AN INVESTIGATION INTO CANCER MORTALITY AMONG MALES IN CERTAIN SHEFFIELD TRADES

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Introduction

In approaching the question of a possible relationship between work environment and cancer mortality, statistical analysis of the experiences of different sections of workers must necessarily be undertaken.

In order to carry out such an analysis reasonably accurate information must be available with regard to (*a*) the workers who have died from cancer in each of the occupational groups under review, and (*b*) the numbers of workers in each occupational group.

With regard to the first point our information is as complete as could be desired. The particulars of deaths were obtained from the official weekly death-sheets returned to the Medical Officer of Health by the local Registrars.

In the case of retired or unemployed workers the previous occupation was given, and such deaths were allotted to their appropriate occupational group.

For information on the second point we are indebted to the Registrar-General who very kindly supplied us with the numbers of occupied and unoccupied in the various occupational suborders. This information was only available for the following age groups: 14–24, 25–44, 45–69, 70 years and up. It would have been an advantage from the statistical point of view if populations for age groups 35–44, 45–54, 55–64, 65 and up had been available. Cancer rates in males under the age of 45 years are so low that the error likely to be introduced by using one age group 14–44 instead of the two age groups, 14–24, 25–44, is negligible. With regard to the "over 45" populations the numbers of workers aged 70 and over in each section are so small that any error arising from merging 70 and up, with 45–69 years could not materially affect the mortality rates. It was accordingly decided to calculate "death rates" and "expected deaths" in the two age groups 14–44 and 45 years and up. The division at 45 years of age occurs conveniently with regard to cancer incidence, as in males broadly speaking under 45 years is a period of low cancer mortality, while over 45 is the period of life at which cancer is a frequent cause of death.

One further point requires mention, namely, the question of the numbers of retired workers in each occupation. Our population figures are for occupied

and unoccupied, no information is available as to the numbers of *retired* workers in each occupational group. In general, however, it may be taken that in the occupational groups with which we are concerned workers do not often retire, they merely become unfit or unoccupied.

Professional men, business men and clerks are an exception to this, consequently their occupational population figures will be lower than the actual, which will cause their cancer mortality rates to be higher than the actual. As the cancer rates for these three groups have been used as the control standard, the effect of any error introduced in this way is to make the control cancer rates rather higher than they should be, and therefore such error does not adversely affect the value of the statistical analysis for the other sections of workers.

We would like to close this introductory section by paying a tribute to Sir Arthur Hall. It was largely as a result of a discussion with him about industrial disease that this investigation was commenced, and we take pleasure in recording our thanks to him for his constant interest and helpful advice throughout the course of the work.

METHODS OF COLLECTION AND ANALYSIS OF THE DATA

The following is a definition of the lines of the investigation:

(1) The investigation was limited to males over the age of 14 years in the City of Sheffield.

(2) It covered the 10 years' period 1926–35 inclusive. This period was chosen so that the census population figures (1931) would be approximately central in point of time.

(3) From the official weekly death-sheets returned to the Medical Officer of Health by the local Registrars a tabulation was made of all cancer deaths of males over 14 years of age, noting the age at death and the occupation. Sources of error in statistical work on death certifications have been well discussed by Kennaway & Kennaway (1936), and it is not necessary for us to labour this point.

(4) These cancer deaths were then allocated to the following occupational groups:

(1) Professional occupations.
(2) Commercial, finance and insurance occupations.
(3) Clerks and draughtsmen.
(4) Coal and shale miners.
(5) Iron and steel workers.
(6) Workers in precious and non-ferrous metals.
(7) Metal grinders, glazers, polishers and buffers.
(8) Builders, bricklayers, stone and slate contractors.
(9) Workers in wood and furniture.
(10) Workers in transport and communication.

(11) Painters and decorators.

(12) Warehousemen, storekeepers and packers.

At a later stage of the investigation it was deemed advisable to split the workers in iron and steel into two sections

(*a*) Engineers, machinists, cutlers, toolmakers, turners, etc.

(*b*) Foundry workers, furnace workers, smiths, etc.

It will be seen that the former category includes all the workers of iron and steel in the cold, whose industrial exposure is mainly to iron dust and chippings, lubricating oils and solutions. The latter category includes all the workers of hot and molten iron, whose exposure is mainly to heat, gases and sparks, the exposure to metal dust being of a subsidiary nature.

