PCB TREATMENT

12TH INTERNATIONAL HCH AND PESTICIDES FORUM

ESM of PCBs from Open Applications

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1 Introduction

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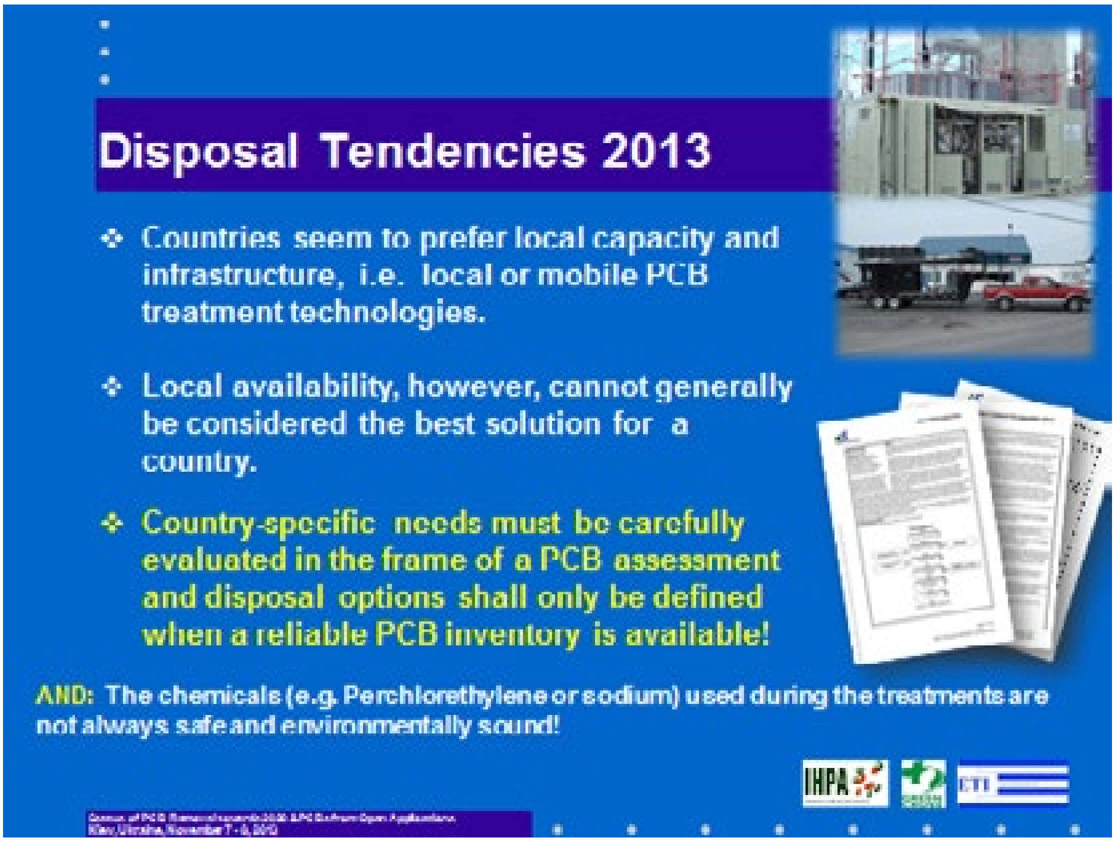
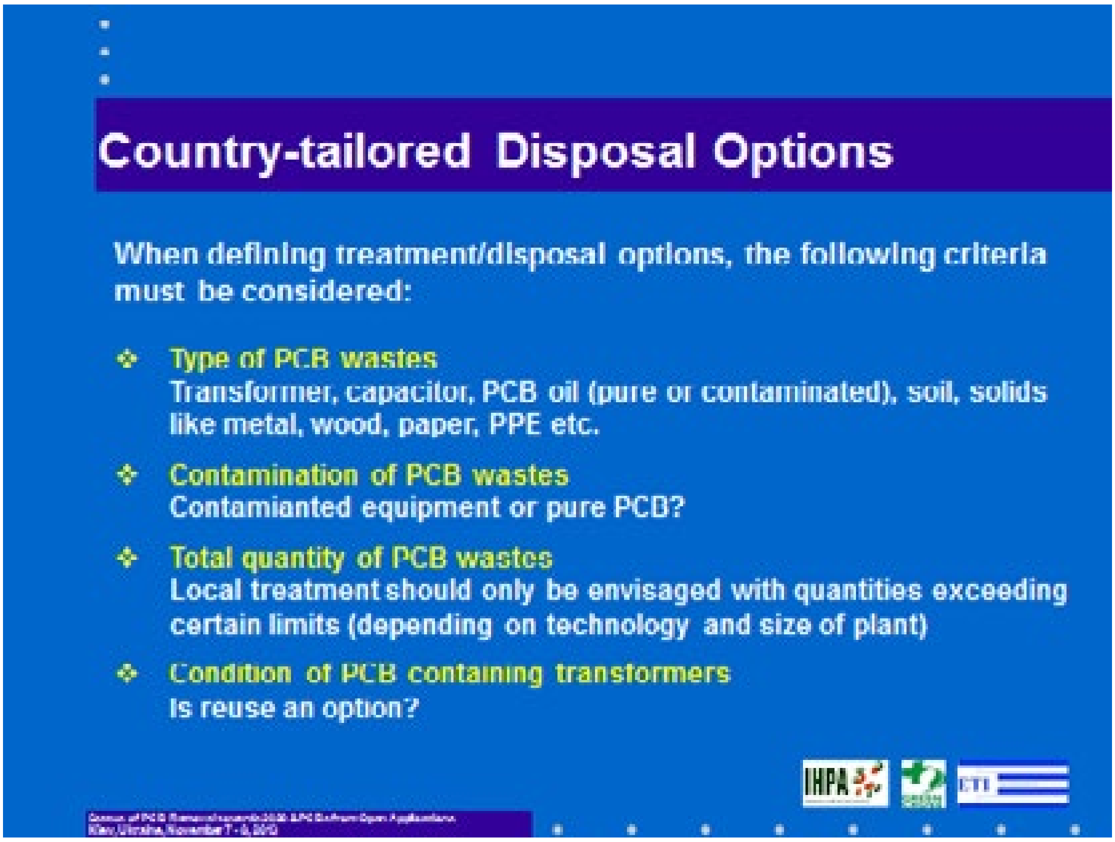
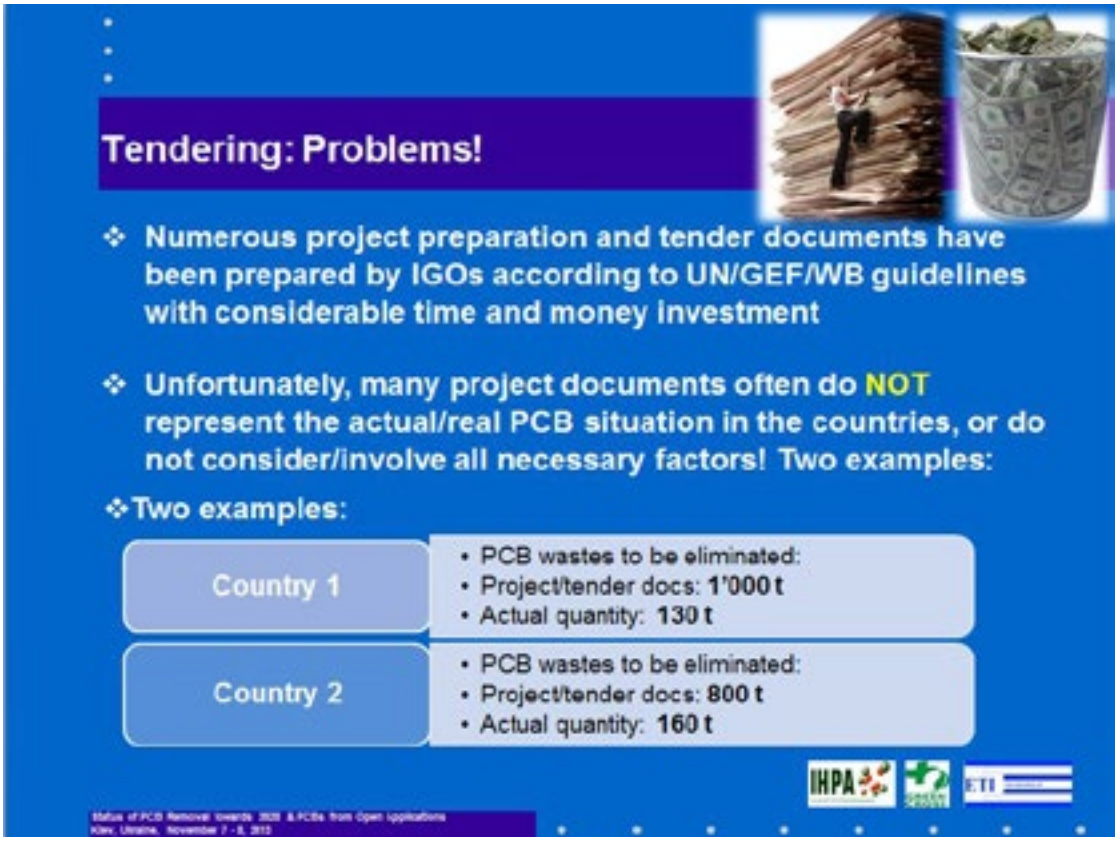
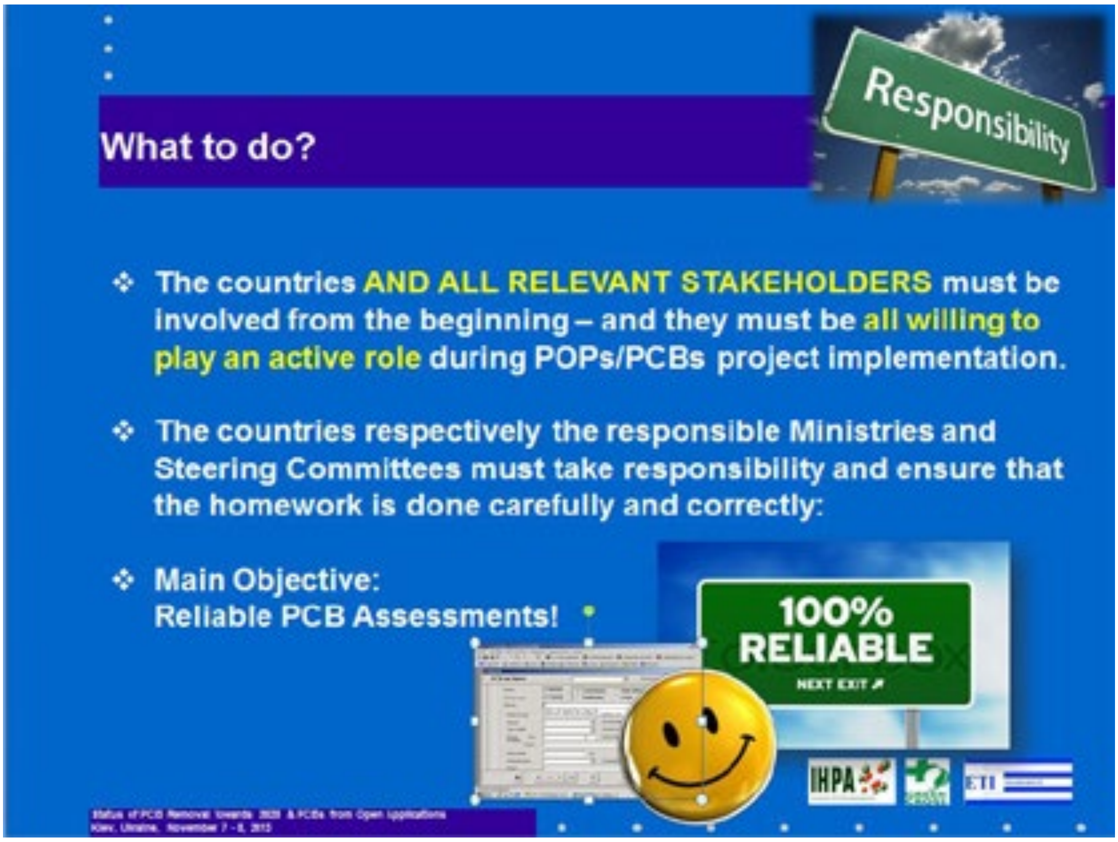
2 Summary: PCB Removal Towards 2013









The following chapters provide useful background information and describe proceedings in order to handle PCBs in an environmentally sound manner:

3 General Information and Hazard Potential of PCBs

3.1 POPs and PCBs

Persistent Organic Pollutants (POPs) have been identified by the international community for immediate international action by means of the Stockholm Convention. The pesticide DDT, highly toxic Dioxins and Furans (unintentionally formed by-products as a result of incomplete combustion or chemical reactions) as well as PCBs count among the POPs.

Polychlorinated Biphenyls (PCBs) are one of the leading members in the group of Persistent Organic Pollutants (POPs). PCBs have serious health and environmental effects, which can include carcinogenicity, reproductive impairment, immune system changes, and effects on wildlife causing a loss of biological diversity (Carpenter 2006, Hotchkiss et al. 2008, Wirgin et al. 2011).

PCBs were manufactured worldwide by a number of companies in many industrialised countries and were mostly used in closed applications such as cooling and isolating agents in transformers and capacitors, in heat transfer systems and hydraulic systems in particular in mining equipment. PCBs mixtures were, however, also widely used in open and partially open applications, for example in caulks/sealants, paints, anti-corrosion coatings, copy paper and as flame retardants.

The Stockholm Convention on Persistent Organic Pollutants (POPs) counts PCBs among the substances targeted for worldwide elimination. The challenge to implement its targets is two-fold:

The existing PCBs and all equipment contaminated with PCBs have to be eliminated in an environmentally sound manner without producing hazards for humans or the environment until 2025.

Most of the existing PCB-contaminated equipment is still in use in the developing countries. The financial burden for safe and environmentally sound replacement of the PCB contaminated equipment is very high, especially for developing countries. For this reason, alternative solutions are needed to keep the cost low. Transformers can be decontaminated and the equipment can be used until the end of its technical life-time.

The technology must comply with the highest safety and environmental standards and must be capable of reducing the PCB contamination level of those pieces of equipment suitable for re-classification below the legally permitted level of 50 ppm as well as assure that the PCB level remains below that limit.

From the technical point of view, the characteristics of PCBs were quite advantageous, thus they found a wide range of applications as mentioned above such as dielectric, cooling and hydraulic fluids as well as fluids for thermal transmission in transformers, capacitors, hydraulic machines, etc.

Only later it was realized that PCB chemicals have serious health and environmental effects.

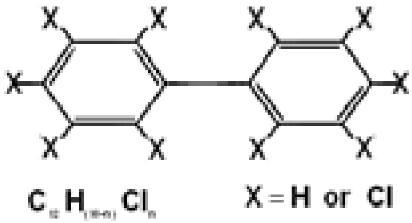
3.2 Definition and History of PCBs

Polychlorinated Biphenyls, commonly known as PCBs, are a group of chlorinated aromatic hydrocarbons characterized by the biphenyl structure (two phenyl rings $(C_6H_5)_2$) and at least one chlorine atom substituted for hydrogen. The chlorine atoms can be attached at any of the ten available sites.

PCBs are colourless liquids and a class of chlorinated organic compounds formed by the addition of chlorine to biphenyl, which is a dual ring structure comprising two carbon benzene rings linked by a single carbon bond. Depending on the number of chlorine atoms in their molecules their physical, chemical, and toxicological properties vary considerably.

A total of 209 PCB compounds with the same basic organic structure but with a varying number of chlorine substituents are possible, but only approximately 70 of these compounds have been found in commercial mixtures. PCBs are fire-resistant, have a low volatility, and are stable and persistent, making them well suited for industrial use but also problematic in the environment.

Picture 1: PCB Molecule



From the technical point of view, the characteristics of PCBs were quite advantageous.

Table 1: Characteristics of Polychlorinated Biphenyls (PCBs)

High heat stability	Only poorly soluble in water, but well-soluble in fat
Hardly inflammable (complete combustion only at > 1000 °C)	Good heat conductivity
Relatively good acid, alkali and chemical resistance	Low vapour pressure
Stable against oxidation and hydrolyse (in technical systems)	Very small electrical conductivity (good insulator)

As mentioned above, there are theoretically 209 different PCB congeners, although only about 70 of these have been found in technical mixtures. Approximately 10 of these congeners are of importance today. The 6 lead congeners are the numbers 28, 52, 101, 138, 153 and 180; and in some countries also 118. The PCB congener 118 is dioxin-like and very likely to be carcinogenic. It therefore needs special attention when for example sampling and analysing indoor air.

