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HEALTH HAZARDS IN THE PLATING ROOM AND THEIR CONTROL

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INTRODUCTION

The electroplating industry can be, but need not be, a highly hazardous one. Although large quantities of toxic and corrosive substances are present and are handled in the usual plating room, the operations performed there can be so conducted as to make them safe and not hazardous to the health of the workers in the department.

Hazards which arise from plating-room operations are usually due to improper use of the various toxic and corrosive substances commonly employed. In this article, an attempt will be made to call attention to the sources of some of the more common hazards in the industry and the means which may be employed to reduce or eliminate these hazards.

There are three kinds of occupational injury which may occur in the electroplating industry, namely,

1. injury to internal organs of the body
2. dermatitis
3. injuries caused by mechanical accidents

They will be considered separately as far as possible, but there will be some unavoidable overlapping as the various substances and operations are being discussed.

Nonindustrial poisoning usually results from the ingestion of a toxic agent and only occasionally from inhalation of toxic gases and vapors, such as carbon monoxide, carbon tetrachloride from cleaning fluids, and benzol from cements. Occupational disease which results from the absorption of some toxic substance into the body is, on the contrary, most frequently caused by the inhalation of that toxic agent.

TOXIC SUBSTANCES

Cyanides

Cyanides are by far the most toxic chemicals used in the plating room. It takes only about 50 mg of hydrocyanic acid or its equivalent of sodium cyanide absorbed in the body to produce almost instantaneous death, and yet there are very few deaths or illnesses from exposure to cyanides in this industry.

Sodium cyanide is a salt of a strong base and a very weak acid. In aqueous solution it undergoes extensive hydrolysis resulting in the formation of the base, sodium hydroxide, and the acid, hydrocyanic acid. Unless a considerable concentration of excess free alkali is added, the hydrocyanic acid in solution can and does evaporate from the solution. As the temperature is increased, the volatility of the hydrocyanic acid is increased.

Zinc plating tanks are usually operated at room temperature and with added sodium hydroxide in the electrolyte. The possibility of the evolution of hydrocyanic acid gas from such a bath is exceedingly low. Copper cyanide plating tanks operated at room temperature contain no added caustic in the electrolyte. The odor of hydrocyanic acid gas can always be detected above such tanks. However, that odor does not necessarily indicate a harmful concentration of the gas in the atmosphere surrounding the plater or his helpers. Such factors as tank areas, room size, and general room ventilation will have an important bearing on the concentration of HCN in the air. The question of whether a harmful or potentially harmful concentration of HCN occurs near such tanks can be readily determined by tests which are not at all difficult to perform. When one deals, however, with strike or high-speed copper plating tanks operating at elevated temperatures, one should not depend on general ventilation to maintain the level of HCN in the air within safe limits. One should employ adequate local exhaust ventilation on such tanks.

Cyanide plating tanks are usually operated at high current efficiencies at both electrodes and with soluble anodes. This means that little, if any, gas is released at either electrode. However, should plating be performed with considerable gassing a mist of the electrolyte containing cyanides would be evolved from the tanks. Obviously, such operations would have to be performed with such ventilation as would prevent the release of cyanide into the workroom atmosphere in quantities that might tend to injure the health of the workers.

Objects entering or being removed from cyanide baths should be rinsed twice, especially if an acid dip is involved, each time in running water. The effluent from rinse baths containing cyanides should not be allowed to run into waste lines containing acid rinse water.

The addition of cyanides to tanks in the making up of electrolytes should be so performed as to protect the worker from dusts and splashes. Adequate personal protective equipment is readily available for this purpose. It includes a U. S. Bureau of Mines-approved toxic-dust respirator, a face shield or goggles, rubber gloves, and similar apparel designed for such operations. Spilled material should be arrested as they pass through the labyrinthian path, permitting the gas to escape somewhat scrubbed of the chromic acid it contained as it first broke through the bath surface. The use of plastic chips should reduce the quantity of air required for the adequate ventilation of a chromium plating tank. Theoretically it does. However, in the State of New York, whereas the use of plastic chips is permitted, reducing the quantity of air which must be exhausted is not. Platers often find the use of chips objectionable since they must brush them aside to hang pieces to be plated into the tank. Such platers would not find it difficult to brush the chips aside permanently. There is also a tendency for these chips to stick to pieces being withdrawn from a tank. For maximum efficiency, the thickness of chips on the surface of the tank must not be less than one inch. It is more difficult to regulate this than to maintain a ventilation system at its initial efficiency. However, there is no doubt that the use of a plastic-chip covering for chromium plating solutions will save some electrolyte which would otherwise be drawn into the ventilation system. It has been reported that the use of balls, such as ping-pong balls, overcame some of the objections to chips, in that the balls do not stick to the work as it is withdrawn.

