperature tar from coal, must necessarily be of a somewhat general character.

Most varieties of high temperature carbonization bituminous coal tar are made by using standard towns gas retorts and by-product recovery ovens of the simple, externally heated, closed type.

As already indicated these include intermittent horizontal gas retorts, vertical, intermittent, continuous, or mechanically continuous retorts or chamber ovens, operated non-steaming, and by-product recovery coke ovens. The temperature of carbonization it will be remembered is extremely high, generally about 1832-2012°F. (1000-1100°C.) with long duration of heating of the charge, which may be over 20 hours in the case of some varieties of coke ovens. As stated, the yield averages 10-11 gallons of tar per ton (2240 lbs.) of coal carbonized, and the product is a black viscid liquid. Average high temperature coal tar of this type also contains at least 150-200 different organic substances of known composition, and there may be hundreds more still unidentified.

In the commercial utilization of coal tar fractional distillation is carried out, generally to give four chief fractions, light oil, middle oil, heavy oil and, with the aid of steaming, anthracene oil, whilst a very large proportion of the original bulk is left behind in the still as pitch, which may be "soft" or "hard", depending upon the extent of the distillation.

The exact methods and temperatures used in obtaining the main fractions vary somewhat but an average result is as follows, based on dry tar (free from liquor) :—

Fraction	Temperature		Percentage by Volume of the Total Tar
	°F.	°C.	
Light Oil	302	150	3–5
Middle Oil	302–410	150–210	8–10
Heavy Oil	410–518	210–270	8–10
Anthracene Oil	518–680	270–360	15–20
Medium Pitch	–	–	60–70
Gas and Loss	–	–	2–3

The four fractions are then re-fractionated, and a number of individual organic compounds are obtained in bulk for sale in a more or less pure condition.

Typical are benzene, benzene-toluene mixtures, toluene, carbolic acid (phenol), naphthalene, and anthracene. Many other known products are present in small amounts. In general all the 150-200 compounds can be divided roughly into three groups. (1) Hydrocarbons, (2) Phenols or "tar acids", soluble in alkali, and (3) Bases soluble in acid. All these groups are represented in the four main fractions.

Thus in treating the light oil and preparing relatively pure fractions, such as benzene and toluene of different grades, washing with alkali to remove tar acids and with concentrated sulphuric acid to remove unsaturated hydrocarbon products and bases is carried out.

Carbolic acid, cresols (higher phenols) and naphthalene are obtained from the middle and heavy oil, along with a large amount of an extremely complicated mixture of products known commercially as creosote. Alkali and acid washing is used as before for the removal of tar acids and organic bases.

When anthracene has been separated from the heavy oil, the residual "green oil", so called from its dull greenish colour, is an extremely complicated mixture of many high boiling point compounds. The residual pitch, equally complicated, with a large number of still higher boiling point compounds is at ordinary atmospheric temperatures, in the case of "hard pitch", a bright jet black solid which does not begin to soften until about 90-110°F. (32-43°C.) and has no very definite melting point.

Well-known hydrocarbons in high temperature carbonization coal tar, present also in the largest bulk, are benzene, toluene, o-m- and p- xylene, mesitylene, pseudocumene, durene, naphthalene, diphenyl, anthracene, and phenanthrene.

The tar acids include phenol (C_6H_5OH) present in much the largest amount, the three cresols (methylphenols) and the α- and β- naphthols. Bases also are represented largely by pyridine and quinoline along with very small amounts of aniline, toluidines, and similiar amides. Other types of organic compounds are the thiophenes and the mercaptans, which contain sulphur. Practically the whole of the products also are of the benzene ring, aromatic, or other "ring" variety, but there are also traces of open chain or aliphatic compounds.

Another method of expressing the quality of coal tar is the "free carbon" content, determined in standard fashion, supposed to represent the actual free carbon formed by excessive decomposition, that is cracking, of many of the constituents of the bituminous content of the coal. Thus average high temperature horizontal retort and coke oven tar with 60-70% pitch has say 15-30% free carbon.

However, much of the "carbon" is actually extremely high carbon content black compounds of unknown constitution.

Vertical retort high temperature carbonization gas retort tar with steaming of the charge, say to the extent of 15-35% on the weight of the coal, gives a tar which in many respects is different from high temperature tar obtained from retorts and ovens without steaming. Average vertical retort tar contains say 45-55% medium hard pitch and 2-5% free carbon, as against 60-70% and 15-30% for horizontal retort and coke oven tar. The amount of actual phenol (C_6H_5OH) is only small, and the tar acids are almost all higher phenols. In steamed vertical retort tar also the benzene, toluene, and naphthalene content is much lower than horizontal retort and coke oven tar.

In comparison, average low temperature tar as obtained by the carbonization of bituminous coal at say 900-1200°F. (482-649°C.) in simple types of retort with external heating only, is a product entirely different from average high temperature tar. Thus it is a brownish oily liquid, much more resembling a crude oil than a tar. On fractionation about 5-7½% light oil is obtained instead of 3-5%

with standard high temperature tar while the middle and heavy oil, up to 680°F. (360°C.), is 50-60% as against 16-20% for high temperature tar. Also the pitch content of low temperature tar is 20-35% instead of 60-70%, with say 2-4% free carbon, as against 15-30% with high temperature tar.

In a number of processes of low temperature carbonization also, such as operated by carefully controlled internal heating with partial gasification of the charge, or the passage through the latter of a gaseous heating medium, the tar much more resembles a crude petroleum oil than the above externally heated retort tar. Thus the percentage of light oil and middle oil is higher and there is no "pitch" in the ordinary sense of the term, only a thick heavy oil residue, and no free carbon.

Whilst typical low temperature tar is probably as equally complicated a mixture as high temperature carbonization tar the general composition, when obtained from the same bituminous coal, is also quite different in its chemical composition.

Thus benzene ring hydrocarbons are almost entirely absent and there appears to be in most cases hardly any benzene, toluene, or xylenes, and almost no trace of naphthalene, anthracene, and phenanthrene, or of the cancer-causing very high boiling point benzene ring hydrocarbons. Instead the tar mostly consists of open chain or aliphatic (paraffin) compounds. Phenols (tar acids) are, however, present in large amount, up to 40-50% of the total volume, but there is only a trace of phenol or carbolic acid, whilst bases are also included, especially the pyridine group.

Of vital importance is the fact that the cancer-causing hydrocarbons are not formed to any extent by the carbonization of coal until the temperature reaches about 1472°F. (800°C.). That is the ordinary cancerous high temperature tar results by the heat decomposition in the retorts or ovens of the low temperature tar, first formed in the earlier stages of the heating. Low temperature tar made under accurately controlled temperature conditions of not over say 842°F. (450°C.), and entirely non-cancerous, can be converted into an active cancer-causing product by heating to a high temperature such as 1472-1832°F. (800-1000°C.).

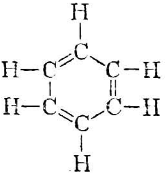
The Research Sub-Committee of the Manchester Committee on Cancer have prepared a whole range of tars and crude oils from coal, oil, shale, and other products at carbonization temperatures within the range of 932-1742°F. (500-950°C.) and have shown in laborious fashion by means of mice that the cancer-causing properties increase with the temperature of carbonization. These cancer poisons begin to appear at 932-1112°F. (500-600°C.) and according to their researches about 1472-1742°F. (800-950°C.) represents the maximum production range under the experimental conditions.

It is necessary to point out also that in practice some types of low temperature tar made from bituminous coal may, like some varieties of petroleum, be very slightly cancerous, because of inefficient carbonization. Thus in many designs of externally heated low temperature carbonization retort, especially when of fireclay, the temperature of the heating chambers has to be somewhat higher than that of 842°F. (450°C.) or whatever may be the required average carbonizing temperature inside the retort. Coal is a bad conductor of heat so that in order to carbonize the centre of the charge it may be necessary to heat the outer portions of the charge to a higher temperature, and in any case for a longer period.

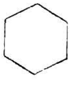
Partial carbonization at say 1112-1292°F. (600-700°C.) may therefore take place, with the formation of a small amount of cancer-causing substances. In low temperature carbonization processes operated on the internal heating principle under such conditions that it is impossible for local overheating to take place, more than say 842°F. (450°C.) there is no trace of cancer-causing substances, even in the soft "pitch" or heavy oil residue. Similarly there cannot be any danger of cancer from low temperature carbonization coal gas. Further the coal tar from high temperature carbonization retorts operated with steaming of the charge is less cancerous than ordinary coal tar and somewhat resembles in general chemical and physical properties a medium temperature tar, or a mixture of low and ordinary high temperature tar. Presumably also the coal tar made as a result of the new principle of operating by-product recovery coke ovens at medium temperatures such as 1292-1382°F. (700-750°C.) to produce a free burning coke for the domestic market will give a tar resembling vertical steamed retort tar, of a less cancer-causing type than ordinary coal tar.

Since the active cancer-causing hydrocarbons in coal tar are of the very high boiling point variety they are chiefly found in the anthracene oil, especially the "green oil" after separation of the anthracene, which boils under atmospheric pressure conditions within the range of 518-680°F. (270-360°C.), and in the residual pitch, boiling over 680°F. (360°C.).

The composition of these cancer-causing hydrocarbons is connected with some of the most intricate and advanced sections of modern organic chemistry so that it is difficult to give a relatively simple description. In general, however, the primary benzene ring hydrocarbon is benzene, melting at 41·7°F. (5·4°C.) and boiling at 176·7°F (80·4°C.), having the formulæ C_6H_6, with the atoms arranged as follows:—

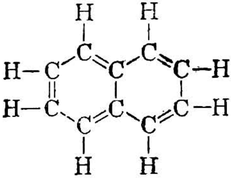


expressed in simple diagrammatic fashion as

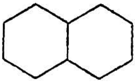


carbon being a tetra-valent element (four combining bonds) and hydrogen a mono-volent (one bond) element.

