DRAFT : NOT FOR PUBLICATION

THE SAFE HANDLING AND DISPOSAL OF POLYCHLORINATED BIPHENYLS (PCBs).

INTRODUCTION AND SCOPE

This guidance is intended to provide information for the employers of persons who may come into contact with PCBs during the course of other work, such as removing or dismantling electrical equipment. It is aimed at specialist and experienced users including the fire service, electrical contractors and trained personnel of large companies. It contains information on the following aspects of work which may result in contact with PCBs:

- removal of transformers and capacitors
- draining of PCB-containing fluid from transformers and capacitors
- precautions necessary for safe cutting of PCB-containing equipment
- facilities required where PCB-containing equipment is dismantled, cut or handled.
- arrangements for local transport
- suitable protective clothing and respiratory protection
- standards of housekeeping
- methods of disposal.

The Guidance Note contains an outline of legislation, brief details of the environmental effects of PCBs, and the requirements for their safe disposal. Sources of further information are at the end of this booklet.

PROPERTIES

PCBs are a family of substances consisting of a biphenyl molecule which has 10 sites available for substitution by chlorine atoms. There are 209 possible isomers or congeners. The number and position of the chlorine substituents determine the classification and properties.

Commercial preparations usually contain a mixture of isomers and are categorised by the chlorine content. There are around 100 isomers which are used commercially.

PCBs are among the most stable organic compounds known. This stability gives rise to the environmental persistence and toxicological properties. The main uses of PCBs are linked to their chemical stability and resistance to fire. They have a low dielectric constant and high boiling point which makes them ideal for use as dielectric fluids in electrical capacitors and transformers. The volatility varies with the degree of chlorination. in general, isomers with a low chlorine content are free flowing liquids. At higher chlorine contents the material becomes more viscous and less volatile.

The solubility of PCBs in water is low and decreases with increasing chlorination. PCBs are soluble in organic solvents, especially chlorinated solvents.

The toxicity of PCBs appears to increase in relation to the degree of chlorination.

Under the Chemicals (Hazard Information and Packaging) Regulations 1993 (CHIP), PCBs are classified as *Harmful* and *Harmful to the environment.*

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EFFECTS ON ANIMALS AND THE ENVIRONMENT

PCBs are very persistent once released into the environment, due to their chemical stability. They are only very slowly degraded and in spite of the low volatility and low solubility in water they are now widely spread, albeit at low concentrations, throughout the environmental media of the planet. Normally this might not be a matter for concern but PCBs are bioaccumulative, which means that even at low concentrations they become incorporated into the food chain resulting in significant levels occurring in the body fats of predatory birds and sea mammals such as seals, otters and dolphins. PCBs have been variously linked with the inability of such animals to reproduce successfully, with birth defects in the young and as the cause of death due to effects on their immune systems. PCBs have been reported to cause damage to the liver of animals.

Although the levels in the environment do not affect man directly there have been several incidents were significant concentrations of PCBs have been released either through fires involving PCB equipment or contamination of products for human consumption.

EFFECTS ON HUMAN HEALTH

The main route of occupational exposure is by skin absorption as a result of direct contact. Inhalation is only likely to result in significant uptake when PCBs are subjected to high temperatures or if aerosols are generated during cutting or cleaning operations. PCBs can also be ingested.

PCBs can build up in the body because of their chemical nature, and remain there for long periods. They cause skin damage through a condition called chloracne, which is characterised by pustules, blackheads and straw coloured cysts.

None of the range of effects seen in animals have been observed in people working with PCBs.

OCCURRENCE, USE AND EXPOSURE

HISTORY

The synthesis of PCBs was first described in 1881 and commercial production began in 1929. Historically PCB usage was divided into two categories; open systems and closed systems.

Open systems describe applications in which the PCB was incorporated into a product and could be released into the environment either through use or disposal of the product. Open systems included plasticisers, carbonless copy paper, lubricants, paints and waxes.