The other development to which reference was made is the use of a material added to the electrolyte which will so alter its surface tension as to permit the accumulation of gas bubbles on the surface. If these remain unbroken until the mist can either settle or reach the bubble surface, the quantity of mist escaping from the tank will be reduced. However, this type of control introduces another potential hazard. The bubbles which gather on the tank surface consist of hydrogen and oxygen. A spark from some electrical contact may set off an explosion which, in itself, may not be violent enough to cause any damage but still be violent enough to splash electrolyte about, possibly injuring personnel.

At this point comment should be made on a piece of equipment which was recently tested by this Division. It is a unit mist separator which can be connected directly to a chromium plating tank or similar tank, or to any other process equipment releasing objectionable or toxic mists. The unit consists of a large metal cylinder with a concentric air-inlet duct extending almost to the bottom and terminating in an exhaust fan. A water nozzle is located at the top of the duct, and a tangential air outlet is located near the top of the outer cylinder. The air inlet is connected to the exhaust duct from the tank or operation to be ventilated. A water overflow is located near the bottom of the cylinder. In operation, the contaminated air enters the separator and comes in contact with a water spray. The air and water descend to the bottom of the inlet duct where the fan throws them against the inner walls of the cylinder. Impingement and centrifugal action separate most of the water from the air, and the latter is discharged through the tangential outlet. This discharge may be either into the workroom or to the outdoors, but preferably to the outdoors.

This equipment has several advantages over the usual method for removing acid and other mists from workroom atmospheres. Should the air be recirculated, heat can be conserved in the winter; in the summer, spraying the recirculated air with cold water may reduce the temperature and humidity of the workroom. If the air is discharged to the outdoors after spraying with water, this air contains much less mist than before the washing. This may be an important consideration in some localities.

The particular unit which was tested was oversized for the chromium plating tank to which it was attached. The efficiency of chromic acid-mist removal was found to be high, but it could not be determined what it would have been had the separator been connected to the size plating tank for which it was rated.

(Continued in the August 1952 issue)

INDUSTRIAL CANCER OF THE LUNGS

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(Continued from the June 1952 issue)

Research

It is quite apparent that industrial lung cancer; indeed, the whole field of environmental cancer has been barely scratched, and that there is still a great deal of pure speculation, current, despite all efforts to establish the facts.

The difficulties which are hindering progress are not immediately apparent, but become quite clear as soon as intensive work is begun. Most important, perhaps, is the fact that a worker's occupation at the time he develops cancer, or dies of it, is rarely the etiological factor. The cause is probably to be found in some previous occupation which he had some 10, 15 or 25 years earlier—an occupation difficult to ascertain at the time of his present illness or death, and difficult to evaluate. Obviously, any investigation made at this later date, will almost inevitably reveal environmental conditions very different from those to which he had been exposed, so many years before. The further fact that rapid technological advances are the order of the day in industry; and that labor, in this country, is highly mobile, presents many serious stumbling blocks to the research worker, at every turn.

The New York State Occupational Cancer Committee tried to overcome these obstacles by interviewing some 4000 cancer patients at the Roswell Park Memorial Hospital where accurate clinical and pathological diagnoses were available. In these interviews, a serious attempt was made to obtain a detailed occupational history, going back to the patient's first job. Each such occupation was then evaluated, by specialists in the field of industrial hygiene, in order to ascertain, as accurately and as completely as possible, *all* of the environmental factors to which *each* patient had been exposed in the course of his working life. Since each patient was found to have had about 4 or 5 different jobs, on an average; and numerous abnormal elements were involved in the working environment of each job, the number of variables which were inevitably introduced into the study was such as to make our statisticians shudder. And yet, these variables are inherent in any effort to get at the facts and they cannot be ignored.

There are a few industries, such as chromate manufacture, for example, or the manufacture of aniline dyes, where one or more active carcinogenic agents so dominate the industrial environment as to highlight the fact of the high incidence of cancer among those workers. It is not that this probably represents one of the more exceptional situations in industry. By and large, the environmental characteristics of a particular industry, a particular process or even a particular workroom are not necessarily, or even usually, pathognomonic for that industry, process or workroom. Many of the same abnormal environmental factors, in different combinations, are to be found in a great variety of totally unrelated industries and occupations. For that reason, statistical correlations between a given primary cancer site and specific industries or occupations are not necessarily fruitful. Until some practical method has been developed for the identification and isolation of these common denominators in the industrial environment and statistical correlations prepared on the basis of these data, there is good reason to believe that the etiological components of this environment will very largely continue to elude the research worker.