It was found that of the occupational groups investigated the three with the lowest cancer mortality were (1) professional, (2) commercial, finance, etc., (3) clerks, in this order. The differences in cancer mortality between these three groups were small and they were accordingly merged into one group. This group has been used throughout the investigation as the standard or control with which cancer mortality in other occupational groups is compared. In doing this we have rejected the usual method of taking the experience of all males as the standard with which each occupational group may be compared, for the following reasons. Cancer rates for all males represent an average of the better and the worse occupational rates. Now the deviation of a cancer rate from the mean is of limited value from the medical point of view. We hold the view that the cancer mortality rates prevailing in the most favourable occupations should be taken as the standard, in that they represent rates which are humanly possible in every other occupational group if adverse factors in the environment of the less-favoured occupational groups could be overcome. The present research being an attempt to throw light on the existence and nature of such adverse environmental factors, it would be irrational to adopt a standard for comparative purposes which would tend to mask the variation in cancer death-rates.

(5) The numbers of males in each occupational group were supplied from the 1931 Census figures by the courtesy of the Registrar-General.

(6) In this type of investigation it is essential to have some method of assessing the statistical significance of the results, as "sampling error", particularly in the smaller occupational groups, tends to be high. We have adopted the method of comparing the actual cancer deaths in each occupation with the number of cancer deaths which could be expected if workers in a particular occupation suffered the cancer rates obtaining in the control group (professional, commercial and clerks). For testing the statistical significance of differences between "actual" and "expected" deaths, use has been made of the formula given by Young & Russell (1926), namely: $\frac{A-E}{\sqrt{E}}$, where A = actual number of deaths, and E = expected number of deaths. Where $\frac{A-E}{\sqrt{E}}$ is greater

than or equal to 2 the differences are considered to be statistically significant, and the greater the value of the fraction over 2 the greater the statistical significance of the result to which it relates. Where the actual numbers of deaths are small any deductions made must of course necessarily be tentative even if $\frac{A-E}{\sqrt{E}} > 2$.

(7) The term "cancer" is used to include carcinomatous growths, sarcomatous growths and growths designated as malignant. In the case of the bladder, papilloma appearing as the cause of death was accepted as malignant whether so specified or not. Cases of tumours of the brain have been excluded from the cancer deaths and returned separately.

THE DATA

Population of the City of Sheffield	511,757 (Census 1931)
All occupied and retired males over 14 years of age	178,559 (Census 1931)

Total cancer deaths investigated	3861
Total tumours of brain and spinal cord ...	92
Grand total	3953

Table I. *Sites of* 3861 *cases of cancer*

	Cases	%
Respiratory system:	618	16·0
Larynx	150	3·9
Lungs and bronchi	372	9·6
Mediastinum	96	2·5
Buccal cavity and pharynx:	468	12·1
Mouth, palate and maxillae	165	4·3
Lips and tongue	187	4·8
Tonsil	81	2·1
Pharynx	35	0·9
Alimentary tract:	1912	49·5
Oesophagus	208	5·4
Stomach	831	21·5
Intestines and colon	482	12·5
Rectum	391	10·1
Liver, gall bladder and pancreas:	291	7·5
Liver and gall bladder	173	4·5
Pancreas	118	3·1
Urinary bladder*	109	2·8
Prostate	130	3·4
Skin	82	2·1
All other sites†	251	6·5

* Including deaths from papilloma of the bladder.

† Excluding cancer of the brain and spinal cord.

In the case of warehousemen and packers it was found that not only was there no significant variation from the control in total cancer deaths, but also there was no significant variation between actual and expected deaths from cancer in any of the sites classified. Accordingly, no further reference will be made to the figures for this occupation.