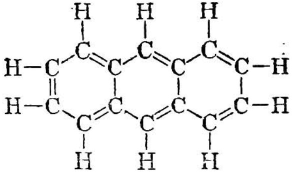
Naphthalene melting at 174°F. (79°C.) and boiling at 424°F. (218°C.) is the simplest of the two benzene ring type of hydrocarbon, with the constitution $C_{10}H_8$, arranged as



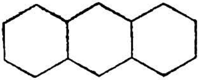
and illustrated for short as



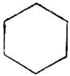
Next is anthracene, $C_{14}H_{10}$, the primary three benzene ring hydrocarbons from which the alizarine dyes are made, melting at 415°F. (213°C.), and boiling at 664°F. (351°C.) arranged as follows.



or

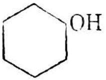


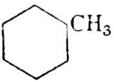
It will now be understood therefore what the diagram

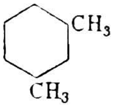


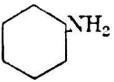
stands for in the following consideration of the more complex hydrocarbons, including the cancer-causing poisons. Further, when one of the hydrogen atoms in a benzene ring is replaced by other atoms the latter are shown in the diagrammatic illustration as added to the simple ring diagram.

That is, for example, phenol (C_6H_5OH), toluene ($C_6H_5CH_3$) m-xylene ($C_6H_4(CH_3)_2$), and aniline ($C_6H_5NH_2$), are illustrated as follows:—



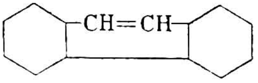






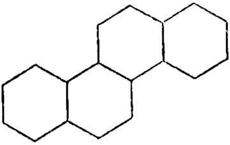
Included in the green oil and the pitch from coal tar are very many other hydrocarbons, mostly present in small amount, with three or more benzene rings or a similar complex ring arrangement.

Of vital importance in this connection as regards cancer is phenanthrene, melting at 210°F. (99°C.) and boiling at 644°F. (340°C.) which is isomeric with anthracene, that is, has the same number of carbon and hydrogen atoms, $C_{14}H_{10}$, but arranged differently as follows:—

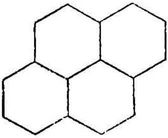


This can be regarded as the parent hydrocarbon of almost all the known cancer-causing poisons.

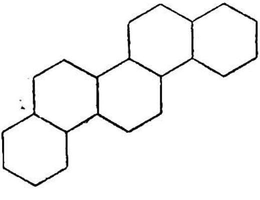
Another well-known complex hydrocarbon in coal tar, particularly the green oil and the pitch, is chrysene $C_{18}H_{12}$, melting at 491°F. (255°C.) and boiling at 838°F. (448°C.) which is



Important is pyrene $C_{16}H_{10}$, melting at 313°F. (156°C.) and boiling at 500°F. (260°C.) under the partial vacuum of 60 m.m. of mercury, with the constitution:—



An additional benzene ring hydrocarbon in high temperature carbonization coal tar, mostly in the pitch, is picene $C_{22}H_{14}$, formed also by the very high temperature heating of other tars and petroleum, which melts at 689°F. (365°C.), the highest known figure of any hydrocarbon, with the constitution:—



The identity and constitution of the cancer-causing hydrocarbons, both in coal tar and obtained by synthesis, has largely been made known because of the brilliant research work carried out for a considerable number of years past by E. L. Kennaway, J. W. Cook, I. W. V. Mayneord, K. Hieger and their associates at the London Cancer Hospital Research Institute.

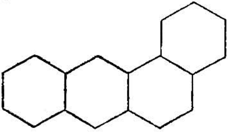
An elaborate series of investigations has been undertaken upon the cancer-causing properties of different varieties of coal tar and their fractions, and upon other tars and crude oils, using mice.

Many individual hydrocarbons were also examined, including synthetically prepared products. For example Kennaway showed in 1924 that the action of aluminium chloride on tetralin (tetrahydronaphthalene) resulted in cancer-causing products, and the same applies to the heating of acetylene or isoprene with hydrogen under pressure. Further, it was proved that by heating non-cancerous tars and oils, including petroleum oils, to a high temperature decided cancer-causing properties are developed.

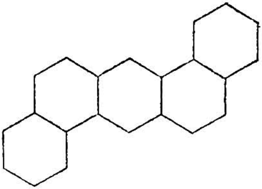
In the earlier stages of the work it was demonstrated also that well-known individual benzene ring hydrocarbons, such as naphthalene, anthracene, and phenanthrene, do not cause cancer, and some hitherto unknown or unrecognized hydrocarbons, or their derivatives, must be present in the higher fractions of coal tar.

One of the most serious difficulties in cancer research until quite recently was that definite results could only be obtained, even when using the most convenient animal, the mouse, after waiting for long periods. Thus say 8-12 months is required for the cancer to develop, and many mice are more resistant than the average, either not taking cancer in a normal period or only developing non-malignant tumours. In 1930, however, I. W. V. Mayneord and I. Hieger made the important discovery that most cancerous tars and oils when examined by means of the spectroscope gave a characteristic 3-band fluorescent spectrum. If every, or even most, cancer-causing poisons give this special spectrum it is obvious that scores of compounds can be examined very rapidly instead of having to use some incredible number of mice and waiting for a long time to obtain the same result.

The first hydrocarbon examined by the spectroscope was anthracene, and the anthracene group of hydrocarbons tend to be fluorescent, as indicated by the colour of the green oil fraction of coal tar. Anthracene itself, however, showed no trace of the spectrum of cancer-causing hydrocarbons, which confirmed the results found by using mice. As the result of the examination of many separate hydrocarbons, most of which had been made synthetically in the laboratory, as distinct from extraction from coal tar, it was found that 1 : 2 benzanthracene $C_{18}H_{12}$ showed the characteristic cancer spectrum, the first definitely known cancer-causing benzene ring hydrocarbon found concerning the chemical constitution of which there is no question.

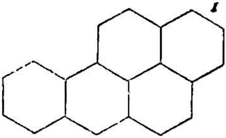


Following upon this J. W. Cook synthesized a series of 1 : 2 benzanthracene derivatives which were examined by Mayneord and Hieger, using the spectroscope. All of these are cancer causing, but the most active was 1 : 2 : 5 : 6 dibenzanthracene $C_{22}H_{14}$, having the constitution:—



This causes cancer in mice in a large number of cases when a 0·3% solution in benzene is painted on twice a week.

Following upon this Cook, Hewett, and Hieger in 1933 set to work upon 2 tons of high temperature carbonization coal tar pitch, and by lengthy and laborious processes of distillation, extraction by solvents, crystallization, including the use of the picric acid addition products, and purification, managed to isolate one of the chief cancer-causing poisons. This was found to be, and confirmed by synthesis in the laboratory, 1 : 2 benzpyrene $C_{20}H_{12}$ closely related to chrysene, pyrene, and 1 : 2 benzanthracene, with the constitution:—



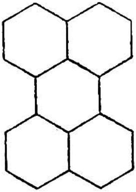
It is now certain that 1 : 2 benzpyrene is largely the cause of the strong cancer-causing properties of high temperature carbonization coal tar pitch, including all the troubles in the briquette industry, although only present to the extent of about 0·003% by weight of the pitch (not the tar), an almost incredibly small amount.

Also 1 : 2 benzpyrene shows the characteristic cancer spectrum and is more active than the synthetic 1 : 2 : 5 : 6 dibenzanthracene, which may not be actually one of the constituents of coal tar.

In addition 1 : 2 benzpyrene used in a 0·3% solution in benzene, applied twice a week by painting, will cause cancer in mice in 5-7 months, whereas 1 : 2 : 5 : 6 dibenzanthracene requires about 8-9 months. Since about 1932, however, the method has been adopted of dissolving the cancer-causing hydrocarbons in lard, oil, or glycerine and injecting, when 1 : 2 benzpyrene for example will give cancer or a non-malignant tumour in say 4-5 months.

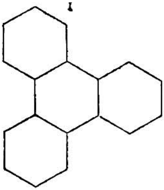
Many other complex benzene ring hydrocarbons, especially of the anthracene and phenanthrene base type, have been prepared synthetically and examined by the spectroscope. Also chrysene and pyrene are found to be only very slightly cancer-causing and this may be due to some impurity. Probably, as already mentioned, impurities are the reason why aniline and other relatively simple dyestuff intermediates sometimes cause cancer of the bladder.

Another complex hydrocarbon found in coal tar is perylene $C_{20}H_{12}$ with a melting point of 509°F. (265°C.) and the constitution:—



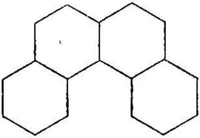
This, however, has only slight cancer-causing properties, and the same applies to such hydrocarbons as 4 : 5 benzpyrene and to 4 : 5 phenanthrylene methane recently discovered in the anthracene oil fraction.

It has now been found also that triphenylene $C_{18}H_{12}$ with a melting point of 390°F. (199°C.) is present in crude chrysene, and possesses little or no cancer-causing properties, the constitution being:—



There are undoubtedly many other hydrocarbons in coal tar not yet identified, and whether any of them have cancer-causing properties remains to be discovered. With regard to synthetic hydrocarbons it is now known that 3 : 4 benzphenanthrene

$C_{18}H_{12}$ is decidedly cancer-causing, with the constitution below, one of the simplest hydrocarbons,



possessing such a property. Thus cancer can be caused in average mice in about 12 months.

Valuable research in the field of synthetic cancer-causing hydrocarbons has also been carried out for some years past in the United States and it has now been shown by Fieser and Newman (*Journal of the American Chemical Society*, 1936) that a strongly cancer-causing synthetic hydrocarbon is 5-10 dimethyl 1-2 benzanthracene. Other hydrocarbons now known to be cancer-causing are triphenylbenzene and tetraphenylmethane.

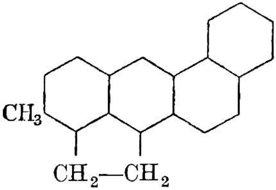
In general it can be stated again that nearly all cancer-causing hydrocarbons have what may be termed the phenanthrene nucleus, or in other words the 1 : 2 benzanthracene ring system or its heterocyclic equivalent.

A very remarkable development, since about 1932, is the discovery that the bile secreted by the liver can produce complex hydrocarbons closely allied to the phenanthrene-base cancer-causing hydrocarbons found in high temperature carbonization coal tar, and those of similar constitution made by synthesis. Human bile is a golden brown alkaline liquid, produced by the liver, stored in the gall bladder and discharged by the latter, accurately as required in small amounts, to the intestines to digest the fats in food. The normal constituents of bile are inorganic salts, small amounts of cholesterol and lecithin, bile pigments, and the sodium salts of bile acids, extremely complicated organic compounds belonging to the sterol and cholic acid groups.