Polychlorinated Biphenyls were synthesised for the first time in 1866 by Schmidt and Schultz, but commercial production started in 1929 by the American company Swan Chemical under the trade name AROCLOR. The company recommended the use of PCBs as a material for protective layers, water resistance, fire protection, glues, and electric insulation. There were times when it was even envisaged to use PCBs as an additive in chewing gums.

Depending on the number of chlorine atoms in the molecule, PCBs have different physical, chemical and toxic characteristics. Polychlorinated Biphenyls are colourless liquids with strong odour. They are stable on higher temperatures. PCBs can only be combusted under extreme and carefully controlled conditions. The current regulations require that PCBs are burnt at a temperature of 1200°C for at least two seconds. PCBs are poorly soluble in water and have low volatility stability on acids and alkaline, oxidation and other chemical reactions. They are semi-degradable; their half-life time depends on the chlorination level and ranges between 10 and 15 years. They are highly soluble in lipids, hydrocarbons and organic compounds.

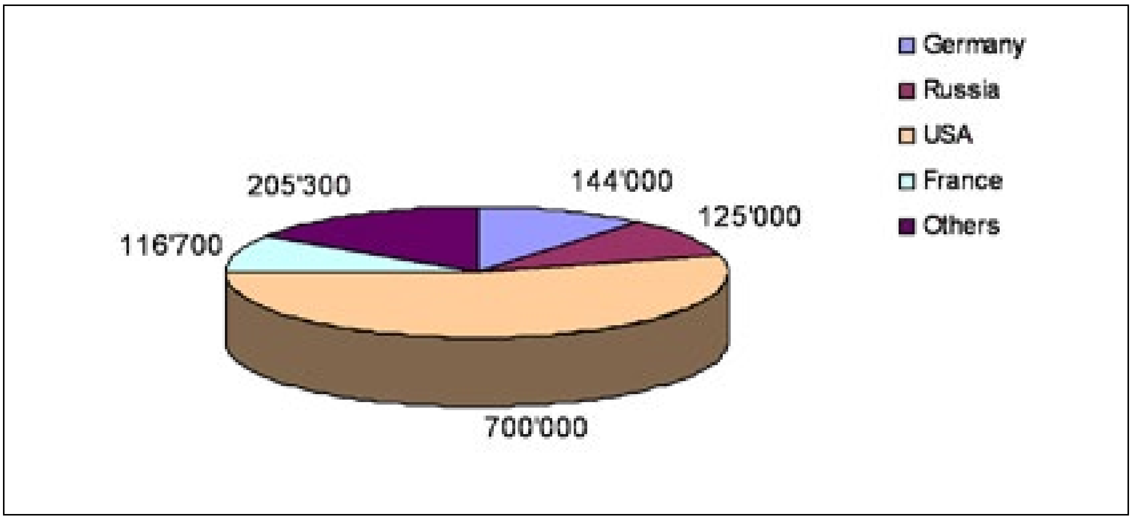
As a result, PCBs may bio-accumulate in fatty tissues of humans and other living organisms. The bioaccumulation shows up to 70’000 times higher concentrations in species at the top of the food chain.

Long-term exposure to even small concentrations can have adverse effects on human health, especially on the unborn child (Brouwer et al. 1999, Schantz et al. 2003).

In the process of the global distillation (evaporation and deposition) PCBs can be transported over long distances to regions where they have never been used or produced before. For example, traces of PCBs can be in the Arctic. This process of evaporation, movement with the air streams, condensation and deposition on the ground is well known as the «grasshopper effect».

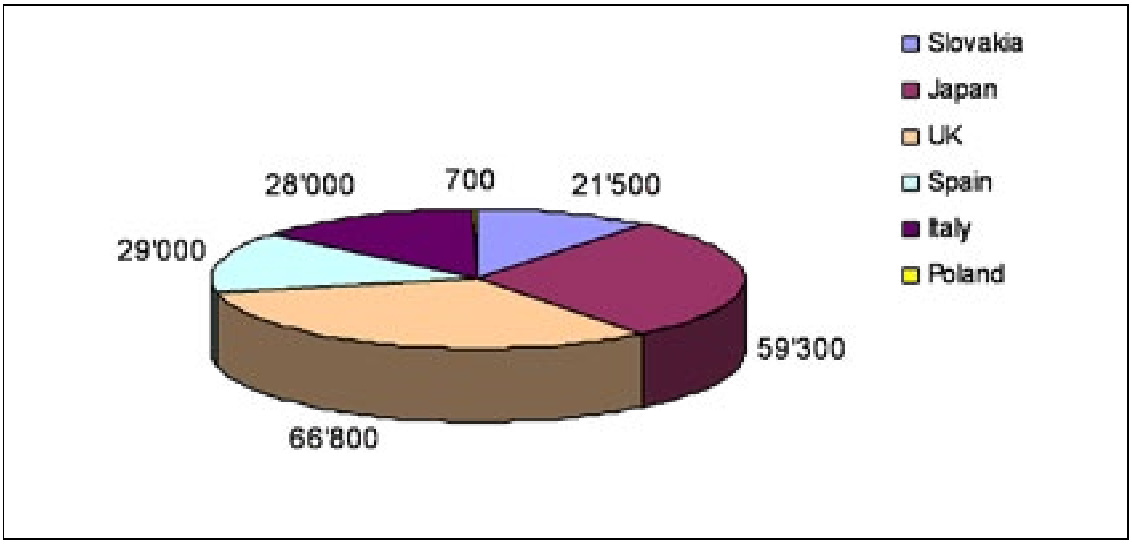
After the 2nd World War PCB production started in Europe and in the late 1960s maximum production was reached with over 60'000 tonnes produced per year. After 1983 production of PCBs was stopped in most countries, except for some Eastern European countries. The Russian Federation, for example, only stopped production between 1987 and 1993 (AMAP, Oslo, 2000). There are rumours, that PCBs are still produced in North Korea.

Chart 1: Total World Production of PCBs in tonnes I



The total world production of PCBs between 1929 and 1989 was approximately 1.5 million tonnes. After the US had banned the production and sale of PCBs in 1976, except for closed systems, it continued at a rate of 16’000 tonnes per year from 1980 to 1984 and approximately 10’000 tonnes per year from 1984 to 1989.

Chart 2: Total World Production of PCBs in tonnes II



The largest quantities of PCBs were produced in the USA, in Germany, Russia and France. Approximately 200’000 tonnes of the total world production originated from other countries like Slovakia, Japan, the UK, Spain, Italy and Poland.

The following table shows some of the brand names used for the various applications of PCBs.

Table 2: Extract of Brand Names for PCBs

Abestol (t, c)	DP 3, 4, 5, 6.5	Phenoclor (t, c) (France)
Abuntol (USA)	Ducanol	Phenoclor DP6 (France)
Aceclor (t) (France, Belgium)	Duconal (Great Britain)	Phyralene (France)
Acooclor (Belgium)	Duconol ©	Physalen
Adkarel	Dykanol (t, c) (USA)	Plastivar (Great Britain)
ALC	Dyknol (USA)	Polychlorinated biphenyl
Apirolio (t, c)	E(d)ucaral (USA)	Polychlorobiphenyl
Areclor (t)	EEC-18	Pryoclar (Great Britain)
Aroclor (t, c) (USA)	EEC-IS (USA)	Pydraul (USA)
Aroclor 1016 (t, c)	Elaol (Germany)	Pydraul 1 (USA)
Aroclor 1221 (t, c)	Electrophenyl (France)	Pydraul 11Y (USA)
Aroclor 1232 (t, c)	Electrophenyl T-60	Pyralene (t, c) (France)
Aroclor 1242 (t, c)	Elemex (t, c) (USA)	Pyralene 1460, 1500, 1501 (F)
Aroclor 1254 (t, c)	Elexem (USA)	Pyralene 3010, 3011 (France)
Aroclor 1260 (t, c)	Eucarel (USA)	Pyralene T1, T2, T3 (France)
Aroclor 1262 (t, c)	Fenchlor 42, 54, 70 (t, c) (Italy)	Pyramol (USA)
Aroclor 1268 (t, c)	Hexol (Russian Federation)	Pyranol (t, c) (USA)
Arubren	Hivar ©	Pyrochlor
Asbestol (t, c)	Hydol (t, c)	Pyroclar (Great Britain)
ASK	Hydrol	Pyroclor (t) (USA)
Askarel (t, c) (USA)	Hyvol	Pyromal (USA)
Auxol (USA)	Hywol (Italy/USA)	Pyronal (Great Britain)
Bakola	Inclar (Italy)	Pysanol
Bakola 131 (t, c)	Inclor (Italy)	Saf(e)-T-Kuhl (t, c) (USA)
Bakolo (6) (USA)	Inerteen 300, 400, 600 (t, c)	Safe T America
Biclor ©	Kanechlor (KC) (t, c) (Japan)	Saft-Kuhl
Chlorextol (t)	Kanechor	Sanlogol
Chlorinated Diphenyl	Kaneclor (t,c)	Sant(h)osafe (Japan)
Chlorinol (USA)	Kaneclor 400	Sant(h)othera (Japan)
Chlorintol (USA)	Kaneclor 500	Sant(h)othern FR (Japan)
Chlorobiphenyl	Keneclor	Santosol
Chloroecxtol (USA)	Kennechlor	Santoterm
Chorextol	Leromoli	Santotherm (Nippon)
Clophen (t, c) (Germany)	Leromoll	Santotherm FR
Clophen Apirorlio	Leronoll	Santovac
Clophen-A30	Magvar	Santovac 1
Clophen-A50	Man(e)c(h)lor (KC) 200,600	Santovac 2
Clophen-A60	Manechlor (Nippon)	Santovec (USA)
Cloresil	MCS 1489	Santowax
Clorinol	Niren	Santvacki (USA)
Clorphen (t)	NoFlamol	Saut(h)otherm (Japan)
DBBT	No-Flamol (t, c) (USA)	Siclonyl ©
Delorene	Non-flammable liquid	Solvol (t, c) (Russian Federation)
Delor (Czech Republic)	PCB	Sorol (Russian Federation)
DI 3,4,5,6,5	Pheneclor	Sovol (Russian Federation)
Diachlor (t,c)	Phenochlor	Sovtol (Russian Federation)
Diaclor (t, c)	Phenoclar DP6 (Germany)	Terpenylchlore (France)
Diaconal	Disconon ©	Therainol FR (HT) (USA)
Dialor ©	Dk (t, c) (decachlorodiphenyl)	Therminol (USA und FR)
Diconal	Ugilec 141, 121, 21	Therpanylchlore (France)

3.3 PCB Production in the Former USSR

PCB production in Russia was terminated between 1987 and 1993. There is no calculation of the total amount of PCB production and use in the former USSR available. PCB was produced at two sites. The largest facility was the «Orgsteklo» Ltd. Production Amalgamation (located in Dzerzhinsk in Nizhni Novgorod Oblast, approximately 300 km east of Moscow); and the second was the «Orgsintez» Ltd. Production Amalgamation (at Novomoskovsk in Tula Oblast, ca. 200 km south of Moscow). PCB was produced under three brand names:

Table 3: Trade names of PCBs produced in the former USSR

➢ Sovol	A mixture of tetra- and pentachlorinated PCBs (used as a plasticiser in paints and varnishes)
➢ Sovtol	Sovol mixed with 1,2,4 trichlorobenzene; especially in the ratio 9:1, named Sovtol-10 (used in transformers)
➢ Trichlorbiphenyl (TCB)	Mixed isomers of polychlorbiphenyls, the main percentage is trichlorbiphenyl (only used in capacitors)

Minor production of special mixtures took place during the early days of PCB production.

Table 4: Trade names of special mixtures

➢ Nitrosovol'	Mixture of Sovol and nitronaphtalene
➢ Mixture of PCB with Paraffin and Cenerezin	This mixture was used to impregnate paper capacitors
➢ Hexol	Mixture of pentachlorobiphenyl with hexachlorobutadiene

Sovol and Sovtol production at the «Orgsteklo» (Dzerzhinsk) facility began in 1939. The TCB production in 1968. Sovtol-10 production was shut-down in 1987, TCB and Sovol in 1990.

At the «Orgsintez» (Novomoskovsk) facility, Sovol and Sovtol production was launched in 1971, and full-size operation started in 1972. «Orgzintez» Ltd. stopped production of Sovtol in 1990 and production of Sovol in 1993. There was no production of TCB at «Orgsintez».

Retrospective analysis of production figures showed that during the period from 1939 to 1993, the factories produced a total of about 180'000 tons of the three main PCB brands.

Between 1990 and 1993, production of PCB at these facilities ceased entirely. According to available information, the only exporter of PCB (Sovtol-10) was Orgsintez Ltd. In Novomoskovsk, which during the period 1981-1989 exported 39.5 tons to certain countries (Cuba, Vietnam, Pakistan).

Import figures are not available. One estimate sets a maximum import of 4,000 tonnes TCB annually for 1980-1983, but this number is based only on a decrease in production capacity at the Orgsteklo plant and not a documented industrial demand for TCB.

<u>Sovol</u>

The plasticiser Sovol was used in a number of industries, especially paint and varnish production as well as in the manufacture of various lubricants. No application in the production of hydraulic oil was identified.

The use of approx. 53'000 tons from the total production of Sovol was estimated as it is shown in Table 5 on page 9.

Table 5: Uses of Sovol

➢ 37’000 tons	Used in the production of varnish and paint
➢ 10’000 tons	Used in the production of lubricants
➢ Approx. 5’500 tons	Used in defence-related industry plants and other industrial enterprises not otherwise included in the inventory

According to estimates, the remaining 127’000 tons of PCB were used as follows:

Table 6: Uses of Sovol

➢ Approx. 57’000 tons of Sovtol-10	Used as a dielectric fluid in transformers
➢ Approx. 70’000 tons of TCB	Used as a dielectric fluid in capacitors

TCB

TCB was used exclusively for capacitor production. Four enterprises produced capacitors in the former USSR. The amounts used, relative to the total TCB produced at «Orgsteklo» (70’000 tons), were approximately:

Table 7: Use of TCB

➢ 38 % in Ust-Kamenogorsk, Kazakhstan
➢ 43 % in two factories in Kamairi (Leninakan), Armenia
➢ 19 % in Serpukhov, Russia

Of the total produced 70’000 tons TCB, 40’000 tons were used for production of industrial capacitors. The remaining 30’000 tons were used for production of non-industrial capacitors (e. g for household appliances), which were produced only in Armenia. The non-industrial capacitors have not been traced.

According to data received from capacitor production enterprises, approx. 60% (24’000 tons) of TCB used for capacitors were delivered to Russian Companies. Of these 24’000 tons, it is estimated that some 14’000 tons of TCB are in industrial capacitors still in Russia today, whereas 10’000 tons have already been released into the environment by improper disposal.

Capacitors

An average amount of PCB in capacitors was estimated from questionnaire responses where this information was provided. These capacitors had an average TCB content of 17.2 kg.

3.4 Applications and Remobilisation

Due to their characteristics PCB mixtures (either pure or together with other substances) have been used in open and closed systems.

Table 8: Extract of Applications in «Closed Systems»

➢	Insulation and/or cooling fluid in transformers
➢	Dielectric fluid in capacitors
➢	Hydraulic fluid in lifting equipment, trucks and high pressure pumps (mining industry especially)

Picture 2: Closed Systems, Transformer

Picture 3: Closed Systems, Capacitors

PCBs were also used in «open applications» such as in paints, in the car industry, sealants in the construction industry, etc.

Table 9: Extract of Applications in «Partially Open applications»

➢	Heat transfer fluids
➢	Hydraulic fluid
➢	Vacuum pumps
➢	Switches
➢	Voltage regulators
➢	Liquid filled electrical cables
➢	Liquid filled circuit beakers

Picture 4: Partially Open applications, Vacuum Pump

Picture 5: Partially Open applications, Liquid Filled Cables

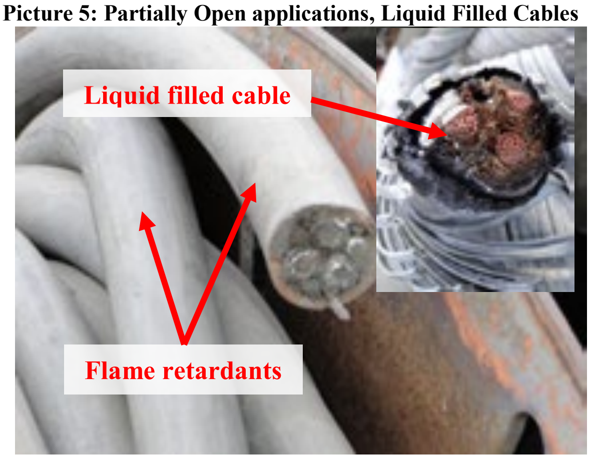


Table 10: Extract of Applications in «Open applications»

➢	Caulks/sealants in buildings
➢	Paints and plaster
➢	Anti-corrosion coatings (indoors and outdoors)
➢	Surface coatings (e.g. floors)
➢	Cables and cable sheaths
➢	Lubricating fluid in oils and grease, cutting oils
➢	Flame retardants and impregnating agents
➢	Adhesives
➢	Carbonless copy paper
➢	Pesticide extenders
➢	Inks

As these materials are not usually defined as hazardous waste at the time of disposal, PCBs often find their way into the environment.