Table II. *Cancer in all sites*

Expected deaths are calculated on the experience of professional men, business men and clerks

Occupation	Actual cancer deaths (A)	Expected cancer deaths (E)	% in excess or defect of expected	$\frac{A-E}{\sqrt{E}}$
Steel foundry, furnace and smiths	758	402	+89	17·8
Metal grinders, glazers and buffers	113	70	+61	5·1
Steel: engineers, machinists, turners, etc.	590	373	+58	11·2
Non-ferrous metal workers	157	113	+39	4·2
Miners in coal and shale	159	123	+29	3·2
All occupied males in Sheffield	3861	3142	+23	12·8
Transport workers	265	232	+14	2·2
Painters and decorators	51	43	+19	1·2
Workers in wood	113	102	+11	1·1
Builders, bricklayers, etc.	217	200	+ 9	1·2
Warehousemen and packers	56	55	+ 2	0·1
Professional, commercial and clerks	521	521	—	—

For the other occupations the analysis will be pursued under the heading of cancer of the various sites. In each site only occupations will be given which show significant or nearly significant differences between actual and expected deaths. It may therefore be assumed that where the figures for an occupation are not given the actual deaths do not differ significantly from the expected deaths.

(1) *Cancer of the respiratory system*

Larynx, lungs and bronchi and mediastinum

Occupation	Actual deaths	Expected deaths	% excess or defect	$\frac{A-E}{\sqrt{E}}$
Foundry workers and smiths	126	54	+133	9·8
Grinders, etc.	21	10	+110	3·5
Engineers, etc.	91	51	+ 78	5·6
Transport workers	43	32	+ 34	1·9
A. Cancer of the larynx:				
Foundry workers and smiths	32	13	+146	5·3
Grinders	4	2	+100	1·4
Engineers	28	12	+133	4·6
Transport workers	12	7	+ 71	1·9
B. Lungs and bronchi:				
Foundry workers and smiths	76	31	+145	8·1
Grinders	14	6	+133	3·3
Engineers	46	29	+ 59	3·1
Transport workers	25	19	+ 32	1·4
C. Mediastinum:				
Foundry workers and smiths	18	9	+100	3·0
Grinders	3	2	+ 50	0·7
Engineers	17	9	+ 89	2·7
Transport workers	6	6	—	—

Three occupational groups show significant excess of cancer of the respiratory system. In the case of transport workers the significance figure is only 1·9, which falls below our statistical standard. It will, however, be seen later that transport workers suffer a significant excess of cancer of the lips and tongue and cancer of the tonsil. It is probable therefore that the excess of laryngeal cancer is real and that the factor causing the excess of cancer in

transport workers in these three sites is exposure to wind containing grit and dust. This view is supported by the findings of Young & Russell (1926), who also show that agricultural labourers suffer a very gross excess of cancer of the lip and tongue and a smaller but still significant excess of cancer of the larynx. It should also be remembered that a small proportion of the transport workers in Sheffield actually work in the steelyards, and some of these will previously have been steelworkers.

Furnace and foundry workers suffer the greatest excess of respiratory cancer, and this excess is found in larynx, lung and mediastinum. The adverse factors in their work environment are (1) gases and smoke, (2) heat, (3) dust, in this order.

Turning to the other section of iron workers, namely, the engineers, turners, cutlers, etc., who work the cold metal, it is seen that they also suffer a significant excess of respiratory cancer in larynx, lung and mediastinum. The possible adverse factors in their work processes are (1) iron dust and chippings, (2) lubricating oils and solutions, particularly used in turning processes. It is the operation of the latter, together with the trauma of the skin by metal particles, that causes engineers to occupy such a high place in the list of occupations liable to industrial dermatitis (Legge, 1934).

Both sections of steel workers suffer a significant excess of mediastinal cancer. The difficulties of differentiation of a primary mediastinal cancer from one secondary to a primary lung focus make it only to be expected that any group of individuals showing an excess of lung cancer will also show an excess of mediastinal cancer. Under the circumstances the excess of mediastinal cancer can be taken to support the fact that intrathoracic cancer is significantly excessive, but could hardly be taken as a real proof of the excess of true primary mediastinal cancer. The occupational hazards of these two sections of steel workers will be further discussed later.

Grinders also suffer a significant excess of respiratory cancer, but this is only statistically significant in cancer of the lungs and bronchi. Their occupational risk is mainly abrasive dust for the most part silica to a much smaller extent there is the inhalation and ingestion of metal dust from the article ground. Even in Sheffield, the home of the metal-grinding industry, this is a small industrial group and the numbers of deaths are relatively small, which makes it difficult to obtain values of $\frac{A-E}{\sqrt{E}}$ above 2 even when the percentage excess of actual deaths is large. It should also be appreciated that over 30% of grinders die of pulmonary tuberculosis (Rennie, 1933); in addition, grinders suffer quite heavily from other respiratory affections. Much of this respiratory mortality operates before the cancer age, so that there is serious depletion of the ranks of grinders by the age of 55, which necessarily reduces the actual number of cancer deaths. Kennaway & Kennaway (1936) found an excess of lung cancer of 129% and an excess of laryngeal cancer of 41%. The prevalence of silicosis amongst grinders proves that the dust inhaled enters the lung parenchyma.