The latter constitute another of the most difficult and abstruse branches of organic chemistry. One characteristic member of this group is cholesterol $C_{27}H_{46}O$ which forms one of the chief constituents of human gall stones. Also about 17% of the solid matter of the brain is composed of cholesterol, which appears to be present also in almost all animal and plant cells and specially in the nerve centres, the brain, spinal cord, and the nerve tissues, and in the yolk of eggs, as well as seeds and pollen. About 12 different sterols are now known, and they occur in animal and plant life as free sterols or as the esters of higher fatty acids.

For example in ox bile four serparate bile acids have been identified, that is, cholic acid, desoxycholic acid, chenodesoxycholic acid, and lithocholic acid. A great advance has recently been made in this field of organic chemistry and the extremely complicated constitutions of cholesterol and cholic acid, the latter being another characteristic member of the group, seem now to have been determined. These are very similar, being essentially in each case, phenanthrene derivatives, that is perhydro 1 : 2 cyclopentenophenanthrenes. It would appear also that the vitamins are closely allied in composition.

Primarily as the result of the work of Wieland in Germany there has now been prepared, by the breakdown of one of the bile acids, that is desoxycholic acid, a product known as methylcholanthrene, which is very strongly cancer causing. This is a derivative of benzanthracene, and therefore also of phenanthrene, and has the constitution:—



Later, methylcholanthrene has been made from cholic acid, a still more characteristic constituent of the bile.

It is a striking fact that methylcholanthrene, as found by the use of mice, is the most active cancer-causing product known, even worse than 1 : 2 benzpyrene found in coal tar. Thus under comparative conditions, a 0·3% solution in benzene used for painting will cause cancer in about 5 months as compared with the 5-7 months for 1 : 2 benzpyrene and the 8-9 months for 1 : 2 : 5 : 6 dibenzanthracene.

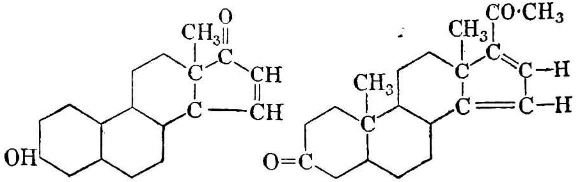
By using special methods also, including injection under the skin, or feeding in pellets of cholesterol, cancer can be caused in mice by methylcholanthrene in less than 60 days.

Here, therefore, is an obvious possibility of another but analogous cause of cancer, that is the slow action on the liver of poisonous products, such as carbon monoxide, or unsaturated hydrocarbons, such as ethylene, or organic sulphur compounds, present in manufactured towns gas, resulting in a partial disorganization of the normal action so that methylcholanthrene is secreted instead of, or along with, cholic acid and the other bile acids. Perhaps the disorganization may be caused by cancer-causing phenanthrene base hydrocarbons, assuming these are present in food that has been brought into contact with manufactured towns gas. This possible action of the liver cannot on present knowledge be regarded as a definitely proved cause of cancer, like soot and high temperature carbonization coal tar and coal tar pitch, but it is obvious that under abnormal or diseased conditions the liver may secrete highly poisonous cancer-causing hydrocarbons of the type of methylcholanthrene.

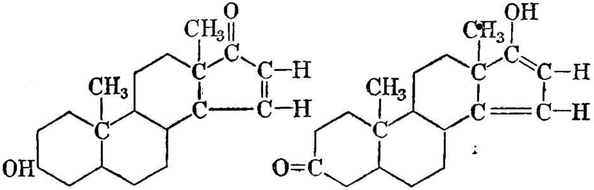
Another amazing triumph of modern organic chemistry, which commenced about 1929, is the discovery, isolation, and preparation of the sex hormones, which are also phenanthrene derivatives.

All animal sexual processes result from the action of minute traces secreted in the body, of extremely complicated organic substances known as sex hormones, both male and female.

As a matter of interest the following is now regarded as the constitution of two of the female hormones, $C_{18}H_{13}O_2$ and $C_{21}H_{18}O_2$:—



Corresponding constitutions for two male hormones, $C_{19}H_{16}O_2$ and $C_{19}H_{16}O_2$, are:—



It is the formation and action of these sex hormones in the body that determines also the sex of the offspring and the outward main characteristics of the two sexes. Since sex hormones are complicated phenanthrene derivatives, like bile acids, it is possible that as in the case of the liver, some type of poisoning may interfere with the normal function of the hormone secreting glands, and cause the body to secrete cancer-causing hydrocarbons of very similar composition.

There seems to be some mysterious connection in this way with the fact that about 40% of cancer cases in women are in the generative organs, that is the womb and the breasts.

It should be pointed out also other phenanthracene derivatives that have a drastic analgesic (pain removing) narcotic, and deadly poisonous effect upon human life are the morphine group of alkaloids, including morphine, apomorphine codeine, neophine sinomenine, and thebaine.

In general, morphine is a complicated hexahydrophenanthrene derivative, whilst codeine is a phenolic methyl ether of morphine which has the striking property, very valuable in medicine, of having the same general effect upon human beings with very much less danger of causing a dangerous craving.

Many plant resins also contain phenanthrene compounds, and in general, as the result of the huge amount of work that has been carried out in this field of organic research in the past four or five years in a number of different countries, there is now known to be a more or less direct connection between the cancer-causing poisons in high temperature carbonization coal tar, and all tars and crude oils that have been heated to a sufficient degree, synthetic cancer-causing hydrocarbons, bile acids and sterols, vitamins, male and female sex hormones, morphine alkaloids, saponins and what are known as heart poisons. Thus the toad secretes poisons of this type, which are cyclopentenophenanthrene derivatives.

For further and detailed consideration of these subjects reference is highly recommended to *The Chemistry of Natural Products Related to Phenanthrene*, by L. F. Fieser, Associate Professor of Chemistry of Harvard University, (*American Chemical Society Monograph*, Second Edition, 1937, Reinhold Publishing Company, New York).

That the anthracene oil and the pitch contain the greater part of the poisonous cancer-causing hydrocarbons, such as 1 : 2 benzpryene, is well known from long experience in the commercial use of coal tar and coal tar pitch. But these products also, in spite of their very high boiling point range, pass over to some considerable extent into the lower boiling point fractions. Thus creosote from coal tar causes cancer by direct contact with the skin, although to a lesser extent than anthracene oil. Further, creosote is apt to be very troublesome as regards general skin afflictions, such as warts and boils, usually a sign of poisoning of the cancer type.

Benzole and the light oil products also generally appear to contain small amounts of the cancer poisons, although the actual cancer-causing properties do not seem to have been investigated in detail. The action of benzene, toluene and similar hydrocarbons on the human body, apart from cancer, is most poisonous. When breathed as vapour, or as liquid brought into continued contact with the skin, or swallowed, a number of troubles are caused. First there is a tendency to capillary hæmorrhage under the skin and in the mucous membranes, benzene poisoning in Germany being called Blutfleckenkrankheit (blood speckled illness). Benzene also and its homologues are strong solvents for the fats in the brain, spinal cord, and general nervous system. The most important matter, however, is the great reduction caused in the number of white corpuscles of the blood (leucocytes). This obviously lowers the resistance of the body to local damage, such as from scratches, cuts, and bruises, and probably to disease generally.

Another theory of the cause of cancer is reduction in the number of white corpuscles, caused by a number of poisons. The general practice in the manufactured towns gas industry in Great Britain and other countries, as already pointed out, different from by-product coke oven practice, is not to scrub the high temperature carbonization gas for light oil, which would recover about 2 gallons per ton of coal carbonized. Possibly this light oil vapour may also play a secondary part, like unsaturated hydrocarbons, in connection with my theory that cancer is partly caused by manufactured towns gas and the presence of traces of the higher poisonous hydrocarbons.

An interesting indication of the fact that benzole when used in the internal combustion engines of motor vehicles gives a more poisonous and dangerous exhaust than petrol (from petroleum) is the work, already mentioned on page 102 of Yandall Henderson, Howard W. Haggard, and their associates at Harvard University. It will be remembered this is described in the *Journal of Industrial Hygiene* (Boston), July and August 1932, being concerned with investigations undertaken in the field of poisoning by motor vehicle exhausts.

Dogs killed with the exhaust of motor car engines using petrol were shown to be much less distressed and had a higher carbon monoxide blood saturation than if benzole was used. Thus four dogs killed with petrol exhaust averaged 83% carbon monoxide blood saturation, with no preliminary symptoms. But in the use of benzole exhausts the saturation at death was only 62% with vomiting and severe and distressing breathing symptoms. In addition the blood had a brownish tinge, showing a strong destructive effect on the hæmoglobin, which is also given by direct benzene poisoning. The efficiency of the combustion of the petrol and the benzole in the engine could be assumed in all cases to be approximately the same.

Some poisonous substance therefore is present in high temperature carbonization coal tar light oils, which go through, either wholly or in part, an internal combustion engine in spite of the very high temperature developed, equal to that of gas flames in a gas cooker.

These poisons also are so active that when breathed in extremely small amounts in a 6% carbon monoxide atmosphere dogs are killed with only 62% carbon monoxide blood saturation instead of the 80-85% necessary with carbon monoxide only.

Experience in more than one country in the briquetting and other industries using coal tar and pitch, combined with extensive experimental work upon mice, shows also that the higher the temperature of carbonization of bituminous coal and the more complete and drastic is the heat decomposition of the bituminous content, the more dangerous is the tar and the pitch as regards cancer-causing properties.

For this reason horizontal retort tar is generally the most dangerous of all, because a relatively shallow layer of coal on the flat bottom of the  shaped retorts used, with thin walls, is subjected to the highest temperature, resulting in the production of a particularly badly cracked and decomposed tar, often containing 65-70% pitch.

A considerable number of years ago, especially before 1910, most manufactured towns gas tar was of the horizontal retort variety. It was known in the briquetting industry in Great Britain, the United States, and other countries, that pitch from gas works tar was more dangerous and injurious to health than pitch from coke oven tar. This is still the case to-day, although gas works tar also now includes the less obnoxious steamed vertical retort tar.

For example, A. F. Sladden in *Pitch Cancer Report of the International Conference on Cancer, London,* July 1928, published by John Wright & Sons (London) 1928, is of the opinion that cancer and skin diseases amongst briquette workers are largely due to towns gas pitch.

Why by-product recovery coke oven tar should be less cancerous than horizontal retort towns gas tar, both made by high temperature carbonization of bituminous coal without steaming, seems mysterious. The main reason, however, is probably the great difference in the weight of the charge of coal in a horizontal retort and a coke oven, although in the latter case the vertical charge is also in a narrow layer but much larger in bulk. Presumably, however, in coke ovens there is some slight but appreciable degree of initial low and medium temperature carbonization at the centre of the charge so that part of the tar is of the medium temperature moderately cancerous variety, which dilutes the main bulk.