Picture 6: Open applications, e.g. Sealants

Picture 7: Open applications, e.g. Corrosive Protection

3.4.1 The Problem of PCBs in Open Applications

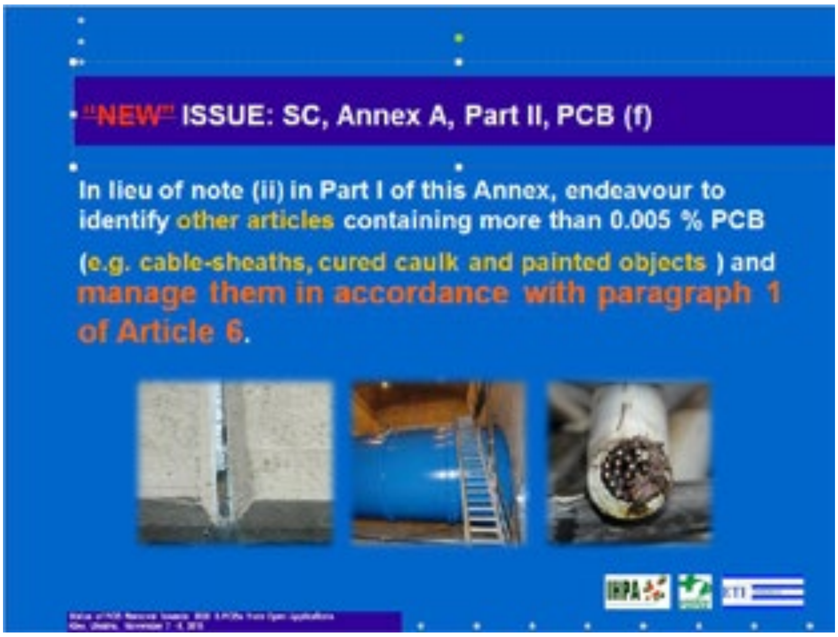
The Stockholm Convention requires in Annex A, Part II (f) that efforts should be made to identify other articles containing more than 0.005 % PCBs (e.g. cable-sheaths, cured caulk and painted objects) and manage them in accordance with paragraph 1 of Article 6.

Apart from Annex A, Part II (f) of the Stockholm Convention, the handling, remediation, removal and disposal of open applications of PCBs are not regulated by any international guideline yet.

Whereas the Stockholm Convention and the PCB Elimination Network (PEN) still focus on closed systems in developing countries and countries in transition, some European countries and the US have been tackling the more complex problem of open applications of PCBs for several years.

To this day, awareness of closed applications of PCBs (capacitors and transformers) is still low in some countries – and awareness of open applications is generally non-existent.

In the past, it was generally believed that expensive products like PCB containing caulks and coatings had not been imported to developing countries because they were rather expensive. Today we know that PCBs have been respectively are still in use worldwide due to development aid projects, and imports of products which were once considered harmless.



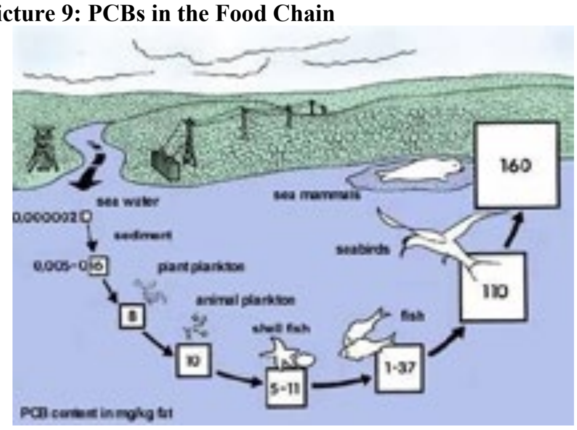
Be aware of hidden sources of PCBs
The largest single hidden PCB source resulting in improper disposal is transformer bushings. The dielectrics in bushings have no fluid connections with the dielectrics in the transformers to which they are attached so analysis of the transformer dielectric will not reveal anything about PCBs in the bushing. "Pot heads," cable termination apparatus that connect transformers to incoming power sources, can be filled with a tar-like material that can contain very high concentration PCBs. Any tar-like or asphalt-like material used as an insulator or dielectric should be suspected of containing PCBs. Small motors often require starting capacitors that can contain PCBs. Voltage regulators and substation transformers can contain load tap changers operated by small motors that contain PCB starting capacitors. Small motor capacitors can leak, contaminating the dielectric fluid. Asphalt material in fluorescent light ballasts, along with lubricants and caulks, are other potential sources. Air compressors have been serviced with PCB containing lubricants. Oil-filled switches, circuit breakers, and enclosures should also be suspect.

Although the release of PCBs into the environment has taken place in very limited areas, global atmospheric and ocean currents have dispersed the substance throughout the whole planet. PCBs can be found in air, water, soil, plants, animals, and humans.

Due to its chemical and bio-chemical stability and its high solubility in fatty tissue, the substance has entered the food chain as a bio-accumulator. As a result, animals at the top of the food chain i.e. predators or humans often show a far higher contamination than plants or water.

Picture 8: PCB Pollution in Glaciers

Picture 9: PCBs in the Food Chain



3.5 PCB in the Mining Industry

In many countries the mining industry regardless of underground mines or open pits is an industrial sector which needs special attendance a regarding PCB.

Abandonment of Polychlorinated Biphenyl (PCB)-containing electrical equipment in surface or underground mines can result in PCB contamination of ground and surface waters which can contribute to local human health hazards and to the already existing PCB contamination of the ocean which is considered to be the final sink for PCBs. PCBs used as dielectrics in transformers, capacitors, and fluorescent light ballasts are common throughout industry worldwide.

PCBs are not the only chemicals used in mines. Underground repair facilities have used chlorinated solvents such as trichloroethane, tetrachloroethene, and methylene chloride for cleaning and degreasing equipment. The release of these solvents, in addition to constituting their own threats of ground water contamination, can mobilize PCBs. Some mines maintain their own landfills which contain improperly disposed PCBs and solvents.

Underground and surface mines and the attendant crushing, milling, and smelting facilities may use PCB-containing electrical equipment. PCBs transformers are usually grouped in substations underground. PCB capacitors are in similar locations. PCB capacitors can be in electric locomotives. In coal mines, PCB capacitors can be in wheel or skid-mounted power centre.
The extent and complexity of underground mines present opportunities for abandonment or illegal disposal of hazardous wastes. The presence of hazardous wastes may not be evident until they are found in the local ground water. Abandoned underground electrical equipment may remain intact and not release PCBs for a very long time. Testing waters issuing from abandoned mines may not indicate whether or not PCBs are present in intact electrical equipment.

In the mining sector, PCBs are most likely to be found in such electrical devices and applications:

Transformers	➢ Grouped in permanent substations ➢ Located singly ➢ Mounted on mine cars that can be transported throughout the mine
Capacitors	➢ Grouped in permanent substations ➢ Located singly ➢ Mounted on mine cars ➢ In electric locomotives ➢ In wheel or skid-mounted power centres
Small Capacitors	➢ Fluorescent light ballasts
Used PCB oils	➢ Drums of used transformer oil / lead cables
Hydraulic oils	➢ Trucks ➢ Cables, Lines

Lot of the closed and open applications are still in use in the mining industries.

Picture 10: Electrical Devices in Mining Locomotives

Picture 11: PCB Ballasts in Fluorescent Lamps

3.6 Impact of PCBs on the Human Health and the Environment

PCBs have a long and documented history of adverse effects in wildlife. They have been associated with poor reproductive success and impaired immune function. An example of this can be seen with captive harbour seals in the Arctic. A major flood in the Saginaw River basin in Michigan in 1986 allowed PCB contaminants to spread through the ecosystem and the following year's hatch rate of Caspian terns in the area dropped by more than 70 per cent. Hatching chicks showed developmental deformities, and none survived more than five days [WFPHA, 2000]. In Switzerland, the otter became extinct because of PCB induced infertility.

How do PCBs get into the human body?
PCBs are mainly taken in via the stomach-intestine tract. In Switzerland, the average PCB intake through the mouth (food and drink) is 3-4 µg per day and person. The tolerable daily intake (TDI) established by the WHO (World Health Organization) for humans is 30-60 µg PCBs, i.e. even a lifelong intake of 30-60 µg PCBs should not cause any damage (based on a person's weight of 60 kg). Furthermore PCBs are absorbed through the skin and the lungs.
Human exposure to PCBs may occur through ingestion of contaminated food and/or water, inhalation of PCB vapors in the air and through direct dermal contact. After absorption, PCBs circulate in the blood throughout the body and are deposited in fatty tissues and a variety of organs, including liver, kidneys, lungs, adrenal glands, brain, heart and skin.

Are PCBs acutely toxic?
Generally immediate risks posed by PCBs are very rare. PCBs are not acutely toxic, i.e. high quantities have to be taken in until immediate effects can be noticed. However PCBs bio accumulate in the human body and are only excreted to a very small extent even over many years. Therefore extensive safety measures must always be taken when handling PCBs.

What are the hidden (latent) risks of PCBs?
It is difficult to estimate the long-term effect of a chronic PCB contamination in small doses. Influences on the thyroid hormones and possible effects on the development of the brain are discussed. Large doses of PCBs in the human body can cause damage to liver, kidneys, and brain. In addition PCBs are thought to influence the reproductive system and cause deformations to unborn children

Are PCBs carcinogenic?
Carcinogenic effects of PCBs on rodents have been proven, however have not yet been confirmed in humans. Based on this research PCBs are generally categorised as carcinogenic (World Federation of Public Health Associations, May 2000).

What are the symptoms of an acute poisoning?
Foodstuffs were contaminated with Kanechlor 400 (a PCB mixture with approx. 48 % chlorine content) during an incident in Yusho/Japan in 1968. The following symptoms were noticed: Swollen lids, chloroacne, skin pigmentations, sight defects, numbness in arms and legs, weakness and tiredness. Later also blindness, hepatitis, diarrhoea, changes in the menstrual cycle, headaches and hair loss could be observed.

Why are fires particularly dangerous?
People are particularly at risk if PCBs are exposed to heat and/or fires. Dioxins and Furans (Polychlorinated Dibenzodioxins, PCDD, and Polychlorinated Dibenzofurans, PCDF) are unintentionally formed and released from thermal processes involving PCBs as a result of incomplete combustion or chemical reactions. These substances are highly toxic, even in very small doses (also known as Seveso poison).

As a result of manufacturing processes, even some applications of PCBs can be slightly contaminated with PCDF (Furans). This applies to cooling fluids in capacitors and PCB containing paints.

Picture 12: Typical Chloracne

Picture 13: Symptom Hair Loss

Another result of the incident was a higher percentage of miscarriages or deformations. The absorption through the skin and the respiring of PCB vapours and contaminated dust particles do not cause such immediate symptoms in general. They are however the main cause of possible long-term damage.

Much of the information on acute toxicity of PCBs comes from serious food contamination incidents in Yusho, Japan, Yusheng (Taiwan) and Belgium. As PCBs are highly lipid soluble, they bio accumulate as they progress up the food chain. As a result, high levels of PCBs exposure can occur through ingestion of game animals or fish and ingestion of breast milk from mothers who draw a daily diet from game meat and fish. This risk is present among people who live near hazardous waste sites and consume game meat and fish that they catch by themselves. Some of the human health effects are associated with PCB exposures, like:

- immunotoxicity - immunosuppression, increased sensitivity towards infectious diseases, increased incidences of ear and upper respiratory tract infections, lower rate of successful immunization;
- reproductive/developmental effects – failure to conceive, decreased birth weight, impairment of neurological development;
- neurological/behavioural effects – impaired learning ability, attention and cognitive deficits, deficiencies in psychomotor development, learning and memory deficits, impaired visual recognition, and
- cancer – postulated that PCBs may be associated with liver, gastrointestinal and skin cancer

Three distinct types of human exposure to POPs and PCBs can be documented:

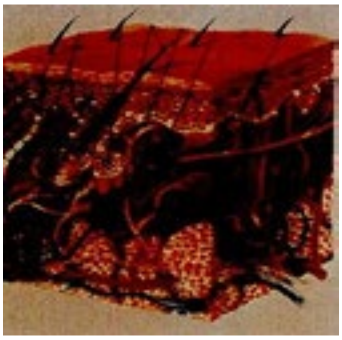
- **High-dose acute** exposure can result from accidental fires or explosions involving electrical capacitors or other PCB-containing equipment, or highly contaminated food. This can cause chloracne (a painful, disfiguring skin illness), liver damage, nausea, dizziness, eye irritation, and bronchitis.
- **Mid-level chronic** exposure is predominantly due to the occupational exposure and in some cases due to the proximity of environmental storage sites or high consumption of a POPs contaminated dietary source, such as fish or other marine animals.
- **Chronic, low-dose** exposure is characteristic for the general population world-wide as a consequence of the existing global background levels of POPs with variations due to diet, geography, and level of industrial pollution. Low level and population-wide effects are more difficult to study. People are exposed to multiple POPs during their lifetime and most people today carry detectable levels of a number of POPs in their body [WFPHA, 2000].

4 Safety

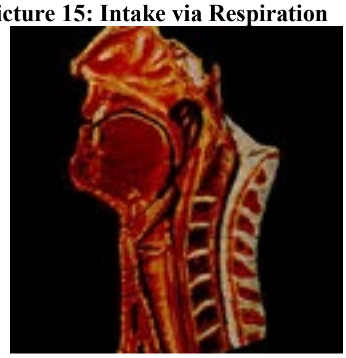
4.1 Exposure to PCBs

There are three possibilities for PCBs to get into the human body: Through stomach and intestine, through the skin and through respiration.

Picture 14: Intake via Skin



Picture 15: Intake via Respiration



Picture 16: Intake via Stomach/Intestine

4.2 Stomach and Intestine Picture

As explained earlier, a very small amount of PCBs is absorbed by the stomach and the intestine from the food we eat. When working with PCB containing equipment and PCB contaminated materials, it is vital to obey the following rules to prevent an increased intake of PCBs:

Foodstuff shall not be stored or consumed near PCB containing equipment or PCB contaminated materials. After handling PCBs containing equipment or PCB contaminated materials, hands shall always be washed with warm water and soap.

4.3 Skin

The biggest risk for people handling PCBs lies in the exposition of the skin, because it absorbs the substance very quickly. It is therefore important to avoid direct contact to PCBs by skin.

To protect skin from direct contact with PCBs, the appropriate Personal Protective Equipment (PPE) must always be worn.

4.4 Respiration

PCBs are not very volatile, therefore the danger of absorbing PCB when facing small amounts of PCB can be neglected, as long as the ventilation is sufficient. If there is a spill of a bigger size, then a respiratory mask with a filter for organic vapours and dusts should be worn.
PCBs adhere to dust though, so when the situation implies that dust (e. g. from drilling in concrete) could be contaminated with PCBs, a respiratory mask with a filter for organic vapours and dusts must be worn.

Protection with respiratory masks with a filter for organic vapours and dusts is a must when facing major spills or activities with contaminated dust involved.