The question of silica must arise in connexion with grinders, as the amount of abrasive inhaled and ingested greatly exceeds the amount of iron dust. The Registrar-General (1921) shows that the cancer mortality for cutlery grinders is only exceeded by that for waiters, while the cancer mortality for tin and copper miners (a definite silica risk in this country) approaches the rate for grinders. In view of the pathological condition induced in the lungs by the prolonged inhalation of silica dust, it must be accepted that silica in the tissues acts as a chronic low-grade irritant. That chronic irritation of tissues, particularly of tissues epithelial in type, may produce cancer will not be denied. When the figures for grinders are consulted, in spite of statistical difficulties owing to the smallness of the group in the cancer ages, it emerges clearly that there is an excess of cancer compared with our control standard. This excess is significant only for lungs and bronchi, buccal cavity, and stomach. It will be noted that all these sites stand in the direct path either of inhalation or ingestion. Probably the most interesting references on the question of cancer in an occupation with exposure to mineral dust are those bearing on cancer in the Schneeberg Mines. Workers in these mines were shown by Harting & Hesse (1879) to be prone to malignant tumours of the lung, and, moreover, that these tumours were preceded by pneumonokoniosis. Schmorl (1928) later showed that there were four cases among men who had been employed for a long time in the Schneeberg Mines, but who had given up work on account of lung trouble. In these cases death from cancer did not occur until between 10 and 18 years after leaving the mines. The Schneeberg Mines are eight in number and extend to a depth of 1500 yards; the ore contains iron, cobalt, bismuth, tin, zinc, lead manganese and uranium, chiefly in combination with sulphur and arsenic (Legge, 1934). The air in the mine is radioactive, and in the drilling of the rock much dust is produced. The potentialities of radium as a carcinogenic agent have been well established (Martland, 1931; Ross, 1932; Daels, 1926; Sabin *et al.* 1932), but the growths produced have been sarcomatous in type, whereas in Schneeberg miners the growths were reported as carcinomatous. Arsenic has only been associated with skin cancer following chronic arsenical dermatitis. So far as we are aware no evidence of carcinogenic properties has hitherto been submitted for iron, cobalt, bismuth, tin, zinc, manganese or lead. With regard to lead Blair Bell (1924) suggested that workers exposed to lead show a reduced cancer mortality. In the present work painters and decorators show a mortality from cancer of all sites which is not significantly different from that in our control—the most favoured section of the community. It has already been shown that engineers, etc., suffer an excess of thoracic cancer, and that the dust they inhale is mainly the dust of iron and steel. It will be suggested later in connexion with cancer of the pancreas that there are further grounds for incriminating iron as a possible carcinogenic factor.

Kennaway & Kennaway (1936) discuss the question as to whether there is any association between silicosis and cancer of the lung. They show that metal

grinders have a high rate for cancer of the lung, while stonemasons show only a slightly increased ratio, and they conclude that the factors which lead to silicosis are not very active in producing cancer of the lung or larynx. The absorption of some metal dust with the silica dust represents one clear difference between the dust hazard of the grinder and that of the stonemason. In view of the experience of engineers, etc., with regard to lung cancer it is worth while to consider the possibility that the cancer excess in grinders may be dependent more on the less obvious iron component of the dust than the more obvious silica content. It is interesting to note in this connexion that Brockbank (1932) in his survey of primary intrathoracic cancer gives full occupational details for fifty-two male cases, and of these thirteen had worked in iron and steel.

