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CHEMICALS IN ELECTRONIC MANUFACTURING: HEALTH AND SAFETY ASPECTS

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ABSTRACT

Most of the chemicals employed in the electronics manufacturing industry are provirg to be carcinogenic on exposure for a long period of tmie, a fact which is concretised by the legal claims made recently by a group of workers of a giant, electronic company in the US. state of California that people working in this company's dust free clean rooms according to the company's own records, developed /certain ypes of cancer and died younger than the rest of population in California[4]. This alarming information has brought to light this paper which deals with the awareness aspects of health hazards of most of these chemicals to people working in the electronics industries and also the threshold limiting values (TLVs) of these chemicals and their monitoring in order to minimise the health risks of people working in such industries.

INTRODUCTION

The elect}onics industry is proving to be one of the major industry after the petrochemical industries, capturing the market with innovative appliances, equipment and instrumentation and thus making it's presence felt in almost every other industry, offices, and even homes through computers, mobile phones, automobiles, automated machinery to mention a few.

MATERIALS AND ADDITIVES

The electronics manufacturing industry depends heavily on the chemical industry for the organic and inorganic chemicals used in the electronics in-

dustry, the latter being metallic and non-metallic in nature. The various types of materials and additives used in the electronics industry could be classified and described as follows.

Dopants

Dopants are metal compounds, which are used to make chips. These are usually injected as a gas or vapour into ovens which are heated to extreme temperature. When heated the metal of the dopant is deposited on the semiconductor wafer penetrating it's surface and giving it the ability to conduct electricity. Dopants are considered to be potentially the most hazardous and highly toxic group of chemicals used in electronics.

Fillers

Fillers are powders or tiny fibers added to resins to give bulk strength form and durability and hence they are used to make printed circuit boards and plastics. They are easily released as harmful dust *when* resin products are shaped, sawn or drilled causing serious lung problems and even cancer.

Metals and their compounds

Metals are good conductors of electricity and hence they are widely used in electronics. They occur as bulk solids, powders and liquid solution suspended in gas form and are emitted as fumes when heated and as dust when drilled, sawn or filed. Exposure to the more dangerous forms of metals (gases, dust and fumes) occurs more frequently during doping, soldering, plating, tining and other metal work.

Oxidisers

Oxidisers are highly reactive chemicals which can be used to clean or to render a metal surface free from corrosion. During oxidation oxygen combines with a metal or semiconductor surface to form a protective oxide layer. Some oxidizers have a strong corrosive action and hence eyes, skin and lungs are to be protected from exposure.

Resins

Most resins used in electronics are man made organic polymers. Most of these contain many poisonous ingredients such as solvents, dyes, stabilizers, fillers, plasticizers, catalyst and monomer residue.

Resins are widely used in making printed circuit boards, melding plastics, bonding, encapsulating, wire coating and packaging. Resins can produce highly toxic vapors and gases when heated or on burning. Uncured epoxy resins are very toxic and penetrate the skin and lungs rapidly.

Semiconductors

Semiconductors are the basic raw materials for makiiig electronic devices. They are treated with dopants and other chemicals to give them special electrical capabilities. These are made by chemical companies, which specialise in supplying chemicals to the electionics industry.

Table 1
Health hazards of chemicals employed in the electronic industry

Chemical name & type	TLV		Toxic effects on Reproduction					Carcinogenic effects		
	ppm	mgm^{-3}	Teratogen	Reduced fertility or sterility	Miscarriage or foetal death	Birth defects foetal damage	Cancer of reproductive organs	Human	Animals
1. DOPANTS									
Arsenic pentafluoride	-	0.5	-	-	-	-	-	Yes	S
Arsine	0.05	0.2	-	-	-	-	-	Yes	S
phosphine	-	-	-	Hs	-	-	-	S	S
phosphorus trichloride	0.5	3.0	-	-	-	-	-	S	S
arsenic	-	0.5	-	Hs	H	A	H	Yes	S
zinc chloride	-	-	-	-	-	-	-	S	S
cadmium oxide	-	0.05	-	-	-	-	-	Yes	Yes
2. FILLERS									
asbestos		5 µm in length , 8 hours TWA in 400 litre air sample						Yes	Yes
chromates	-	0.001	-	-	-	-	-	S	S
fiber glass	-	-	-	-	-	-	-	S	S
silica (quartz)		50 μ/m^3 TWA respirable free silica						S	S
titanium	-	-	-	-	-	-	-	S	S
3. METALS									
aluminium	-	-	-	-	-	-	-	S	S
antimony	-	0.5	-	A	HA	H	?	S	S
beryllium	-	0.002	-	-	-	-	-	S	Yes
lead	-	0.15	-	HAsi	H	H	?	S	Yes
manganese	-	0.3	-	Hsi	-	-	?	S	S
mercury	-	0.1	-	HAsi	HA	HA	-	Yes	Yes

Con-td.....