Table 11: Basic Emergency Guidelines

Hazard potential of PCBs - The PCB decomposition products in fires («Dioxins») are regarded as a major hazard - PCBs are only very slightly volatile and the greatest danger is therefore that of absorption of the substance through the body surface (e.g. as a result of splashes, leakage) - PCBs adhere to dust so that this substance can enter the respiratory organs via dust particles - Since PCB accumulates in the human body and is excreted only to a very small extent, extensive safety measures should always be taken when handling PCB (protective clothing, etc.)
Basic personal protection for works with liquid PCBs - Suitable respiratory protective device - Safety goggles or eye protection in combination with respiratory protective device - Plastic or Neoprene gloves, Tyvek or other protective clothing, boots - Eyewash bottle with clean water
Immediate action during transport - Notify specialists and police or fire brigade - Move vehicle away from rivers and lakes to open ground and stop the engine - No smoking, no naked lights - Mark roads and warn other road user - Keep public away from danger area - Keep upwind
Spillage - Put on protective equipment before entering danger area - Stop leaks if possible (e.g. with SEDIMIT) - Contain or absorb leaking liquid with suitable material (absorbents or sand or earth) - Prevent substance entering sewers and work pits - Advise an expert and police
Fire - Keep equipment and/or container(s) cool by spraying with water if exposed to fire - Extinguish secondary fire, extinguish with foam or dry chemical - In case of fire, warn everybody, «Toxic hazard» - Advise an expert and fire brigade
First aid - Remove contaminated clothing immediately and wash affected skin with soap and water - If substance came into the eyes, wash out with plenty of water, require medical assistance - Person who have inhaled the gas or fumes produced in a fire or who have come into contact with the substance may not show immediate symptoms. They should be taken to a doctor with the Transport Emergency Card. Patient must be kept under medical supervision for at least 24 hours.

5 Sampling and Screening

5.1 General Sampling Procedures

Before leaving for a site inspection, it must be ensured that all relevant parties at the site have been informed, and that all sampling and safety equipment is ready. Before starting the sampling on site, the general safety rules as well as the specific precautions when working with electrical devices shall always be communicated during a specific briefing and/or personal instruction. Work may only be carried out in the presence of a local electrician.

Picture 17: Ensure having all sampling/safety material

Picture 18: Consider all Safety Precautions (Power!!!)

The main source of error in an inventory process is the sampling.

Therefore the following points must be particularly considered:

Risk of Cross Contamination
Contamination is easily spread from one sample to another. When using one-way material (e.g. Kleenex, pipettes, metal scoops, etc.) it must be ensured that a new product is used for every new sample. If this is not possible, the used equipment must always be cleaned before another sample is taken. If possible solvents (e.g. technical acetone) should be used for this purpose.

No Confusion of Samples
In order to prevent a confusion of samples, it is crucial to clearly mark the sample containers immediately when a sample has been taken. The identical data must also be recorded in a sampling report. A label must be affixed to the sampling containers.

Picture 19: Taking all records of sampled electr. devices

Picture 20: Labelling BEFORE Sampling

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Sampling Report

The sampling report must be filled in immediately. If it is completed at a later stage important information could be lost or forgotten. Take your time go gather all necessary information and perform a brief risk assessment (condition of device, any leakages, water or agriculture nearby etc.).

5.1.1 Sampling of Transformers

Safety Precautions

In order to prevent the skin from coming into contact with PCBs, one-way protective gloves must be worn. The eyes must be protected against possible oil splashes by wearing goggles.

Position of Sampling

The sample can be taken by using the drain tap, which usually is at the bottom of the transformer. If a transformer has been disconnected from power for over 72 hours the sample should generally be taken from the bottom, as PCB sinks to the lower level because of its higher density. Sometimes the gasket gets damaged when the drain tap is opened. It is therefore advisable to always have a spare gasket ready.

Alternatively transformers can be sampled via the oil filling cap by using a hand pump (consider: a new hand pump must be used for each transformer). Oil samples from the expansion receptacle cannot always be regarded as representative, because the oil does not circulate and thus it is not really mixed.

Usually, transformers are sampled when they are in use and thus when they are live. Corresponding protective measures and safety regulations must be known and considered at any time!

Extend of the Screening/Analysis

If a PCB inventory demands an analysis of the cooling fluid, the owner has the possibility to test the oil quality at the same time. This is dependent on the age and condition of the equipment. Such a preventive maintenance allows an assessment of the technical condition of the transformer and thus helps prevent possible damages/failures resulting from e.g. acidity or increased dampness.

Oil quality analyses must only be run after a negative PCB result; otherwise the laboratory equipment will be contaminated with PCB.

The following steps must be followed when sampling a transformer:

- Place a drip tray under the drain tap,
- Drain off the required amount of oil into the sampling bottle – quantity depending on the intended analysis, and
- Carefully retighten the seal.
- Then affix a label both on the sampling bottle and on the transformer with the same serial number as can be found on the eco-card. The eco card contains the following information:
  - Site (Substation)
  - Manufacturer of Transformer
  - Power (KVA) or (MVA)
  - Serial number
  - Year of manufacture
  - Date of sampling
  - Name of person in charge.

Remark: Sampling is also an opportunity to collect information for the database.

Picture 21: Place Drip Tray under Drain Tap

Picture 22: Open Drain Tap/Valve

Picture 23: Sampling

Picture 24: Control of labels and closed glass vial

If the **oil quality** shall also be tested, the following steps have to be considered:

- Sampling via drain tap: Drain off 1 to 2 litres of oil first in order to clean the drain from particles which might have accumulated in that area,
- Amount of oil required: 0.5 to 1 litres,
- Leave the oil for 24 hours, in order to allow particles and water to settle,
- Take sample from the upper third of the oil for the analysis using a pipette, and
- Return the drained 1 to 2 litres of oil back into the transformer (only if the oil filling cap is out of reach of the high voltage, otherwise shut off the transformer before refilling the drained oil)

All wastes must be disposed of in an environmentally sound manner – the disposal method always depends on the analysis result.

IMPORTANT: Experience has shown that numerous transformers that were sold as PCB free equipment actually **do** contain PCB. In the 70s transformer manufacturers and oil suppliers often were not informed about the risks and the potential of cross contamination of PCB by using identical cisterns, transport containers, pipe systems and fittings for mineral oil and PCBs. Therefore many new transformers were unintentionally contaminated by PCBs. Some transformers were also contaminated by the user during refills or maintenance work.

5.1.2 Sampling of Cooling Fluids

Sample Containers (glass vials)

If only the PCB content of the oil is analysed, 20 ml glass vials can be used provided analysis is performed on site. If the analysis is performed elsewhere and the samples have to be transported over long distances, 30 ml glass bottles should be used as sample containers because they are more robust. If a holder of a transformer also wants to have the quality of the oil tested, a 500 ml glass bottle should be used.

Often transformers have already been phased out, temporarily stored and drained at the time a PCB inventory is compiled. In such cases, it needs to be decided on site, how the sampling shall be performed. But even if a device has been drained, there should be still be some oil present in the passive part of the transformer due to the leaching in the days and week after the draining. Usually there is not enough oil to sample it via the drain tap, as the oil layer is deeper then the valve. In such cases, the device needs to be sampled through an opening in the top. Stiff tubes (e.g. glass or PE) can be used to take a sample of the oil at the bottom of the transformer.

If there is no oil at all left in the device, solid materials from the active part of the transformer could to be sampled and analysed (wood or insulation paper). However, such analysis can only be performed in a laboratory.

Due to practical reasons it might be advisable to label such drained transformers as PCB-suspected and note it accordingly in the physical site inspection report (respectively inventory questionnaire) and leave it for future investigations.

Picture 25: Sampling of oil drums (different layers)

Picture 26: Affix labels while sampling and later final one

5.1.3 Sampling/Evaluation of Capacitors

Power capacitors are built into hermetically closed containers and there is no direct access to the cooling liquid.

In many cases, the manufacturer provided information about the type of dielectric liquid, either with identification on the nameplate or with a separate tag confirming that the contents are harmful for the environment. Such capacitors do not need further investigation. They definitely contain PCBs and must be treated accordingly.

Picture 27: Identification of Capacitor Fluid

Picture 28: Tag Information on Capacitor

If a designation is missing and relevant information from the manufacturer is not available, the only way to test the dielectric liquid is to drill a hole in the casing on the top or cut the isolator and retrieve an oil sample. This can be done by (e.g.) using a pipette (using only once).

After this exercise the capacitor is unusable and as it is now damaged it must be stored in appropriate containers (e.g. in an UN-approved steel drum). Therefore it is advisable to only sample capacitors that are already out of service. If there is a series of the same capacitors, it is usually sufficient to sample only two devices out of the series.

Thus only phased out capacitors can undergo this procedure. Capacitors still in service and manufactured before 1993, with missing information about the dielectric liquid have to be labelled as PCB suspected equipment.

However, it was also said that there are no reliable information available by when the PCB production has been stopped in Countries like e.g. China and North Korea. There are rumors that in North Korea PCB are still produced nowadays.

Preferably a mixed sample originating from the two capacitors with the lowest serial numbers should be analysed. Caution should be taken if the analysis reveals PCB, even if it is only a slight contamination. Such contamination could have been caused during the production e.g. when using the same pumps for mineral oil and PCB oil. In such cases all capacitors of one series must be analytically tested.

Personal Protective Equipment (PPE)
The PPE for these activities consist of protective gloves and goggles. Respiratory protection is not necessary when taking single samples. If several samplings are carried out at short intervals light respiratory protection is recommended.

Sampling of Small Sized Capacitors
Usually capacitors of a smaller size do not contain PCB as a floating liquid in the casing, but rather as an impregnating agent of the insulation layers in the capacitor. It is therefore not possible to drill a hole in the casing and take an oil sample with a pipette.

Prepare the working place with oil carpet and a tray (metal if available). The personal protection protective equipment comprises gloves, safety goggles and in case of poor ventilation a respiratory mask. Firstly, a circle has to be cut around the top end of the capacitor casing near the contacts using a small iron saw. Once the top has been lifted, it is usually possible to pull out the active part. With a tool remove about 1 cm^3 of the insulation and conductor layers and place them in a 60 ml glass vial. The samples can then be prepared in the laboratory and analysed by gas chromatography.

All tools and materials that came in contact with the capacitors have to be cleaned e.g. with acetone, or disposed of as hazardous waste.

Picture 29: Small Sized Capacitors

Picture 30: Sampling of Small Sized Capacitors

5.2 Introduction to Field Screening Test Kits and Laboratory Analysis

PCB analysis can be divided into two categories: Specific and non-specific methods. Specific methods include gas chromatography (GC) and mass spectrometry (MS) which analyse for particular PCB molecules. Non-specific methods identify classes of compounds such as chlorinated hydrocarbons, to which PCBs belong. These non-specific methods include PCB field screening tests like CLOR-N-OIL and CLOR-N-SOIL test kits as well as the L2000 DX field analyser.

In general PCB specific methods are more accurate than non-specific methods but they are more expensive, take longer to run, qualified staff is needed, and they cannot be used on site.

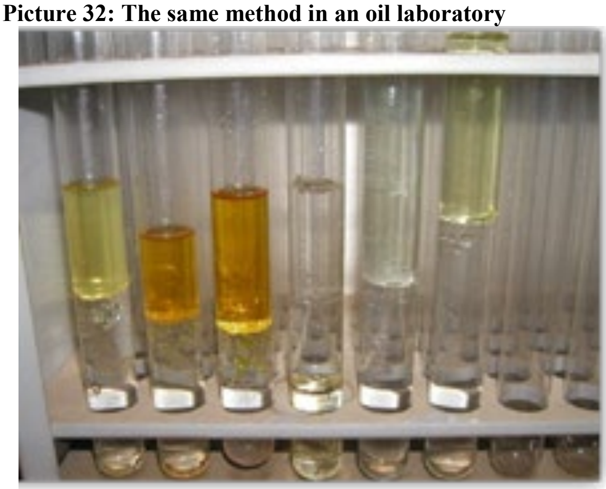
Two non-specific tests are below described which are however ABSOLUTELY NOT recommended to be used due to uncertainties in results and high potential of polluting water and air!

Density Tests

The easiest way to verify whether or not oil contains heavy concentrations of PCBs is a simple density test: → Use a 10 ml glass vial → pour some water into the vial → add some dielectric liquid
If the oil layer is at the bottom of the vial the density of the oil is > 1. In such a case there is no doubt that the PCB concentration is rather high. If the oil layer remains on top of the water layer; it can be assumed that it is a mineral oil with a density of < 1.

Picture 31: Density Test with oil in water on a scrap yard

Picture 32: The same method in an oil laboratory



However, a density test is only an emergency method in order to identify a pure PCB source. It cannot be recommended as a reliable tool for inventory purposes, as contaminated oil cannot be detected. Furthermore, there is a high risk of water/sewage contamination by hydrocarbons.

Beilstein Method

A piece of copper oxide fastened to a platinum wire is moistened with the oil to be tested and held in the outer zone of a Bunsen flame. As soon as the carbon has burned away, the presence of chlorine is indicated by the greenish or greenish-blue colour of the flame. This colour is produced by volatilizing copper chloride and its intensity and duration depends on the amount of chlorine present.

This test may only be performed in laboratories in chapels by experienced chem

There is a risk that highly toxic dioxins are unintentionally formed and released.

5.3 PCB Screening Test Kits

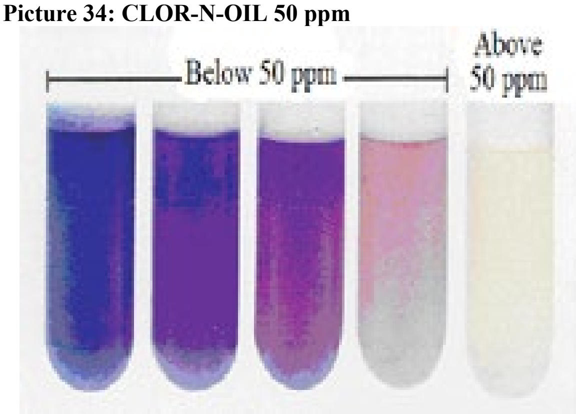
Chlorine Detection Test Kits

There are a variety of different brands of chlorine detection test kits available: Immunoassay technology ENVIROGARD by Millipore, KWIK-SKRENE by the General Electric Company and CLOR-N-OIL and CLOR-N-SOIL by Dexsil. The Dexsil test generally distinguishes between the PCB tests kits for oil (e.g. CLOR-N-OIL) and for soils (e.g. CLOR-N-SOIL).

The two Dexsil tests rely on the same principle: The chlorine atoms are chemically stripped away from the PCBs, the total chlorine concentration is determined and indicated by a colorimetric reaction. Three different test levels are available: **20 ppm, 50 ppm and 500 ppm**. Each kit is used in the same way. The end point for each has been adjusted so that it changes colour at the required level. The kit is a «GO / NO GO» type of test where the result is either positive or negative.

Picture 33: CLOR-N-OIL

Picture 34: CLOR-N-OIL 50 ppm



Instrumental Detection of the Chlorine Concentration

Instrumental detections of the chlorine concentration are methods that use instruments or analysers to determine the chlorine concentration in the samples. The L2000DX relies on the same basic chemistry as the CLOR-N-OIL test kits, however instead of a colorimetric reaction; the L2000DX uses an ion specific electrode to quantify the contamination in the sample. Sample analysis is available for transformer oils, soils, water and surface wipes. The usable measurement range for oils and soils is 2 to 2000 ppm; 20 ppb to 2000 ppm for water and 2 to 2000 µg/100 cm^2 for wipe samples.

The L2000DX Analyzer is pre-programmed with conversion factors for all major Aroclors and most chlorinated pesticides and solvents. The built-in methods include corrections for extraction efficiencies, dilution factors and blank contributions.

Picture 35: Soil Sampling of Contaminated Area

Picture 36: L2000 PCB/Chloride Analyser on site use

The L2000DX can be used in the field or laboratory by non-technical personnel. An oil sample requires about five minutes to run while water, soil and surface tests take about ten minutes each.

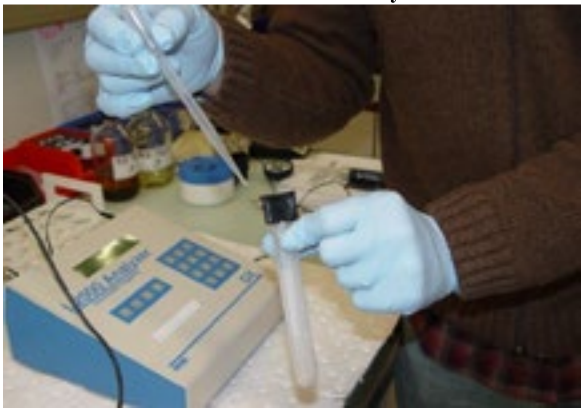
This eliminates the need to wait days or even weeks for laboratory results. Crews working at a site can take immediate action to secure equipment, isolate a site, or remove contaminated soil.

Instrument calibration is required at the beginning of each day (takes about 2 minutes). After calibrating, a reagent blank is tested to ensure the analysis is being run properly and to provide a baseline for accurate low-level results. Blank subtraction can be incorporated into the method and is automatically updated upon calibration. The preparation steps involve extracting the chlorinated organics from the soil, water or wipe material, (not required for PCB in transformer oil), and reacting the sample with a sodium reagent to transform the chlorinated organics into chloride. The resulting chloride is quantified by the L2000DX Analyzer. Several samples can be prepared concurrently, then analysed in less than a minute per sample. Samples can be prepared and analysed at a later time. One operator can complete about 65 oil tests, or 45 soil or surface wipe tests in an eight hour day.

