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TECHNICAL BULLETIN ISSUE 63

Condition Monitoring Specialists

ELIMINATION OF POISONOUS PCB CONTAMINATION IN ELECTRICAL EQUIPMENT

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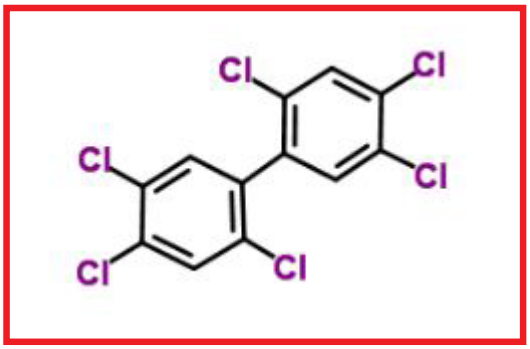
INTRODUCTION

PCB (polychlorinated biphenyl) is a highly toxic combination of molecules, which first came into existence in the late 1800s. The prevalence of PCBs mushroomed in the late 1920s as the technical benefits of the chemical compound were recognised and developed. Present day scientists, governments and businesses are tasked with eliminating PCBs as much as possible, due to their harmful, carcinogenic properties.

BACKGROUND

The PCB molecule consists of two phenyl molecules joined together with two or more hydrogen atoms replaced by chlorine atoms, which gives a total of 209 possible compound variations. The most commonly-recognised commercial brand names in most countries are Askarel and Arachlor.



Structure of a PCB molecule – Araclor 1260 ($C_{12}H_4Cl$)

The commercial use of PCBs, particularly as insulating fluid in oil-filled electrical transformers and switchgear, was largely based on their chemical stability, low flammability and their excellent electrical insulating and cooling properties.

PCBs are, however, highly dangerous to humans and animals, and exposure to PCBs can occur mainly through inhaling the vapours or touching any substance contaminated with PCB. Electrical equipment can also contaminate the soil and water supplies if leakage occurs. During catastrophic transformer failures, PCBs exposed to fire will give off extremely toxic vapours.

PCBs do not easily break down or degrade in nature, and accumulation occurs through the food chain. The types of PCB found in electrical equipment in South Africa are mainly: Aroclor 1242, Aroclor 1254 and Aroclor 1260.

Though PCBs were banned worldwide in the 1980s, they are still very prevalent in electrical

equipment and in the environment. This is mainly because of cross-contamination of transformer oil due to poor handling and disposal practices, negligence and sometimes, even, illegal dumping. Exposure to PCBs can cause PCB accumulating in the fatty tissue and liver of the humans and animals, which can ultimately lead to these diseases in humans:

- Cancer
- Some skin diseases
- Damage to reproductive, neurological and immune systems
- Fatigue
- Headaches
- Thyroid problems
- Increased risk for type 2 diabetes.

1. Elimination of PCB

One of the aims of the Stockholm Convention on Persistent Organic Pollutants of 2004 is to completely eliminate PCB in electrical equipment by 2025. More than 180 countries are signatory to this document, including South Africa. All industries in the member countries are legally required to conform to the conditions, restrictions and limitations as set out in this convention.

PCB content is strictly governed by guidelines and legislation in most countries. Any company that owns PCB-contaminated equipment is, by law, responsible for this PCB and remains responsible for it "from cradle to grave". It is essential that disposal of the PCB-contaminated oil is done by a reputable company, as the owner of the contaminated oil is still responsible for this PCB right up to and including its disposal.

2. Legal Aspects

References to PCB and the legislation of it can be found in South African law as follows:

- South African Constitution (1996)
  - 'All persons have the right to an environment that is not harmful to their health and well-being, and to an environment that is protected for the current and future generations.'
- Hazardous Substances Act (1973)
- National Environmental Management Act (1998)
- Occupational Health and Safety Act (1993)
- National Water Act (1998)
- National Traffic Act (1996)
- National Policy "Minimum Requirement for the Handling, Classification and Disposal of Hazardous Waste" (1998)

Management of PCBs in electrical equipment and insulating oils in South Africa is prescribed by the SANS 290:2007 standard. Other countries employ similar standards. The standard provides guidelines for handling, labelling and transporting PCB-containing material, treating leaks and spills, as well as storage and disposal of waste.