Closed systems, by comparison, contained the PCB fluid within the equipment. In the mid 1970's environmental concerns led to the restriction of the use of PCBs to four closed systems only: transformers, capacitors, heat exchangers and hydraulic equipment. The use of PCBs in open systems was prohibited.

PCB manufacture in the UK and USA ceased in 1977 although it continued in parts of Europe for some years after.

In 1986 the use of PCBs in new plant and equipment and the sale of secondhand plant containing PCBs was prohibited. Existing plant installed before this date could continue in use until the end of its working life.

In 1991 the UK and all the countries bordering the North Sea agreed to phase out all remaining identifiable uses of PCB by 1999, and a UK Action Plan is being prepared to ensure the withdrawal and destruction of PCBs by 1999. The definition of PCBs for the purposes of the controlling regulations is any material containing 50ppm or more of PCB.

PRESENT POSITION

Occupational exposure to PCBs mainly occurs when old closed system equipment is tested, repaired or destroyed. Leaking or defective equipment may be first be reported to general electrical contractors. There have been incidents where electrical contractors have been contaminated with PCBs, and it is important that the PCB-containing equipment is identified promptly and specialist contractors called in if necessary.

Equipment for decommission now consists almost totally of transformers and capacitors.

Capacitors are hermetically sealed units ranging in size from those fitted to fluorescent lights, containing a few grammes of PCB to high voltage units containing up to 60kg of PCB liquid. Capacitors are maintenance free but may weep or leak at welds. There are estimated to be 400,000 low voltage capacitors, 20,000 high voltage capacitors and 10,000 furnace capacitors still in service. Capacitors contain the lower chlorinated and therefore more volatile congeners such as Aroclor 1016 and 1242. PCBs were gradually phased out of use in electrical products in the late 1970's and in the absence of further information equipment manufactured before 1980 should be assumed to contain PCBs.

Transformers are sealed containers with magnetic coiled windings and radiator manifolds immersed in an insulant fluid. There are estimated to be 1000 transformers containing PCB fluid still in service in the UK and at least another 1000 units containing retrofilled oils with a significant level of PCB contamination. The main difficulty with retrofilling is that it is virtually impossible to remove all traces of PCBs from the transformer, so that when it has been refilled with non-PCB dielectric, the PCB leaches out from the interior of the transformer and may reach levels of several thousand ppm in the replacement dielectric.

The dielectric fluid in large transformers is sampled in order to determine the degree of deterioration which may be caused by water ingress or operation at high load conditions. This may expose operators to a potential source of contamination with PCBs. Before sampling it is recommended that equipment should be isolated from all sources of electrical and mechanical energy by persons competent to do this.

PCBs may be encountered in other equipment still in use, including vacuum pumps, hydraulic equipment and process heating plant. With these items the oil charge may be consumed through leaks, during maintenance and losses during operation. Since PCB recharges have not been available for some 15 years it is unlikely that these represent a significant problem in total, but caution should be exercised particularly with plant that has been unused for a number of years. In the UK no PCB-containing hydraulic fluid was used underground so mining equipment should be PCB free unless it has been imported.

ENVIRONMENTAL LEGISLATION

Legislation to limit the use of PCBs has been in place since 1980. The use of PCBs is currently restricted through the Control of Pollution (Supply and Use of Injurious Substances) Regulations 1986 which defined PCBs at the 50ppm concentration level (as amended by the Environmental Protection(Controls on Injurious Substances) Regulations 1992). The use of PCBS is banned in all new plant and equipment and the sale of secondhand equipment is prohibited. plant installed before 1986 could continue in us to the end of its working life in specified exempt cases.

A draft European Directive on the disposal of PCBs is under discussion. The Directive is likely to include requirements for the listing, labelling and disposal of all forms of PCBs by 1999, and the tighter regulation of those involved in the disposal process. No further details are available at the time of writing.