Table 12: Advantages and Disadvantages of Field Screening Tests

Advantage	Disadvantage
➢ Time: Within minutes it is known whether the sample contains > or < than 20/50/100 ppm PCB.	➢ Can provide false-positive results (but never false-negative).
➢ Easy to use: The tests follow a simple procedure that can be performed by anyone in the field or lab.	
➢ Inexpensive: A PCB determination by test kits is less expensive than analysis in the laboratory.	
➢ Economical: Many samples do not need to be analysed by GC at all.	

Picture 37: L2000 use in the Laboratory



Picture 38: Use of Clor-N-Soil on Site

To save analysis costs and time it is advisable to use screening tests whenever applicable. Nevertheless it has to be considered that these methods test for the presence of chlorine in the sample being examined. As a result other chlorinated compounds, which can be part of the sample, could cause false positive results because the analysis method assumes all chlorinated compounds are PCBs. False negative results are not possible as if there is no chlorine present, PCBs cannot be present either.

Thus, if a test kit or the L2000 DX analyser shows positive screening results (PCB > 50 ppm) verification by gas chromatography is always necessary.

In this case the sample for gas chromatography analysis is to be kept and forwarded to the appropriate laboratory. If results of a GC analysis show a significantly lower result than the screening tests there is no reason to be alarmed. The tests are standardised for Aroclor 1242 with chlorine content of 42 %. Analyses with higher chlorinated PCB samples (e.g. Aroclor 1260 with chlorine content of 60 %) consequently show a higher result than the true PCB content. Thus the screening tests are always on the safe side.

6 Maintenance of Equipment Containing PCB

The maintenance of a device should be performed according to the procedures issued by the manufacturer and by the corresponding standard manuals of the electric industry associations. In the following, a general view of the key elements of the maintenance of PCB containing transformers and capacitors is presented.

6.1 Best Working Practices

When performing light repair or maintenance work on PCB containing equipment, the following safety precautions for the protection of the employees and the environment have to be taken:

- Direct contact of the skin with PCB contaminated materials must be avoided by wearing gloves and safety goggles. According to the type of work to be performed, protective clothing and a respiratory mask must also be put at the workers' disposal,
- The working area must be adequately ventilated,
- Spills must be prevented in every case by using drip trays or adequate plastic tarps,
- Every contact of PCBs with a flame or any other heat source over 300 °C and use of a grinder must absolutely be avoided (risk of highly toxic Dioxins and Furans),
- All used tools and other working materials that got in contact with PCBs must be disposed of as PCB contaminated waste in an environmentally sound manner or otherwise have to be decontaminated with an appropriate solvent (technical acetone). The only possible materials to be decontaminated are steel, glass, and ceramics, and
- Operations which involve draining, rewinding of coil, etc. may only be performed by companies approved for such task.

Picture 39: Transformer Maintenance

Picture 40: Active transformer part in service station

Furthermore we have to ensure that workers are aware of the PCB's, they shall respect the harm but not be afraid. They shall follow the hygiene rules and of course the respective tools and materials must be available to handle PCB-containing electrical devices.

7 Temporary Storage Considerations

PCB containing wastes should generally not be stored on sites that are not specifically designed for interim storage of hazardous wastes. Usually, there is no appropriate infrastructure to guarantee a safe storage. Uncontrolled and inexpert interim storages as shown in the pictures below endanger people and the environment, and result in unnecessary additional costs.

Picture 41: Bad Example I (open air storage)

Picture 42: Bad Example II (no tip trays)

PCB containing devices should be packed safely and in compliance with the applicable laws as soon as they have been phased out, even if their disposal takes place at a later stage. Irrespective of the quality of the temporary storage, the final and environmental sound disposal of the waste must be scheduled and coordinated that storage will not exceed twelve months. Generally, electrical equipment should only be phased out and stored, once an appropriate method of disposal has been chosen.

When setting up a temporary storage for PCB wastes it is important to choose an appropriate storage site/area. Locations close to rivers, groundwater, residential or farming areas, and ecological reserves or for example food processing industries CANNOT be considered suitable. If possible, the interim storage should be specifically designed for PCB containing equipment and wastes.

The Basel Convention recommended procedures for the storage of PCB waste are:

- Storage sites inside multi-purpose buildings should be in a locked dedicated room or partition that is not in an area of high use.
- Outdoor dedicated storage buildings or containers (often shipping containers are used) should be inside a lockable fenced enclosure.
- “Sensitive sites” such as hospitals or other medical care facilities, schools, residences, food processing facilities, animal feed storage or processing facilities, agricultural operations, or facilities located near or within sensitive environmental sites should not store PCBs, PCTs and PBBs on the premises if possible. If transfer to another location or immediate destruction is not possible then the storage site should be a dedicated storage building situated as far away from the high-traffic and operational areas of the property as possible.
- PCBs, PCTs and PBBs may be stored together but should not be stored with any other materials including other types of hazardous wastes. The exception to this rule is that other chlorinated organics similar to PCBs, PCTs and PBBs awaiting destruction and any materials resulting from the cleanup of PCB spills or fires may be stored in the same site with the approval of the appropriate government agency.
- Storage rooms, buildings and containers should be ventilated to the outside air or should be completely sealed to prevent any escape of volatile contaminants. These are distinctly different options and the choice of option depends on local and national law and policy, local health and safety policy and concerns and site-specific variables.

- Ventilating a site to the outside air is considered when exposure to vapours for those who work in the site is a concern. Adequate ventilation ensures that the air inside the site is breathable, non-explosive, and has contaminant concentrations below applicable human health exposure limits. If mechanical exhaust ventilation to the outside air is used an organic vapour capture system (e.g. activated carbon) should be considered to minimize the release of contaminants to the environment.
- Completely sealing a site so that no vapours can escape to outside air is considered when environmental concerns are paramount and there is minimal entry into the site by humans. If a site is sealed with no ventilation then all persons entering the site must wear respiratory protection at all times and may need to use supplied air. In a sealed site the oxygen level, contaminant level and explosive atmosphere must be determined before each entry. An entry system may need to be installed that prevents the escape of inside air when the site is accessed. An internal air treatment system may be used to reduce the build-up of contaminant and explosive vapours.
- Dedicated buildings or containers should be in good condition and made of hard plastic or metal, not wood, fibreboard, drywall, plaster or insulation.
- The roof of dedicated buildings or containers and surrounding land should be sloped so as to provide drainage away from the site.
- Dedicated buildings or containers should be set on asphalt, concrete or durable (e.g. 6 mil) plastic sheeting.
- The floors of storage sites inside buildings should be concrete or durable (e.g. 6 mil) plastic sheeting. Concrete should be coated with a durable epoxy.
- Storage sites should have a fire alarm system.
- Storage sites inside buildings should have a fire suppression system; preferably a non-water system. If the fire suppressant is water then the floor of the storage room should be curbed and the floor drainage system should not lead to the sewer or storm-sewer or directly to surface water but should have it's own collection system such as a sump.
- Liquid wastes should be placed in containment trays or a curbed, leak-proof area. The liquid containment volume should be at least 125% of the liquid waste volume taking into account the space taken up by stored items in the containment area. The curbing or sides of the containment must be high enough, or the wastes kept back from the edge of the curbing far enough, that a leak in any drum or container would not "jet" over the edge of the curb or side.
- Contaminated solids such as lamp ballasts, small capacitors, other small equipment, contaminated debris, contaminated clothing and spill cleanup material and contaminated soil should be stored in containers such as barrels or pails, steel waste containers (logger boxes) or in specially constructed trays or containers. Large volumes of soil or other contaminated material may be stored in bulk in dedicated shipping containers, buildings or vaults as long as they meet the safety and security requirements as described herein.
- A complete inventory of the PCB, PCT and PBB wastes in the storage site should be created and kept up to date as waste is added or disposed. A copy of the inventory should be kept at the site, another copy kept in the corporate offices and a copy filed with the emergency response plan.
- The outside of the storage site should be labelled as a PCB, PCT and/or PBB site. Specific labelling requirements vary by jurisdiction but the intent is to notify anyone approaching the site of the contents of the site.
- All containers of materials in the site should be labelled with hazard labels that clearly indicate the contents of the container.
- The site should be subjected to routine inspection for leaks, degradation of container materials, vandalism, integrity of fire alarms and fire suppression systems and general status of the site.
- Rusting or degrading drums or equipment bodies should be placed inside larger "over pack" drums instead of attempting to transfer the fluid to a new container.
- Draining of equipment or drums should only be performed by a qualified and experienced individual or company.

- All wastes created by transferring PCB, PCT or PBB wastes or by cleaning up spills or drips become wastes that must be stored for destruction or disposal.
- PCB, PCT and PBB wastes should not be diluted in order to avoid a certain type of destruction or disposal unless the resulting diluted material is to be destroyed so that the same quantity of the PCBs, PCTs or PBBs are destroyed as would have been destroyed using the more advanced or expensive technique.
- Wastes should be stored in a safe manner. Drums or pallets should not be stacked more than two high and only if this can be done safely (i.e. the drums are stackable).
- The site should have an emergency response plan and a copy of this should be reviewed and kept on file by the local fire protection agency.
- The site should have a health and safety plan if PCBs, PCTs and/or PBBs are not dealt with in the master health and safety plan for the property, company or agency.

When setting up a temporary storage for PCB wastes it is important to choose an appropriate storage site/area. Locations close to rivers, groundwater, residential or farming areas, and ecological reserves or for example food processing industries CANNOT be considered suitable.

If possible, the interim storage should be specifically designed for PCB containing equipment and wastes.

Minimum Requirements for Temporary Storage Site

Packing

- Capacitors must always stand upright. The insulators are the weakest parts. Never lift a capacitor by holding the insulators, they can easily break off.
- Capacitors must be stored on steel drip trays and leaking devices should be sealed. It is advisable to add absorbents to the steel trays.
- It is possible to put capacitors and contaminated solids into containers that are not UN approved. However, such containers must be checked for damage and leaks before use and cannot be utilized for transports. After use, the containers must be regarded as contaminated and also be disposed of as hazardous waste!

Building

- The floor of a temporary storage must be solid and tight. The storage must be walled and protected against the weather on all sides.
- All entrances to the storage must be marked with an appropriate warning, and access for unauthorized people must be forbidden.
- The area must be fenced and controlled.
- Display emergency procedures and best working practices
- The building should have some openings for permanent ventilation (ventilation systems with filters).
- Increased risks of fires must be excluded (no wooden shed, no storage of inflammable goods in the same building or in the neighborhood). A smoke and fire alarm system should be installed.
- Fire extinguishers (powder) and absorbents (e.g. sawdust) must be available and easy accessible.
- The building should be separated in different areas (reception, handling, separate storage of different waste categories, equipment, etc.)
- No food storage or food processing companies in the neighborhood.

Control

- The temporary on site storage must be authorized by the Competent Environmental Authority.
- The regional fire brigade must be informed about the temporary storage and the kind and quantity of the goods/wastes (by means of copies of storage lists).
- Depending on the size of the storage and the kind and condition of the stored goods/wastes, daily, weekly or monthly visual inspections should be scheduled.

All goods/wastes must be clearly marked giving information about the kind of waste, the date of packing, the weight, the origin and further important data. An up to date storage list must be accessible at any time.

Temporary storage CANNOT be accepted as long-term solution. Therefore it is advisable that the interim storages shall not be designed too large.

8 Disposal Considerations

To select the most appropriate technology several rateable and non-rateable criteria have to be considered. Among "non-rateable", or relative criteria, are included public acceptability, risk and environmental impacts, which depend on the specific geographic site location. The rateable criteria may include the applicability of the method (in accordance with its development status), overall cost, minimum achievable concentration, clean-up time required, reliability, maintenance, post treatment cost and ability to use soil after treatment.

The difference between technologies that only separate and/or concentrate a pollutant (e.g. solvent extractions, thermal desorption) and those which destroy the contaminant (e.g. incineration, dechlorination or biodegradation) must be considered. Those technologies that only immobilize contaminants (e.g. landfill systems, stabilization and vitrification) should also be clearly differentiated.

The technologies available cover a wide range of degree of treatment and recovery of transformer components, a factor which must be taken into account in comparing technologies. Decontamination is never completely applied to all components, and this means that a residue remains which must be incinerated. In the best case this will be just the porous parts (wood and paper) unless the solvent technique is applied for long process times, and a product finally obtained which may be sent for land filling if the residual PCB levels are legally acceptable. In other words, the total cost of treatment, including the cost of final disposal of residues, must be taken into consideration.

Whatever technology is chosen, it has to be performed by a company which is approved for this task by the respective authority, respectively, if the PCB waste is exported, approved by the competent authority in the concerned country.

In December 2004, the United Nations Environment Programme published an updated version of the inventory of worldwide PCB Destruction Capacity. It can be downloaded from the Internet:
http://www.chem.unep.ch/pops/pcb_activities/pcb_dest/PCB_Dest_Cap_SHORT.pdf

„POPs Technology Specification and Data Sheets" providing detailed information on various decontamination/disposal methods are being prepared at the moment and should be available by the end of 2013. At the moment the provisional data sheets can be downloaded at:
http://www.ihpa.info/resources/library/

There are a number of emerging technologies, which are not presented in the frame of this handbook. There is a GEF supported "review of emerging, innovative technologies for the destruction and decontamination of POPs and the identification of promising technologies for the use in developing countries" available in the internet:
http://www.chem.unep.ch/pops/pcb_activities/PCB_proceeding/Presentations/PCB%20Global%20McDowall.pdf and
http://www.chem.unep.ch/Pops/pcb_activities/default.htm#Guidance

9 Glossary

ADR	European agreement on the international road transport for hazardous goods
Askarel	Trade name of PCB cooling fluid (USA, Monsanto)
BAT	Best Available Technique
BEP	Best Environmental Practice
Capacitor	Equipment or unit to supply lagging kilovars for power factor correction of an electric system; some capacitors were manufactured with PCB as cooling fluid
Capacitor Bank (General)	Practically there are three different ways of power factor (PF) correction: Capacitors for "individual" PF-correction; the capacitor is directly connected to the terminals of an equipment (motors, welding machine etc.) producing the "lagging kilovars"
Capacitor Bank (LV)	Capacitors for "group" PF- correction; the capacitor(s) is (are) connected to the LV-busbar of a transformer station, which feeds a number of consumers with individual motors, welding machines etc.
Capacitor Bank (MV)	Capacitors for "central" PF-correction; Large capacitor installation connected to the Middle- or High Voltage busbars of a substation where many individual electrical appliances (motors etc.) of various size operate at different times and periods.
Closed applications	Capacitors and transformers, where the PCB itself is in completely closed containers; PCBs rarely emit from closed applications (in good condition)
Congener	Depending on the number and position of the chlorine atoms in the Biphenyl molecule, 209 isomers and homologue Chlorine Biphenyls are theoretically possible. A single compound from this group is called PCB congener.
Container 20’	Internationally used expression for Transport or Storage Containers with the Standard size of 2 x 2 x6 meters (40’ Container – 2 x 2 x 12 meters)
Container Box	There are various types of 20’ and 40’ Containers available, the most common is the Box Container with a front door, from an open top Container the roof can be removed for loading and off-loading activities (e.g. ideal for transformers)
Cooling Fluid	Dielectric fluid
DIN	Deutsches Institut für Normung (German Institute for Standardisation)
ECD	Electron Capture Detector; Detector for GC
ELV	End of the life-vehicles
ESM	Environmentally Sound Management
ETI	Environmental Technology International Ltd., Chur / Switzerland
EU	European Union
GC	Gas chromatography; Procedure for the determination of evaporating substances
GEF	The Global Environment Facility (GEF) is an international financial entity with 177 countries as members
HV	High voltage
IATA DGR	IATA regulations on the transport of hazardous goods / transport by air
IMDG	International maritime dangerous goods code / transport by sea
kV	Kilovolts
kVa	Kilovolt ampere
kW	Kilowatt
LRTAP	Long-range Transboundary Air Pollution