There is, however, one practical contribution which can be made by almost every practicing physician whether in his office, in the outpatient department or in the hospital; and that is to take a careful occupational history on *all* patients—whether they are suspected of having cancer or not—and to record successive occupations on subsequent visits. More than that, social welfare services can contribute by providing for a good occupational history on all Forms to be filled out on applicants. This would include applications for Workmen's Compensation, Unemployment Insurance, Placement, Sickness Insurance, and any other type of social security. Labor Unions' sickness records could similarly include this type of information. Aside from the fact that social security numbers on death certificates are now beginning to make it possible to go back and learn something of the cancer patient's previous work, records along the lines above indicated are nowheres to be found at the present time. If conscientiously compiled from now on, however, a vast source of information would become available during the next 15 or 20 years, as to the occupational exposures of persons who ultimately develop cancer. Whether this vision of future benefits is sufficiently inspiring to overcome natural resistance to undertaking additional work, in the present, is the big question mark.

The great value and the limitations of research work with experimental laboratory animals, as a method of developing leads for the detection of carcinogenic agents in the industrial environment, are too well known to this audience to warrant more than passing mention.

Summary & Conclusions

There has been a striking increase in the incidence of lung cancer; and because this has largely coincided with advances in technological progress in this country, there is a very natural suspicion as to cause and effect. Of the many organic and inorganic chemical and physical agents which are suspect, and under investigation at the present time however only a few have been definitely implicated as causative agents in the production of industrial lung cancer: The chromates, nickel carbonyl in English nickel factories, radioactive substances, and probably asbestos.

An effort was made to evaluate the role of both chronic and acute irritation of the respiratory tract due to air contaminants in the workroom, in the production of industrial lung cancer, by reviewing what is known of some of the more familiar occupational diseases which are characterized by chronic and acute pathology of the upper respiratory passages and the lungs. No necessary relationship could be demonstrated. However, a final determination must await the development of far more precise and complete data than are now at hand.

Attention was directed to the difficulties confronting the research worker in this field because of the complexities of the industrial environment, the mobility of labor and the time lag between environmental exposure and the development or diagnosis of the cancer.

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It is a familiar phenomenon in the occupational diseases and in environmental cancer. Among persons doing essentially the same work, some, apparently, get lead poisoning or develop cancer while their co-workers do not.

Age and sex differentials are not well understood, in general. But in the field of lung cancer, there are indications that there may be significant shifts both in age and sex incidence when, exogenous carcinogens are responsible. Thus, while the incidence of lung cancer is higher for men than for women, in the general population, this relative sex incidence may apparently be significantly altered in situations where women have the same occupational exposures as the men. Similarly, the incidence of occupational lung cancer appears to affect a somewhat younger age group than that characteristic for the population as a whole.

Safe Dosage and Prevention—Since toxicity is, in general, a function of dosage — where dosage is measured in terms of intensity and duration of exposure — the occupational diseases are amenable to control by well established industrial hygiene techniques. For that reason, it has been useful to develop safe standards for exposure to potentially toxic substances in industry. These are known as Maximum Allowable Concentrations (M. A. C.). While allergy, synergism and some other matters, which we need not go into here, present complications, these standards have proved invaluable for the prevention of occupational diseases. They are constantly being improved and extended as new scientific data become available.

It is unfortunate, therefore, that equally convenient and simple relationships between dosage, toxicity and carcinogenicity do not seem to exist in the field of environmental cancer. It is not helpful to know that a chemical substance is toxic because this does not apparently indicate anything as to its carcinogenicity and vice versa. Lead has already been cited as a toxic chemical which is not carcinogenic. Beta naphthylamine, conversely, is carcinogenic but has never been known to produce systemic poisoning. And so, the maintenance in a factory workroom of Maximum Allowable Concentrations will not necessarily insure safe working conditions, if a potential carcinogen happens to be present.

It has recently been suggested that there *is* a critical dose for each carcinogen of exogenous origin; and that cancer will ultimately develop once this dose has been reached, whether as a result of a single exposure or cumulative absorption over a period of time. But even could such dosage be accurately determined one would still, for purposes of prevention, face the formidable problems created by the fact that cancer may take a great many years to develop; that it may also develop after a relatively short exposure; and that there may be a lag of many years between the pertinent exposure and the development of the cancer.

Known and Suspected Carcinogens

Let us, now, turn to a consideration of specific factors in the industrial environment which are known to produce lung cancer, or which are suspect and under investigation.