The At the Third International Conference on the Protection of the North Sea the UK agreed, along with the other participating states, to phase out and destroy all identifiable PCBs by 1999. The Department of the Environment is preparing a UK Action Plan to meet this objective.

The main features of the Action Plan are likely to be:

- the progressive withdrawal of the existing exemptions from the ban on the sale and use of PCBs;

- the requirement to register PCBs with a company licensed to destroy PCBs, by 31 December 1995 and to agree a date for their destruction;

- a complete ban on supply, storage and use of PCBs from 31 December 1999.

Controls on the storage and handling of waste oils containing PCBs are governed by requirements laid down in the Waste Management Licensing Regulations 1994.

LEGISLATION CONTROLLING WORKPLACE EXPOSURE

The use of PCBs in work activities is subject to the Control of Substances Hazardous to Health (COSHH) Regulations 1988. The Health and Safety Commission's Advisory Committee on Toxic Substances (ACTS) recommended a Maximum Exposure Limit (MEL)of 0.1mgm^{-3} 8 hr TWA for all PCBs. It is likely that the MEL will be adopted in 1996, following public consultation. Until the MEL is adopted, the following guidance values are listed in EH 40:

CHLORINATED BIPHENYLS (42% chlorine): 1 mgm^{-3} (8 hr TWA) : 2 mgm^{-3} (10 mins)
CHLORINATED BIPHENYLS (54% chlorine):0.5 mgm^{-3} (8 hr TWA) : 1 mgm^{-3} (10 mins)

The MEL and guidance limits are only relevant to uptake by inhalation. This is not generally the major route of PCB uptake, except where PCBs are likely to form aerosols, as may occur during the dismantling, cleaning out and cutting of PCB-containing equipment.

The main route of occupational exposure to PCBs is via skin absorption following contact with liquid PCB. The COSHH assessment should consider the possibility of uptake through

the skin. Compliance with the MEL is thus only part of the control measures required under COSHH.

Suitable personal protective equipment (PPE) will be required if there is a possibility of contact with PCBs. The selection and use of PPE should comply with the Personal Protective Equipment at Work Regulations 1992.

IDENTIFICATION OF PCBS

Accurate identification of PCB fluids in capacitors and transformers is essential. In the case of capacitors there is often no indication at all and they may only be labelled as *'non-flammable oil'*.

a) ASKARELS

There is no absolute method of identifying a PCB type transformer. Points to look for include the transformer construction, manufacturers name plate and manufacturers identification plates. Most PCB-containing transformers were hermetically sealed. There are great variations between transformers from different manufacturers, but some common features included:

> Lids welded to the tank in later transformers;
> Drain and sample valves not usually fitted;
> Pressure relief valves often fitted, and usually looked like a large electric bell;
> Disconnecting link boxes often fitted so that cable testing was possible without requiring access to the transformer unit.

Composition of the fluid may have to be determined by sampling and analysis. PCBs are usually heavier than their replacement mineral oils. Typically the specific gravity of a PCB coolant is about 1.5 while that of a mineral oil is less than 1. Therefore if the weight and volume of cooling fluid is shown on the equipment's name plate, the specific gravity of the dielectric fluid can be calculated. If it is greater than 1 then it is possible that the equipment contains PCBs. In case of doubt advice can be obtained from specialist contractors.

PCB dielectric fluids were often a blend of PCB and Trichlorobenzene (TCB) which was added to reduce viscosity. These mixture are termed askarels. There were a large number of general or trade names and the list below gives some idea of the number.