The general experience in the United States is that horizontal retort gas works tar is much more dangerous than by-product recovery coke oven tar, as well as total gasification (producer gas and water gas) tar. For example, cancer in tar distilleries in the United States has much decreased in recent years. The reason given is the decline of the manufactured towns gas industry so far as making its own gas is concerned, with the result that the tar distilleries are using a larger amount of coke oven tar and less horizontal retort gas works tar.

Workers in tar distilleries in Great Britain at the present time are much more subject to cancer and general skin troubles than in the United States, partly because the proportion of towns gas retort tar is higher.

An interesting fact also is that many of the employees of the tar distilleries in the United States are negroes. The latter are much more resistant to skin cancer, and other skin troubles caused by tar and pitch, than the white races. Thus the total deaths from skin cancer amongst the latter in the United States are more than three times that of the negroes. Presumably the reason is connected with the different average thickness of the skin. No detailed statistics seem to be available showing the total deaths from cancer of the white and black races, particularly as regards the regions of the body affected by cancer.

Further as showing the much more dangerous character of gas works tar in the United States the following are the approximate average percentage number of deaths from cancer caused by all tars and tar products over a number of years.

70.0%	Gas works tar
5.0%	Coke oven tar
11.0%	Mixed gas works and coke oven tar
5.0%	Heavy tar oils
9.0%	Uncertain origin.
100.0	

It should be pointed out in this connection most of the gas works tar is of the horizontal retort type, since the vertical retort is not used in the United States to the same extent as in Great Britain, whilst the amount of coke oven tar produced is enormously greater. Thus during the 12 year period 1924-1935 the average amount of coal carbonized per annum in the United States in by-product recovery ovens was 49,540,000 metric tons and in gas works retorts 3,200,000 metric tons.

According to laboratory investigations carried out in Holland in 1922, using mice, vertical retort tar from the Amsterdam gas works was much less cancer causing than horizontal retort tar. Presumably the vertical retorts were steamed and the same quality of coal was carbonized.

Many facts indicate that different qualities of bituminous coal under identical conditions of carbonization give different qualities of high temperature tar so far as cancer causing is concerned. It would seem also that on the average British bituminous coal, perhaps because of its high quality for coking and combustion produces a more cancerous tar than that of some other countries.

One striking example of this has already been given on pages 35-36, in connection with the works at Cleveland, manufacturing carbon products.

There is considerably less cancer amongst by-product recovery oven workers in the United States, France, and Germany than in Great Britain, and one of the reasons seems to be the nature of the coal. From this it might be gathered that the higher the "rank" or geological age of coal the more cancerous is the high temperature carbonization tar. It is not known definitely, however, whether the "rank" of carbonaceous materials in the whole solid fuel range, from peat to the highest grade Welsh or Pennsylvanian anthracite, is a guide to the cancer-causing properties of the tar obtained by similar high temperature carbonization. Coke oven tar pitch, however, from high grade Durham coking coal seems to give a more dangerous tar and pitch than from Midland coal.

In Germany also many cancer deaths are caused by the heavy anthracene oil fractions of coke oven and gas works tar, whilst the deaths in the aniline dye industry are about 3½ times that of the average for the whole population.

One of the usual difficulties, however, in all such considerations is doubt as to the accuracy or completeness of the cancer statistics of one country as compared with those of another.

World statistics for the production and consumption of coal tar and other carbonization tars are most incomplete and in the case of many individual countries have no existence.

Since, however, about 193,000,000 metric tons (2205 lbs.) of coal are carbonized per annum under high temperature by-product recovery conditions (152,000,000 tons in coke ovens and 41,000,000 tons in towns gas retorts), the total world production of tar will be about 8,940,000 metric tons per annum. This is based on an average yield of 10 gallons of tar per long ton (2240 lbs.) from coke ovens and 11 gallons from towns gas retorts.

There are also no detailed world statistics concerning the main uses of high temperature carbonization coal tar from gas works and by-product oven tar.

The average selling price has decreased enormously in recent years, and in a number of countries coal tar is rapidly reaching the stage of by-product ammonia, that is more of a liability than an asset. Consequently a considerable amount of coal tar is burnt as a fuel, whilst there are minor uses, such as briquetting, the manufacture of carbon black, and painting roofs and walls.

It is not known what percentage of the world's production of coal tar is distilled for the production of benzole, toluol, carbolic acid, creosote, naphthalene, anthracene, and other products, as well as pitch. One of the most important applications of coal tar is in connection with the construction and upkeep of modern dust-proof roads for motor vehicles. The rapid development of the latter from about 1900-1905 altered the whole situation as regards roads. In general the practice in Great Britain and other countries before the arrival of the modern motor vehicle was to construct country roads of water-bound macadam (graded broken stone mixed with water and rolled with a heavy roller), and towns roads of stone setts, mostly granite or syenite, or wood blocks. The water-bound macadam road is a hopeless proposition for motor vehicles fitted with pneumatic tyres because of excessive dust formation. Consequently in Great Britain there was introduced about 1905 the principle of dressing and treating the water-bound macadam road surface with tar, bitumen, and other material to try and prevent the dust to some extent.

About 1915 also there began to be introduced on the large scale the much more efficient principle of the bitumen, asphaltic bitumen, or coal tar macadam road. This is made by mixing graded stone with the bituminous material and laying over the road in simple fashion, followed by rolling, forming a dustless surface. The most valuable material for this purpose is natural bitumen, such as obtained from the so-called "pitch" lakes of Trinidad, Venezuela, and other countries, and at various places from the earth, of which examples are Pechelbronn in France and Neuchatel in Switzerland.

Mesopotamia, Persia, and the Caspian Sea areas have also been famous for bitumen (often called "pitch") for several thousand years.

Natural bitumen is probably the heavy residue from evaporated petroleum wells and is an ideal substance for macadam, and for road work generally, but in many areas, including Great Britain, it is too costly.

Gigantic amounts of heavy petroleum residues or asphaltic bitumen obtained in the refining of petroleum are used in making macadam for roads. Both natural bitumen and asphaltic bitumen in addition to being, according to many opinions, superior to heavy coal tar fractions as regards physical properties, making a tougher and more resistant road surface, have the great advantage of being non-poisonous and completely devoid of cancer-causing properties.

In Great Britain, as in many other non-petroleum producing countries, both asphaltic bitumen and coal tar macadam are extensively used for road making, and there is keen competition between the two. As already mentioned asphaltic bitumen only is now used in the United States for roads, which is the obvious method in petroleum-producing countries.

Millions of tons of high temperature carbonization towns gas and coke oven tar, mostly cancer causing, have already been used for many thousands of miles of British roads, both for spraying the surface and in the form of coal tar macadam. Approximately the total production of coal tar in Great Britain is 1,750,000-2,000,000 tons per annum, and about 45% of this or 787,000-900,000 tons per annum, is made into road tar (heavier fractions). Apart from the extremely serious possibilities in the way of causing cancer, nearly all high temperature carbonization tar has another obnoxious property, that of containing a certain amount of unseparated carbolic acid and higher phenols (cresols). These are particularly poisonous to fish life, only the merest trace in water being fatal.

It is interesting to note that the solubility of phenols in water increases with the complexity of the constitution and the boiling point. That is the cresols (methyl phenols) are more soluble than phenol and the xylenols (dimethyl phenols) more soluble than the cresols. Road tar also is apt to contain a very small amount of water soluble bases, such as the pyridines and the quinolines, which are extremely poisonous.

Consequently in heavy rain these phenols are dissolved from roads that have been sprayed with tar, or made of tar macadam, and the water, running off the surface into the nearest streams and rivers, poisons the fish. This has happened repeatedly in

Great Britain, sometimes on a wholesale scale, and many Fishery Boards and other Authorities have protested in vigorous fashion to the Government and demanded that poisonous coal tar shall not be used on roads. It is alleged also, but apparently not proved, that animals, such as cows, have been killed by drinking water drained off tar-sprayed roads.

Because of the uproar due to direct poisoning of fish from road tar the manufactured towns gas industry have endeavoured to produce what they call a "non-poisonous" or "non-toxic" road tar. In 1936 the claim was made that such a tar had become available in bulk, although to what extent is not revealed. Apparently this is produced by fractionating coal tar down to the relatively high temperature of about 572°F. (300°C.) to remove most of the phenols present and give what might be termed a medium hard instead of a soft pitch, followed by blending with alkali-treated creosote (medium tar fraction) to produce a product sufficiently liquid for general road work.

Creosote contains a high proportion of poisonous tar acids (phenols) but these are removed by washing with dilute caustic alkali so that they pass into solution in the wash liquor and are separated. Treatment of the creosote with acid is also included to eliminate poisonous bases, whilst in addition naphthalene is removed. Such a specially prepared tar will not of course poison fish but to call it "non-toxic" in general is grossly misleading since, presumably, the cancer-causing properties remain unchanged.

For a considerable number of years it has been thought that tarred roads are the cause of the increase in lung cancer to which motor vehicle drivers are liable, and I have long had the same opinion. Over a million vehicles in Great Britain and an incredible number of thousands of tons of traffic a day over many roads, especially in the London area, results in disintegration of the road surface and a certain amount of dust formation. In the case of a tar macadam or tar sprayed road this dust breathed into the lungs will contain the cancer-causing poisons forming part of the tar.

Statistics are wanted concerning the number of cases of cancer amongst motor vehicle drivers in countries such as Great Britain, using tar macadam roads, as compared with countries such as the United States and Canada with non-cancer causing asphaltic bitumen macadam roads.

CHAPTER XIV

COMPOSITION AND PROPERTIES OF OTHER CARBONIZATION AND GASIFICATION TARS AND CRUDE OILS, AND OF PETROLEUM

ANY solid carbonaceous product, not only coal, lignite, cannel, torbanite, oil shale, peat, wood, and bitumen-impregnated rock and sand, but all animal and vegetable matter will give a tar or crude oil on carbonization. Thus general organic material found in towns refuse has been carbonized experimentally on the large scale, and bone oil, obtained by carbonizing bones, is a well-known product. The world also has now reached such a stage of lunacy that coffee beans are, or have recently been, carbonized in Brazil to make towns gas, which will result in a "coffee tar" of somewhat the same type as ordinary wood tar.