1. Organic Chemicals

Among the organic chemicals, none, thus far, has been definitely shown to be capable of producing lung cancer. Many are still under investigation, but the data now available are inconclusive and contradictory.

The products of incomplete combustion of coal have been studied, as well as its various distillation and fractionation products. These studies have included such substances as tar, asphalt, pitch, oil, lamp blacks, carbon blacks and various types of soot. Thus far, the results in all cases have been either negative or inconclusive insofar as cancer of the respiratory tract is concerned.

Soot has always been of special interest because it was responsible for the classical scrotal cancer of chimney sweeps. However, these boys must have also inhaled considerable soot in the course of their work; and yet, no suggestion has come down to us to the effect that they also developed lung cancer. Perhaps the diagnostic techniques of those days were too inadequate. This historical background lends special interest to a statistical study made by Dr. Dorn of the relation of lung cancer to atmospheric soot from domestic and industrial sources. In this study he found the incidence to be *low* in Pittsburgh as compared with five other large cities.

Commercial soots prepared from natural gas and oil residues are also under investigation. The carbon black industry is now supporting experimental research in this field and further data of interest may be forthcoming in the near future.

Exhaust gases from diesel and gasoline engines have very naturally come under suspicion. But here again, investigations as to the incidence of lung cancer among persons heavily exposed, such as policemen, street cleaners, garage mechanics and automobile drivers, have all been negative.

Crude mineral oil and tar are still in the doubtful category. Inhalation of aerosols of processed mineral oil and shale oil; fumes from creosote and anthracene oil (3, 4 benzpyrene) and particularly crude paraffin oils or the heavier fuel oils are all under suspicion at present. They are being investigated, but no conclusive data are available thus far. Special attention is being given to tar fumes in tobacco smoke. Isopropyl oil, inhaled as a vapor, in connection with the manufacture of isopropyl alcohol, is the only chemical in the aliphatic group that is now suspect as a cause of lung cancer.

2. Inorganic Chemicals

Asbestos — The relation of asbestos to lung cancer, long suspected, has received new confirmation from the 1949 Annual Report of the Chief Medical Inspector of Factories in England. During the period from 1924 to 1946 inclusive, 235 deaths were reported either caused by asbestosis or in which asbestosis had been established at necropsy. Cancer of the lungs or pleura was found in 31 of these cases or 13.2 per cent. This is very high compared with a general incidence of 1 per cent for cancer of the lungs among all adults examined at necropsy in England. Moreover, the sex distribution seemed also to suggest the presence of an occupational carcinogen. The histologic character of the cancers—squamous cell, instead of adenocarcinoma—and their histogenetic derivation, in that the bronchial mucosa was involved rather than the alveolar epithelium, was interpreted to indicate the presence of a specific exogenous carcinogenic agent as the etiological factor; in this instance, inhalation of asbestos dust.

The development of cancer of the lungs is believed to be more directly related to asbestosis, the disease, than to the inhalation of asbestos dust per se. Differential diagnosis by X-ray between asbestosis and lung cancer presents all of the difficulties one would anticipate. It has been suggested that cytological examination of the bronchial secretions might well be made in workers exposed to asbestos dust, whenever clinical or X-ray evidence suggests the possibility of a pre-cancerous lesion. Careful histological studies of lung tissue, postmortem, in all such cases would also provide valuable data.

It has been estimated that approximately 20,000 workers are now employed in asbestos-producing industries in this country and Canada.

Nickel Carbonyl—Exposure to nickel carbonyl in the nickel works in England has also been the subject of special investigation and report by the Chief Medical Inspector of Factories. In a review of the incidence of nose and lung cancer between the years 1923 and 1948, inclusive, he found 47 cases of cancer of the nose, and 82 cases of cancer of the lungs among these workers. The average duration of exposure before the development of cancer was 23 years for the nose cases, and 25 years for the lung cases. The average length of time between diagnosis and death was short; and by the end of 1948, 46 of the nasal and 72 of the lung cases had died. The precise causative agent has not yet been identified and the matter continues to be under active investigation. There is no comparable experience in this country.

The Chromates—The etiological role of the chromates in the production of lung cancer has been pretty well established in this country in the last few years; and these findings have confirmed previous European experience.

In 1948, at the request of the chromium-producing industry, Drs. Machle and Gregorius made a study of deaths from cancer of the respiratory tract from 1937-1947, in five chromium-producing plants. Dr. Mancuso, the year following, examined the records of all employees who had worked one year or more between 1931 and 1949 in a chromate-producing plant in Ohio. Dr. Baetjer then reviewed all of the European and American experience, and reported on a study of her own in which she analyzed the records of two hospitals in Baltimore located near a chromate-producing plant. In each of these studies the incidence of lung cancer among the chrome workers was significantly high.

