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Observations on the Toxic Effects Resulting from Exposure to Chlorinated Naphthalene and Chlorinated Phenyls with Suggestions for Prevention

By EMIL H. VON WEDEL, M.D., WILLIAM A. HOLLA*, AND DR. JAMES DONTEN

Department of Pathology, White Plains Hospital, and the Department of Health, Westchester County, New York

FOR over twenty years chlorinated naphthalenes have been extensively used for insulating wire and in the manufacture of certain electrical equipment. Chlorinated naphthalenes and chlorinated phenyls (sold under the trade names of Halowax and Arochlor) have marked electrical, heat and moisture resisting properties and are practically non-inflammable. Their use in the manufacture and preparation of many types of electrical equipment has been tremendously increased, due to the enormous increase in the use of such equipment for the prosecution of this present world war.

In some mills hot concentrated Halowax is used to saturate wire insulation, while in other mills the compounds are dissolved in organic solvents, the solutions then being used cold to saturate the insulation. In both these processes the wet insulated wires are dried in drying tubes or ovens. During this drying process dangerous concentrations of chlorinated compounds are given off.

It has been known for many years that these compounds cause acne-like eruptions. In recent years serious systemic effects have been recognized. During the past year many cases of skin eruption and in addition six fatal cases of a peculiar type of subacute yellow atrophy of the liver have occurred among the workers in two wire and cable mills. At the request of the management of one of these mills and in cooperation with the Department of Health of Westchester County (N. Y.), one of the authors undertook an investigation of the mill in order to advise the management and the Department of Health as to means of prevention of the cutaneous lesions and systemic effects resulting from these toxic hydrocarbons. This mill used the cold process for saturating the wire insulation.

As the study progressed, it became apparent that the toxic lesions resulted from inhalation by men working in or near the drying ovens and also by some other method of absorption, presumably through the skin. This fact was clearly shown, because many of the acne-form eruptions occurred among the men operating the saturation baths and not exposed to the inhalation hazard. A few of the acne-form eruptions occurred among workmen handling the cold finished wire in a mill-room far removed from any possible inhalation

*Commissioner of Health, Westchester County, N. Y.

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hazard. Women working in the same mill rooms with the affected men showed no acneform eruptions. None of these women handled the toxic substances.

An investigation was begun to determine what systemic effects would result from the administration of these substances to experimental animals by inhalation, ingestion and by surface application of the substances to the skin. This article describes pathological changes observed in man and experimental animals resulting from absorption of these toxic substances and suggests means of preventing this absorption.

Earlier

Lehmann in 1919 *(1)* found that animals which were fed or which inhaled chlorinated naphthalenes lost appetite and at death showed peculiar lesions in the liver.

Flinn and Jarvik *(2)* in 1936 reported three cases of yellow atrophy of the liver occurring in three widely separated plants. Experimental studies on rabbits using different compounds of chlorinated naphthalenes, indicated that the toxicity of these compounds increases with the increasing degrees of chlorination.

Flinn and Jarvik *(3)* later reported nine cases of yellow atrophy of the liver occurring in mills where chlorinated naphthalenes were being used to impregnate wire and other electrical equipment. They concluded that the cases of yellow atrophy of the liver occurring among the employees were probably due to exposure to chlorinated naphthalenes.

Drinker, Warren and Bennett *(4)* in 1938 described the morphological changes in the livers of rats exposed to chlorinated naphthalenes and chlorinated phenyls. These investigators administered the toxic substances by inhalation, feeding and subcutaneous injection. They found that the tri and tetra chlorinated naphthalenes produced only slight pathological changes in the liver, unless extremely high concentrations were used. However, animals exposed for six weeks to the higher chlorinated naphthalenes in low concentrations regularly showed marked liver damage, even though they gave no clinical evidence of such toxicity before death. The toxicity of each compound seemed directly related to its degree of chlorination.

Widespread liver degeneration can exist for several months without producing any evidence of ill-health in the animals, suggesting that the alterations take place slowly. Animals given a sublethal dose of chlorinated compounds, when given a very small dose of carbon tetrachloride immediately died, even though such a small dose of carbon tetrachloride given to a normal animal would not materially affect it. Exposure of rats to either highly chlorinated naphthalenes or chlorinated diphenyl results in a type of liver injury differing considerably from the liver lesions resulting from carbon tetrachloride *(5, 6)* and chloroform *(7)* poisoning.