ACECLOR, *APIROLIO*, AROCLOR, ASBESTOL, ASKAREL, AUXOL, *CHLOREXTOL*, CLOPHEN, *CLOPHENHARZ*, CLORESIL, DIACLOR, *DELOR*, *DELORENE*, DK, *DYKANOL*, *ELAOL*, ELECTROPHENYL, ELEMEX, *FENCLOR*, *FENOCLORO*, *GILOTHERM*, HYVOL, *INERTEEN*, *KANECHLOR*, KENNECHLOR, LEROMOLL, *NO-FLAMOL*, *OLEX-SF-D*, OROPHENE, *PHENOCLOR*, PRODELEC, *PYDRAUL*, *PYRALENE*, *PYRANOL*, *PYROCLOR*, SAF-T-KUHL, *SANTOSAFE*, *SANTOSOL*, *SANTOTHERM*, *SANTOVAC*, *SANTOWAX*, SOVOL, SOVTOL, TERPHENYCHLORE, *THERMINOL*, *TURBINOL*.
(Those in italics are trademarks.)

Santotherm is still used as a trade name but no longer contains PCBs.

In the case of fluorescent lights, the LIGHTING INDUSTRY FEDERATION or THE LIGHTING ASSOCIATION may be able to advise on suitable contractors.

b) PCB CONTAMINATED OILS

It is now appreciated that any transformer can potentially contain a level of PCB contamination even if the original fill was with mineral oil to BS 148. Cross contamination of PCB streams and mineral oil dielectrics is believed to have occurred at both the equipment manufacturing stage and during oil reconditioning for reuse. It is recommended that equipment which is not sealed for life should be sampled and tested for PCBs even if the original fill has been identified as non PCB. Hermetically sealed equipment should be tested prior to disposal.

CONTROL MEASURES

1) GENERAL CONSIDERATIONS

Before work is carried out on PCB-containing equipment the employer should carry out an assessment of the risks likely to be created by that work and decide on the control measures needed, as required by the Control of Substances Hazardous to Health Regulations 1988 (COSHH). The operations that give rise to PCB exposure need to be identified and the type of exposure determined, e.g.. skin contact, inhalation or ingestion of vapour or aerosol. Methods of work need to be planned to minimise the exposure and suitable PPE should be provided. Work on site should be restricted to that necessary to make the equipment safe for transportation. All dismantling should be carried out at specialist facilities.

PERSONAL PROTECTIVE EQUIPMENT.

The main danger from PCBs is skin absorption, thus careful consideration should be given to the choice of protective clothing including overalls, boots or overshoes, gloves and eye protection. PCBs will penetrate most materials, but certain materials including natural rubber are particularly permeable to PCBs and are thus unsuitable for use as protective garments. Viton is much more suitable and laminated materials offer the best protection against PCBs. No material is completely impervious to PCBs and so all PPE must be changed regularly to remain effective. The speed at which PCBs penetrate protective equipment is known as the breakthrough time. The manufacturer should provide details of the breakthrough time and whether there is a need to reduce this time to allow for the effects of factors such as abrasion. The breakthrough time should not be exceeded. Wellington boots, if not disposable, should be regularly discarded and the foot protection reinforced by the use of disposable overshoes to be worn either inside or outside the boot. All potentially contaminated protective equipment should be treated as PCB waste and incinerated.

For laboratory work, laboratory coats and suitable disposable gloves are required for protection against skin contact. If there is a danger of dust or fume formation (for example by heating) then the use of a fume cupboard is recommended.

RESPIRATORY PROTECTIVE EQUIPMENT

The COSHH assessment should enable the employer to decide if respiratory protective equipment (RPE) is needed. Particularly careful consideration should be given to areas of work where ventilation is poor, where work involves the lower chlorinated congeners, where there is a danger of aerosol formation or where work processes give rise to elevated

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temperatures. When selecting RPE it needs to be both suitable and to be approved by HSE or have a CE mark.

Manufacturers and suppliers of RPE will be able to give advice and should be consulted before a choice is made. Further information is also given in HS(G) 53 (Respiratory Protective Equipment: A Practical Guide to Users).

When RPE is used regularly in a dirty area there is a chance of facial skin contamination due to breakthrough through the material or, more likely, hand contamination from handling and use of the mask. Operators must be aware of this possibility, and instructed how to minimise the risk including cleaning and maintaining the equipment as part of a regular maintenance schedule.

