

# Oil and Cancer

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## Summary

*A relatively high incidence of cancer of the skin, especially of the scrotum, due to occupational contact with mineral oil has been observed among shale oil workers and cotton mule spinners and, since the Second World War, among machine operators in the Birmingham region. A study has been made of the factors causing this high incidence and evidence is given that the respiratory and digestive tracts as well as the skin may be affected. The preventive measures are described and the suggestion made that they appear at the present time to be effective.*

## Prologue

*'The proper study of mankind is man.'*

Joseph Henry, after whom this lecture is named, qualified in Ireland 100 years ago, in 1874. He set up in practice in Rochdale and was appointed Medical Officer of Health, Superintendent of the Fever Hospital, and Medical Referee, in which capacity he would have been well acquainted with industry.

I have had the pleasure of meeting his son, Dr S A Henry, the joint donor, with his sister, of this lecture, and I have steeped myself in his writings. The more I have read the more I have admired and envied. Dr Henry, of course, is famous for his work on industrial cancers, but he did much else as a Medical Inspector of Factories. For example, in one year he examined india-rubber, electric

accumulator, benzene, bichromate, and lead smelting workers. He investigated dermatitis from teak, sugar, brazil nuts, orange peel, jam, baking, lubricating oil, shellac, and sulphide of phosphorus. Following a suggestion that cotton weavers suffered from deafness he confirmed that 24% of over 1,000 were affected—one of the first surveys on a subject which has become of such great importance recently. These were not academic exercises; in many cases they were the forerunners of legislation.

When sponsoring this lecture Dr Henry expressed the hope that candidates would be forthcoming to put forward a thesis of work which was original and not a hashed-up dish of material culled from the lectures and publications of others. I have done my best to follow his wish but I trust I will be excused if much is, of necessity, taken from his own works and that even what appears to be new had in fact already been studied by him.

## Oil

Mineral oil is the product of decomposition of animal and vegetable matter and its appearance and composition vary according to its site of origin. By distillation of crude oil it is possible to separate different constituents according to their varying boiling points, which depend to some extent on the number of carbon atoms in their molecules. The products from the distillation of crude oil, in ascending order of boiling point, are:

(1) hydrocarbon gases such as butane; (2) petrol; (3) naphthas, including solvents like white spirit; (4) kerosene or paraffin; (5) gas oil, diesel oil, and furnace oil; (6) lubricating oil and paraffin wax; and (7) residues such as asphalt and bitumen.

### Uses of oil

Cutting oils, our main concern, are used for cooling and lubricating the cutting edges of tools in such operations as turning, grinding, milling, and honing. They prevent welding between the metal and the tool tip from the heat generated. The oil is poured on to the cutting edge at the rate necessary for effective cooling, which may be as high as 30 gallons (136 l) a minute. They are used either neat or as an emulsion in water, diluted in ratios varying approximately from 1:3 to 1:100. Additives may be used to make the oil more suitable for particular purposes. These include chlorine, sulphur, or phosphorus compounds, detergents, anti-rust and anti-oxidant compounds, and antiseptics. The study of bacterial contamination of oil has become an important science—tribology. The bacteria are mainly of the pseudomonas type, and after a short period of use oil may consist of over 50% of bacterial matter. Bacteria pathogenic to humans do not survive in oil, but viruses, as exemplified by the wart virus, may do so—a fact which could conceivably be of interest in the study of cancer. Until recently cutting oils were normally formulated from oils that had not received the final solvent refining because they more readily received the additives and were cheaper. Besides their use for lubrication and as fuel, mineral oils are used for quenching, in electrical transformers, in moulding cement, tiles, and bricks, and in tube drawing, metal rolling, and drop forging.

### Epidemiology of oil cancer

**Scrotal cancer** The study of the epidemiology of oil cancer has been concentrated mainly on cancer of the scrotum as it is a rare disease usually of occupational origin. Only 3% of cases occurring in the Birmingham region are not connected with known external causes and 80% can be attributed to oil. Scrotal cancer was first described by Treyling in 1740, who wrote of the disease in a Batavian cavalryman caused by trauma against his saddle. Dr Henry always considered there was a connection between riding and cancer of the scrotum. Muleteers in Mexico are said to be sufferers, and we have had one case in Birmingham in an officer of the horse artillery. Animal and vegetable oils were normally used for polishing harness, though not invariably. Vegetable tar has, in Birmingham, been considered an iatrogenic cause.

