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BENZENE POISONING IN INDUSTRIES AND ITS PREVENTION

The authors give a review of benzene poisoning in Swedish industry, and discuss the methods for its prevention. Benzene poisoning was observed in Sweden in rubber plants, raincoat factories, printing works, shoefactories, in watchmaker's shops and laboratories. Prevention of benzene poisoning in a raincoat factory and in Swedish printing works during the war is described in detail.

Of the different aromatic hydrocarbons, benzene is the most dangerous, and the severe lesions of the blood forming organs, which may cause death, have been observed beyond doubt only with benzene poisoning. The American Committee on Treshold Limits indicates the following allowable maximum concentrations:

Benzene:	35	p. p. m.	corresponding	to	0,1	mg	per liter
Toluene:	200	p. p. m.	»	»	0,8	»	» »
Xylene:	200	p. p. m.	»	»	0,9	»	» »

Benzene is a liquid of high refractive index and has, at least in small concentrations, a not unpleasant aromatic odour. The boiling point is 80,1° and the melting point 5,5° C. Benzene is slightly soluble in water: 0,08 gram per 100 ml at 20° C. On the contrary, benzene is miscible with ether, alcohol, glacial acetic acid, white spirit and similar organic compounds. Benzene occurs in considerable amounts in coal tar, where it is a component of the light-oil, which is the superior raw material for the manufacturing of benzene in Sweden. The light-oil is that fraction of the coal which distils at about 200° and contains about 60—65% benzene and its homologues. Benzene, toluene and xylene are separated through fractionated distillation. The high boiling component of coal tar consists mainly of cumene, cymene and similar compounds and this fraction is sold commercially under the name of solvent naphta.

From the point of view of occupational hazards the industrial uses of benzene can be classified in two main groups. To the first group belong such industries as 1. distillation of coal and coal tar in the production of benzene, 2. the blending of motor fuels, and 3. the chemical industries including oil extraction, dyes and dye intermediates, manufacture of paints, varnishes and stains, of paint

and varnish removers, where benzene is used in large quantities. In these types of industries, however, it is prescribed, that benzene must be stored and handled in closed systems and leakage must be avoided for various reasons.

In the second group of processes, represented by the use of benzene, 1. in rubber industry, 2. in artificial leather manufacture, 3. in dry cleaning, 4. in connection with the handling of paints, lacquers, varnishes and stains, and 5. in rapid rotogravure printing and quick drying in general, benzene is used chiefly as a solvent or a vehicle. In these processes a necessary phase is to remove benzene from the dissolved substances. This is usually done by evaporation, in some cases at room temperature, in other cases at an elevated temperature.

The greatest number of acute benzene poisoning happens in industries of the first type in connection with occasional faults in equipment or during repair work, when benzene may come out in the factory from leaking pipes or containers. Workers who enter reservoirs not sufficiently aired, without any protection may also incur acute benzene poisoning. In industries of the second group, vapors may be liberated, if benzene is allowed to evaporate in workrooms, where the ventilation is not sufficient. In this latter case chronic poisonings are most common.

In Sweden benzene poisonings have occurred mainly in the following types of factories: rubber plants, raincoat factories, when rubber is glued, printing works in rotogravure printing, shoefactories when using sole-cement, in watchmaker's shops when using benzene for cleaning and in certain laboratories. In the following I will dwell on those cases of poisoning which occurred in a raincoat factory in middle Sweden and some cases in some of the rotogravure printing works of the country.

In a raincoat factory the glueing of raincoat cloth had for a time been made with a rubber solution containing about 90% benzene. The glueing was performed partly by hand and partly by machine. The machine glueing was made only on small scale and the machines were enclosed and equipped with satisfactory exhausting appliances for benzene vapors. The glueing by hand on the contrary, took place on open tables. Pieces were placed together with sewing machines on both sides of a travelling band. The details were pasted with glue, and before the pieces were put together, all the solvent had to evaporate. The evaporation took about a minute. At full operation about 50 kg benzene was liberated in 8½ hours in the factory. This was the normal working time. The volume of the air in the working-room was 3.000 m^3 (about 100.000 cu. feet). The workers were mainly women. Owing to enlarged production and changes in the composition of the glue to a higher content of benzene the risk of benzene poisoning gradually increased. In this factory