	-	0.1	-	HAsi	HA	HA	-	Yes	Yes
nickel	2	0.015	-	-	-	-	-	S	Yes
molybdenum trioxide	-	-	-	Hs	-	-	-	S	S
phosphorous	-	0.1	-	-	-	-	-	S	S
selenium	-	0.2	A	-	-	-	-	S	S
tellurium	-	0.1	A	-	-	-	-	S	S
4. OXIDISERS									
nitrous oxide	25	30	-	-	HA	HA	-	-	-
perchloro ethylene	-	-	-	-	-	-	-	S	S
silver nitrate	-	0.01	-	HAs	-	-	-	S	Yes
5. RESINS									
i) Epoxides									
diepoxybutane	-	-	-	-	-	-	-	S	Yes
epichlorohydrin	5	19	-	-	-	-	-	S	Yes
Triethylene glycol	-	-	-	-	-	-	-	Yes	Yes
ii) Curing agents									
aromatic amines	3	6	-	-	-	-	-	Yes	Yes
methylene dianiline	2	9	-	-	-	-	-	Yes	Yes
(iii) Monomers acrylonitrile	20	45	A	-	-	-	?	Yes	Yes
ethylene oxide	50	90	- A	-	-	-	-	S	S
vinyl chloride	-	-	H	H	H	HA	?	S	Yes
iv) Polymers									
trichloroethane	350	1900	A	-	-	A	-	-	-
polyurethane	-	-	-	-	-	-	-	S	Yes
(v) Resins ingredients /additives									
formaldehyde	2	3	-	-	-	-	-	S	Yes
ethyl acrylate	25	100	A	-	-	-	-	S	S
phenol	5	19	-	-	-	-	-	S	S
~~benezene~~	~~10~~	~~32~~	~~A~~	~~HSi~~	~~-~~	~~A~~	~~?~~	~~Yes~~	~~S~~

Con-td.....

toluene	100	375	A	-	-	A	-	-	-
Xylene	100	435	A	-	-	A	-	-	-
polychlorinated biphenyls	-	0.001	-	A	H	H	?	S	Yes
6. SEMI CONDUCTORS									
Cadmium sulphide	-	0.05	-	HAsi	H	H	H	Yes	Yes
7. SOLVENTS									
Carbon- disulphide	20	60	-	HAsi	HA	HA	-	-	-
carbon tetrachloride	10	65	-	A	-	A	?	-	-
methyl ethyl ketone	200	590	-	-	A	-	-	S	Yes
chloroform	25	120	-	-	A	-	-	S	Yes
Chlorobenezene	75	350	A	A	-	H	-	-	-
methylene chloride	100	360	-	-	-	H	-	-	-
ethylene dichloride	50	200	H	H	H	-	?	S	Yes
ethylene dibromide	0.13	1	-	HAs	HA	HA	-	S	Yes
tichloroethylene	100	535	-	HSi	H	HA	?	S	Yes
stryene	100	420	-	-	-	-	-	S	S
ethylene glycol	25	120	-	-	-	-	-	S	Yes
glycidil ethers	0.2	1	-	A	-	-	-	S	S
dimethyl formamide	10	30	A	-	-	-	-	-	-
8. RADIATION	-	-	-	HA	HA	HA	H	Yes	Yes

~~H = Evidence for Humans; A = Evidence for animals, HA = Evidence for humans and animals S = Reported to cause sterility in~~ men;

i = Associated with male impotence: TLV = Threshold limit value representative of weighted average concentration to which ai! workers are reportedly exposed day after day without any adverse effects for occupational exposures to toxic gases, vapour or dust; ? = Cancer of reproductive organs Yes = Sufficient proof of causing cancer; S = Suspected of causing cancer.

Solvents

Solvents arc organic in nature and are used in nearly every phase of electronics manufacturing primarily for cleaning, degreasing, and thinning plastics, resins, glues, inks paints, and waxes. Solvents range from mild lo highly toxic ones such as aromatic compounds and chlorinated hydrocarbons which are dangerous causing cancer and other diseases.

HEALTH HAZARDS

Although the work place in an electronics industry is apparently very clean and dust free, the awareness of the , health hazards associated with the chemicals used as materials and additives being employed at the work place and their threshold values (Table -1) are of prime importance to prevent health risk to the workers at the work place.

PATHWAYS OF CHEMICALS INTO THE BODY

Chemicals can enter the body by :
- inhalation through the lungs
- absorption through the skin
- ingestion through the mouth.