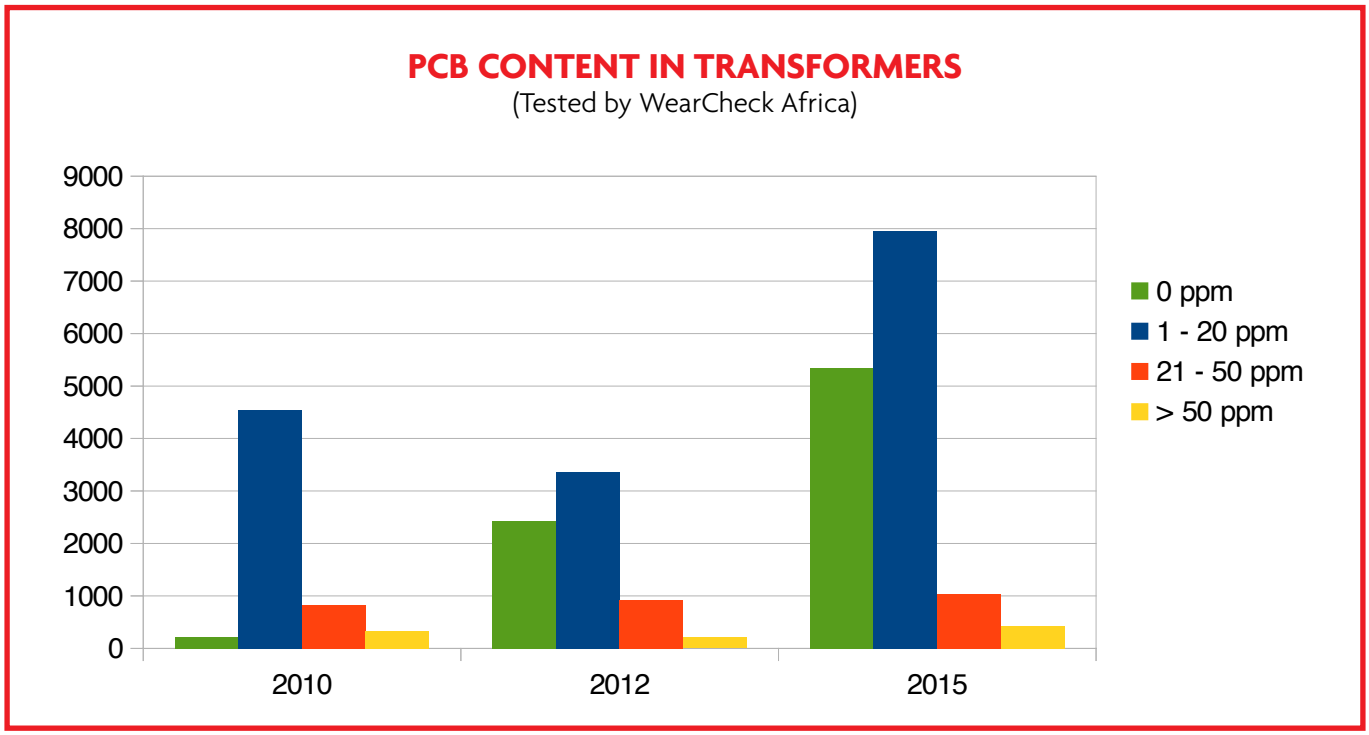
All electrical equipment containing insulating oil must be tested at least once to determine the PCB level and the equipment should then be labelled to indicate the PCB level classification. The current maximum allowed PCB level in oil is 50 ppm (parts per million or mg/kg). If the PCB level exceeds this limit, the oil must be drained and disposed of in an approved manner. Retesting will also be required after the addition of any recycled oil, or after any filtration or regeneration of the oil in a unit has taken place.

3. PCB Level Classification

PCB content levels, mg/kg	PCB level	PCB levels, common names
<1	0	PCB free materials
1 – 10	1	Non PCB materials
11 - 20	2	
21 - 50	3	
51 – 500	4	PCB contaminated materials
>500	5	PCB materials

The following graph is a representation of the PCB content measured in oil samples from electrical equipment over a six year period. Please note the increase in the transformers that contain zero ppm PCB and the proportional decrease of the PCB content in the higher ranges.