The first case of cancer of the scrotum attributed to oil was described in 1876 by Joseph Bell—the model for Sherlock Holmes. Later Dr Alexander Scott, an appointed factory doctor, listed 65 cases of cancer of the skin between 1900 and 1921 in the 5,000 workers in the shale oil industry in Scotland. In this industry Dr Henry recorded 3 scrotal cases in paraffin press workers and 28 among the other workers. Shale oil was used at first in the mule spinning industry and Dr Henry traced a fatal cancer of the scrotum that occurred at the age of 30 in 1875. Following this he found over 800 cases of scrotal cancer in the textile industry and over 600 fatal cases.

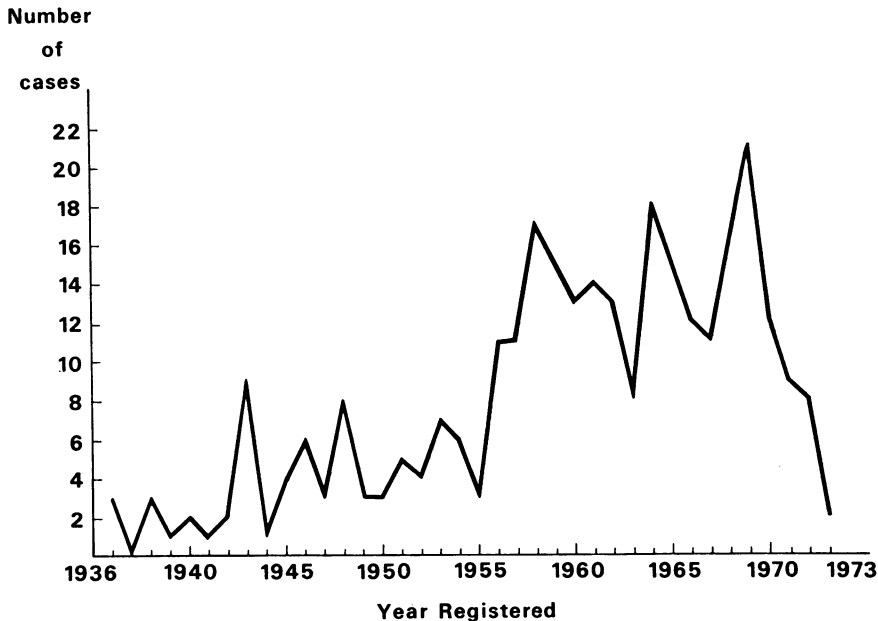
The epidemiological study of cancer associated with cotton mule spinning would not be complete without a mention of the striking fact that no cases of cancer of the scrotum have occurred in the mule spinning of linters, or waste cotton, where the workplaces are at normal room temperature rather than the 80°F (26.7°C) that is traditional in cotton

mule spinning and where the spindle speed is less. The apparent absence of cases in the cotton industry in the USA except among immigrant British workers may be accounted for by the same factors and perhaps differences in the supply of oil. It is possible to postulate that the oil used in mule spinning was of comparatively low carcinogenicity, as witnessed by the long exposure time and the late age at which cancer occurred and that it was only the exceptional heat with resultant sweating and lack of clothing under the overalls that enabled it to produce carcinoma.

**Incidence of scrotal cancer** Our knowledge of the incidence of the disease is gained from the statutory requirement for notification under the Factories Act, from death certificates, and from the list of persons claiming benefit for a prescribed industrial disease. Since 1948 the growth of the cancer register

in Birmingham under Dr J A H Waterhouse has ensured that 96% of all cases of cancer are known and that all scrotal cancers in the regions are now registered.

The original observations in the Birmingham region were made in 1949 during a survey of industrial dermatitis for the Medical Research Council by Dr C N D Cruickshank and the late Professor J R Squire, assisted by Dr Joan Cottrell of the Medical Inspectorate, and in a further investigation with Mr A Gourevitch. All the workers in the automatic machine shops of three factories were examined and records of local hospitals searched. It was found that 33% suffered from keratoses attributed to oil and that of 15 cases of scrotal cancer, oil was the cause in 12. They forecast the possibility that since automatic tools had been in use for 20 years an increasing number of cases could be expected—a forecast that has proved correct.