LV	Low voltage (230/400 V)
µg	Microgram
mg/kg	Milligram per kilogram
MV	Medium voltage (Normally in the range between 11 and 66kV)
MVA	Megavolt ampere
NAP	National Action Plan
ng	Nanogram (1000 ng = 1 µg)
NIP	National Implementation Plan
OECD	Organisation for Economic Cooperation and Development
Open applications	Applications where PCB is consumed during its use or not disposed of properly after its use or after the use of the products that contain PCB; Open applications emit PCB directly in the environment (e.g. softeners in PVC, neoprene and other rubbers containing chloride)
PBB	Polybrominated Biphenyl
PCB	Polychlorinated Biphenyls
PCDD	Dibenzo-p-dioxins or dioxin; Highly toxic by-product of PCB
PCDF	Dibenzofurans or furan; Highly toxic by-product of PCB
PCT	Polychlorinated Triphenyls
Persistent	Very slightly degradable in the environment
PIC	Prior Informed Consent
POP	Persistent Organic Pollutants
PPE	Personal Protective Equipment
ppm	Parts per million (mg/kg)
Primary source	A product to which PCB was added voluntarily to influence the product's characteristics (e.g. cooling fluids for transformers like Sovol, Sovtol, Askarel, Pyralene, Clophen, etc.). Such products emit PCB continuously
RID	Regulation for the international transport of hazardous goods / transport by rail
Secondary source	A product that originally was free of PCB, but later contaminated by PCB emitting from primary sources (e.g. by emission from primary sources or use of contaminated pumps, hoses, etc.). Such products also emit PCB
Seveso	Place near Milan/Italy, where dioxin was released in 1976 during an accident and consequently contaminated wide areas of the region
TCDF	Tetrachlorodibenzofuran
TDI	Tolerable daily intake
Transformer	Equipment used to increase or reduce voltage; PCB containing transformers are usually installed in sites or buildings where electricity is distributed.
UN-approved	Equipment that fulfils the specific United Nations testing procedures
UNEP	United Nations Environment Programme
WEEE	Waste electric and electronic equipment
WHO	World Health Organisation

10 Useful Links

Basel Convention	➢ www.basel.int
Basel Convention Leaflets	➢ http://www.basel.int/pub/leaflets/index.html
Capacitor Register, ANZECC	➢ www.pops.int/documents/guidance/NIPsFinal/eagov.pdf
ETI Environmental Technology Ltd.	➢ www.eti-swiss.com
PEN – PCBs Elimination Network	➢ http://chm.pops.int/Programmes/PCBs/PCBsEliminationNetworkPEN/tabid/438/language/en-US/Default.aspx
Rotterdam Convention	➢ www.pic.int
Stockholm Convention	➢ www.pops.int
Stockholm Convention Training Tool	➢ http://chm.pops.int/Portals/0/flash/popswastetrainingtool/eng/index.html
UNDP – United Nations Development Programme	➢ www.undp.org
UNEP - United Nations Environment Programme	➢ www.unep.org
UNEP Chemicals	➢ www.chem.unep.ch
UNEP Chemicals Manuals on PCB	➢ www.chem.unep.ch/pops/newlayout/repdocs.html
UNEP Chemicals Manuals on POPs	➢ www.chem.unep.ch/pops/newlayout/repdocs.html
UNIDO - United Nations Industrial Development Organization	➢ www.unido.org
UNITAR - United Nations Institute for Training & Research	➢ www.unitar.org

Guidance documents for identification, management and destruction of PCB

- Destruction and decontamination technologies for PCBs and other POPs wastes under the Basel Convention. A training manual for hazardous waste project managers Secretariat of the Basel Convention
  http://archive.basel.int/meetings/sbc/workdoc/TM-A.pdf
  http://archive.basel.int/meetings/sbc/workdoc/TM-B.pdf

- Guidelines for the identification of PCBs and materials containing PCBs
  UNEP Chemicals
  http://www.chem.unep.ch/Publications/pdf/GuidIdPCB.pdf

- Inventory of World-wide PCB Destruction Capacity
  UNEP Chemicals
  http://www.chem.unep.ch/pops/pcb_activities/pcb_dest/PCB_Dest_Cap_SHORT.pdf

- PCB Transformers and Capacitors - From Management to Reclassification and Disposal
  UNEP Chemicals
  http://www.chem.unep.ch/Publications/pdf/PCBtranscap.pdf

- Provisional POPs Technology Specification and Data Sheets
  Secretariat of the Basel Convention
  http://www.ihpa.info/library/2009/08/02/pops-technology-specification-and-data-sheets/

- Selection of Persistent Organic Pollutant Disposal Technology for the Global Environment Facility
  A STAP advisory document
  http://www.thegef.org/gef/pubs/STAP/selection-persistent-organic-pollutant-disposal-technology-gef

- Survey of Currently Available Non-Incineration PCB Destruction Technologies
  UNEP Chemicals
  http://www.chem.unep.ch/Publications/pdf/SurvCurrAvNIncPCBDestrTech.pdf

- Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs)
  Basel Convention
  http://chm.pops.int/Portals/0/flash/popswastetrainingtool/eng/All_technical_guidelines_on_POPs_4.pdf

- Updated technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with polychlorinated biphenyls (PCBs), polychlorinated terphenyls (PCTs) or polybrominated biphenyls (PBBs)
  Basel Convention
  http://archive.basel.int/pub/techguid/tg-PCBs.pdf

- Draft guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C Stockholm Convention
  http://www.pops.int/documents/guidance/batbep/batbepguide_en.pdf

11 Capacitor Registers

11.1 List on PCB Capacitors Codes of Products from the Former USSR

БКС250/40030/3,3; БКС250/40060/4,7; **ГСТ**-1-50;

ИС-16-0,8; ИС-2,8-300; ИС-20-0,5; ИС-20-6,65; ИС-25-13; ИС-2-52; И[illegible]; ИС-5-200;ИС-6-200; ИС-6-5,5;

КС-0,5-19; КС0-0,22-4; КС0-0,38-12,5; КС0-0,66-12,5; КС0-10,5-25; КС0-3,15-25; КС0-6,3-25; КС1-0,22-6; КС1-0,22-8; КС1-0,23-6; КС1-0,23-9; КС1-0,24-10; КС1-0,38-14; КС1-0,38-16; КС1-0,38-18; КС1-0,38-20; КС1-0,38-22,5; КС1-0,38-25; КС1-0,40-14; КС1-0,40-16; КС1-0,40-22,5; КС1-0,415-14; КС1-0,415-20;КС1-0,4-15-ОМ4; КС1-0,4-30-ОМ4; КС1-0,44-14; КС1-0,44-16; КС1-0,44-22,5; КС1-0,50-14; КС1-0,50-16; КС1-0,50-18; КС1-0,66-16; КС1-0,66-18; КС1-0,66-20; КС1-0,66-22,5; КС1-0,66-25; КС1-1,05-30; КС1-1,05-34; КС1-1,05-37,5; КС1-10,5-30; КС1-10,5-34; КС1-10,5-37,5; КС1-10,5-50; КС1-11-34; КС1-11-40; КС1-3,15-30; КС1-3,15-34; КС1-3,15-37,5; КС1-3,15-50; КС1-6,3-30; КС1-6,3-34; КС1-6,3-37,5; КС1-6,3-50 КС1-6,6-40; КС2-0,22-12; КС2-0,22-16; КС2-0,23-12; КС2-0,23-18; КС2-0,24-20; КС2-0,38-28; КС2-0,38-32; КС2-0,38-36; КС2-0,38-40; КС2-0,38-45; КС2-0,38-50; КС2-0,40-28; КС2-0,40-32; КС2-0,40-45; КС2-0,415-28; КС2-0,415-40; КС2-0,4-15-ОМ4; КС2-0,4-30-ОМ4; КС2-0,44-28; КС2-0,44-32; КС2-0,44-45; КС2-0,50-28; КС2-0,50-32; КС2-0,50-36; КС2-0,66-32; КС2-0,66-36; КС2-0,66-40; КС2-0,66-45; КС2-0,66-50; КС2-1,05-30; КС2-1,05-60; КС2-1,05-67; КС2-1,05-75; КС2-10,5-100; КС2-10,5-60; КС2-10,5-67; КС2-10,5-75; КС2-11-67; КС2-11-80; КС2-3,15-100; КС2-3,15-60; КС2-3,15-67; КС2-3,15-75; КС2-6,3-100; КС2-6,3-60; КС2-6,3-67; КС2-6,3-75; КС2-6,6-67; КС2-6,6-80; КС2-3,15-60; КС2-3,15-75;

КСК-0,5-38; КСК1-0,66-40; КСК1-1,05-63; КСК1-10,5-75; КСК1-3,15-75; КСК1-6,3-75;КСК2-0,66-80; КСК2-1,05-125; КСК2-10,5-150; КСК2-3,15-150; КСК2-6,3-150; КСКФ-4,4-150;КСКФ-6,6-150; КСКФ-7,3-150;

КСП-0,66-40; КСП-1,05-120; КСП-1,05-75; КСТС-0,38-9,4;КСФ-6,3-50; КСШ-6,3-50; КСШК-6,3-100; КСЭ-1,05-75; КСЭК-1,2-150;

ПС-0,3-0,4; ПСК-0,4-30; ПСК-0,4-90; ПСК-0,65-36; ПСК-0,7-20; ПСК-0,7-30; ПСК-1,25-200; ПСК-1,6-100; ПСК-4,5-4; **РСТ**-2-2,12; РСТ-2-4; РСТО-2-6,15;

ФС-1-600; ФСТ-0,75-300; ФСТ-2,1-160; ФСТ-4-40;

ЭС1000-0,5; ЭС1000-1; ЭС1500-0,5; ЭС1500-1; ЭС2000-0,5; ЭС400-1,5х3; ЭС500-1; ЭС750-0,5;ЭС750-1У3; ЭСВ-0,5-10; ЭСВ-0,5-2,4; **ЭСВ**-0,5-4; ЭСВ-0,8-0,5; ЭСВ-0,8-1; ЭСВ-0,8-10; ЭСВ-0,8-2,4; ЭСВ-0,8-4; ЭСВ-1,0-0,5; ЭСВ-1,0-1; ЭСВ-1,0-2,4; ЭСВ-1,0-4; ЭСВ-1,6-0,5; ЭСВ-1,6-1;ЭСВ-1,6-2,4; ЭСВ-1,6-4; ЭСВ-2,0-0,5; ЭСВ-2,0-1; ЭСВ-2,0-2,4; ЭСВ-2,0-4; ЭСВК-0,5-10;ЭСВК-0,5-2,4; ЭСВК-0,5-4; ЭСВК-0,8-0,5; ЭСВК-0,8-1; ЭСВК-0,8-10; ЭСВК-0,8-2,4; ЭСВК-0,8-4;

ЭСВК-1,0-0,5; ЭСВК-1,0-1; ЭСВК-1,0-2,4; ЭСВК-1,0-4; ЭСВК-1,6-0,5; ЭСВК-1,6-1;ЭСВК-1,6-2,4; ЭСВК-1,6-4; ЭСВК-2,0-0,5; ЭСВК-2,0-1; ЭСВК-2,0-2,4; ЭСВК-2,0-4; ЭСВП-0,8-10; ЭСВП-0,8-2,4; ЭСВП-0,8-4; ЭСВП-1,0-2,4; ЭСВП-1,0-4.

11.2 Extract of Capacitor Register / 1997 Australian and New Zealand Environment and Conservation Council (ANZECC)

http://www.pops.int/documents/guidance/NIPsFinal/eagov.pdf

12 PEN Application Form / PEN Magazine

БЛАНК ЗАЯВЛЕНИЯ НА ВСТУПЛЕНИЕ В ЧЛЕНЫ СЕТИ ПО ЛИКВИДАЦИИ ПХД

1. Персональная информация

Я желаю зарегистрироваться в качестве: ☐ учреждения ☐ физического лица

Учреждение			
Имя		Титул (г-н/г-жа, д-р)	
Фамилия			
Должность			
Почтовый адрес		Почтовый индекс	
Город		Страна	
№ телефона	(просьба указать международный код)	№ мобильного телефона	(просьба указать международный код)
№ факса		Эл. почта	

2. Дополнительная информация

Просьба указать, к какой категории участников вы принадлежите:

☐ Правительство (министерства, госучреждения, природоохранные инспекционные органы и т.п.)
☐ Отрасль промышленности, связанная с ПХД (хозяйствующие субъекты, оказывающие услуги по техобслуживанию, обработке или уничтожению ПХД)
☐ Владелец ПХД (частные или государственные предприятия, владеющие загрязненным оборудованием или маслами)
☐ Международный эксперт (консультанты, заинтересованные физические лица, региональные центры)
☐ Межправительственная организация
☐ Донорская организация
☐ Неправительственная организация
☐ Научно-исследовательские/учебные учреждения

Просьба кратко описать в нижеприведенном поле вашу работу с ПХД.

Я заинтересован в следующих областях, относящихся к ПХД (можно поставить галочку в нескольких клетках):

☐ Перечень ПХД
☐ Техобслуживание оборудования ПХД
☐ Незаконное использование ПХД
☐ ПХД в открытом применении
☐ Удаление ПХД
☐ Хранение оборудования ПХД
☐ Трансграничные перевозки
☐ Прочее:__________
☐ Технологии уничтожения

3. Заявление

Настоящим заявляю, что я буду принимать решительные меры по обеспечению экологически обоснованного регулирования (ЭОР) ПХД. Я согласен, что вся представленная информация может быть открыта для всеобщего доступа.

Дата:__________ Подпись:__________

Просьба направить заполненный бланк по электронной почте, факсом или обычной почтой на имя секретаря СЛП по следующему адресу:
Secretary of the PEN, Secretariat of the Stockholm Convention
11-13 Chemin des Anémones
CH-1219 Châtelaine, Geneva, Switzerland
Факс: +41 22 917-8098; Эл. почта: pen@pops.int

The PEN Application form (in Russian) can be downloaded from:
http://chm.pops.int/Implementation/PCBs/PCBsEliminationNetwork%28PEN%29/PENMembership/tabid/567/Default.aspx

The PEN Magazine (in Russian) is available from:
http://chm.pops.int/Implementation/PCBs/PCBsEliminationNetwork%28PEN%29/PENmagazine/tabid/738/Default.aspx

13 Personal Notes

PCB PROJECTS IN EMERGING ECONOMIES: ENVIRONMENTAL AND ECONOMIC BALANCE BASED ON CORPORATE SOCIAL RESPONSIBLE INNOVATIONS

D. J. Hoogendoorn
CEO, Orion b.v., the Netherlands

About Orion

Orion B.V. is an internationally operating company specialized in the treatment and handling of Polychlorinated Biphenyl's (PCB's). Orion was founded in 1985.

Orion's mission is to be recognized as a reliable partner in safeguarding the environment by safe and cost-effective removal and destruction of PCB containing equipment.

Our procedures foresee in packing the PCB-waste on location and sending it in containers to the Netherlands for destruction in our treatment facility in Drachten.

Of course Orion is not unique in providing this kind of service, and as a dedicated and specialized company, we have (a need for) a unique and different philosophy.

Our vision is to transfer know-how and expertise to local partners aiming to enable each country to have a company trained in the handling of PCB waste. In our experience, the advantages are as follows:

- "In country" competence to offer transformer life cycle management and to handle PCB waste and PCB calamities;
- Trust, understanding and good communication between the local company, the environmental authorities, the owners of the PCB waste and Orion;
- Much employment and revenues remain in the local economy;
- Local temporary storage is created, so PCB waste disposal is also available to the owners of small PCB waste amounts;
- Fast and professional domestic intervention in case of a calamity;
- Local co-processing in licensed cement kilns or high temperature rotary kilns of PCB liquids and solids like PPE and absorbents assures that 95% of hazardous substances do not have to be exported;
- Combination of "end of life" treatment with "life cycle management" for transformers in order to re-use as much resources at the highest level as possible in the "Waste Hierarchy":

Finding a local partner

Orion looks for partnership with existing local companies in the area of hazardous waste collection and treatment. This way, we use the local expertise and capacity in a country and we avoid to disturb the local market.

When Orion starts business in a new country, we introduce our company to the local government (Competent Authorities) and ask them for a list of suitable and licensed organizations for the treatment, collection, storage and transport of PCB containing waste. Most of the time, the Dutch government is able to support Orion during this introduction.

The next step is to ask PCB-waste owners, like the local power companies and the industry, for recommendations of PCB-waste collectors. By matching these lists, we aim to find licensed and service-oriented partners in each country outside the Netherlands.

The type of company that we usually form partnership with are the industrial & hazardous waste collectors, PCB waste treatment companies or transformer-service companies.

Cooperation between Orion and her local partners
The local partner is supported by Orion when needed. Mostly this will be in the field of marketing, technical support and logistic services. During the first projects, Orion will send a specialist to assist the local partner. When the local partner has demonstrated sufficient know how and technical skills, the projects will not be supervised by our specialists.

The period of extra support is typically 1 to 3 projects. This depends on the level of existing experience at the local partner and the speed of the market development.

Also personnel from the local partners come for training to Orion's facility.