The changes resulting from exposure to the compounds employed in their study involved all portions of the liver lobule, even though the initial morphological changes were more pronounced in the liver cells nearest the hepatic veins. The changes were degenerative in nature, first cloudy swelling then fatty infiltration and fatty degeneration. Complete disintegration of the cells with areas of necrosis finally resulted, regardless of the method of administration. This degeneration was characterized by accumulations of large amounts of acidophilic hyaline material. The characteristics of the liver changes produced can be markedly altered, quantitatively and qualitatively, by varying the degree of exposure. Blood examination during life revealed no significant abnormalities and the injurious effects of these compounds were manifested solely in the liver.

The investigators concluded from their experiments that lower air concentrations must be obtained in the case of the more highly chlorinated naphthalenes and chlorinated diphenyls, than for trichlorinated naphthalenes, if a safe environment for workmen is to be assured.

Yaeger, Sands and Drinker *(8)* reporting on the ventilation of wire impregnating tanks using chlorinated hydrocarbons, showed that the requirements for the ventilation of such tanks varied greatly with the type as well as with the size of the tank. They suggest that an exhaust slot about 2 inches high extending along the full length of the tank with lateral ventilation was the most effective method of ventilating such tanks. For any given concentration of chlorinated naphthalene the degree of chlorination had no appreciable effect on ventilation requirements.

Greenburg, Mayers and Smith *(9)* in 1939 reported three cases showing the occurrence of similar pathological changes in the liver in three young adults known to have been working with chlorinated naphthalenes and diphenyls. They briefly summarized the systemic effects resulting from this exposure and made recommendations for prevention.

Drinker *(10)* in 1939 reported further observations on the possible systemic toxicity of certain of the chlorinated hydrocarbons. From this study he concluded that the permissible limit for air contamination with trichlor naphthalene was 10 mgm. per cu. m.; for tetra and penta chlor naphthalene, 1 mgm. per cu. m.; for penta and hexa chlor naphthalenes, 0.5 mgm. per cu. m.; and for the various chlorinated diphenyls 0.5 mgm. per cu. m.

Cleary, Maier and Hitchings *(11)* in 1938, reporting on the metabolism of chlorinated naphthalenes, stated that no significant storage of the material could be detected in lung, liver, skin or kidney, nor was any significant amount excreted in the urine. Both the rat and the dog apparently were able to remove and excrete the chloride promptly. A rise in the urinary ethereal sulphate fraction, but no significant change in the neutral sulphur excretion, was noted after chlorinated naphthalene feeding in the dog.

Riley *(12)* in 1943 stated that poisoning may result from inhalation of vapors, from prolonged skin contact with the vapor, liquid or solid phase, and from ingestion of the chlorinated material.

Cranch *(13)* in a recent personal communication to one of the authors, stated that the effect of these waxes on the skin resulting in the appearance of acne is not determined by the presence of chlorine alone, but is due rather to the compound effect of chlorine and a tar derivative. No such marked tendency to acne formation results from exposure to chlorinated petroleum derivatives, such as chlorinated paraffin. When chlorinated naphthalene is combined with chlorinated diphenyl, a more active acne is produced. Liver damage is not likely to occur following exposure to chlorinated naphthalene alone, but may occur from exposure to chlorinated diphenyl combined with chlorinated naphthalene or other tar derivatives. The severity of the acne is not correlated in any way with the degree of liver damage which might occur.

Cranch suggests that other factors are probably in-

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volved in the cases showing liver damage besides exposure to chlorinated waxes alone. The main point brought out in this communication was the fact that skin reactions with acne formation have been noted in men handling only the finished product, with no appreciable vapor exposure. As far as he knew, no liver cases had been attributed to skin absorption. He suggests that the absorption of these materials through the skin is very slow as compared with inhalation absorption.

Cranch also suggests that prevention depends first on the greatest possible reduction of vapor exposure and skin contact; second, on protection of the skin by means of cold creams and adequate bathing.

Toxic Effects in Man Resulting from Exposure to Chlorinated Naphthalenes and Diphenyls

It has long been known that chlorinated naphthalenes and diphenyls are skin irritants. The lesions have been described by Schwartz *(11)* and others. The effects are first noted on exposed parts—either from fumes or from direct contact with the chemicals. Contamination of clothing results in more generalized distribution of the irritant effects. In workers with greasy skins and hypertrophied sebaceous glands, the effects are more frequent and prompt. After exposure of about six months, few workers fail to develop lesions.

The skin affection usually begins as a generalized folliculitis. Occasionally there is diffuse pigmentation of the skin of exposed areas. Later comedones, acne-like pustules and sebum cysts develop. These latter lesions tend to be chronic and on healing may leave permanent scars. Generalized papulo-pustular eruptions have been described. In the cases observed in this mill the skin lesions have been confined to the extensor surfaces of the arms, the back of the neck, the mandibular surfaces of the face, and along the hair margins. The lateral surfaces of the thighs have frequently been involved.