In addition, producer gas tar, water gas tar, and blast furnace tar are produced in large amounts. This is due to the fact that in the producer gas generator, operated with a blast of air and steam, using bituminous coal or similar material, and in the blast furnace, using splint coal instead of coke (or charcoal), operated with a blast of air only, an appreciable degree of carbonization takes place in advance of the total gasification, and the tar passes out in the gas.

The whole of these tars and crude oils, like coal tar (low, medium and high temperature carbonization) are an extremely complicated mixture of organic compounds, probably at least several hundred in number in each case.

It can now safely be assumed that in almost all cases if the temperature of the actual carbonization has not exeeded about 842-932°F. (450-500°C.) no cancer-causing constituents are present and if the temperature has been say 932-1292°F. (500-700°C.) there is only a trace. Further, if any of these non-cancer-causing tars or the higher boiling point fractions, are heated to say 1472°F. (800°C.) or over, they become strongly cancer causing because of the appearance of complicated high boiling point hydrocarbons, just as in the case of low temperature carbonization coal tar.

The long practical experience of tar users shows that producer gas and water gas tar made from bituminous coal, as well as their heavy residues, do not cause cancer to any extent, and are entirely different in this respect from high temperature carbonization coal tar. With regard to blast furnace tar the almost universal opinion is this does not cause cancer, and attempts to give mice cancer with this tar do not seem to have been successful. Statements have, however, been made regarding an occasional case of cancer due to blast furnace tar, but the matter is obscure and more evidence is required.

Lignite tar in Germany has no particular tendency to cause cancer but a few cases seem to be known from the very heavy oil fractions corresponding approximately to the "green oil" of coal tar fractionation, squeezed out in purifying the lignite wax. Germany is the only country in the world where lignite carbonization is carried out upon an extensive commercial scale, originated about 1850, largely by the pioneer work of Edmund Rolle.

The "Rolle" retort still represents the standard German practice so far as the number of retorts is concerned, consisting of a high, vertical, externally heated, cylindrical retort unit with an internal perforated "pipe" or small diameter cylinder of louvred pattern. Raw lignite enters at the top and passes down in the concentric space between the outer cylinder and the inner perforated cylinder with slow progressive heating. Under these particular circumstances the tar is mainly produced under low temperature conditions, although the final degree of carbonization is at high temperature.

Shale oil, however, causes a considerable amount of cancer, alike in the carbonization of oil shale and the distillation of the crude oil, and in the use of the fractions and the refined products. It will be remembered that a large number of cases of cancer have resulted in the Scottish oil shale industry and that mule spinners' cancer in Lancashire was partly caused by lubricating oil made from shale oil.

The Scottish industry, now centred in the Edinburgh area, is much the most important in the world, and is over 80 years old. Even older, although smaller, is the oil shale carbonization industry at Autun in France (Soane-et-Loire). Nothing seems to be known as regards cancer in the latter connection, and the only other important centres of oil shale carbonization, Estonia and Fushun (Southern

Manchuria) have not been operated long enough to affect cancer statistics. In Scotland the oil shale workers are stated to be considerably troubled with rashes, warts, boils, and general skin irritation, the usual indication of the presence of cancer-causing hydrocarbons or similar poisons, presumably small in amount. An important contribution is *The Occupation Dermatoses of the Paraffin Workers of the Scottish Shale Oil Industry*, by Dr. A. Scott, published in 1923, being the Eighth Scientific Report, Investigations of the Imperial Cancer Research Fund (London). It is stated that out of 65 cases of cancer in the Scottish oil shale industry during the period 1900-1921 inclusive, 45 were men brought into contact with the fractions richest in paraffin wax. Also 19 were amongst wax pressmen exposed to the solution of the wax in the heavy oil, and 1 only was in the wax refining departments, emphasising that the complicated high boiling point liquid products from the paraffin wax, and not the wax itself, are cancerous.

Obviously the reason why shale oil causes cancer is that part of the carbonization takes place under high temperature conditions. In general the standard type of retort used in the Scottish industry, of which the "Pumpherston" is now the main representative, is a very high, vertical, mechanically continuous, externally heated design, with low temperature carbonization of the descending charge in an upper cast iron portion and high temperature carbonization in a lower fireclay portion, where the charge is also steamed to increase the ammonia yield. Presumably, therefore, the carbonization in the upper low temperature carbonization portion of the setting is not so complete as generally believed, and an appreciable proportion takes place in the high temperature portion. It is this portion of the crude oil, mixed of course with the total oil, that causes cancer. For example, if the Scottish shale industry used retorts in which the temperature of carbonization could never exceed about 842°F. (450°C.), such as by passing through the charge a gaseous heating medium, heated separately to the latter degree, the shale oil would be non-cancerous. In any case the present shale oil from the Scottish industries is nothing like so cancerous as high temperature carbonization coal tar.

Petroleum, like carbonization and gasification tars and crude oils, is a product of extraordinary complexity, containing a number of hundred different products that have been identified, very largely hydrocarbons, and practically all belonging to the aliphatic or open chain series. One great group is the paraffin or saturated series, having the general formula $C_nH_{2n}+_2$ the simplest being methane (marsh gas, CH_4) of which natural gas, from petroleum wells is almost entirely composed.

Apparently more than 75 open chain paraffin hydrocarbons are known to occur in petroleum, those of the simplest composition such as methane, ethane, and propane, being gases at ordinary atmospheric pressure and temperature. At the other end of the scale the most complicated compounds, containing over 20 carbon atoms, are solid. The great bulk, however, are liquid at atmospheric temperatures and pressures, and particularly important are pentane CH_3-$(CH_2)_3$-$(CH_3$, isopentane C_2H_5-CH-$(CH_3)_2$, hexane CH_3-$(CH_2)_4$-CH_3, and heptane CH_3-$(CH_2)_5$-CH_3, which form the main constituents of petrol, that is very low boiling point hydrocarbons suitable for use in the high speed internal combustion engine, which also have an extremely low specific gravity, generally below 0·70.

Another important series of aliphatic or chain hydrocarbons in petroleum are the olefines, of the standard formula C_nH_{2n}, as already stated, which are unsaturated, the simplest in this group being ethylene (C_2H_4). Some of the least complicated of the olefines, including propylene and butylene, are gases at atmospheric temperature and pressure, and are therefore found to a slight extent in natural gas. There is known to be a considerable number of olefine hydrocarbons in petroleum, and as the number of carbon atoms increase the products cease to be liquid at atmospheric temperature and become solids.

A further set of aliphatic hydrocarbons in petroleum are the di-olefines, C_nH_{2n-2}, while there are also unsaturated acetylene hydrocarbons, also of the C_nH_{2n-2} series, of which the simplest is acetylene (C_2H_2).

Petroleum contains in addition a large number of cyclic (non-benzene ring) hydrocarbons known as naphthenes, the simplest being trimethylene or cyclopropane (C_3H_6). Still another series of hydrocarbons in petroleum are the monocyclic terpenes, while oxygen, sulphur, and nitrogen compounds are also found in petroleum to a limited extent.

Benzene ring hydrocarbons are present in small amount, particularly of the benzene varieties, but apparently as a rule there is no trace of naphthalene, anthracene, or any of the higher cancer-causing hydrocarbons, whilst crude petroleum varies greatly in composition according to the locality, even in the case of neighbouring wells. The characteristics of all petroleum may be summed up as the presence of a number of hundred organic products, nearly almost entirely of the aliphatic or open chain series, no free carbon or "pitch" in the ordinary sense of the term, almost always no cancer-causing properties, a specific gravity at 60°F. (15·5°C.) within the range of say 0·785-0·940, a carbon content of 79·5-88·5%, a hydrogen content of 9·5-14·5%, and rarely more than 1·0% sulphur but with variable oxygen and nitrogen content, say 0·10-6·0% and 0·25-1·00% respectively.

All kinds of theories as to the origin of petroleum have been suggested during the past century, not one of which has yet found universal acceptance. The best known, in various modifications, is the action of heat in the earth upon oil shale and similar material consisting of mineral matter impregnated with organic material in the shape of dead marine life, so as to cause a very slow low temperature carbonization. Bacterial action also may play an important part in the matter whilst according to other theories the origin is inorganic. Thus one of the chief methods of producing synthetic liquid fuel to-day, the "Fischer-Tropsch" process, as previously stated, is the reaction of carbon monoxide and hydrogen gas in the presence of catalysts to form a whole series of liquid products of which the simplest is methanol or methyl alcohol ($CO + 2H_2 = CH_3OH$).

I have already expressed the opinion that the presence of cancer-causing compounds to a slight extent in some petroleum, as shown by mule spinners' cancer, and occasional minor troubles with warts, boils, and skin troubles in petroleum refineries, indicates that formation has taken place at temperatures about say 932-1112°F. (500-600°C.) or slightly higher.

This would seem to prove also the "carbonization in the earth crust" theory of the origin of petroleum, especially in view of the fact that a non-cancerous variety can be made cancerous by heating to beyond a certain temperature. For this reason the gas oil cracked in carburetting water gas will in most cases form cancer-causing hydrocarbons. Another important point also is that much petrol to-day is probably cancerous because of the great increase in the addition of "cracked gasoline" made by high temperature heat decomposition of medium petroleum fractions. Apparently the tendency to cancer-causing in petroleum only occurs in low asphaltic base oils, such as found in Oklahoma, North Texas, Central Texas, Kentucky, and part of Pennsylvania. Refining of these oils also sometimes causes boils and other skin troubles. The higher asphaltic base petroleum oils such as those in the United States from South Texas, Louisiana, parts of California, Wyoming, Colorado and Montana as well as other countries, including Mexico and Venezuela, are completely cancer-free.

Because of this relative freedom of petroleum from cancer, various industrial operations in the United

States, such as briquette making and the manufacture and laying of asphaltic bitumen macadam, do not cause cancer as they do in Great Britain, where high temperature carbonization coal tar is the source of the bituminous material. Similarly very little cancer is caused by lubricating oil, and lubricants generally, used in enormous amount all over the world and made chiefly from petroleum and animal and vegetable oils and fats, which contain no trace of cancer.

Dr. Imre Heller (Baltimore) had advanced the theory that the cancer-causing properties of coal tar, shale oil, and some petroleum is due to olefines and other unsaturated hydrocarbons. It is somewhat difficult to reconcile this, considered as a general statement, with the fact that most petroleum is non-cancerous, or only slightly so, although high in unsaturated hydrocarbon content, while non-cancerous low temperature carbonization coal tar is higher in unsaturateds than the extremely cancerous coal tar.