A total of 122 case reports, were thus collected, of cancer of the respiratory tract among workers exposed to chrome. Of these, 109 worked in the chromate-producing industries; 11 in the manufacture of chrome pigments; 2 in other industries. Sixty-three of the cases occurred in Germany, 57 in the United States, and 1 each in Switzerland and England. The chemical substances believed to be responsible are the hexavalent chromium compounds, particularly Na and K monochromate or dichromate; and zinc chromate, inhaled as dusts.

While the mechanisms are not known, certain observations were made which are of interest:

1) Most cases were found to be primary bronchiogenic carcinomas. In a few instances, the upper respiratory tract or the oral region were involved. The incidence of cancer in other tissues was not high.

2) In some cases, an exposure of four years appeared to be sufficient. In most cases, however, a great many years of exposure were necessary. In some instances there was a latent period of variable duration between leaving the exposure and the development of the cancer.

3) The intensity of exposure could not be evaluated in these cases. Presumably, however, in years gone by, this type of work was very dusty.

4) Lung cancer in these workers showed a somewhat younger age distribution than that for non-occupational lung cancer.

5) There was no indication that persons exposed to chromates in other occupations were more than normally liable to cancer of the respiratory tract.

In New York State there is exposure to chrome and its compounds in a variety of industries: In the mining and extraction of chrome ore, which is ferrous chromite; in the manufacture of chrome pigments, including zinc and lead chromates; in chrome-plating operations, where there is exposure to chromic acid and chromic acid mist; in the leather industry where chromium sulphate and sodium bichromate are used in tanning. Photo-engravers are exposed to ammonium bichromate and also to asphalt. Since both of these substances are under suspicion, the Division of Industrial Hygiene decided to make a special study of photo-engravers.

In photo-engraving, the copper plates are coated with a thin light-sensitive film of gelatin and ammonium bichromate, and the plate is then exposed to light behind a negative. The penetration of light through the transparent areas of the negative, causes the formation of a water insoluable chromium-gelatin film, which is resistant to acid. The parts not exposed to light remain soluble and are washed off. Prior to etching all large surfaces, which are gelatin-free and which would ordinarily have to be eaten away, are coated with an asphalt paint, which is resistant to acid. After the plates have been etched in a ferric chloride solution, these areas are reamed out with the aid of rotary electric cutting tools.

An unselected series of 684 photo-engravers were X-rayed in cooperation with the chest clinic of the New York City Department of Health. No pulmonary neoplasms were found. At the same time a preliminary examination was made, under Dr. Hueper's direction, of the health records of the Photoengraver's Union at its central headquarters in St. Louis. The results are inconclusive, thus far, however, and further study is necessary.

3. Radiation

Exposure to radiation is on the increase not only in industry but in hospitals and in research laboratories everywhere. Radium dial painting is booming again as a result of industrial expansion for defense. The examination of metal castings for flaws by the use of radium and X-ray has become routine in foundry operations. Radioactive cobalt is being used increasingly for this purpose at present. The fluoroscope has not only made its way into retail shoe stores, but is used in many industries as an inspection device — for the detection of misplaced nails in shoe manufacture; for examination of metal inserts in plastics; for the detection of foreign bodies in packaged foods, and so on. Radioactive static eliminators are utilized to prevent fires in dozens of industries and operations. These include publishing houses, plastic fabric manufacture, teletype machine installations, etc. Radioactive isotopes are stepping out of the expert hands of technical personnel, in research laboratories, and are now finding their way into the hands of lay workers, not at all familiar with the potential hazards to health which are involved; or with the precautionary measures which are essential for safety.

Wherever there is radioactive dust in the workroom air —however invisible to the naked eye—one is presented with a known etiological agent in the production of lung cancer. There is, as yet, very little information as to what constitutes a "safe" dust count; or how much radioactive dust one might, in general, anticipate in specific operations. Too few dust counts have, as yet, been made to provide this basic experience. However, standards for radon gas in the air of the workroom, emanating from radioactive materials present there, have been established; also for radon in the expired air of individual workers. Taking of the air samples is not too difficult. But these samples must be sent to highly specialized radiation laboratories for analysis, and this is fairly expensive.

In such plants there is usually simultaneous exposure to various types of external radiation. This type of exposure will not produce lung cancer; but adequate lead shielding and other control measures are nevertheless essential for the prevention of cancer elsewhere in the body.

(Continued in the July, 1952 issue)