In addition to the skin lesions, symptoms of systemic poisoning have appeared in some workers. The first complaints are digestive disturbances, burning of the conjunctivae, and in some instances sexual impotence and haematuria.

It is not known just how frequently fatal poisoning results from absorption of these chemicals. It is worth noting, however, that six workers, formerly employed in these two mills, have been studied post mortem. One of the post mortems was performed by one of us and the other five by pathologists in this industrial area. We have had the privilege of examining the pathological material from some of these necropsies. In these six cases, death was in every instance due to subacute liver necrosis.

Since subacute liver necrosis is an uncommon disease and since all six workers had been exposed to absorption of the chemicals in Halowax and Arochlor, it is logical to suppose that these chemicals were the cause of the liver necrosis. In all these cases the livers were much reduced in size. Their weights ranged from 400 grams to 1100 grams. A review of the pathological changes in the autopsy material shows nothing of much significance, except in the livers. The hepatic lesions varied in character and intensity in the different cases, apparently depending upon the susceptibility of the different subjects, or possibly upon the length of time of exposure to the toxic agents.

All the livers were markedly distorted in shape, extremely granular and mottled in yellow and red. For the most part they were very firm, although some showed large soft red areas. On section, their cut surfaces varied from mottled yellow and red with scattered necrotic areas to large yellow-gray areas showing small necrotic centers. In our case, there was a complicated melange of liver necrosis and cirrhosis. In all of the cases, however, there were large areas of degeneration and necrosis. The distinctive feature of this chemical intoxication is, clearly, liver necrosis. The cirrhosis and scarring are apparently attempts at repair.

In the autopsy material it is difficult to determine what portion of the liver lobule is primarily affected. In some the whole lobule is involved, while in others the lobules are so deformed that definite localization is impossible. In general, it appears that in the more acute cases, necrosis of the liver cells is the prime feature. In the more chronic cases the liver necrosis was complicated by scarring repair and regeneration of liver lobules.

Experimental

Materials employed: In the animal experiments which we have conducted, the chemicals used were those regularly employed in and supplied to us by the mill for this purpose. They were Halowax and Arochlor in concentrated state and dissolved in naphtha and troluoil. The effects of the solvents alone (naphtha and troluoil) were also studied. In these experiments white mice, guinea pigs and rabbits were employed.

Three routes of introduction of the chemicals have been used—viz: by inhalation, by ingestion and by application to the skin. The first two avenues of absorption have been extensively investigated by other workers, but to the best of our knowledge there has been no systematic study of the systemic effects of skin absorption of these chemicals. Observation at the plant leads us to the conclusion that the skin is an important avenue of absorption of these chemicals. Therefore we have in our experiments directed particular attention to this mode of absorption. The inhalation and feeding experiments which we have carried out have conformed to the methods outlined by Bennett, Drinker and Warren *(4)*. They have proven useful, as controls, in gauging the importance of lesions produced by skin absorption.

The skin absorption experiments were performed for the most part with rabbits. Approximately 9 square inches of the hair on the backs of a series of rabbits was removed with clippers, the remaining hair shaved off and the resulting small skin abrasions allowed to heal for three days. These experimental animals were kept in cages alongside normal control rabbits. ½ ml., 1 ml., and 1½ ml. of diluted Halowax and Arochlor, containing 0.8 grm. dry Halowax per ml. and 0.6 grm. Arochlor per ml., respectively, was dropped on the shaved areas by means of a calibrated syringe. After allowing the chemicals to partially dry for about five minutes, the animals were returned to their cages. The substances were administered daily, in the above-described manner. Because of possible criticism that some of the chemicals might have been absorbed by ingestion or inhalation, this entire series of experiments was duplicated, following the same procedure cited above, but with the precaution of covering the application areas with molded celluloid guards.

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These celluloid guards were made by cutting and bending sheet celluloid into proper shapes and binding their sharp edges with adhesive tape. After each daily skin application the guards were replaced and firmly strapped in place with adhesive tape passing completely around the animals' bodies. This procedure we believe precluded any possibility of inhalation or ingestion of the toxic substances. In no instances were the guards removed or loosened by the animals' movements in their cages. To avoid skin irritation the inner surfaces of the guards which might come in contact with the skin were coated with vaseline.

A third series of skin absorption experiments was conducted in a similar manner, except that before the daily skin applications were made the shaved areas were covered with a thin layer of Protek. This substance is a cheap and apparently efficient type of cold cream used by mill workers.