*Annual incidence of epithelioma of the scrotum. Midland Region, 1936-73.*

Later, experience showed that their observations were not entirely applicable to all similar factories in the area—they had by chance visited two with a high incidence. The average yearly number of cases of cancer of the scrotum recorded in the Birmingham region has been 12 between 1950 and 1970, which is four times that in the South-West Metropolitan region. These figures confirmed the suspected high incidence in the Birmingham region which, until 1970, showed a marked rising trend (see figure) as opposed to a decline in the country as a whole—50 deaths in 1950 falling to 20 in 1970. The number at risk may be roughly estimated from the fact that approximately 5,000,000 gallons (22,700,000 litres) of oil are used yearly in 220,000 machines in the region, of which 28% work dry, 50% use soluble oils, and 22% neat cutting oils.

#### *Occupational variations*

Within the Birmingham region there are marked differences in incidence according to place of work and type of work. A fresh case on investigation is usually found to occur in a man who is working, or has previously worked, in a factory where cases have already occurred. An investigation was undertaken with Mr A J Williams, of the Factory Inspectorate, into this phenomenon.

Four automatic shops, one nut and bolt factory, and one cold steel rolling factory in which cases had occurred were surveyed and conditions compared with similar factories in which no cases had occurred—for example, one auto shop with at least 16 cases of carcinoma of the scrotum as well as skin lesions out of a workforce of 85 was compared with one in the same firm with no cases. It was found that differences in conditions between those factories affected and those not affected were slight. The same range of standard machines were used for the same materials, and the actual exposure to oil was generally

the same, with some workers more contaminated and others less so. No significant variation was found in any factor that could be correlated with the pattern of incidence.

The type of work is of great importance—tool setters or setter operators on automatic machines are particularly at risk. The work inevitably requires them to lean over their machine, with contact at the groin. The same hazard from contact among much smaller numbers arises in sheet metal rollers and tube drawers, where the steel or non-ferrous metal sheet lubricated with oil is conveyed at groin height. Drop forgers, brick and tile moulders, and metal hardeners, who lower heated metal parts into oil baths with ensuing dense oil fumes and heavy contamination of the lips of the baths, are also at risk. Cases have occurred in workers engaged in the cleaning of swarf from the machines and the recovery of oil, in painting and spraying concrete moulds with oil, recently with a gun held between the legs, and in the removal of transformer oil—the oil in which switchgear that is constantly adjusting the output of electricity required by the consumers is immersed. In the jute industry a small number of cases have occurred from the small quantities of oil sprayed on the fibres. Besides variations connected with type of work and employment in certain factories it would appear that work in nut and bolt and ball bearing factories has particularly led to an increased incidence. The greatest number of cases occurs among tool and auto setters, a highly paid group of workers with a high standard of living among whom lack of cleanliness cannot be a major factor.

*Age incidence* The age of incidence in Birmingham has varied from 27 to 71 years, with an average age of 58. In the literature cancer was described by Earle in a boy of 8, and Dr Henry recorded it in a man of 91. The shortest length of exposure recorded is

3½ years and 4 years in Birmingham and the greatest 75 years noted by Dr Henry. It has been observed, as with other cancers, that the greater the age of first exposure, the shorter the exposure time required.

*Geographical differences* The findings in the Birmingham region may be compared with those of an exact study of cancer of the scrotum in Scotland by Dr A T Doig, HM Medical Inspector, who visited all patients on the Hospital In-patient Diagnostic Index for 1967. There were 18 cases, of which 4 were not occupational, 2 probably not occupational, and 12 occupational. Doig stressed the role of dirt and senility in Scotland, noting that the latter was mainly a factor in the non-occupational group, and he also stressed the high mortality—9 of the 12 patients had died and 3 were seriously ill. In a study undertaken in Manchester, among 81 cases between 1962 and 1968 there were still 65 mule spinners.