one of the workers died in December. The cause of death was not considered to be due to occupational poisoning. When, howerer, two female workers became sick in February of the next year, and one of them died in hospital after 12 days, benzene poisoning was suspected. Only at this stage, the Department of Occupational Hygiene of the National Institute of Public Health was informed. At a medical examination of the workers, about 60 cases of benzene poisoning were proved, amounting to 30% of the working staff in the departments where benzene was used. Soon after the establishment of poisonings, mechanical ventilation blowing 12.000 m^3 (about 400.000 cu. feet) per hour was introduced. Despite this ventilation, analyses of air showed amounts of 0,44—0,70 mg benzene per liter of air, corresponding to 150—280 p. p. m. These samples were taken in the breathing zone. Before the mechanical ventilation was put in operation, the amounts of benzene were certainly much higher than those found at the time of the analyses. However, the concentrations were too high to allow people to work in such an atmosphere. Therefore, exhaust-ventilated tables for glueing were constructed. The tables were equipped with casings which could be elevated or lowered. The casings were connected to exhaust ducts under the travelling band. When these and some other measures were adopted it became impossible to detect benzene in the working room. It was also impossible to smell the odour of benzene. Furthermore, a rubber solution containing mostly special boiling point spirit (bensine) and only small quantities of aromatic hydrocarbons could be substituted for the benzene solution. Formerly it had been impossible to use SBP-spirit as a solvent for rubber although these solutions must be considered rather harmless compared with benzene solutions. The strong smell, however, impeded the use of SBP-spirit as a solvent for rubber. Only when increased exhaust ventilation was introduced, SBP-spirit could be used.

Before the last world war, German rotogravure printing ink was used in Swedish printing works. The printing ink was diluted with pure toluene. However, after the outbreak of war it was impossible to get toluene, and therefore it was necessary to choose another diluent. As it was still possible to obtain sufficient quantities of benzene, this solvent was chosen. In the printing works at this time nothing was known about the hazards connected with the use of benzene. As it became more and more difficult to get the German printing inks manufactured with toluene, printing inks containing benzene found also use.

After benzene had been used for some time in the printing works, a great number of people working with rotogravure printing got severe symptoms of poisoning. When the National Institute of Public Health became engaged in these problems, several serious cases of poisonings had already been reported. Amounts of 1 mg benzene per liter of air or more could often be found.

These observations were of course extremely alarming and immediate and drastic precautions were necessary. Fortunately it appeared possible to make immediate changes in order to reduce the amount of benzene in the rooms. Usually the rotogravure printing machines are connected with filters, filled with activated carbon for recovery of the solvents in the printing ink. The vapors coming from the printed web of paper were absorbed in the activated carbon. It was, of course, rather important from the economical point of view that the solvent vapors arrived to the filters as concentrated as possible. Very often, however, the printing rollers were not fully enclosed, and lids of the printing ink boxes were left open etc. Thus the velocity of the air in the suction openings of the evacuation system could not be sufficiently high to avoid leakages of solvent vapors into the working rooms. This was gradually changed and the printing machines were better enclosed, and strict instructions were given that all lids of printing ink boxes must be kept closed. For cleaning of printing rollers and filling of ink, gas masks must be used. Owing to these precautions and to increased exhaust ventilation the amount of benzene in the air was lowered to safe concentrations. Special signal systems were also arranged in order to control the ventilators. For the cleaning of impression rolls, of doctor blades (scrapers), floors and hands, the workers generally used benzene without suspecting the risks involved. The use of benzene was prohibited and other solvents such as white spirit were recommended.

The Institute considered it to be of the greatest importance to avoid benzene completely and to use another solvent as a substitute for benzene. Thus, on the recommendation of the Institute, xylene was used as diluent. In order to remove benzene from the premanufactured printing ink, it was necessary to distill it. However, it was possible for benzene to be introduced by mistake or through careless supervision in the system and therefore in a number of printing works samples of the recovered solvent were taken once a fortnight by the Institute for determination of the amount of benzene.

The following graph shows how the amount of benzene decreased in the recovery system. As a further precaution all the workers using benzene had to pass a medical examination regularly.

According to the Swedish regulations for poisons, benzene is a secondclass poison. This regulation prescribes that compositions containing benzene as an essential component must be labelled with the following text: »*Dangerous to consume. Poisonous vapors. Provide good ventilation. Keep vessels well closed. Observe prescribed protective measures!*« As several solvents fall under the same paragraph in this regulation, it was not evident, however, from this label whether the preparation contained benzene or not. This had therefore to be dicided by a thorough chemical analysis. By a new

regulation issued in 1949 it has been prescribed, however, that the label should indicate whether a preparation contained benzene. Nowadays most responsible manufacturers of paints, inks, thinners and similar compounds avoid benzene more and more as a component except for some special purposes. In certain cases, benzene has been found in the sole-cement for the manufacturing of leathershoes, and benzene poisonings could not be excluded as causes of some deaths in the shoe manufacture. For this reason, a law was enacted prohibiting the use of leather glue containing benzene in the manufacture of shoes. As a matter of fact it is not necessary from a technical point of view to use benzene in the manufacture of leather shoes.