After experiments with naphtha and trofuoil alone, extending over four months, no animal showed any skin lesion resembling those caused by Halowax or Arochlor, either by inhalation, ingestion or skin absorption, and no animal died of whatever mild effects these substances might have caused. We therefore felt that the acne and the systemic effects observed in the remaining experimental animals could not have been caused by either naphtha or trofuoil. The results of all three methods of absorption with both chemicals showed essentially the same type of skin lesion and liver necrosis. It was found that the rabbits were more uniform in their reactions, and the dosage could be more easily evaluated. Therefore, all the last experiments were made on rabbits. The extent of the skin lesions and liver necrosis depended on the size, frequency and number of inoculations.

Animals inoculated with large doses every day, whether by inhalation, feeding or skin absorption, died before definite liver necrosis developed. Animals inoculated with moderate and small daily doses lived for longer periods, and at necropsy showed skin lesions and subacute yellow atrophy of the liver, simulating the lesions observed in man. Animals sacrificed after a short series of small doses, showed slight to moderate degrees of liver degeneration, evidenced by fatty infiltration.

Four to five days after the first dose of chemical was dropped on the skin, all regrowth of hair was completely destroyed. The skin became markedly reddened, small papules and blisters formed, and finally the external epidermal layers desquamated. Some pustular lesions developed which were very similar to those seen in man. On necropsy, the livers of the animals were the only viscera showing any definite changes. The animal livers varied in appearance. Externally they were mottled in red, yellow and brown. They were finely to coarsely granular, and showed no marked abnormality in size. On section, the livers of the animals receiving the smallest dosage showed only a change in color, being more or less diffusely yellow with no gross evidence of necrosis. In animals receiving larger or more numerous doses of the toxic substances, there were opaque yellow areas of necrosis scattered throughout the liver substance.

The lesions were definitely degenerative in type, ranging from moderate degrees of fatty degeneration to marked hepatic degeneration and necrosis. Those resulting from skin absorption of Halowax and Arochlor were essentially identical to the lesions produced by inhalation of these substances. The rabbits treated with Protek before application of the chemicals to their skin, were partially protected and the chemical absorption retarded. There were similar but milder skin and liver lesions. Normal control animals kept in identical environment as the experimental animals developed no skin lesions and showed no fatty degeneration or liver necrosis at autopsy.

Methods Recommended to Safeguard Workers Exposed to Chlorinated Naphthalenes and Dibenzyls

The first step taken should be the formation of a working committee consisting of the superintendent, the chief engineer, the chief chemist and the consulting or plant physician of the mill. This committee should formulate practical changes, wherever found necessary, to as far as possible protect the workers from the hazards of these toxic compounds. Because of the urgent need for these critical war materials, no changes should be advocated which will in any way slow down or prevent the greatest possible productivity of such important mills.

Protection must consist of prevention from inhalation, ingestion and skin absorption of these chemicals. Skin absorption, while long recognized as causing acne-form eruptions, has not in our opinion received proper consideration from the standpoint of systemic effects.

Toxic effects from inhalation are without question the most important because of the speed of absorption and the probable high dosage of toxic substances absorbed. Therefore, adequate ventilation is the primary consideration in any mill. The mill rooms and mixing house should be ventilated by intake and exhaust fans of sufficient volume and velocity to remove the majority of the fumes.

The drying tubes and drying ovens should be adequately ventilated and sealed as nearly air tight as practicable. To accomplish this, large intake vents should be placed near the floor in the doors of the drying ovens. Large high-velocity exhaust fans and an adequate number of large exhaust stacks leading up above the roof of the mill should be installed. After the steam in the drying ovens has been turned off, fresh cool air from the mill room should be pumped through the ovens for a sufficient time, in sufficient volume and of a velocity of approximately 2000 cub. ft. per minute, to bring down the temperature of the drying ovens to that of room temperature, before opening their doors to unload.

Daily analysis should be made of the air in these ovens. They should not be opened for unloading until chemical analysis reveals less than 0.5 mgm. of chlorine, expressed as Halowax or Arochlor, per cubic meter of air. The drying tubes surrounding the wet impregnated cable should be ventilated by suction applied at the far end of the tubes. The air flow through the tubes should be sufficient to cool the saturated cable to a temperature at which no significant amount of vapor is given off from the cable after it leaves the drying tubes.