Export documents

TFS documents
Orion opens Trans Frontier Shipment (TFS) Documents for a country for one year from our local partner to Orion. The procedures for obtaining these documents are very familiar to Orion and our requests have been rewarded by all the different competent authorities up till now.

Duly Motivated Request
To obtain the TFS documents for a project, the competent authorities have to give their written statement, in which they allow export of PCB-waste to the Netherlands, because there is no capacity for destruction of PCB-waste in their own country. To obtain this statement, the assistance of the local partner is very welcome.

Example from Bulgaria – working with a local partner

In 2004, to prepare for the enlargement of the EU the Dutch trade minister visited all the potential new country-members of the EU, including Bulgaria.

During this visit, Orion, among other Dutch exporting companies, joined the minister. In this week we were introduced to the Bulgarian ministry for environment. The ministry has introduced us to Balbok. After two more visits to Bulgaria, Orion signed the contract for partnership with Balbok in 2005 and the first PCB-project was finished in 2006.

Balbok is specialized in hazardous waste in Bulgaria. For PCB-waste, they did not have a partner with the recycling options Orion could offer.

During the last 3 years, Orion and Balbok developed a very nice cooperation. Exchange of logistic and technical knowledge, both ways are working out very nicely. Orion assisted Balbok during the first project with a sales visit at the client and supervision of the first PCB-project at the client's factory.

Balbok assisted Orion in obtaining the TFS documents and the transport permits.

Balbok works according to the high international standards for the handling, treatment and storage of hazardous waste. Because of their impeccable reputation, the PCB-project runs very smoothly, and the level of confidence of the clients and the authorities is very high.

This partnership helps to strengthen the reputation and the services of both partners.

Both companies are very enthusiastic about this partnership and both the economy and the environment of Bulgaria and The Netherlands benefit from this cooperation.

PCB treatment and transformer life cycle management

To build and to operate our treatment technology costs are comparatively low. Orion has already been using this technology for over 20 years. One of Orion's unique features is to use no heating for the rinsing/washing nor for the distillation of the solvents. This is safe, easy to use and very cost effective. In cooperation with our partners, we also offer insulating oil treatment technology and services for transformers in-use.

Transformers during use stage

Since 2012, we cooperated with transformer oil analyses laboratories and transformer oil (mobile) treatment solution providers at an international level in order to offer life cycle management for mineral oil transformers during the use stage. Life cycle management is not restricted to PCB contaminated oil transformers. It is applicable to all mineral oil transformers and allows the transformer owners to monitor the quality and remaining thermal life of their capital equipment using all the data and experience available today. Modern life cycle management allows the owners to better assess the quality and reliability of their transformers and make the optimal investment and maintenance decisions.

If a transformer owner and/or a governmental organization perform a PCB inventory study much money and effort is required. In that case it makes sense for transformers which are in use in order to:

1. collect additional technical data about the transformer, and

2. do additional analyses (not only PCB content but also quality parameters) on the oil samples

to assess the quality and remaining thermal life of the transformers. Based on that information, a life cycle management plan can be drafted.

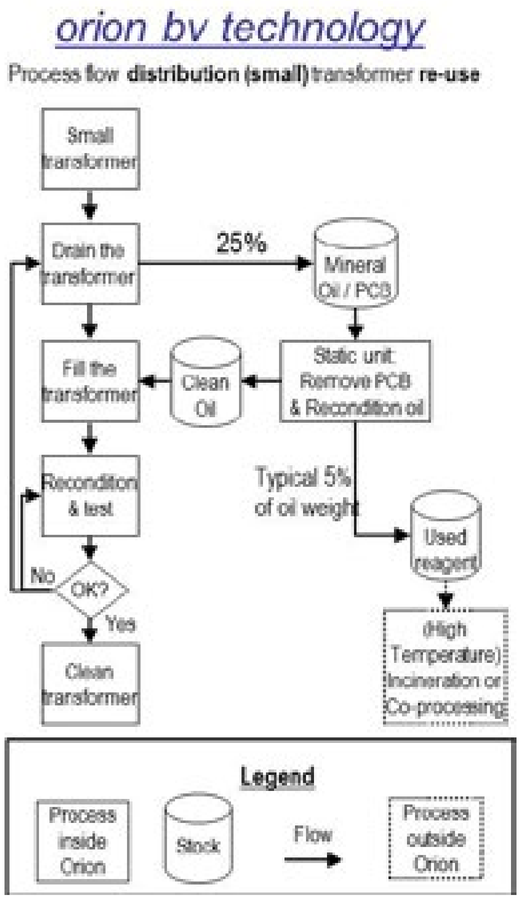
Low PCB contaminated oil transformers can be treated by retro-filling for small oil transformers or direct treatment for large transformers with more then 15 000 liters of oil inside.

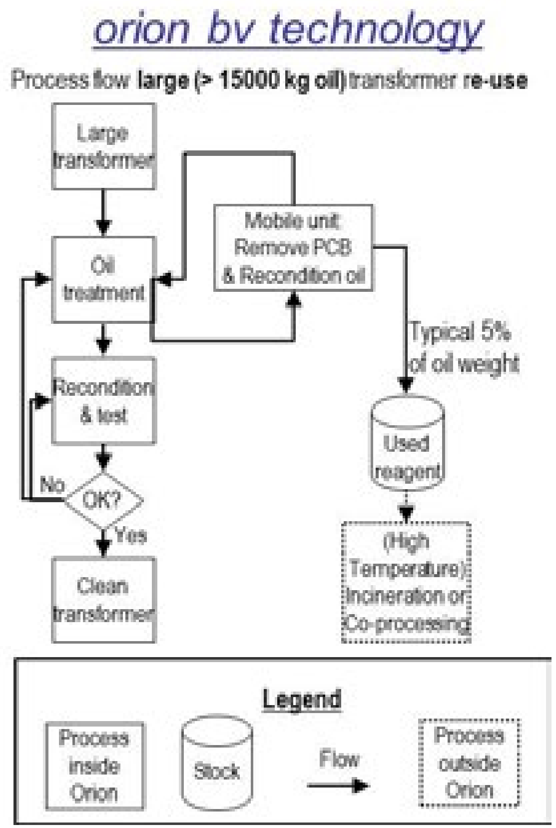
In case of high shut-down costs, it is also possible to do the direct oil treatment on-load (energized) with only a short shut down time of 2 to 4 hours to connect the oil treatment equipment. This option is used often at power generation plants where a shut-down of 1 line can cost 400 000 Euros per day. Also, in industries without sufficient backup capacity, the on-load option may be used. Treatment time on-load is typically 2 to 3 times as long as off-load due to the reduced oil flow rates.

When PCB is removed from the oil, the oil quality is also improved as all the other parameters (water, particles) are treated at the same time and also problems like corrosive sulfur are eliminated.

For transformers without PCB contamination but other oil quality and thermal life issues the same oil treatment procedure can be applied where necessary.

In the next figures the process flow for oil treatment for small and large transformers is shown:





Transformers in the waste stage

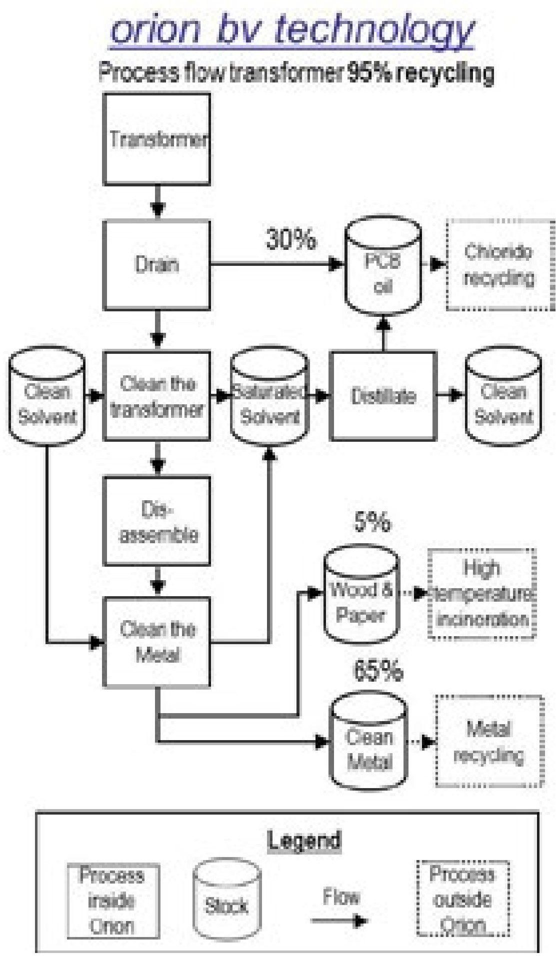
If a transformer cannot be used anymore, it is in the waste stage. At this stage, oil treatment is typically more expensive than dismantling and cleaning for several reasons:

1. Oil treatment creates additional waste like used reagents and in the case of washing with oil extra contaminated oil

2. If the transformer is not in use during or after the treatment, the internal (active) part / core material will not be cleaned and will retain the high PCB-levels. The core contamination will only be reduced after some months of use (typically 3 to 6 months) after the oil treatment where the PCB level in the oil will rise again from < 2 ppm to higher levels. The final level will depend on the original PCB contamination level.

3. Even if we take the transport cost and the scrap (copper / iron) revenues into account, the dismantling treatment is less expensive than the oil treatment. The economic advantage of the oil treatment is only when the transformer can be re-used because it saves the cost for a new transformer and its installation

The PCB transformer dismantling treatment is done as follows: PCB-containing transformers are drained, and the inside is cleaned with solvents. After this cleaning operation, the transformer is opened, and all the parts separated. Copper, aluminum and sheet metal are rinsed with fresh solvents. The cleaned metal parts are sent to smelters as base materials for new metals, and the solvents are cleaned by vacuum distillation. We can recover approximately 95% of all materials, the only exception being insulating materials, which cannot be cleaned.



Capacitors
PCB-containing capacitors are recycled in a similar fashion to transformers. The capacitors are drained and opened, after which, the metal case is rinsed with solvents. Approximately 50% of the materials are recovered. The remaining 50% consist of insulating materials and aluminum foil, which cannot be cleaned.

Technology and know-how that Orion licenses or sells:

Orion has developed a mobile solution in cooperation with one of our technology partners for on-site dismantling for low contaminated transformers if export is not possible, and quantities are limited (between 5 000 000 and 10 000 000 kg).

For higher quantities and pure PCB transformers, a fixed installation can be offered in case export is not feasible. However, including amortization of the capital expenditure required, the total treatment costs per kg are typically higher than if the PCB waste can be exported to the EU. This is mostly caused by the fact that the EU treatment centers have already absorbed the capital expenditures in the past en are now operating at variable cost plus revenue only.

Orion's technology as it is used in our plant at Drachten for dismantling of transformers, capacitors and cleaning of the metal parts

1) Access to Orion's proven and approved technology and know-how for the following facilities:

• Specifications for liquid proof and PCB resistant floors as used at our plant;

• Specifications for construction of cranes as used at our plant;

• Specifications for ventilation and air treatment systems as used at our plant;

• Specifications for Fire protection measures and detection systems as used at our plant;

• Lay-out of our treatment centre with area's for:

o PCB-waste reception,
o draining and rinsing,
o (intermediate) storage for liquids, metals and solids,
o dismantling,
o solvent distillation,
o offices,
o locker rooms, showers and restrooms for workers;

• Specifications of required personal protection equipment as used at our plant;

• Specification of the equipment and materials we use at our plant in Drachten like:

o shredders and separators
o shears
o cutters
o tap-sets
o pumps
o hoses
o sawing machines
o vacuum chambers
o solvents
o distillation equipment for solvent recuperation
o monitoring systems
o tanks
o containers for storage and ADR transportation
o etcetera's

• Safety plans and procedures for environmental protection as used at our plant;

• Safety plans and procedures for worker protection as used at our plant;

• Emergency and contingency plans and procedures as used at our plant;

• Quality control plans and procedures as used at our plant;

2) Education, training and visits to Orion's dismantling facility at Drachten, the Netherlands. Travel and housing expenses to be paid by the client.

3) 200 hours of advice during the first year after purchasing the license are included for each client. Travel and housing expenses to be paid by the client.

SODIUM TECHNOLOGY
– THE CHOICE FOR TREATMENT OF POP`S

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Abstract
The Sodium Technology was initially developed for the treatment of PCB-contaminated oils, such as transformer oils.

The Sodium Technology involves the complete mineralization of organic chlorine containing compounds (such as PCBs and further POP`s) by sodium.

POP`s in liquid or dissolved form are destroyed, and only non dangerous compounds such as rock salt and organic polymers remain as final products.

The efficiency of the Sodium Technology is at > 99.9999%.

There is no fear of formation of dioxins and furanes as compared to incineration. Further advantages are as follows: the low investment costs, the inexpensive nature of reagent sodium, the likelihood of stationary as well as mobile detoxification units.

Keywords
Sodium, PCB-destruction, POP-Destruction, operating temperature, mobile unit, approved technique, high efficiency.

Introduction
The handling of sodium is well-understood from industrial application since many decades. The annual consumption of sodium is more than 100,000 mt worldwide. In the field of environmental technology, sodium is used for the dechlorination especially for PCB-destruction in transformer oil. Due to the high reactivity, additional fields, such as treatment of any of the POP`s up to chemical warfare agents of application, can be identified .

Both stationary and mobile units can be set up and operated with very high efficiency.

Basis
The chemical principle in any reaction with sodium is the cleavage of the C-Cl-bond to yield sodium chloride and a mixture of organic molecules without any chlorine.
The overall chemical reaction of halogenated compound with sodium will follow

$$2\,R-X \;+\; 2\,Na \;\rightarrow\; R-R \;+ 2\,NaX$$

$$X = F, Cl, Br$$

and is valid for any kind of halogenated organic compound within the POP`s and all other organic chemical compounds. Even halogenated gases can be treated in a modified way of the sodium treatment process.

The required efficiency of > 99.9999 % can be achieved in any case, when:

operating temperature meets the requirements (approx. 120-150°C)
sodium-dispersion in sufficient quantity is offered

Preconditions for the success are the following:

1. POP dissolved in mineral oil, or
2. grinded and mixed with mineral oil

Our objective: Make it simple and efficient!

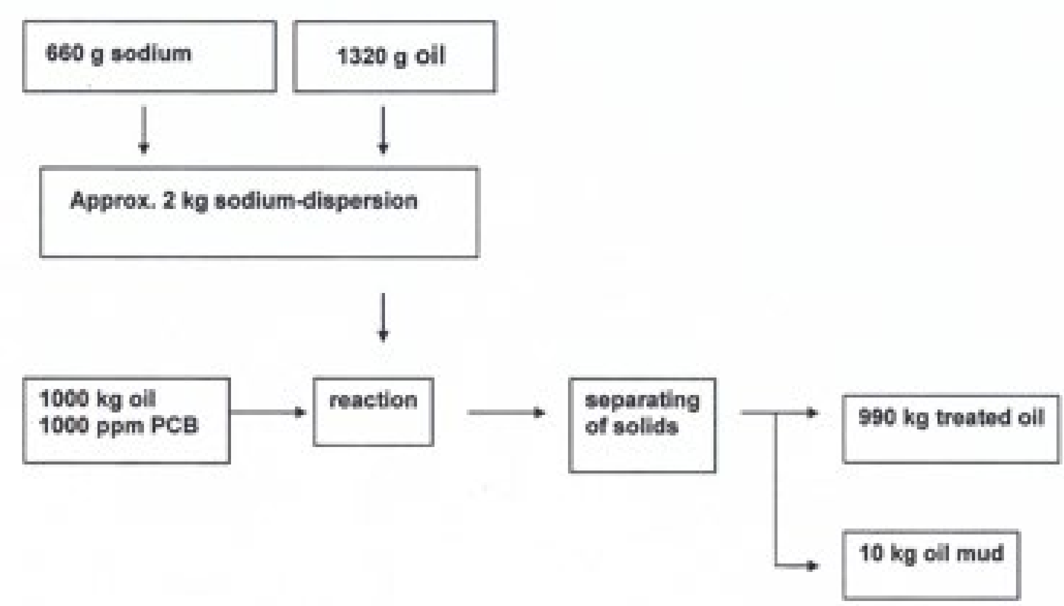
General operation path

Pre-treatment:

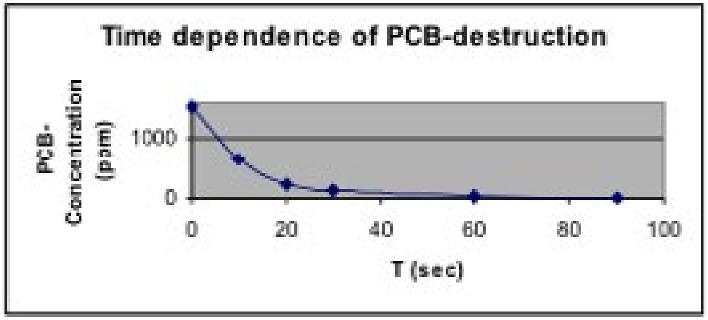
Pre-treatment includes filtering and de-watering to avoid violent reactions with metallic sodium. Drying of oil/organic solvent is sufficient if moisture content is about 100 ppm.