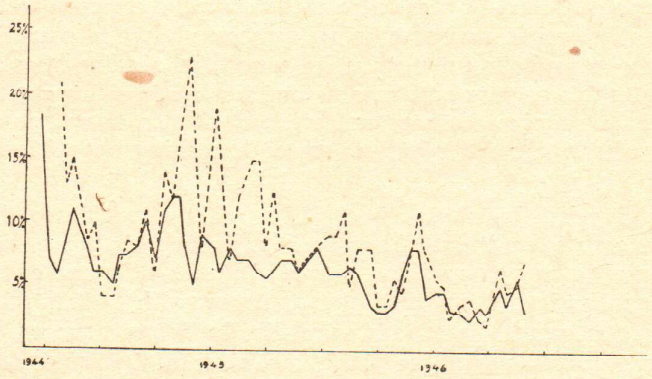

Fig. 1. The Content of Benzene in the Recoveries

There are two ways to prevent benzene poisoning: *by substituting less poisonous solvents such as toluene, xylene and SBP-spirit for benzene, and by arranging effective ventilation in the working rooms where benzene is used.* The first alternative is possible e. g. in printing works, where preferably toluene and SBP-spirit, but also xylene, can be used. That aromatic hydrocarbons must be used, has its reason in their greater dissolving power for certain compounds as e. g. rubber and dyes for printing ink. Recently, however, dyes for printing ink are manufactured which are considered to be soluble in exclusively aliphatic hydrocarbons. In rubber factories mixtures of aliphatic hydrocarbons and the higher aromatic hydrocarbons can be used as solvents for rubber. As solvent for grease and similar material, white spirit can be used instead of benzene. Dichloromethane can be used with advantage instead of benzene in paint removers when SBP-spirit, toluene and xylene are used as substitutes for benzene, it is of the greatest importance, that pure qualities, as free from benzene as possible, be used.

Rather often it is, however, neither possible nor desirable to substitute other solvents for benzene. In such cases all those special precautions must be taken which are necessary to protect the workers against poisoning. The best measures are then to use closed systems, and if this is not practicable, to enclose the machinery as much as possible and set up a local exhaust for the vapors at the points where they are formed. The exhausted air must be replaced by fresh air which must be preheated during the cold season of the year. If no particular ventilators are installed, the drying of articles treated with glues, paints, lacquers etc. containing benzene should be performed in special rooms, separated from working places. Vessels containing solutions of benzene should not be left open. If there is a risk for workers to be exposed to benzene vapors at special manufacturing processes, personal protective equipment must be used. An air-line respirator is then preferable as it is comfortable and has no breathing resistance. However, it requires compressed air, and if this is not possible to arrange, absorption filter gas masks or breathing apparatuses must be used.

The Swedish legislation has paid a great attention to the risks of benzene poisonings, and benzene is mentioned in the law on assurance against occupational diseases and in the regulations on poisons. Among others it is prescribed that employees must be examined medically before they are allowed to begin to work whenever there are risks of benzene poisoning. Furthermore, workers must be examined medically at least every two months if the work involves risks of benzene poisoning. Children under 18 are not allowed to work with benzene, if special permission is not given by the factory inspector. It is completely prohibited to use benzene in the manufacture of leather shoes. All preparations containing benzene must be provided with label indicating the content of benzene.

Finally it may be interesting to know, that the Swedish professor *C. G. Santesson* was one of the first to detect the poisonousness of benzene. In the year 1898 he published a report on »Coal tar benzene, the commercially sold impure benzene«, in which he pointed out that benzene is highly dangerous for health and may cause death.

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SADRŽAJ

OTROVANJE BENZOLOM U INDUSTRIJI I NJEGOVO SPREČAVANJE

Sa stajališta industrijske higijene mogu se industrije, gdje se upotrebljava benzol podijeliti u dvije glavne grupe: a) industrije, gdje se benzol upotrebljava ili proizvodi u velikim količinama (destilacija ugljena i katrana, ekstrakcija ulja, proizvodnja boja, lakova i t. d.) i b) industrije, gdje se benzol upotrebljava u manjim količinama kao otapalo (industrija gume, umjetne kože, kemijsko čišćenje, tiskare, i t. d.) i gdje se u toku procesa benzol uklanja isparivanjem, obično kod sobne temperature. Najveći broj otrovanja događa se u industrijama prve grupe. Otrovanja benzolom u Švedskoj opažena su u industriji gume, u tvornicama kišnih kabanica, u tiskarama, u tvornicama cipela, urarskim radionicama i u nekim laboratorijima.

Autori detaljno opisuju svoja opažanja o otrovanju benzolom u jednoj tvornici kišnih kabanica. Problem je bio riješen izgrađivanjem prikladnog ventilacijskog sistema i zamjenom benzola s manje otrovnim otapalima (SBP spirit).

Nadalje su opisana otrovanja benzolom u švedskim tiskarama. Do te je pojave došlo u vrijeme rata, kad je zbog nestašice toluola za razrjeđivanje tiskarske tinte upotrebljen benzol. I taj problem je bio uspješno riješen tehničkim dotjerivanjem uređaja u tiskarama poboljšanom ventilacijom i napokon zabranom upotrebe benzola. Kao zamjenu za benzol preporučio je Institut za javno zdravlje u Tomtebodi ksilol.

Švedsko zakonodavstvo je obratilo veliku pažnju sprečavanju otrovanja benzolom. Svi preparati, koji sadržavaju benzol moraju biti naročito označeni točnom naznakom sadržaja benzola.

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Odjel za higijenu rada,
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