The impregnating vats should have permanently hinged covers fitted with flanges that extend downward inside the tank, to avoid soiling the outside of the tank from dripping. These vats should be completely enclosed in a ventilation hood, with a hinged door in front. These hoods should be ventilated through a properly constructed lateral exhaust ventilation system. Yaglou, Sands and Drinker (8) recommend an ex-

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...slot approximately 2 inches high extending along the back, the full length of the tank, placed approximately 6 inches above the level of the liquid wax in the impregnation vat. Various speeds of exhaust should be tried until the proper speed is indicated by chemical analysis of the air in front of each hood.

In the cold process, Halowax and Arochlor are dissolved or diluted with solvents in mixing vats. The Halowax and Arochlor should be introduced into these vats with as little manual handling as possible. The vats should be kept covered at all times with a hinged cover, except when actually being filled. The workmen should not be allowed to place their hands inside these vats, even for taking the specific gravity of the mixtures. This can easily be accomplished by a long-handled glass thief introduced through a small opening in the cover of the tank. The specific gravity should be observed outside the tank, after removing the thief. The chemicals should be pumped outside of the mixing house to a loading platform through permanent pipes fitted with proper gate valves. Such pipes should be connected by proper couplings to tank trucks.

The tank trucks filled with the chemicals should then be driven to the felting mills, where they are emptied into conveniently located distribution tanks. The chemical compound should then be pumped or fed by gravity from the distribution tanks to the impregnation vats through appropriate sized pipes, not less than 2 inches in diameter. Separate lead pipes should extend downward to the vats from the main feed lines. Each pipe, just before it empties into the impregnation vats, should have a gate valve the full size of the pipe and of simple design so that it cannot become clogged by the mucilaginous fluid.

After the fluid chemical in the impregnation vats becomes contaminated by too much asbestos debris, the sludge remaining in the tank should be exhausted through exhaust pipes at least 4 inches in diameter, connected at or near the bottom of each impregnation vat. Such exhaust pipes should be attached at an angle leading out from the back of the vats and extend into receiving sludge vats with a simple gate valve the full size of the pipe placed near their lower ends. The remains of the asbestos sludge, which does not flow

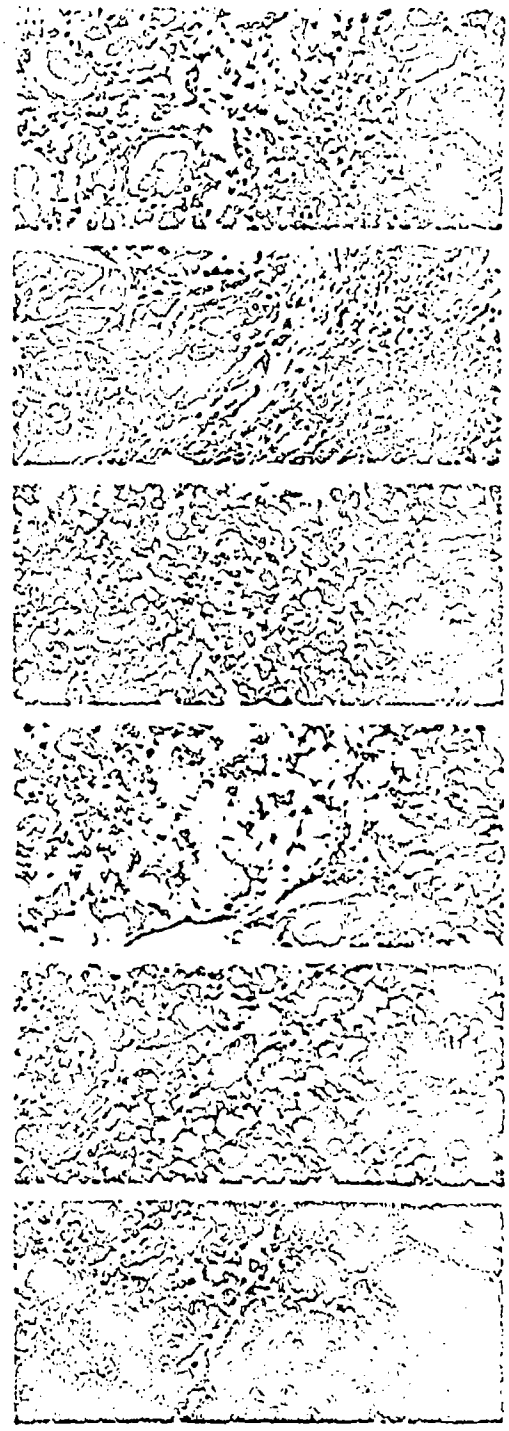


FIG. 1—Human Liver: Late effects of liver necrosis. Bile ducts and capillaries, no liver cell regeneration.

FIG. 2—Human Liver: Right half of the field shows destroyed liver lobules without repair, the left half of the field shows regenerated and degenerated liver cells.