These figures are unfortunately only a reflection of the owners of electrical equipment who take PCB levels seriously. Worryingly, there are items of electrical equipment that have been tested by WearCheck in the past which contained 20,000 ppm and higher levels of PCB.



4. Contamination

PCB material is still wide-spread in electrical equipment the world over and contamination still occurs at present during the following procedures:

- Residual Contamination – when a contaminated transformer undergoes a complete oil change, PCB will remain impregnated in the insulating paper and other porous media. This contamination will then leach out into the new oil and result in a significant PCB level.
- Purification of electrical transformers – mobile purification plants generally contain around 400 litres of oil before and after work is done, and if filtration is carried out on a transformer which contains PCB, the contaminated oil will then be transferred via the rig to a transformer that contained less or no PCB. In 2010, a site in Pretoria was contaminated during this process, and the end result was that some transformers that contained less than 50 ppm PCB were contaminated and some of the smaller transformers ended with around 2000 ppm PCB.
- Changing oil in a transformer or topping up - regenerated oil sold in South Africa must have a PCB content of less than 20 ppm. The client should always buy oil from a reputable supplier and always check the batch certificate to ensure the following values are within limits:
  - PCB content
  - Moisture content and dielectric strength
  - Tan delta value
  - Absence of corrosive sulphur

5. Reduction and disposal of PCB material

PCB level in insulating oil can be lowered by chemical treatment or the oil may be disposed of by one of several destructive methods. It must be remembered that the insulating media as well as all structural parts of the electrical equipment will also be contaminated.

Many techniques have been developed to reduce or destroy PCB. The following methods remain most popular and widely available. (Please note that disposal must be carried out by a licensed facility and the equipment owner remains liable and responsible for the contaminated product during storage, transport and disposal. That also applies to clean-up and remediation after spills, leaks and accidents.)

1. Encapsulation & land-filling – material is placed in metal containers, then encapsulated in concrete before land-filling. Can be used for oil in drums and complete electrical equipment. The PCB is not reduced or destroyed.
2. Incineration – the most common method of disposal. A temperature exceeding 1350°C is required to prevent the formation of toxic by-products. Can be used to destroy oil and insulating material.
3. Thermal desorption and oxidation – this process is used to destroy oil containing more than 2000 ppm PCB. The process takes place in a kiln at a temperature of more than 1000°C and may also be used to treat contaminated soil.
4. Dehalogenation – also called dechlorination.