CHAPTER XV

SCIENTIFIC, EFFICIENT, AND HEALTHY METHODS OF LIGHTING, HEATING, AND COOKING

If this new theory of cancer is correct the most scientific, efficient, and healthy methods of operating a house or other building, especially as regards lighting, heating, and cooking, become of supreme importance. For the average house in a temperate climate it is necessary, assuming a reasonable degree of luxury, to have lighting, heating in varying degree according to the seasons, facilities for cooking, and a considerable supply of hot water for baths and other requirements.

Much the best for all these purposes is electricity, which also provides power to work such domestic equipment as wireless sets, vacuum cleaners, hot irons for clothes, and sewing machines. In the first place electricity operates under the conditions that no pollution of any kind from gaseous, liquid, or solid fuel can enter the house, and therefore no possibility exists of contamination of the food and of the atmosphere with unburnt gas or gaseous products of combustion.

Electricity also is extremely convenient, being controlled merely by a button or switch, requiring no matches or other method of ignition, and lending iself to easy use for lighting, heating, and cooking in all kinds of ways to a degree impossible with any variety of fuel. Further, electricity does not cause a smell, give rise to fumes, smoke, soot, and dust, or require storage space and constant labour in the way of conveyance from the store place, firing, cleaning out the fires, and disposing of ash and clinker.

The inherent and serious disadvantage of electricity, however, in many areas of the world is the high cost, which prevents complete use in houses, including the heating of every room and hot water supply. Consequently the general practice in Great Britain for middle and upper class houses when a supply of electricity is available is to use the latter throughout for lighting, to a certain extent for power purposes, especially wireless and vacuum cleaners, and to a much less degree for cooking, including electric ovens.

Thus in many large towns and industrial areas in Great Britain electricity for domestic use costs 0·5—1·0 pence per unit (kWh.) for power and heating, which is too costly for complete replacement of coal or manufactured towns gas.

Quite apart from the use of water power, with which Great Britain is badly provided, electricity could be made from coal at a much cheaper price than the present average. Standard practice in electricity stations using coal (or other fuel) is to generate power by means of condensing steam turbines, under which conditions about 60% of the total heat in the coal is thrown away in the cooling water, because of the latent heat of steam. In Great Britain about 10,000,000 tons of coal per annum are burnt in public supply electricity stations, of which 6,000,000 tons are wasted in warming up the cooling water.

The world consumes about 69,000,000 metric tons (2205 lbs.) of coal (not lignite) per annum (1924-1935 period average) in the steam driven, public supply electricity stations of over 50 countries, and 41,000,000 tons perform no useful work because of steam condensation.

The only scientific practice is to operate with back-pressure or pass-out turbines and sell the exhaust, as low-pressure steam or very hot water, to an inner ring of factories and buildings, such as shops, restaurants, theatres, hotels, and hospitals, and an outer ring, extending far afield, of houses and flats. By this means the cost of the production of electricity would be enormously reduced, and for domestic houses and other buildings both electricity and hot water could be purchased on the basis of accurate meter measurement in each case.

Such a method from the point of view of the domestic user is almost equal to the complete use of electricity, since no fuel, gaseous, liquid, or solid, would be taken into the house to contaminate the food and the atmosphere.

However, the civilized world has not yet reached the general state of mental development necessary for the adoption of such advanced methods. But many countries are now beginning to use "district heating" extensively for general town supply by means of low pressure live (not exhaust) steam. The most up-to-date country in this field is the United States, but prominent also are Soviet Russia, Germany, Switzerland, and France. In Great Britain the development so far is negligible, while the absence of scientific and co-ordinated control of fuel and power is well illustrated by the fact that Greater London alone has about 70 different electricity authorities.

Under the conditions that electricity is too costly for complete use in houses and other buildings the next best method in Great Britain, and other non-petroleum producing countries possessing no natural gas, is to use electricity for lighting, power purposes, and part cooking, with solid fuel under correct conditions for the rest of the cooking, general heating, and hot water supply. For the solid fuel coal is most generally used, and the best method to adopt in these circumstances, especially in Great Britain, is extensive development of low temperature carbonization at about 900-1200°F. (482-649°C.) for the production of a free-burning smokeless fuel.

Carbonization under these conditions, it will be remembered, forms no cancer-causing poisons, and the fuel, when prepared from washed coal of not over say 6% ash, is of high-grade quality which, like bituminous coal, does not contaminate the atmosphere to any appreciable extent when burning in an open grate.

Only very slow commercial progress has, however, been made with low temperature carbonization, in spite of all the different processes, and in Great Britain for example the present production of smokeless fuel of this type is at the rate of about 245,000 tons per annum, carbonizing 327,112 tons of coal per annum (1935 figures). The domestic consumption of coal in Great Britain is approximately 40,000,000 tons per annum, which includes a proportion of anthracite.

Bituminous coal as a domestic fuel has the pronounced disadvantages of black smoke, the production of dust and cancer-causing soot, necessity of storage, labour and attendance in firing, and the production of ash and clinker, involving labour and disposal.

As against this, however, bituminous coal has important advantages in comparison with any other method of supplying potential energy to houses and other buildings. Thus in coal-producing countries, and in many others to which coal is exported, it is much the cheapest source of energy, alike in competition with electricity, manufactured towns gas, petroleum oil, and wood. For example, in a given London suburb high-grade domestic bituminous coal is 45/- per ton, and manufactured towns gas of 500 B.Th.U. per cubic foot costs 3/7½ per thousand cubic feet (8·7 pence per therm), whilst electricity is 1·0 pence per kWh. for power, heating, and cooking, and 3·0 pence for lighting. On this basis towns gas costs about five times as much as bituminous coal, calculated on the actual heat content, and electricity is still more expensive.

Bituminous coal also, when burnt in the open grate and the ordinary designs of kitchen grate and cooking oven characteristic of Great Britain, gives an extremely efficient ventilation, which in the first place means that practically no traces of cancer-causing poisons and of carbon monoxide, sulphur dioxide, and other combustion products enter the atmosphere of the room. In addition the ventilation is very valuable because of the constant renewal of the air. Consequently it is possible to sit in front of a bituminous coal fire for many hours without feeling the slightest discomfort, which also applies to wood and low temperature carbonization fuels.

There is also no feeling of draught with a coal fire when the velocity of the air does not exceed about 3 feet per second. From the theoretical point of view, however, a minor disadvantage is that the air is taken out near the floor level instead of the ceiling.

The most efficient and healthy method of heating a living room in a temperate climate is a particularly complicated problem, and every method, even cheap electricity, has disadvantages. In Roman times the whole floor, made of tiles, was warmed from underneath by means of a hypocaust, that is a series of narrow flues through which hot combustion gases were passed from a solid fuel fire outside the building, generally at one end. In some respects this is excellent, since if the feet are warm the rest of the body soon becomes the same, and theoretically no pollution of the air results from combustion products. In practice, great difficulty was experienced in keeping the floor gas tight, while from the labour point of view the position is hopeless in modern times.

With hot water supply from power stations or other available source, including self-contained private supply with a closed stove boiler, which should be outside the home, the best practice is to maintain the air at say 55-60°F. (13-16°C.) by means of pipes and radiators. The living rooms would then have open fires with efficient chimneys, burning coal or smokeless low temperature fuel, to retain the healthy and cheerful open fire and raise the atmosphere to say 70°F. (21°C.), with a modern solid-fuel fired range in the kitchen for cooking and hot water, or alternatively cooking and water heating both by electricity.

The English open fire using coal has many advantages not always realized. Apart from the extremely efficient ventilation it is convenient and cheerful. One cannot, for example, have a convivial evening round a set of blackened hot water pipes, a gas fire, or an electric fire.

The net thermal efficiency of the open fire is also much greater than generally imagined. Mostly some such figure as 20% is mentioned, but the matter is obscure and some of the experimental methods used are not on scientific lines so far as concerns the total efficiency. Many types of open fire, for example, heat the mantelpiece, made of ceramic material and hollow for the purpose, and the net efficiency of a large proportion of kitchen range fires is probably more like 35-40%, including the heat used in cooking, warming the kitchen, and supplying hot water.

Heating of the body should be as much as possible by radiation from the fire and also the surrounding walls, with the air itself kept relatively cool.

The principle of the complete heating of rooms, say up to 70-75°F. (21-24°C.) by steam or hot water, so characteristic of the United States and Canada, is extremely bad. As a result hot air is breathed into the lungs, resulting in excessive evaporation of moisture in the mouth and throat, while the natural ventilation is only very slight. What is required for heating under present average conditions, especially the high price of electricity, is a compromise between central heating with hot water (or steam) and open fires burning solid fuel.

The closed slow-combustion stove used in many countries is a thermally efficient apparatus, much superior to the open fire in this respect, and possesses the great advantage also that all types of solid fuel can be used—anthracite, bituminous coal, coke, low temperature carbonization fuel, wood, and general kitchen and household refuse. But when placed out on the floor of a room with a metal flue leading to a vent, instead of in a corner or a special chimney hearth, it is apt to be a dangerous contrivance, if only because of carbon monoxide poisoning.

The conditions also are ideal for the formation of cancer-causing hydrocarbons by partial carbonization of the fuel, but whether any actual cancer, say of the tongue, throat, or lungs, or other disease results from breathing the vapours is a matter for investigation. It is interesting to note that asthma is much less prevalent in Great Britain than in Germany and France, which are closed stove countries.

Petroleum oil is not used to any appreciable extent in Great Britain as a domestic fuel, and the same applies to wood, although in country districts oil lamps and log fires are still to be found.

With regard to the use of manufactured towns gas for lighting, this is now almost universally regarded in Great Britain as obsolete practice for houses and other buildings, and obvious disadvantages, as compared with electric lighting, are the troubles involved with gas mantles, the bad smell, and the heating caused in the room. A serious matter also is that the air is being continuously polluted with waste products of combustion, and in many cases with unburnt or partly burnt poisonous gas, especially in the case of a defective mantle. Accordingly unburnt carbon monoxide and sulphur dioxide from the combustion or partial combustion of the organic sulphur are present.