FIG. 3—Rabbit Liver: Effects of skin absorption of Arochlor—moderate dosage—half of the liver cells are opaque and granular, the other half contains large fat droplets. The darker areas are haemorrhage.

FIG. 4—Rabbit Liver: Effects of inhalation of Halowax—18 doses—showing complete liver necrosis.

FIG. 5—Rabbit Liver: Effects of skin absorption of Halowax, showing complete liver necrosis.

FIG. 6—Rabbit Liver: Effects of skin application of Halowax after application of Protek, showing partial liver necrosis.

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through the pipes, should be scraped out of the vats and pushed into the sludge vats by means of a long-handled square-ended steel paddle. If the exhaust pipe should become clogged by the thick mucilaginous substance, a 4-foot long steel push rod with a 3-inch flat bell at its end should be used to push the obstructing sludge into the receiving vat. Both the paddle and the push rod should be stored in a vertical metal container.

The sludge vats should be of the correct capacity to receive the largest amount of sludge that may be exhausted into them, and of appropriate height and diameter, so as not to obstruct the passage ways. All such vats should be interchangeable. The tops of these vats should be constructed so that their entire top, with the exception of a 1-inch overhang rim, is open. A slide sleeve should be placed in this overhang rim. A strong metal sliding cover should be provided for each vat. An opening to receive the metal pipe should be placed in the slide cover, fitted with an angle extension to receive the solid 4-inch pipe from the saturation vat.

After the sludge vats have sedimented for an appropriate time, the good fluid Halowax should be pumped into receiving tanks through a pipe containing a glass observation window. After all the good chemical has been removed from the sludge vats, the remaining sedimented sludge should be dumped into burial ditches by placing the vats in an automatic dumping machine, so that no hand will have to touch the edges of the vats. The vats should not be cleaned out until their inside surfaces become covered with too much hardened chemical. The hardened sludge is then softened with an appropriate solvent and scraped off the sides of the vats with a long-handled square-ended steel paddle.

Elbow-length, thin, impermeable gloves should be used by the men when they adjust the nuts and screws of the mechanism in the vats. They should be taken off immediately, when the men have finished the job, to avoid excessive perspiration. The outsides of the impregnation vats should be frequently washed down with a proper solvent, to keep them free from the toxic chemicals.

After the above recommendations have been followed out, the personal factor has been almost completely eliminated. Clean working clothes, consisting of long-sleeved overalls fastened at the neck and wrists, should be provided. These clothes should be laundered frequently, daily if possible.

All eating of lunches, etc., should be forbidden in the workrooms. Candy, cigarettes, chewing gum and other vend[illegible] of such nature should be placed in rec[illegible] should be provided for the work-[illegible]

[illegible] and shower baths should be [illegible] men coming to work leave [illegible] the outside locker room and pass through the shower room to the inside locker room, where they put on their clean work clothes and cover their hands, faces and necks with some type of cold cream or skin lotion. They should then be checked out by a checking system before they are allowed to go into the mill. When leaving work for lunch, they should be checked back through the inside locker room, where they should thoroughly wash their hands, faces and necks with soap and water before going to lunch. If they are going home they should also check through the inside locker room, where they leave their soiled clothes, take a complete hot soap shower bath (therefore sufficient shower baths should be provided) and are then checked out to the outer locker room. Here they put on their street clothes. This not only protects the workmen, but also their families, as it has been shown (11) that wives handling and washing such clothes and children playing with their father while he was wearing the soiled work clothes acquire the same type of skin lesion as the workmen themselves.

All new workers should be examined by the mill physician, and all men and women with a history of previous jaundice, liver diseases or skin diseases should be rejected or should be placed in departments where toxic substances are not handled. All workers in the mills where cables saturated with chlorinated naphthalenes and phenyls, whether wet or dry, are handled, should be periodically examined for skin lesions and systemic effects. No women who are pregnant should be allowed to work in these rooms as they are notably very susceptible to liver toxemia. All workers in these mill rooms and all new employees should have frequent periodic laboratory tests made to determine whether or not any liver disfunction is present. Such laboratory examinations should include Hanger's Cephalin-cholesterol flocculation test, bilirubin content of the blood serum, and icteric index. If any one of the three show results exceeding the normal limits, the worker should be re-tested within one week and if such abnormality persists or increases such workman should be removed from this toxic hazard at once.

As it is a known fact that other conditions, such as gastro-intestinal upsets, etc., may cause one or more of these tests to show transient moderately abnormal findings, the first test should not be considered conclusive, nor should such workmen be barred from their work until such abnormal findings persist or increase.