Disposable respirators are being developed and information will be available from the manufacturers on availability and applicability.

HOUSEKEEPING AND MONITORING

Because of the possibility of skin absorption it is essential that a good standard of housekeeping is maintained in all areas and a regular decontamination programme implemented. Wipe sampling techniques may be used to check that the control regime is working and that PCB contamination does not spread to clean areas. Tests of likely contamination should include sampling floors outside dirty areas as well as door knobs and stair rails. The changing areas and clean areas should be checked regularly and remedial action taken at once if any samples show a significant increase. Monitoring levels of surface contamination may be unreliable to compare the cleanliness of different sites and should not be used for this purpose.

2) REQUIREMENTS FOR SPECIFIC TASKS

HANDLING OF PCB-CONTAINING CAPACITORS

Capacitors are best removed from the site of origin as whole units and placed in sealed metal containers to await transportation to a licensed storage site or directly to an incineration facility. Leaking units require specialised handling. All leaks should to be absorbed with sawdust, sand or earth and the units and the absorbing material, when used, should be stored in metal containers ready for disposal. As capacitors are likely to contain more volatile congeners, large spills or spills in confined spaces may require respiratory protection as well as skin protection to be worn.

HANDLING OF PCB-CONTAINING TRANSFORMERS

Transformers should be drained on site before transportation to the specialist facility. The PCB fluid needs to be transferred to secure metal drums for transportation. Absorbent material should be readily available to deal with any spillage. To reduce potential exposure to the fluid all manual operations such as decanting should be avoided. Mechanical pumping of fluids is the preferred option. Personal protective equipment is required during these procedures to prevent skin absorption and during draining there will be a need to prevent splashing and any spillage. Precautions should also be taken to prevent the spread of any leaks or overflow. Respiratory protective equipment will be required if ventilation is poor.

PROVISION OF FACILITIES FOR HANDLING AND DISMANTLING EQUIPMENT CONTAINING PCBS

The central facility should be divided into clean and dirty (work) areas. All clean and changing areas should have smooth impermeable surfaces. Transformers and capacitors should only be dismantled in the dirty area. The dirty area should be a discrete area,

preferably a separate room and should have a low retaining wall to contain spillage. For the access of transformers and capacitors into the dirty area a large enough opening should be provided and screened by plastic strips or other suitable means to reduce potential back contamination. Personal access should only be by way of a changing area. The facility itself should consist of the following:-
(a) An entry to the clean side.
(b) Shower/toilet area.
(c) Dirty side where PPE may be donned.
(d) An exit to the work area.
For midshift and other breaks there may have to be an area set aside for this purpose and this area would have restricted access. No one wearing contaminated PPE should be allowed in. In the shower/toilet area individual lockers would allow storage of clean clothing.

Capacitors need to be punctured and drained in a manner which minimises the production of aerosols or vapour. If this process is automated then it should be confirmed, by testing, that any aerosol or vapour is localised to areas around the process where there is unlikely to be any personnel. If this process is performed manually then local exhaust ventilation may be required in this area.

PRECAUTIONS NEEDED FOR CUTTING PCB-CONTAINING EQUIPMENT
When working on sealed transformers there is the potential to generate fume or aerosol when the equipment is cut open to allow access to the core. Operations generating heat should be avoided. Any sort of flame cutting or welding process will produce heat, either locally or generally and will result in increased volatilisation of any PCBs present. As examples, the vapour pressure of Arochlor 1260 increases ten-fold between 30°C and 60°C and that of Arochlor 1248 increases 100-fold between 0°C and 50°C. Although the increased vapour pressure is still very low it demonstrates the enormous difference a rise in temperature can make. Temperatures between 200°C and 450°C will produce slow formation of furans from the PCBs and if the temperature rises to between 450°C and 700°C there is a chance of furan and dioxin generation.