(2) *Cancer of the buccal cavity and pharynx*

Occupation	Actual deaths	Expected deaths	% excess	$\frac{A-E}{\sqrt{E}}$
Foundry workers, smiths, etc.	115	33	+248	14·3
Engineers, etc.	80	30	+167	9·1
Grinders	15	6	+150	3·7
Builders, bricklayers, etc.	33	17	+ 94	3·9
Workers in non-ferrous metals	18	10	+ 80	2·5
Transport workers	30	18	+ 67	2·8
(*a*) Mouth, palate and jaw:				
Foundry workers, etc.	40	13	+208	7·5
Engineers, etc.	31	11	+182	6·0
Grinders	4	2	+100	1·4
Builders, etc.	13	6	+117	2·9
Workers in non-ferrous metals	9	4	+125	2·5
Workers in wood	7	3	+133	2·3
(*b*) Lips and tongue:				
Foundry workers, etc.	45	13	+246	8·9
Engineers, etc.	30	11	+173	5·7
Grinders	7	2	+250	3·5
Builders, etc.	15	6	+150	3·7
Transport workers	17	7	+143	3·8
(*c*) Tonsil:				
Foundry workers, etc.	25	3	+733	12·7
Engineers, etc.	11	3	+267	4·6
Transport workers	6	2	+200	2·8
(*d*) Pharynx:				
Foundry workers, etc.	5	5	—	—
Engineers, etc.	8	4	+100	2·0

Cancer in these sites is again grossly excessive for foundry workers, engineers, and grinders, in this order, while builders and bricklayers also show a significant excess. Transport workers show an excess only for lips, tongue and tonsil, and this finding has been previously discussed above. Foundry workers have the worst figures in all the sites in this group, except pharynx, where the figures are too small for any conclusions to be drawn. They are closely followed by the workers in cold iron and steel—the engineering group. Builders show excess of cancer in mouth and jaw and in lips and tongue. It should be remembered that some of these builders, etc., are continuously employed in the big steel works and share to some extent the risks of foundry workers. Workers in non-ferrous metals have an excess of cancer only in mouth, palate and jaw.

In this latter site woodworkers also show an excess, but the number of deaths is so small as to make it of little significance.

The excess of cancer of the tonsil in both sections of steel workers is very striking. In the total male population of Sheffield covered by this investigation there were only eighty-one deaths from cancer of the tonsil, twenty-five of these deaths occurred in the group of foundry workers and eleven in the engineering group. These figures undoubtedly underestimate the real incidence on steel workers, as a proportion of the other cases occurred in "labourers" who have not been allocated to these two groups of workers, although a great number of them will have been employed for many years earlier in life in the steel trade. Cancer of the tonsil would therefore appear to be one of the cancers to which steel workers are specially liable.

(3) *Cancer alimentary tract*

Occupation	Actual deaths	Expected deaths	% excess	$\frac{A-E}{\sqrt{E}}$
Foundry workers, etc.	346	214	+ 62	9·0
Engineers, etc.	274	197	+ 39	5·5
Grinders	59	37	+ 59	3·6
Workers in non-ferrous metals	79	61	+ 30	2·3
Miners	87	64	+ 36	2·9
Builders, etc.	103	107	− 4	0·4
A. Cancer of oesophagus:				
Foundry workers, etc.	45	18	+150	6·4
Engineers, etc.	33	17	+ 94	3·9
Grinders	6	3	+100	1·7
Builders, etc.	21	9	+133	4·0
Miners	10	5	+100	2·2
B. Cancer of stomach:				
Foundry workers, etc.	162	81	+100	9·0
Engineers, etc.	111	74	+ 50	4·3
Grinders	36	14	+157	5·9
Workers in non-ferrous metals	34	23	+ 48	2·3
Builders, etc.	47	40	+ 18	1·1
Miners	38	24	+ 58	2·9
C. Cancer of intestines and colon:				
Foundry workers, etc.	77	71	+ 8	0·7
Engineers, etc.	70	66	+ 6	0·5
Builders, etc.	23	35	− 34	2·0
D. Cancer of rectum:				
Foundry workers, etc.	62	44	+ 41	2·7
Engineers, etc.	60	40	+ 50	3·2
Miners	21	13	+ 62	2·2
Workers in non-ferrous metals	20	13	+ 54	1·9
Builders, etc.	12	23	− 48	2·3

Having before us the experience of the foundry workers and engineers with regard to cancer of the buccal cavity, it is not surprising to find that both these groups suffer significant excess of cancer of the oesophagus and stomach. Builders, etc., suffer an excess of cancer of the oesophagus only, and, what is more remarkable, they show fewer deaths than the expectation in the two sites intestines and rectum. It would therefore appear that the factor which leads to cancer excess in builders and bricklayers for the sites, lips and tongue, mouth and jaw, and oesophagus is abolished when the stomach is reached, and that their occupation is favourable as regards cancer in the remainder of the alimentary tract.