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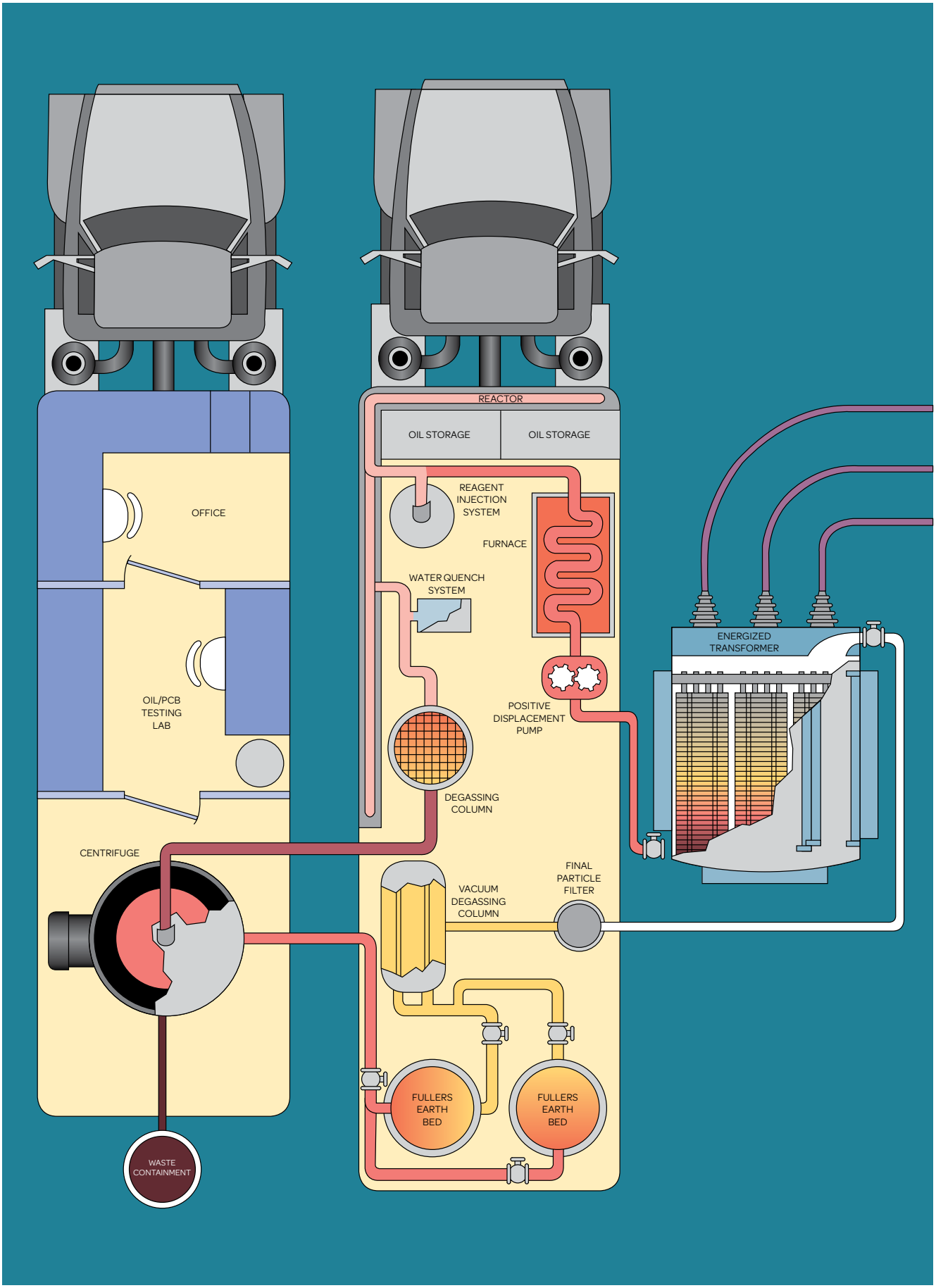
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FULLERS EARTH BED
WASTE CONTAINMENT

This is a process which can be used on oil with a PCB content of less than 2000 ppm. There are two processes, both remove the chlorine atoms from the PCB molecules. These processes do not destroy the oil, which makes them currently the most desirable way of eliminating PCB in oil. The oil would need to be sent to a dechlorination installation, to return the oil at 0 ppm PCB.

5. Bioremediation – these processes utilise micro-organisms to break down or detoxify organic compounds in soil and in certain aqueous media. The process is very slow.

The diagram on page five shows the process used by American Power Substation Services (PSS). The process is EPA-approved (U.S. Environmental Protection Agency):

SD Myers company in the U.S. is also offering the PCB Gone method, which uses a proprietary dechlorination reagent that provides for safe operation, and is non-destructive to the transformer oil's dielectric properties.

There is, however, a drawback to the dechlorination process. Dechlorination of PCB-contaminated oil depletes the uninhibited mineral oils of their natural inhibitors, thereby resulting in reduced oxidation stability and ultimately reduced life expectancies of transformers in which such oils are used and or reused. Research into the dechlorination of transformer oil is still far from complete and further investigation in this regard is needed.

Dechlorination is, however, by far the best option currently in the market, even if the oil's life span is reduced by this process. The health and environment benefits far outweigh the few small drawbacks of the dechlorination process.

6. Conclusion

While the world has recognised the long-term dangers of PCB contamination and a start has been made to implement legislation preventing the use of PCBs, as well as the development of several methods to reduce or eliminate PCB levels, there is still a very long road to travel before our environment is PCB-free – particularly with regards to compliance with legislation, and research into newer and more effective methods of PCB elimination.

For more information on testing PCB content in transformer oil, please contact WearCheck on (031) 700-5460 or email support@wearcheck.co.za or visit www.wearcheck.co.za

REFERENCES:

Environmentally Sound Management of PCBs – UNEP 2015
Stockholm Convention publication of 2004
SANS 290:2007 Mineral insulating oils – Management of polychlorinated biphenyls (PCBs). Currently under revision.

Copies of previous Technical Bulletins can be accessed on WearCheck's web site: www.wearcheck.co.za

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