Mechanical cutting can also generate localised heat or aerosol formation. When possible, cold, cutting techniques should be used and cutting speeds reduced to as low as possible consistent with effective use.

PRECAUTIONS NEEDED FOR FLUSHING EQUIPMENT TO REMOVE PCBS
If the transformers are washed through with solvent before they are opened then exposure to these solvents must be considered as part of the COSHH assessment. Reduction of exposure may be accomplished by increased ventilation at the work station or by a system of work which reduces the need for operator presence when the flushing takes place. Personal protective equipment should be regarded as the last option when it is necessary.

Adequate ventilation will help to ensure that a hazardous level of PCB vapour or aerosol does not build up. For purpose built premises ventilation can be an integral part of the design. Ventilation, natural or mechanical, should ensure that the rate of air change is adequate and that the air is extracted to a air handling plant with suitable filtration. To prevent environmental contamination these filters may need to be two stage. A fabric or electrostatic filter will remove aerosol and an activated carbon filter will remove vapour. For non-purpose built premises or on temporary sites good general ventilation should be adequate as long as air is supplied at a higher level than it is extracted thus ensuring a down draught. PCB vapours and aerosols are likely to be heavier than air and more easily controlled by this method.

LOCAL TRANSPORT OF PCB-CONTAMINATED EQUIPMENT

Once the equipment has been cut up the components may need to be moved to where incineration or cleaning takes place. All solid articles should be protected so as to prevent or contain drips when it is moved out of dirty areas. This may mean rimmed trays are required to transport solid pieces of equipment to incineration. In any case measures to prevent contamination of flooring, soil or vegetation on site by transformer/capacitor carcasses are essential. If any metal components are to be decontaminated and sold on then it is recommended that the surfaces are checked for PCB levels to ensure that they are as low as is reasonably practicable and do not represent a hazard to whoever they are passed on to.

ASSESSING EXPOSURE

Assessment of exposure to PCBs can include measurement of airborne concentrations, surface contamination and biological monitoring.

Long and short term personal air sampling can be achieved using pumped sampling through a glass fibre filter and a NIOSH type florisil tube connected in series.[1] The filters and tubes are desorbed using hexane. Surface contamination can be sampled using swabs moistened with iso-octane. Biological monitoring is based on the analysis of PCBs in blood.

Samples can be analysed using gas chromatography with electron capture or mass spectrometric detection. HSE recommends the use of the method[2] due to be published in 1994 by the International Electrotechnical Commission Working Group on the analysis of PCBs in insulating oils. The analytical procedure is suitable for use in all matrices and uses gas chromatography with electron capture detection. The 209 PCB congeners are separated into about 100 peaks and each peak is quantified.

PCB DISPOSAL

The methods which are suitable for handling and disposal of PCB waste are discussed in the Department of the Environment Waste Management Paper no. 6. Destruction in high temperature hazardous waste incinerators which have an authorisation to treat PCBs is used for the disposal of capacitors and transformer dielectrics. Transformer casings can be decontaminated to allow recovery of the scrap metal or be incinerated. There are also a number of dechlorination processes which chemically destroy PCBs. these processes are particularly suitable for treating transformer oils which have become contaminated with PCBs. This process allows the oil to be reused.

REFERENCES

1. NIOSH Manual of Analytical Methods, 3rd edn, DHEW Publication No 84-100 (1984, revised 1987), Method 5503.

2. International Electrotechnical Commission, Determination of PCBs in Insulating Liquids. To be published in 1994.

DoE Waste Management paper No. 6. This paper is currently being revised. Publication is planned for 1994?

COSHH ACOP and HS(G) 97: 'A step by step guide to COSHH assessments'

HS(G) 52: 'RPE - A practical guide'.

'PCBs and You' leaflet

FURTHER INFORMATION

HSE and DoE contacts: addresses for HSE Books and HMSO
Other sources of information