If it is correct that manufactured towns gas contains cancer-causing hydrocarbons these also will be in the atmosphere, and therefore breathed into the lungs. Further, in order to get over the trouble of continually striking matches a large proportion of gas burners with incandescent mantles have a small "pilot" light, that is a tiny flame that burns continuously day and night, so that the main light can be ignited at any time by pulling a loose chain or other device. These pilot flames are in addition continually polluting the atmosphere. Any other method of lighting also that involves combustion and direct discharge of all the combustion products to the atmosphere of the room, such as candles and oil lamps, is objectionable for the same reasons.

For general heating, such as fires and hot water supply, manufactured towns gas has the objections inherent in the use of any gaseous fuel, including the fact that the degree of ventilation is in nearly all cases much inferior to a coal fire. As a result the room is apt to be polluted to a more or less degree with unburnt and partly burnt gas, and the atmosphere therefore is usually nothing like so fresh and comfortable as when burning coal.

It is familiar knowledge that most gas fires, even when fixed below the large open-fire chimney intended for coal, cause after some some hours an uncomfortable dry and slightly irritating feeling in the atmosphere. Many gas fires also, large and small, are being operated without flues of any kind, discharging all the combustion gases direct into the room.

Another inherent disadvantage of all gaseous fuel in buildings is the almost continual slight leakage from the valves, pipes, and meters, quite apart from accidental large leaks, liable to cause fire, explosion, and death by poisoning, not only inside houses and other buildings, but also from the street mains outside.

Gaseous fuel, however, has a number of obvious advantages, including ease of transport, simple control by valves, absence of ash and clinker, no storage room, and absence of black smoke, that is visible unburnt products.

In Great Britain the smoke caused by burning bituminous coal has been an outstanding national problem for over 600 years. In 1306 a proclamation was issued by Edward I prohibiting the burning of coal in London, and it is stated that one man, a blacksmith, was hanged for persistently using coal and causing smoke. However, since by about 1300 the supply of wood and of charcoal had begun to fail and London could not carry on without fuel, this early attempted solution of the black smoke problem by executing the culprits was not a practical proposition.

A great sea traffic in coal soon developed between the Newcastle area and London, and coal at that time was called "seacoal" or "seacole", in opposition to "charcoal". There is still in existence Sea Coal Lane (Ludgate Circus, E.C.4) where the early coal merchants of London transacted their business on the banks of the Fleet river, then navigable by small sailing ships from the North-east coast.

The smoke problem, to which domestic fires very largely contribute, constitutes a most serious disadvantage of the use of bituminous coal and is probably responsible for a considerable proportion of the ill-health of the community. Included is cancer from the soot.

But if all the 40,000,000 tons of coal now used per annum in the domestic market were replaced by manufactured towns gas of the present high temperature carbonization and carburetted water gas type, and to some extent by gas coke, to prevent the smoke, the general position would be very much worse than at present. For example, the existing manufactured towns gas industry would need to be enlarged to an enormous extent, with a corresponding increase in deaths and accidents from gas poisoning, fires, and explosions, and in the production of cancer-causing coal tar and coal tar pitch.

The main point of importance, however, in the operation of houses and other buildings, especially as regards the present theory of cancer, relates to cooking, and particularly roasting of meat and poultry and baking of bread, cakes, pies, biscuits, and similar food. Throughout the world a number of basic methods are used, some of which are thousands of years old. One is by direct contact with red-hot stones or other objects, first heated in a fire, as used by many savage tribes. That is the stones are placed in a small pit or hollow in the ground, the meat placed on top, more stones added and the whole covered with damp leaves or other material to keep in the heat. As a result the food is cooked slowly and with a gradually declining temperature, constituting a most scientific and thermally efficient method, which retains all the flavour and juices and prevents any contact with combustion products. Fruit, vegetables, cereals, and fish are cooked the same way.

In my house we have often used a similar principle, that of red-hot small iron discs placed in a closed, heavily insulated, compartment along with the meat or other food in a baking tin, a modification of the "hay box" for boiling and stewing. The only objections to the hot stone method are the time and trouble involved. Probably in this way also prehistoric man first learned to boil water, placing the latter in small baskets lined inside with clay and adding very hot stones.

Another standard principle of cooking is by direct radiant heat in the open air, placing the meat in front of a fire or furnace, which may be operated with almost any fuel. This was for centuries the usual custom in medieval times in Europe, using a rotating spit to give uniform exposure to the heat, and in simpler fashion has been the standard practice for thousands of years of many savage tribes, and of every one who uses a camp fire. Radiant heat cooking of this type is also extremely healthy, giving a fine-flavoured product under conditions of no contact with poisonous combustion products; that is of course unless the food is placed direct over the fire.

In connection with camp fires other methods are to cook on the red hot ashes, either direct or after wrapping tightly in paper or cloth to keep in the juices, on the same lines as modern "paper bag" cookery. This is also a good, though troublesome method, giving no actual contact with gaseous combustion products.

In modern grilling in restaurants and similar establishments, the custom is to place the food on a "grill", an arrangement of iron bars sloping over the top of a "red" fire, generally of coke or coal (which has been converted into coke before grilling commences). Under these circumstances it is difficult to imagine that any cancer-causing or other poisonous products can come into contact with the food, but as a precaution it would be better to grill in front of the fire and not over it.

Excellent also for cooking is the old type of internally-heated brickwork oven, another contrivance used for many centuries. This consists of a large brick compartment with thick walls, in which a fire is lighted, generally of wood, and allowed to burn for a considerable period. As a result the walls are heated to a high temperature. The fire is then pulled out through a door, the interior swept clean of ash and dust, and baking carried out by placing the food inside for the necessary period. Again this is a highly scientific and efficient method, using radiant heat only, in what may be termed bulk amount, and in absence of any contact with combustion products, leaving the maximum degree of flavour in the food.

People still living who have used this type of oven in country districts state that it makes bread of a flavour and general quality superior to any other method. The general custom was to heat up the oven say once every 10 or 15 days and bake sufficient bread for this period, and advantage was also taken, as the oven cooled, to bake cakes and pies, and to cook meat. As usual, however, for modern domestic use the main disadvantages are the time and trouble involved.

The method still used to a considerable extent in the domestic field, at one time almost universal in Great Britain before the extensive adoption of the gas cooker, is the externally-heated iron oven, generally using bituminous coal, forming part of the kitchen range. That is, the oven consists of an iron box, with a front door, externally heated at the two sides, the back, and the top and bottom, controlled in degree by small dampers in the flames and hot combustion gases, circulating from the adjacent fire. In this way the food is heated up to within the range of say 350-500°F. (177-260°C.) or whatever temperature is required, out of all contact with waste combustion products, while the flavour is excellent.

During the past 10-15 years great improvements have taken place in the design of the coal-fired kitchen range, including the provision of efficient grates, adequate damper control, effective heat insulation, stainless steel fittings, light-coloured enamels, box containers for easy and rapid withdrawal of the ash, and wrought iron instead of cast iron hot water boilers that can be removed and replaced, easily and rapidly, without knocking down half the kitchen. Even more recent is the "heat storage" range, using anthracite or coke, which operates at a remarkable thermal efficiency.

Still another method, now being extensively adopted in many countries, is the internally-heated electric oven, that is an iron box with a front door, having inside, generally near the top, electric resistances by which the interior is very rapidly raised to the desired temperature. The cooking is carried out by radiant heat only, under extremely high thermal efficiency conditions, with outlets to the air for the "steam" formed, and no trace of cancer or other type of poisoning can take place, since there is no combustion.

From both the hygienic and the gastronomic points of view all these methods—red-hot stones, iron discs or other objects, radiant heat in the open air, red-hot ashes, paper-bag cookery, internally-heated radiant heat brick oven, externally-heated iron oven of the coal kitchen range type, and internally-heated electric oven, are good. As against this the average internally-heated gas cooker or oven is, in my opinion, extremely bad, for two main reasons, that is the cooking is carried out in a constant rapid stream of very hot gaseous medium and in intimate contact with waste products of combustion, and often therefore with unburnt or partially burnt gas.

It is not a scientific principle to cook food, and especially meat, in a stream of hot gas because of the loss of moisture, flavour, and liquid products, such as fat. This applies to the direct use of all gaseous fuel and to any gaseous mediums, such as air or steam, heated separately to the desired temperature, such as 400-500°F. (205-260°C.) and passed through an oven or other compartment containing the food. Superheated steam, for example, is used in this way for cooking on the commercial scale, including the preparation of cattle food.

With regard to the effect of direct contact of the food with gas flames and products of combustion this is a most objectionable method of cooking, since, in addition to the possibilities of causing cancer, most manufactured towns gas contains organic compounds of unknown composition, of which the smell is an indication, whilst carbon disulphide and organic sulphur compounds are present, along with a considerable amount of ethylene and other unsaturated hydrocarbons, which have an extremely poisonous action on many forms of life.

To repeat, since cancer-causing high boiling point hydrocarbons are formed in appreciable amount during the high temperature carbonization of coal and the manufacture of carburetted water gas, and are present in coal tar, and in the various fractions, it seems well within the range of possibility they are also present in the gas. If this is the case they will undoubtedly, in many cases, because of the incomplete combustion under the difficult conditions of internally-heated ovens, come into contact with, and be absorbed by, the food during cooking, escaping decomposition at the temperature of say 350-500°F. (177-260°C.) because of their great stability and high boiling point. Such food also is eaten regularly by a very large proportion of the population almost every day for a long period of years, almost from infancy, and may therefore in a large number of cases result in cancer, after say 30-40 years, since the average age for contracting the disease is 35-65 years. No excuse is needed for repeating also that a huge amount of food prepared on the industrial or semi-industrial scale, quite apart from home, club, restaurant, and hotel cooking, is now brought into direct and effective contact with the flames from gas burners, and often therefore unburnt manufactured towns gas as well as the resulting waste products of combustion.

The other main methods of cooking, that is apart from roasting, grilling, and toasting, are boiling, stewing, and frying. When heating a pan, kettle, casserole, or other utensil under these conditions the food is not in direct contact with the source of heat, alike in the case of gaseous, liquid, and solid fuels.

Whether cancer can result from the absorption of poisonous carbonization or combustion hydrocarbons from the surrounding atmosphere, and milk for example has peculiarly powerful properties in this connection, is another matter for future investigation.

CHAPTER XVI

CONCLUSION

THIS new theory of the cause of cancer being due primarily to complex benzene ring hydrocarbons, formed by high temperature carbonization, general heat decomposition, and combustion under certain conditions can be proved or disproved in two ways.