In other countries figures are more difficult to obtain as there may be no cancer register, no recording of occupation, no cause of death on death certificates, and no industrial compensation. However, some evidence is available. Recent publications record no cases in 20 years caused by oil in the Netherlands and one case in an autsetter in Germany, in Norway 30 non-occupational cases were recorded in the cancer register over 20 years, and in Sweden 18 cases have been reported, of which, in the absence of any occupational details, it was considered that at least 3 were due to oil. A paper in the *Scandinavian Journal of Plastic Surgery* in 1967 reports 8 cases in 13 years in a Swedish ball bearing factory. In America Henricks in 1965 gave an account of 6 cases of scrotal cancer among American paraffin pressmen. The cancer register in Victoria, Australia, recorded 5 cases in 1966 and 1967; 3 of the patients had worked with oil, one as a lathe operator

in England.

In France in 1955 surgeons noted an increasing number of patients with epitheliomata who came from the valley of the River Avre below Chamonix in the Savoy Alps, and the subsequent account of the epidemic by Drs C and J Thony is the only published work that rivals Dr Henry's. In this valley the manufacture of clocks began as a cottage industry in the early 19th century, followed at the beginning of the 20th century with the making of other metal parts. During the Second World War the industry turned completely to munitions and now many differing types of article are made. *Décolletage*, literally 'removing the neck', equivalent to machine operating and setting, is largely centred in France in this valley. Exact figures of the population at work are available—a total of 5,054, of whom 2,238 are *décolleteurs*—but the number of cases is not exactly known as there is no registration, compensation, or diagnosis on death certificates; however, since the area is small, undoubtedly most cases were known to Dr Thony. He found that between 1955 and 1969 there were 62 cases of cancer of the scrotum, and before preventive measures were taken the death rate was at least 50%. The disease particularly affected small establishments employing under 10 men and the workers in their own homes. Those affected were almost entirely *décolleteurs*. The age of onset averaged 54, with a longer average exposure time than in Birmingham, probably because there were not the older men starting in the industry as in Britain. The oil used during the war was distilled from coal, but cases have occurred since this source was discontinued. Dr Thony stressed lack of hygiene as a cause in these workers. It is difficult to understand why a high incidence of disease has occurred only in two such dissimilar environments as the industrial Midlands of England and the

Savoy Alps, in spite of the fact that occupational conditions may be similar elsewhere in the world.

**Cancer of the skin** Dr Waterhouse and I have concentrated on cancer of the scrotum because knowledge of its incidence is accurate and comprehensive. However, epithelioma of the skin from oil does occur, but the extent is not so clearly demarcated because it is not an uncommon disease in the general population and its occupational origin is not always recognized. In 1954 Dr Robert Murray, then of the Medical Inspectorate, found that of 130 cases of epithelioma treated in one Manchester hospital in one year, 81 were likely to have been of occupational origin and yet only 3 had been notified. Dr Waterhouse has shown that the incidence varies in different places and different sexes in our region and this may be due to variations in occupational risk or precautions. A survey of female machine operators' clothing in the region failed to show any obvious reason for these findings. Mr Gourevitch has shown that the mortality from skin cancer is not negligible, and he stresses, from his series of 400 cases, that the persisting smell of oil is an important diagnostic sign, that epitheliomata are often multiple, and that surgery is the treatment of choice.

**Cancer of the vulva** There are some women exposed to neat cutting oils and a large number of soluble oils, and though the extent of oil contamination in women does not approach that of men, yet it still occurs. A fastidious lady factory inspector told me that when she was an operative on a broaching machine, despite all her efforts she always found her body at the end of the day covered with a thin film of oil. Dr Henry described vulval cancer in cotton spinners and in his second Hunterian Lecture he quoted a gynaecologist in Manchester as having found

that out of 100 cases, 59 were in cotton operatives. He attributed this to their squatting on the floor when cleaning, with subsequent contamination by oily fluff. The risk appeared to have been reduced when bloomers and knickers replaced open drawers. Mr J E Stacy, an obstetrician and appointed factory doctor in Sheffield, attributed a high incidence of cancer of the vulva in 1936 among butty girls to their employment of the rags for polishing silver as toilet paper. The oil in use was found to be old reclaimed stock. We have seen at Birmingham a case of cancer of the vulva in a driller who later developed a primary carcinoma of the lung.