At present the New York State laws relating to health in industrial plants are placed under the jurisdiction of the State Department of Labor and the local health department. Where a county health department has been established or where a properly functioning city department exists most of the health hazards in industry could be handled more readily by the local department than by the state. This is due to the fact that the state has but few employees to cover a large area, while the local health department is immediately available and often more familiar with local conditions and hence able to keep in closer contact with the industry and over a long period of time if necessary.

Laws should be passed making it necessary for medical directors of industrial plants to report at once all toxic disease conditions relating to industrial employment directly to the local health department, who would then make an investigation of existing conditions and, if possible, arrive at the solution of the difficulty then make the necessary recommendations to the industrial plant, also furnishing the State Department of Labor a report of the investigation and the recommendations made. In cases where the investigation discloses that more extensive work is needed or the services of specialists required, the Department of Labor should then be called upon to complete the work. In this manner the state could be saved considerable time and trouble and be able to devote itself to more intensive work in other plants where its services were more urgently needed.

The responsibility for the enforcement of the laws relating to protective measures in industrial plants should be placed upon the local health departments

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In localities where no competent or responsible health department exists, the investigation and enforcement should be made by the Department of Labor.

At present in Westchester County there is a sanitary code established by the County Health Department which covers the regulations relating to food handling, food inspection, dish washing, management of cafeteria in general, together with sanitation and water supplies. These regulations are enforceable by the County health authorities and are in addition to those covered in the state sanitary code.

Only by compulsory reporting of all toxic industrial conditions and the cooperation of the state and local departments with the industry can these conditions be eliminated. The plant management must be assured that the aim of such procedures is to aid them and that production will not be interfered with.

Discussion

For over twenty years reports have been published dealing with the toxic hazards of chlorinated naphthalenes. Every one agrees that definite systemic effects can occur from inhaling or ingesting these toxic substances. There is also general agreement regarding the acne-form eruptions that are caused by skin contact to them. To our knowledge no one has stressed the importance of the systemic effects caused by skin absorption.

Therefore this publication is primarily concerned with the systemic effects caused by skin absorption. It is very difficult in humans to prove that systemic effects occur from skin absorption, because the workmen quite naturally are subject not only to skin absorption but also to the hazards of ingestion and inhalation. Workmen in mills far removed from inhalation hazards and working only with the cold finished impregnated wires and cables, have in many instances acquired acne-form eruptions due to these chlorinated naphthalenes and chlorinated phenyls. None of these workmen, as far as we can ascertain, have shown recognizable systemic effects due to their absorption. This is understandable, as we know that liver function tests only show definite results when an appreciable liver degeneration has occurred. None of the six fatal cases showed any evidence of jaundice or other systemic effects until a few days to a week before hospital admission. They were in contact with these toxic substances for periods ranging from two months up to nine months. They all died within one to three weeks after hospital admission.

All of our experimental animals showed definite liver degeneration or necrosis in varying degrees, whether or not they were protected by Protek, when liquid chlorinated naphthalene or diphenyl was administered by dropping it on their shaved skins. Every precaution possible was taken to safeguard these animals against the toxic effects of inhalation and ingestion.

Parallel experiments were conducted by inhalation, by feeding and by skin absorption. All three series of animals showed the same type of liver degeneration. The difference in liver lesions found depended entirely on dosage and number of inoculations. During these experiments, none of the animals showed recognizable systemic effects until a few days before death. The animals killed during the course of the experiments showed no recognizable effects. Every animal killed showed some degree of liver degeneration. Normal control animals showed no liver lesions.

The experiments cited indicate that chlorinated naphthalenes and diphenyls cause systemic effects in animals whenever they absorb these toxic substances, whether by inhalation, ingestion or skin absorption. It would therefore seem probable that if experimental animals react in this way, man will also.

Because of the aforementioned facts, recommendations were made to the mill and were to a great extent followed out. For the past five months, not one single case of skin eruption or systemic disease, attributable to these toxic compounds, has occurred in this mill. Two deaths and between fifty and one hundred cases of acne-form eruptions occurred in this mill within the previous six months, before these changes were instituted. Therefore, the practical evidence would seem to indicate that if the above recommendations are carried out workmen will be almost completely protected. The cost of such changes will be quickly absorbed by the saving in man-hours, lowering of insurance rates and greater efficiency of the workers. The relations of the workers towards the management must of necessity be vastly improved.

Summary

1. Studies concerning the toxic effects of chlorinated naphthalenes and diphenyls on experimental animals are reported.

2. These studies were undertaken because of the occurrence of acne-form eruptions and deaths among workmen in two wire and cable mills where these compounds were being used.