In considering cancer of the alimentary tract, the question of alcoholic indulgence must be considered, but there is no reason to believe that foundry workers and engineers are more addicted to alcohol than miners, grinders or builders. All these men live side by side in the City and intermingle in their pleasures and amusements. The case for alcohol as a carcinogenic agent rests first upon the adverse cancer experience of barmen, cellarmen and waiters; these men as a group are essentially spirit drinkers, whereas steelworkers, grinders, engineers and miners as a group are essentially beer drinkers when they indulge in alcohol. While it is easy to visualize 30–40% alcohol in the role of an irritant which might over a long period act as a carcinogenic agent, it is difficult to accept beer as an irritant of this class. The remaining evidence for the carcinogenic properties of alcohol rests on coefficients of correlation between cirrhosis of the liver and cancer, the reliability of the premises in this argument becomes increasingly open to question. The findings for cancer of the alimentary tract in furnace workers suggest the conclusion that these workers are ingesting a substance from their work environment which causes an excessive incidence of cancer of the alimentary tract. It would seem that the potency of this substance decreases in the intestine and increases again in the rectum, this suggests that the substance is either a dust or a chemical compound which is not easily absorbed by the mucosa and which regains its concentration as an irritant after the faecal material has been concentrated by water absorption in the colon. The fact that cancer of the liver in furnace and foundry workers is not significantly different from the control standard is strong evidence against the theory that the irritant is absorbed in the intestines and excreted lower down the alimentary tract. That furnace and foundry workers suffer constant exposure to hydrocarbons in smoke and furnace fumes is evident, and we think that the carcinogenic substance ingested is mainly of this nature. The experience of gas stokers and patent fuel workers with regard to cancer (Registrar-General, 1921) affords direct evidence of the danger of this type of compound in industry, while the work of Cook & Dodds (Dodds, 1934) is a valuable contribution to the more rational understanding of the carcinogenic properties of some hydrocarbons. In the case of engineers the obvious work factor is excessive ingestion of iron. It is well established that only a fraction of ingested iron is absorbed into the system, and that the normal daily absorption of iron from the intestines is small. It is therefore apparent that where the ingestion of iron is excessive the system can absorb an excess of iron, and the iron residuum of the intestinal contents may still remain excessive. The absorption of water from the faeces in the colon will cause a concentration of any mineral residua in the rectum. The constipating action of iron may also be noted as a possible factor in the excess of rectal cancer in this group of workers.

(4) *Cancer of the liver and gall bladder*

Occupation	Actual deaths	Expected deaths	% excess or defect	$\frac{A-E}{\sqrt{E}}$
Liver and gall bladder:				
Engineers, etc.	31	25	+ 24	1·2
Workers in non-ferrous metals	11	8	+ 38	1·1
Miners	10	8	+ 25	0·7
Foundry workers, etc.	23	27	− 15	0·8
Builders, etc.	9	13	− 31	1·1
Cancer of the pancreas:				
Engineers, etc.	25	10	+150	4·7
Workers in non-ferrous metals	9	3	+200	3·5
Foundry workers, etc.	11	11	—	—

No group of workers shows a significant excess of cancer of the liver, although engineers, etc., and non-ferrous metal workers show an excess, it is within the limit of chance variation. In spite of the gross excess of alimentary cancer shown above, the foundry workers return quite favourable figures for cancer of the liver.

Turning to the findings for cancer of the pancreas, it is seen that the two groups of workers showing an excess of cancer of the liver show a significant excess of cancer of the pancreas, and further, that these two groups, the engineers, etc., and the workers in precious and non-ferrous metals, are the only groups to show any excess of cancer of the pancreas. What therefore are the factors (or a common factor) present for these two groups of workers, and absent in the case of the other occupations, which might have an adverse effect on the incidence of cancer of the pancreas? We suggest that a factor is the relatively gross absorption of metal, iron in the case of the engineering group and probably copper in the case of non-ferrous metal workers. The word "absorption" is used advisedly, as the pancreas is one of the organs classified by the Registrar-General as an "inaccessible site". That the excess of cancer of the pancreas in these two groups is not secondary to a high cancer incidence in the alimentary tract is proved by the experience of foundry and furnace workers, who have higher rates for alimentary cancer but absolutely normal rates for cancer of the liver and pancreas. The same reasoning excludes alcohol as a factor, for engineers and craftsmen in non-ferrous metals are certainly not more prone to alcoholic excess than the workers in the hot processes in foundry and furnace room.