**Oil mist** In any machine shop where oil is used as a coolant the rotation and heating create a fine mist or fume which permeates the atmosphere, and recently a form of cooling by blowing an oil mist on the cutting edge has been evolved. My erstwhile colleagues in the Factory Inspectorate, Dr Joan Cottrell and Dr A I G McLaughlin, investigated the hazards in 1954, and in 1958 we arranged with the Medical Research Council and Dr G Kazantzis the examination of 120 workers in Coventry exposed to oil mist. It was found that sufficient oil was inhaled to outline the trachea. Later it was noted, with Dr J G Holmes, that 2 men who were attending the skin clinic in Coventry for multiple oil keratoses and epitheliomata later died of respiratory cancer, and further evidence accrued when at 3 successive post-mortems on cases of epithelioma of the scrotum primary growths of the lung were found. Dr Waterhouse showed that there was a very significantly increased incidence of primary growths of the respiratory tract and upper digestive tract in 228 cases of cancer of the scrotum, and this has been confirmed. There are now 51 cases of second primaries known, including 12 of the respiratory tract. At the same time another investigation on multiple

primaries showed the same relationship and, to complete the picture, in another investigation he demonstrated that primaries elsewhere were allied to an increased risk of cancer of the scrotum.

There is, however, little new in this. Butlin in 1892 considered that chimney-sweeps had an excess of other cancers, Southam thought the same of mule spinners, and it has been suggested in the case of paraffin press workers. Dr Henry, working with Sir Ernest Kenaway, did large-scale but indecisive statistical investigations to establish the truth. Dr E L Middleton, of the Medical Inspectorate, in 1925 measured the number and size of oil droplets in the atmosphere of mule and card rooms and as a control in ring spinning rooms. Dr Waterhouse and I consider that there is now reasonable evidence that oil that has shown its carcinogenic powers by producing skin lesions may also affect the internal organs which may be in contact with oil. The concept of some oil as a carcinogen for the lung is greatly supported by the increased incidence of the condition from pitch and tar in gas works in this country and from coke ovens in America and Japan, and perhaps also because neoplastic changes have been described in oil granulomata of the lungs. Mr V C Thompson has observed in clinical practice both skin and lung cancer in the same cases among gas workers.

I cannot conclude my remarks on epidemiology without referring to the pioneer studies of Sir Henry Butlin, Surgeon at St Bartholomew's, who travelled widely to discover why chimney-sweep's cancer occurred only in Great Britain. His papers were perhaps the first studies in the epidemiology of cancer, which I think should be more widely recognized.

### **Experimental studies**

The knowledge that oil as well as tar and pitch caused cancer in humans led to an

outburst of experimental work to isolate the carcinogen or carcinogens. Much of the work was done in Manchester with Dr Henry as secretary of the committee. Crude shale oil was shown to be a skin carcinogen in 1922 and petroleum oils to possess a lesser carcinogenic power in 1929. In 1948 the Medical Research Council undertook large-scale studies on crude mineral oil at centres in Manchester, Exeter, and Birmingham and published their report in 1968. The practical result of this work was the confirmation that carcinogenesis was concentrated in the aromatic part of the higher-boiling fractions and that the polycyclic aromatic hydrocarbons may be removed by refining with solvents such as furfural, phenol, or sulphur dioxide, but no known or new carcinogens were isolated.

Later studies have shown that the oil used for batching of jute contains both complete and incomplete carcinogens, and benzpyrene has recently been demonstrated in crude mineral oil. Cocarcinogens or synergists may occur in oil from additives or solvents and may be of the greatest importance. As an example, the solvent dodecane may enhance the carcinogenic effect of benzpyrene on mouse skin 1,000-fold.

The possibility of the production of carcinogens from oil by the action of heat during use was much stressed by Dr Cruickshank, and has been shown to occur with shale oil, and recently in Russia with cutting oils. In metal hardening the oil is exposed to much concentrated heat, in electric transformers to the continuous electrical discharge of the switchgear, and in cutting oil to the small amount of heat generated at the cutting edge.