The first is by extracting from manufactured towns gas, and from the waste combustion gases any products that cause cancer. This might be carried out for example by passing the gas, as delivered from the main, continuously for a long period, many days or weeks, through solid absorbents, such as activated carbons, or perhaps silica gel.

One or other of the huge number of organic compounds liquid, at atmospheric pressure and temperature, may also be particularly efficient as a solvent for the cancer poisons, such as 1 : 2 benzpyrene, which could then be isolated by passing a very large volume of gas through laboratory scrubbing apparatus, containing this particular solvent.

Another general method which seems to offer possibilities is liquefying the gas fractionally by the use of very high pressures and extreme cold on the usual "Linde" compression and expansion principle, to find if one or other of the liquid fractions contains more cancer-causing constituents than the average of the total volume of liquefied gas.

It is essential also to make similar investigations upon the waste gases of combustion from the burning of manufactured towns gas. Most important is to do this using bunsen burners operating with a continuous luminous flame only, and the necessary defective air supply, under the conditions of "burning at the bottom". Quite apart from cancer this would be an interesting piece of research since no one has yet investigated in detail what happens under these circumstances, including the composition of the peculiarly obnoxious products formed.

Other operating conditions to be studied would include the waste combustion gases from an actual gas cooker, operating under more or less the average conditions obtaining in a kitchen, and with absolutely clean burners and scientific laboratory control of the gas and air supply to give as near 100% efficiency as possible.

Similarly the cancer-causing products almost certainly present in carburetted water gas made from gas coke, and the waste combustion products from such gas, should be determined.

For this purpose blue water gas (non-carburetted) could be used for "blank" experiment along with average semi-carburetted and carburetted water gas typical of the manufactured towns gas industry. Most important also is the preparation of special very highly carburetted water gas, using much more gas oil than the normal to find out any increase of cancer-causing products that may result.

In connection with smoked food one general method would be to smoke say fish continuously for months instead of the usual number of days so that if cancer-causing products are present in such food they will be in relatively large amount, and therefore easier to extract or to otherwise be identified.

The second way to prove or disprove the theory, although not so good as the first, is by means of statistics. One of the most serious handicaps not only in the fight against cancer but also in relation to the adaption of scientific methods in the whole field of fuel, as I know from long experience, is the lack of more or less reasonably reliable statistical information.

Probably well over 1,000,000 people in the world are at present suffering from cancer under conditions of continuous medical attendance. A large proportion of these patients could be interrogated as to the conditions of their life from the point of view of the use or otherwise of gas cookers or closed stoves in their houses, and of the extent to which they have eaten smoked fish and meat.

Detailed investigation should also be made as to the number of cases of cancer amongst races known to eat a large proportion of smoked food, and also the total production of such food in different countries.

In general cancer statistics require not only to be extended greatly but also studied from the entirely new angle of the effect of carbonization and combustion products.

Whether cancer is caused by manufactured towns gas and defective or partial combustion or not there is no question as to some of the methods that should be adopted immediately to protect the community.

The manufactured towns gas and the by-product recovery coke oven industries of the world are carbonizing about 193,000,000 metric tons of bituminous coal per annum under high temperature conditions and producing therefore in this time, as already indicated, about 2,002,560,000 gallons or 8,940,000 tons of coal tar which is a dangerous and actively cancer-causing product.

Already thousands of unfortunate men have died the terrible death of cancer because of direct contact with coal tar and coal tar pitch. One of the methods that should have been adopted long ago is either to prohibit entirely the use of cancerous coal tar pitch as a binder for briquettes, and for other purposes, or to allow it only under the most stringent conditions and inspection, equal for example to the manufacture of explosives, as regards the type of plant and the operating methods.

In any case assuming the briquetting industry is of any particular importance in modern civilization it can be carried out by using alternative non-cancerous harmless products as a binder that will give almost equally good results, such as starch or flour paste, various pulped vegetable materials and sulphite liquor (the liquid from the manufacture of wood pulp by boiling rasped wood under pressure with sodium sulphite solution).

The best general method of dealing with most coal tar pitch would seem to be to burn it as a dangerous product although complete very high temperature carbonization, down to carbon, and burning of the gases and vapours evolved might be adopted.

In my opinion also the spraying or dressing of roads with cancerous high temperature carbonization coal tar from gas works and coke ovens, often carried out every 12 months, should be prohibited as a public danger.

Roads to-day can be maintained in an almost completely dust-proof condition by the more efficient convenient and healthy method of covering the surface with a "carpet" or very thin layer of natural bitumen or asphaltic-bitumen macadam, using a light roller.

It is doubtful also whether the use of tar macadam should be allowed in making roads since this probably results in some cancer-causing dust when tar-spraying is not used.

With regard to the sale and use of manufactured towns gas a number of obvious alterations in the general regulations are required.

The first concerns the extremely poisonous and dangerous "sudden death" character of the gas due to the carbon monoxide content. For this reason a very large number of people are killed by gas throughout the world every year (accidents and suicides), according to some statements over 100,000, whilst in the same time a number of million people must be gassed to a more or less serious extent, often requiring treatment with oxygen or carbon dioxide. Here again full statistics are wanted.

As already stated, high temperature carbonization coal gas contains about 6-7% carbon monoxide, which itself is highly objectionable, but the position becomes much worse when total gasification water gas containing say 35-40% carbon monoxide is added.

In some countries it is illegal to supply manufactured towns gas with over 12% carbon monoxide, a method strongly recommended by one of the British Royal Commissions on Gas Poisoning.

Sooner or later the manufactured towns gas industry throughout the world will be compelled to supply a gas that does not cause wholesale sudden death, either almost devoid of carbon monoxide or containing only a small percentage. The new "de-toxification" process in Germany, using iron or nickel catalysts, is an indication of the trend of developments.

Quite apart from carbon monoxide also the removal of poisonous carbon disulphide and other organic sulphur compounds either completely or to the extent of at least say 90% of the present average content, should be compulsory.

Another long over-due requirement is much more strict regulations regarding the serious and almost constant leakage from gas mains. In the United States, one of the most advanced countries as regards the prevention of gas poisoning, the principle is used, although largely for natural gas, of adding to the mains at one point in the circuit a small amount of some organic substance that has an atrocious and penetrating smell or stench, such as amyl mercaptan. By this means all leakages are located, even in many miles of gas mains, and can therefore be repaired. Leaks are often extremely difficult to find by ordinary means and when an extensive gas pipe circuit is first tested by this "stench" method the huge number of leaks usually found is astounding. The gas supply mains of all large towns should be tested in this way, say once a year.

It ought to be made compulsory also that every gas cooker, gas fire, and gas water heater, of no matter what size, has an adequate discharge flue or chimney leading direct to the outside air, and that the arrangement be officially inspected and passed by the appropriate local Authorities before use.

Should it be proved that the burning of manufactured towns gas in contact with food and the smoking of meat, fish, and other products are responsible for a considerable proportion of cancer cases, 60,000 per annum in England and Wales alone as stated, then the remedies are obvious.

The by-product coke oven industry for the production of extremely hard metallurgical coke is, on present knowledge, essential for the operation of the modern high duty blast furnace and the manufacture of iron.

All the high temperature carbonization coal gas produced can be used to heat the coke oven settings and, under up-to-date conditions, the steel and other metallurgical furnaces as well.

In many cases an alternative method is to utilize coke oven gas as a raw material for the production of hydrogen, used in the synthetic ammonia, hydrogenation, synthetic liquid fuel, and fat hardening industries, with the coke oven settings heated by blast furnace gas or producer gas. Cheap power production for the manufacture of carbide is another obvious use in Great Britain for coke oven gas.

Surplus coke oven gas can also be conveyed through long distance pipes for ordinary industrial use. A large proportion of the world's iron and steel and coke oven industries is, however, inefficient and out-of-date, with coke oven plants, blast furnace plants, and steel plants operating separately, and often a long distance apart, with no scientific co-ordination, thus squandering energy in the shape of waste heat, coke breeze, blast furnace gas, and coke oven gas.

The by-products produced would be recovered as usual, the tar distilled under much more stringent conditions as regards protection of the attendants from cancer and other diseases, and the pitch burnt or carbonized down to carbon.

The manufactured towns gas industry is in a very different position because in most industrial countries with electricity and modern scientific solid fuel ranges, it is no longer essential for general heating and for the supply of potential energy to houses and other buildings.

Even if this was the case there is no reason to make poisonous "sudden death" gas, which could be de-toxified by elimination of the carbon monoxide, most of the organic sulphur, and perhaps also cancer-causing hydrocarbons if these are present.

Further there is no need to supply high heating value gas, 400-600 B.Th.U. per cubic foot, made by high temperature carbonization of bituminous coal and by total gasification of coke and production of water gas, along with carburetting, involving therefore the production of a considerable amount of dangerous cancer-causing hydrocarbons as well as other poisons such as organic sulphur and cyanogen compounds.

Thus low temperature carbonization of the coal at say 900-1200°F. (482-649°C.) could be used, when no cancer-causing poisons are formed and the heavy oil residues, as well as the gas and the oil fractions, are harmless in this respect.

Such low temperature carbonization also can be carried out according to two general principles. First, external heating with the production of 75% of smokeless free-burning fuel on the weight of the coal and only 4000-6000 cubic feet of rich gas per ton. This would necessitate therefore the carbonization of a greatly increased amount of coal to produce the same volume of gas as the present methods of high temperature carbonization and water gas made from coke.

The other principle is combined low temperature carbonization and partial gasification by a regulated blast of air and steam admitted to the bottom of vertical, mechanically continuous retorts. By this method part of the residual coked fuel is gasified in the retort and a high yield of low grade gas is obtained, say 50,000-75,000 cubic feet per ton of coal, but low in heating value, 200-250 B.Th.U. per cubic foot. Under these conditions of slow progressive low temperature carbonization of the descending charge no trace of cancer-causing poisons result, and the gas is very suitable for distribution and general use, as shown by the Nuneaton Gas Company. Such gas, however, is high in carbon monoxide content, but no more so than average rich manufactured towns gas, and it could be "detoxified".

Other general methods that can be adopted immediately to reduce the risk of cancer are to ensure that all lubricating oil is free from cancer-causing products, even if much shale oil has to be cut out of use entirely until true low temperature carbonization methods are universally adopted in this field.

In a final paragraph I should like to state the new theory and the long consideration of the different factors concerned have suggested the use of new methods of attempting to cure cancer.

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