Research into the sites and functions of elements of the reticulo-endothelial system has shown that this system is richly represented in both the liver and the pancreas and that it is intimately associated with, among other things, iron metabolism. In the rare disease haemochromatosis, iron accumulates in the body owing to a failure in the excretory mechanism. The iron accumulation takes place mainly in the liver and pancreas and to a less extent in the kidney, spleen, adrenal and heart (Boyd, 1934). The symptomatology of the disease mainly springs from the effects of the severe cirrhosis of the liver and pancreas caused by this iron accumulation. Two more relevant points in connexion with

haemochromatosis deserve mention. First, primary cancer of the liver is said to occur more frequently in haemochromatosis than in simple cirrhosis of the liver (Hurst, 1934). Secondly, that Mallory (1925) believes that haemochromatosis in man is the result of chronic copper poisoning extending over a period of years. Mallory finds that long-continued administration of copper to rabbits leads to the deposition of haemofuscin and the development of a pigment cirrhosis of the liver similar to that of haemochromatosis. Mallory's theory has not yet received general acceptance.

The normal daily ingestion of iron is 10–30 mg. That a gross excess of iron (or metal) dust will be ingested in the processes of filing or turning will readily be accepted by all with knowledge of these processes. One of us who is interested in metal work as a hobby can testify from personal experience that after turning soft iron castings on a lathe the operator's teeth and nasal passages are filmed over with iron dust. We feel, therefore, that there are grounds for suggesting that the high incidence of cancer of the pancreas in engineers is intimately connected with excessive absorption of iron in the course of their work. Turning to the workers in non-ferrous metals we suggest that in their case the same theory may hold good, but that a different metal, possibly copper, is responsible.

(5) *Cancer in various other sites*

Cancer of the urinary bladder.

No occupation showed a significant difference between actual and expected deaths due to cancer of the bladder.

Cancer of the prostate.

Occupation	Actual deaths	Expected deaths	% excess	$\frac{A-E}{\sqrt{E}}$
Engineers, etc.	23	15	+ 53	2·1
Foundry workers, etc.	25	17	+ 47	1·9

The recorded excess of cancer of the rectum in engineers and foundry workers may explain the excess of cancer of the prostate. From its anatomical position in relation to the rectum it is possible that some cases of cancer of the rectum may be certified as prostatic cancer. It will be noted that the excess is barely significant for engineers and not quite significant for foundry workers.

Cancer of the skin.

Occupation	Actual deaths	Expected deaths	% excess	$\frac{A-E}{\sqrt{E}}$
Foundry workers, etc.	30	4	+650	13·0
Engineers, etc.	16	4	+300	6·0
Builders, etc.	8	2	+300	4·3
Miners	5	2	+150	2·1

The four groups of workers who show excess of skin cancer are all exposed to varying degrees of skin trauma in their work. It is interesting to record that of the thirty deaths from cancer of the skin in foundry workers ten were due to cancer of the penis and six to cancer of the scrotum. Work in front of

furnaces will necessarily lead to an undue amount of moisture in the perineal region as a result of perspiration. The men are forced to work lightly clad, and it is easy to see that the trousers will become impregnated with dust, ash, soot, etc., which could act as an irritant to the moist parts. Of sixteen deaths from cancer of the skin in engineers nine were due to cancer of the penis. Here again, metal dust is likely to work into the fabric of the trousers and friction is likely to be the greatest at and around the fork.

All other sites not included in previous headings

Only one occupation gave an excess of deaths under this heading, namely, the foundry workers, smiths, etc. The figures were: actual deaths 62, expected deaths 27, an excess of 130% with a significance figure of 6·7.

Eight of the sixty-two deaths were due to cancer of glands in the neck, which merely supports the excessive incidence of buccal and tonsillar cancer previously shown. There were sixteen deaths from cancer in bone, in a number of cases sarcoma or carcinoma of spine. This number of deaths from bone cancer is certainly absolutely and relatively high and we can offer no explanation of this finding.