3. The compounds experimentally studied were administered to animals by inhalation, ingestion and skin absorption.

4. Liver degeneration in experimental animals is caused by skin absorption of either chlorinated naphthalenes or chlorinated diphenyls.

5. Histological examination of the viscera of these experimental animals showed that important toxic effects are manifested only in the skin and liver.

6. The liver degeneration has been described and illustrated.

7. The degenerative effects in the liver have been shown to be essentially identical regardless of whether the toxic substances were administered by inhalation, ingestion or skin absorption.

8. Methods are recommended to safeguard workers in mills using these toxic compounds.

9. Laws should be passed making it compulsory for all mills using toxic chemicals to adequately safeguard their workmen from such toxic hazards.

10. Inspection of the plants and authority to enforce protective measures should be placed under the Department of Health.

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Reanite Bonding Process

A NEW method of bonding natural or synthetic rubber to metal, or plastics to metal, recently announced by the U. S. Stoneware Company, Akron, Ohio, manufacturers of Tygon synthetic materials and corrosion-resistant equipment, is reported to not only do away with costly brass plating processes, but to develop a bond from three to five times as strong. The new method, known as the Reanite Bonding Process, develops a bond between rubber and metal ranging from 900 lbs./sq. in. to as high as 1200 lbs./sq. in. on a pull test. This compares with bonds ranging from 250 to 400 lbs./sq. in. obtained by present methods.

While the bond develops its maximum strength at room temperatures, its strength over a range of —40°F. to as high as 300°F. is said to be substantially stronger than bonds obtained by conventional processes. A national independent research laboratory, using methods similar to those specified by ASTM, reported as follows: "Discs of rubber, half an inch thick, were vulcanized between two steel discs, two square inches in area, which had been cleaned and coated with Reanite cement. The direct pull necessary to tear the assembly apart was then determined (a) at room temperature, (b) immediately after immersion in boiling water for five minutes, and (c) after heating for 30 minutes in an oven at 300°F. The following figures are typical of tests made during the year, although in a considerable number of cases still higher figures were obtained."

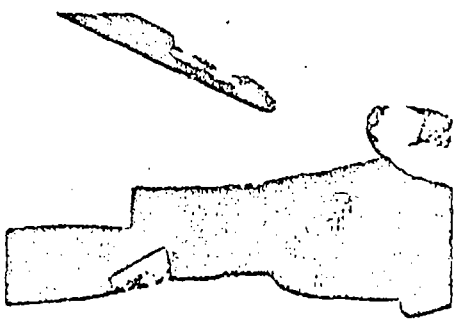
TEST OF BOND STRENGTH

Hardness of Rubber	*Strength of Assembly (in pounds)*		
(Shore)	*Room Temperature*	*212 F.*	*Steam*
50	1863	565	340
60	1912	592	367
50	1894	540	312

The Reanite Bonding Process is suitable for bonding natural or synthetic rubber, or plastics, to almost all metals, iron, steel, stainless steel, magnesium, aluminum, aluminum alloys, copper, bronze or brass. The accompanying illustration shows a test sample of aluminum, 5¾ in. long by 1½ in. wide by 1/16 in. thick bonded to tire tread rubber ¼ in. thick. The rubber was cut away from a portion of the aluminum strip, and conventional line-pull tests were applied. Standard specifications call for such an assembly to withstand a direct pull of 19 pounds. On this test no separation of the bond occurred under pulls well above 300 pounds.

The process is simple in application. The surfaces to be joined are brushed, sprayed or dipped with Reanite. After being permitted to dry for an hour the surfaces are joined and the unit vulcanized by any of the conventional methods. It may also be used to bond metal to metal, or leather or wood to metal or to each other. The bond—metal to metal—ranges from 1,000 pounds to as high as 3,000 lbs./sq. in. on a combined shear-pull test. On bonds formed between synthetic rubber and metal, plastics and metal, or wood and metal, the materials themselves gave way before the bond.

The Reanite joint is unaffected by fresh or salt water, is non-corrosive to metals, possesses excellent corrosion-resistance in itself, and has high dielectric strength. While Reanite is formulated through cyclic modifications of materials high on the critical list, it is available for immediate shipment for essential end-uses. Present applications include fabrication of airplane assemblies, motor mounts, sound and vibration dampeners, instrument mounts, composite metallic and plastic units, and tank lining assemblies.



Test sample of aluminum, 5¾ in. long by 1½ in. wide by 1/16 in. thick, bonded to tire tread rubber ¼ in. thick, as described by the Reanite Process. In the test specified, no separation of the bond occurred under pulls well above 300 pounds.

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