The chemical and biological work on oil carcinogens has been vast and the experimental evidence has shown that mixtures of polycyclic aromatic hydrocarbons are the likely

carcinogens. This conclusion can also be deduced from the knowledge that epithelioma is not a risk among the large numbers of garage workers in contact with lubricating oils that for technical reasons are always solvent-refined.

The monograph published by the International Agency for Cancer Research of the World Health Organization on polycyclic aromatic hydrocarbons sums up the present value of chemical estimation of polycyclic hydrocarbons thus: 'No prediction as to human cancer risks can be made from a simple knowledge of the levels of polycyclic aromatic hydrocarbons existing in the environment'.

### **Natural history**

It is possible there is a predisposition to cancer of the scrotum, as Sir Astley Cooper noted. Earle described the condition in father and son, and this has occurred in Birmingham. Clinically the impression is gained that a clear complexion which fails to tan in sunlight is not uncommon, although pigmentation is not a complete protection. Epitheliomata of the scrotum have been described in yellow- and black-skinned individuals.

Workers with scrotal cancer may give a history of oil acne on the thighs in early working life which may be related to hyperchlorination of the oils or conceivably, since esterase suppression in the mouse sebaceous gland is a test for carcinogens, it could be a manifestation of some carcinogenic-like property.

Rarely the neoplastic process has started at the site of minor trauma or burn, but more commonly it appears as an ulcer, keratosis, or eczematous patch. Growth may be continuous or may, as in one case, remain quiescent for as long as 23 years. Pathologically the growths are always epitheliomata arising in scrotal skin. There is no increased incidence of melanomata or other tumours in the exposed population, nor is there any

increase in the incidence of cancer of the neighbouring penis.

### **Prevention**

Prevention of oil cancers ideally requires the removal of the carcinogen from the oil or the complete protection of the worker by special clothing or the removal of oil from the skin by washing. The serious consequences can be avoided by immediate reporting and recognition of the lesion by the medical profession. The Mule Spinning (Health) Special Regulations 1953 fulfilled these conditions by specifying the type of oil to be used and requiring the institution of periodic medical examinations and the issue of a warning card and leaflet. The success of these regulations is undoubted but their introduction coincided with an almost complete decline of the industry.

In the engineering industry the use of an oil as defined in these regulations is impossible. Following the work of the Medical Research Council, HM Factory Inspectorate advise the use of solvent-refined oils, but owing to the variety of sources of crude oil and their varying aromatic content it is impossible at present to lay down firm standards. Some firms, however, have instructed their buyers to require a definite maximum allowable content of polycyclic aromatic hydrocarbons. There is little doubt that solvent-refined oils are now in widespread use and, elsewhere, neat cutting oils have been replaced by the less hazardous soluble oils or non-oil-based coolants.

Protective clothing in the form of impervious aprons are used by some workmen, but because they tend to be hot to the wearer and are not traditional they are not in general use. Approximately 20% of workers wear some type of protection for their clothing. The provision of freshly laundered overalls is, of course, important. Good washing facilities are also important and showers are



desirable. The education of workpeople and management is now ensured by the issue of over 1,000,000 coloured leaflets to those at risk. I have seen its success in ensuring early reporting and it has also the advantage of rendering the worker more at ease when he visits his doctor and reminding the doctor of a little-known and rare condition.

Routine medical examination of all exposed to oil is an impossibility and would be almost completely unrewarding, but in workshops where there have been cases there is a very definite place for it, particularly if those absent for any reason or retired are not neglected.

The possible hazard of oil mists has been thoroughly investigated by the Industrial Hygiene Unit of HM Factory Inspectorate, who measure the amount of oil in the atmosphere,

for which a threshold limit value was set at 5.0 mg/m<sup>3</sup> of air. Oil mist extractors are now being installed in growing numbers.

The possibility that preventive measures over the past 5 years have been unexpectedly successful in their effects is illustrated by the graph on p. 73, showing an apparently declining incidence of cancer of the scrotum since 1969.

I am obviously deeply indebted to my fellow workers in medicine and industry, and in particular to Dr J A H Waterhouse, to my colleagues in HM Factory Inspectorate, and—it goes without saying—to the greatest pioneer in the investigation of occupational cancer, Joseph Henry's son, Dr S A Henry.

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References may be obtained on application to the author.