Tumours of the central nervous system

On account of the difficulty in deciding whether a given tumour in this category was benign or cancerous we felt that it was advisable to exclude all such tumours from the main investigation and to consider them separately. No occupational group showed any significant deviation between expected and actual deaths from tumours of the central nervous system. This is a result which could reasonably be expected if the population figures for the various occupations are reasonably accurate, which we have no reason to doubt.

Summary

1. Details have been given of the cancer mortality for twelve occupational groups of males in the City of Sheffield 1926–35 inclusive.

2. Of these groups six show a significantly greater cancer mortality than that experienced by clerks, business and professional men in the City. The six groups are:

(1) Engineers, machinists, cutlers, etc.
(2) Steel foundry and furnace workers, etc.
(3) Grinders and sandblasters.
(4) Workers in precious and non-ferrous metals.
(5) Workers in transport and communication.
(6) Coal miners.

3. The excessive cancer mortality in certain of the sites in the first three of these occupational groups is thought to be definitely associated with their occupation.

4. Cancer of the tonsil is particularly excessive among the steel workers both in the foundry and the shop.

5. Significantly excessive mortality from cancer of the respiratory tract is marked in engineers, foundry workers and grinders and is seen in no other occupational group.

6. Cancer of the alimentary tract is most excessive in foundry and furnace workers. It is suggested that the carcinogenic factor may be hydrocarbons ingested from smoke and fumes.

7. Cancer of the pancreas is excessive only in engineers, etc., and in workers in non-ferrous metals. The theory is advanced that excessive absorption of iron in engineers, and possibly copper in workers in non-ferrous metals, are the respective causes of the findings with regard to cancer of the pancreas in these two occupational groups.

8. Cancer of the skin is significantly excessive in both foundry, etc., workers and engineers, and this is believed to be a direct result of their occupational environment.

9. Tumours of the central nervous system showed no significant variation from the control in any occupational group.

10. The findings in this research indicate that there is a field for further investigation with regard to the carcinogenic properties of iron and copper, particularly with reference to cancer of the pancreas. Some further investigation is required with reference to the occupations exposed to the inhalation and ingestion of silica. Is the high cancer rate amongst grinders associated with the silica risk or with the inhalation and ingestion of iron dust from the article ground? On the preventive side the findings support the view that measures should be elaborated to improve the protection of workers from gases, fumes and dust in the iron and steel and allied industries.

REFERENCES

BLAIR BELL, W. (1924). *Public Health*, **37**, 217. London.

BOYD, W. (1934). *Textbook of Pathology*, 2nd ed. p. 45. London.

BROCKBANK, W. (1932). *Quart. J. Med.* N.S. **1**, 34.

DAELS, F. (1926). *Bull. Assoc. franç. pour l'étude du cancer*, **15**, 102.

DODDS, E. C. (1934). In BEAUMONT, G. E. & DODDS, E. C. *Recent Advances in Medicine*, 7th ed. p. 3. London.

HARTING, F. H. & HESSE, W. (1879). *Vierteljahrschr. Gerichtl. Med.* N.S. **31**, 102. Berlin.

HURST, A. F. (1934). In PRICE'S *Textbook of Medicine*, 4th ed. p. 688. London.

KENNAWAY, N. M. & KENNAWAY, E. L. (1936). *J. Hygiene*, **36**, 236–67.

LEGGE, T. (1934). *Industrial Maladies*, pp. 156–7, 180. London.

MALLORY, F. B. (1925). *Amer. J. Path.* **1**, 117.

MARTLAND, H. S. (1931). *Amer. J. Cancer*, **15**, 2435.

REGISTRAR-GENERAL'S DECENNIAL SUPP. (1921). Part II, pp. xxvii, xxviii–xxix.

RENNIE, J. (1933). *Ann. Rep. M.O.H. City of Sheffield*, p. 20.

ROSS, J. M. (1932). *J. Path. Bact.* **35**, 899.

SABIN, F. R. *et al.* (1932). *J. exp. Med.* **56**, 267.

SCHMORL, G. (1928). *Rep. Int. Conf. on Cancer*, London, p. 272.

YOUNG, M. & RUSSELL, W. T. (1926). *Med. Res. Council, Spec. Rep.* No. 99, p. 16.

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