Once toxic chemicals get into one's body they cause a variety of harmful and toxic effects specially in the reproductive system and also lead to cancer. These effects may show up only after many years after the exposure has occured. These toxic chemicals can also produce local and systemic effects depending on the nature of the chemical and the route of exposure. A large number of chemicals are used in electronic manufacturing in gaseous form and workers are directly facing these emissions during work and hence besides being toxic to reproduction and carcinogenic most of them cause burns, irritation of skin, digestive tract and eyes besides irritating the entire respiratory system.

The consequences of toxic exposure to the respiratory tract and the lungs are as follows; the upper respiratory tract through the bronchial system is connected with an intricate network of honey combed like air filled spaces, the alveoli. Between the alveoli and the blood capillaries there is only a very thin membrane which is the site of gaseous exchange between the inhaled air and the blood for the two physiological gases: oxygen and carbon dioxide, but this is also the place for the uptake and release of toxic gases. Though the bronchial system takes no parts in the physiological gas exchange; every water-soluble compound can be dissolved in the watery layer of the mucus membrane.

However high water solubility offers a protection as the dissolved compound is more easily cleared from the lungs. Although the immediate irritative effect of the water soluble sulphur dioxide might be more pronounced than that of poorly water soluble nitrogen dioxide the later is more likely to produce pulmonary oedema.

Lungs oedema and respiratory irritation have a pronounced detrimental

effect on gas excnange. If the respiratory irritation is too strong the lumen cf the bronchial tree constricts and increases the resistance to the respiratory air flow. Irritative chemicals such as formaldehyde, nitrogen dioxide, sulphur dioxide are all able to increase the respiratory resistance and many are able to cause oedematous changes in the lungs. The bronchial tree has a mechanism which removes particles from lungs and hence any damage to it promotes sensitivity to infections or dust. These secondary effects along with the primary irritant effects can lead to irreversible structural changes in lungs manifested by a decrease in the surface suitable for gas exchange and this factor could eventually lead to cancer of the lungs.

PROTECTION FROM CHEMICAL EMMISSION

Adherence to healthy practices and adequate protective measures at the work place will go a long way not only to make the work place healthier to the workers working with toxic chemicals in the indoor environment but also lessen the burden of monitoring of chemical emissions on a regular basis. The protective measuresto be used at such work places is as follows :

(I) Use of local exhaust ventilation system

A local exhaust ventilation system should be set up at the work place such that it sucks the dust and fumes produced in very minute amounts a way from the breathing zone of the worker such that the worker is prevented from breathing in the same.

(II) Implementation of healthy and sound work practices

The workers have to be made aware of the nature of the chemicals used, the way they are to be handled and other relevant precautionary measures at the work place.

(III) Availability of personal protective equipment (PPE)

The type of PPE one needs to use depends on the chemical hazard; how the exposure can affect one's body and how long one is exposed to it. As far as possible the use of PPE is to be avoided due to inconvenience caused to the worker and instead the chemical hazard at the work place is to be controlled with engineering controls at the work place such as looking into use of adequate local exhaust ventilation required, area of work place and periodic monitoring of chemical pollutants at the work place.

(IV) Monitoring of chemical emissions

Work place air monitoring on a continuous basis becomes necessary to provide information on sources and intensities of pollutant emissions, pollutant levels in ambient air and correlation of pollutant levels based on TLVs of pollutants set by the Environmental Protection Agency such as NIOSH and OSHA. Monitoring of pollutants most of the time requires their sampling and analysis, which is very challenging to the chemist

For most analysis various types of sampling techniques are required For organic compounds emissions sampling, personnel organic vapour monitors

such as sorption tubes or badges having a certain weight of charcoal impregnated in a specific carbon matrix such as *a* strip of a sheet which absorbs the pollutant for a certain period of time at the work place can be use. The badge strip is subsequently tested for the adsorbed concentration of the pollutant by analysis on a gas chromatograph (GC) using a flame ionisation detector or GC combined with a mass spectrometer. (GC/MS) For inorganic elements or compounds sampling, electrochemical or chemical impregnated tape techniques can be used with subsequent analysis by using instruments such as infrared spectrometer and atomic absorption spectrometer.

CONCLUSION

There is no doubt that the electcomc industry is very crucial to the development of technology and at the same time for providing employment but ihe health of the people employed in the industry work piace should in no way be compromised for whatever possible reasons.

The paper hopes to be instrumental in creating this awareness specially to those associated with the electronic industry about all types of health hazards due to the chemicals emissions likely to be present at the work place, the monitoring of these emissions so as to limit them at least upto the threshold limit values and the protective measures to be taken to maintain the health of workers in this respect so as to increase their work efficiency and thus productivity in the electronic industry.

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