The Sodium Technology is applied by adding the sodium dispersion to the oil stream (particle with a diameter of approximately 2 to 10 µm) at low temperatures. Generally the operating temperatures vary from 100°C to 150°C, depending on the compound being destroyed, with temperatures of 130°C to 140°C being more typical. This relatively low temperature provides an important safety feature for application of the technology, since the formation of reaction heat can be quickly reduced in an emergency case by removing the applied heat and cooling the treatment vessel. The technology operates at atmospheric pressure.

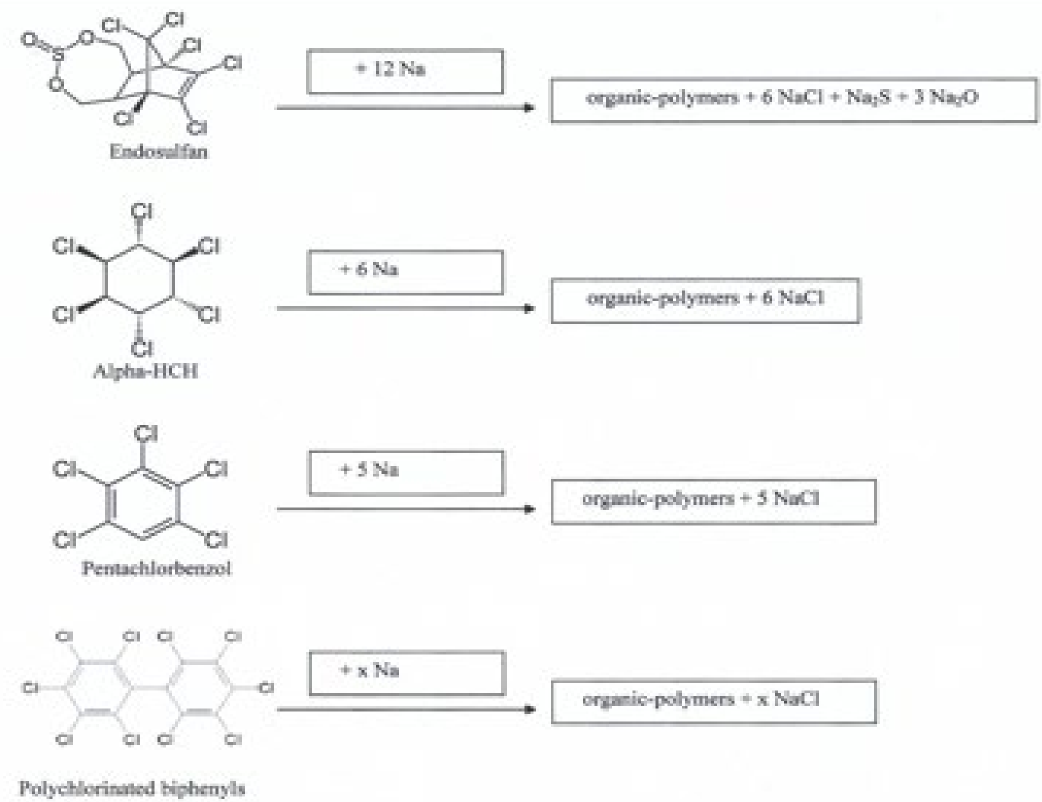
In the flow diagram illustrated below, the general procedure for the sodium treatment is depicted on the base of contaminated oil:



The efficiency of the process is revealed in the diagram depicted below:



Some examples for the chemical equations are given below:



Practical experience

Operating units have been set up in Germany, the Netherlands, France, the United Kingdom, Czech Republic and South Korea.

The size of the unit can be adapted to the specific requirements and can be realised either in stationary or mobile units.

The most experienced industrial operation unit has been in process since 1989 until today without any alterations in mechanical equipment. In all cases, the operating company was able to guarantee a limit of < 2 ppm for their clients. More than 20,000 tons of transformer oil have been processed up to now.

A semi-continuous plant in the U.K. was able to treat 5 m³ per batch a total quantity of 10,000 tons of transformer oil processed with a limit of < 2 ppm after treatment with sodium.

In South Korea, Seoul, the limit of < 2 ppm has been approved by the Ministry of Environment in as well as the South Korean Institute for Science and Technology (KIST) at the day of the first start of the unit covering a capacity of 1000 lt/h. The unit can operate 24 hrs per day.

Even the very low Japanese limits of < 0.5 ppm can be guaranteed.

Vast own experience has been made with POP`s from effluents of a local landfill in Hamburg. A wide range of POP`s have been found in the effluent in high concentrations. After the treatment with sodium, no organic compound with chlorine could be found.

The cumulated results are given in the table below:

Compound	Before	After Treatment
PCB	80 ppm	< 0,1 ppm
PCDD	17 ppm	< 0,0002 ppm
PCDF	8 ppm	< 0,0002 ppm
HCH	2000 ppm	< 0,1 ppm
Chlorobenzene	30000 ppm	< 0,1 ppm
Chlorophenole	900 ppm	< 0,1 ppm

Concentrated POP`s have to be diluted to keep the heat evolution of the exothermic reaction under continuous control.

The steps for concentrated POP`s will include the following:

- heating oil to 160 °C

- adding POP`s to get concentration not greater than 5%

- treating with sodium dispersion

- separating solids

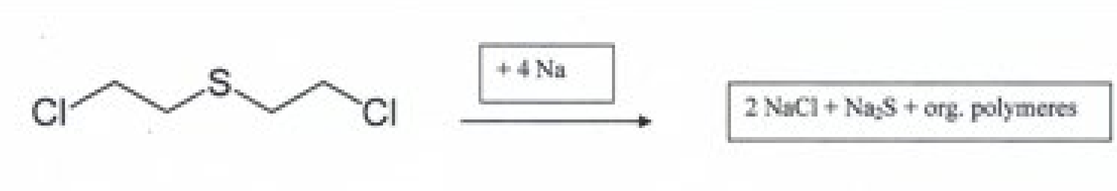
- returning the oil for additional use

Chemical warfare agents:

The Sodium Technology can also be applied for the destruction of chemical warfare agents.

In approved laboratories, it was possible to demonstrate that Adamsite (an arsenic containing molecule) can be destroyed down to below detection limit within one hour at 60 °C

Later in other licensed laboratories more warfare agents such as S-Lost, Clark1, Pfiffikus Phenylarsindichlorid and Triphenylarsin have been treated successfully. This work was done on the lab scale.



Example

Conclusion

The Sodium Technology is a straightforward and widely approved method for the safe decomposition of any kind of POP’s with final products that are easy to handle. Due to long lasting experience in handing of sodium specific solutions for the decomposition of POP’s can be evaluated and realised.

BAT/BEP – LCM: INVENTORY, CONTROL, MANAGEMENT, INTEGRATED DECONTAMINATION & DEHALOGENATION OF PCBS & OIL AND TRANSFORMERS - SOME CASE HISTORIES

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Abstract

This paper describes the "state of the art" for inventory, control, management, decontamination of electrical equipment and insulating liquids containing PCBs &POPs.

A new diagnostic method (developed by Sea Marconi-patent pending), called "Total Chlorine and PCBs screening -TCPs", to quantitatively determination of Total Chlorine and PCBs screening in the oil, is described. The best available techniques (BAT) and best environmental practices (BEP) for life cycle management (LCM) of electrical equipment impregnated with insulating liquids, according to the prescriptions of the Stockholm Convention on Persistent Organic Pollutants (POPs) entered into force on May 17th 2004, are presented.

The paper offers a review of the standards: *IEC 60296 Ed.4-2011"unused mineral insulating oils for transformers and switchgear";IEC 60422 Ed.4-2013"mineral insulating oils in electrical equipment-supervision and maintenance guidance"; CENELEC CLC/TR 50503 February 2010 "Guidelines for the inventory, control, management, decontamination and/or disposal of electrical equipment and insulating liquids containing PCBs."; CIGRE 413 Working Group D1.01(TF 12)April 2010"Insulating Oil Regeneration and Dehalogenation".*

The most recent decontamination and dehalogenation technique ("CDP Process patented by Sea Marconi) in continuous mode by closed circuit process, uses a solid reagent consisting of a higher molecular weight glycol mixture, a mixture of bases and radical promoter or other catalyst for chemical conversion of organic chlorine in inert salts, on a high surface area particulate support. This process normally runs at 80-100 °C and has the capability to decontaminate equipment on-site through continuous circulation of the oil a closed system (without draining the oil or using auxiliary tanks) using the solvent capability of the oil for continuous extraction of PCBs from solid materials inside the equipment. This solution prevents the critical reactions (reaction with Sodium at 150-300 °C and risks of explosion and fire; reaction with KPEG at 130-150 °C), ensuring at the same time, higher efficiency and lower operating costs. They are also capable of working on-site, both on large transformers and medium/small size ones, and when accessibility to the site is difficult, by using compact decontamination mobile units (DMU). In the specific case of chemical dehalogenation of PCBs, the change of oil and the creation of PCBs classified wastes are prevented.

The countermeasures available to prevent and or mitigate the effects of PCBs & POPs are reported hereby, with regards to their effectiveness. The case history of decontamination and dehalogenation of PCBs by mean of on-load and off-load

“CDP Process” is compared with other techniques.

Keywords
Transformer, Mineral insulating oil, Additive, PCBs, Diagnosis, Countermeasure, CDP Process, Dehalogenation.

ntroduction

This paper reports on the results of a four decades long expertise by Sea Marconi, an independent third party company with respect to electrical equipment and insulating fluid manufactures, in the field of diagnostics for the prevention of failures and integrated treatments of insulating liquids for Life Cycle Management of transformers.

The identification of PCBs, as harm to the environment, is symptomatic of a typical application scenario common to many other synthetic chemical compounds (i.e. POPs – Persistent Organic Pollutants). The time characterising the “PCBs Problem”, spans over three centuries (1867 – First lab synthesis by Griefs in Germany). The PCBs are characterised by extraordinary features that resulted in a large commercial application (1927. First industrial application by Swan in USA). Later on, the discovery of its incompatibility with the biosphere resulted in their designation as an environmental pollutant and the “PCBs Risk” was recognised as a global problem over three decades (1966 First discovery in the environment by Jensen in Sweden), (1969 – First serious accident in Yusho – Japan, where 31,180 persons were involved by intoxication with 26 deaths, as a consequence of a leak of PCBs from a heat exchanger into rice oil).

The risks generated by PCBs in the ecosystem resulted in the promulgation of numerous rules at international level on the prohibition and use of these substances (1976 – EEC Directives 76/405 and 76/769; USEPA 1979 40 FR Part/761). Also, international agreements were reached finalised toward the elimination of these toxic and persistent compounds within the established time limits. These include the water resources of the Great Lakes Region (18% of the global reserve of drinking water) several European Directives [1] [2] and the Protocol of Stockholm of May 2001 on POPs.

It must be noted that the term “PCBs” as defined in article 2 of Directive 96/59 EC [2], for the first time also includes other halogenated compounds, besides the 209 possible congeners of the Polychlorinated biphenyls. They are the PCTs equivalent (8557 possible congeners) and PCBTs (several thousand congeners) with a concentration exceeding the limit of 0.005% by weight (50 mg/kg or ppm). These compounds are classified as dangerous, persistent and bio-accumulable, creating an unreasonable risk for the environment and Human Health (such as contamination of food, as occurred in June 1999, in Belgium, France and Italy).

In the event of uncontrolled thermal oxidation, during the operation of transformers (hot spots > 150-300 °C) or in the case of failures (arching of electrical systems) with explosions and fires, significant concentrations of very dangerous compounds occur, such as PCDFs- Furans (135 congeners) and PCDDs-Dioxins (75 congeners).

The use of PCBs as insulating liquid in electrical equipment, particularly transformers and capacitors, caused a significant contamination of the environment. It is estimated that about 30 million of such units are in operation world-wide. This equipment represents an enormous contaminating load; the mass of contaminated oil, just in the OECD Countries, is estimated in several million tons. The equipment and materials contaminated represent a high strategic and investment value of several billion dollars. The obligation to eliminate and/or decontaminate such a mass of equipment and materials involves risks and costs connected with technical and logistic difficulties.

This paper analyses the PCBs problem, the technological options for the decontamination and/or disposal, the asset management options as well as the description of the performance and functional features of a continuous mode dehalogenation process designated as CDP Process ® by SEA MARCONI TECHNOLOGIES.

The efficiency of this process was demonstrated successfully on the 2,3,7,8 TCDD (dioxin) in the Seveso accident (starting from 1982), through laboratory experiments and field industrial applications (since 1989) for the dehalogenation/detoxification of PCBs/PCTs/PCBTs/PCDDs/PCDFs on electrical transformers.

Normative references-IEC & EN

The International Electrotechnical Commission (IEC) and European Standards (EN) cover terms and definitions, specification for mineral insulating oils.

Decontamination - Regulatory References:

- IEC 60422 Ed. 4 2013 Supervision and maintenance guide for mineral insulating oils in electrical equipment (Art.12.4)

- IEC 61619 – EN 12766 Insulating liquids – Contamination by PCBs, (PCBs, PCT and PCBsT). Methods of determination by capillary column Gas chromatography

- *CENELEC CLC/TR 50503 February 2010 "Guidelines for the inventory, control, management, decontamination and/or disposal of electrical equipment and insulating liquids containing PCBs.";*

- *CIGRE 413 Working Group D1.01(TF 12)April 2010"Insulating Oil Regeneration and Dehalogenation".*

Strategies and Opportunities

Life Cycle Management (LCM) of insulating Oils & Transformer has been developed, in 10 key steps, in accordance with the following objectives:

A. Prevention and/or mitigation of losses (direct and indirect) and risks for workers, assets, public health and environment, arising from human error, malfunction, or failures of the equipment that cause fires or spillage of hazardous compounds (Oils, PCA, etc.) and Persistent Organic Pollutants (POPs; PCBs, etc.);

B. Implementation of "State of the Art", IEC Standards, "Best Available Techniques" (BAT), "Best Environmental Practices" (BEP) and methodologies available for safety, whilst taking into account the surroundings and the criteria of self-sufficiency and functional recovery;

C. Technical feasibility of the activities within the prescribed time schedules, according local regulations, based on cost/benefit analysis and economical feasibility. (CENELEC CLC/TR 50503 – February 2010, etc.)

LCM: Key Stepr for Oils & Power Transformer

LCM according with IEC Standards, CIGRE Guidelines, local Regulations and specific requirements:

I. Inventory of oils and electrical equipment filled with insulating liquids.

II. Requirements and General Specifications **Acceptance**: Tests of unused insulating oils & fluids

III. Factory Test

IV. Commissioning and Prior Energisation

V. Energisation

VI. Infancy: Control, Diagnosis, Prognosis and Solutions for Insulating Oils & Equipment

VII. Operation – Oils & Fluids Maintenance: Integrated Treatments & Processes

On-Load/Off-Load (physical decontamination/reconditioning; selective depolarisation-DBDS, metal dissolved, acid and polar compound/reclaim; dehalogenation/detoxification of PCBs & POPs; transformer drying; transformer desludging; additives; etc.), electrical maintenance, etc.

VIII. Aging

IX. End of Life - Post Mortem: decontamination, material recovery and waste disposal, etc.

CDP PROCESS: Scope and Applications

The Chemical dehalogenation process (CDP ®) in continuous mode by closed circuit ,integrated in Decontamination Mobile Units (DMU), is the BAT / BEP technique (Italian Ministry of Environment, D.M. 29/01/2007 - G.U. no. 133 of 7/06/2007 art. D.2.2.2.3 and art. E.3) applicable for transformers and electrical equipments on site and in operation filled with mineral insulating oils contaminated by PCBs.

The [1] CDP & DMU solution is capable to re-classify as "NO-PCBs" the oil & transformer and restore the best environmental and functional conditions in compliance with the local regulation, international standards and technical guidelines. This solution satisfies the European regulations and standards in terms of BAT/BEP and sustainability (technical feasibility, economic-cost/benefits, environmental benefits and social-green jobs), safety (for workers, public health and environment-emissions CO2 etc.),proximity, self-sufficiency and functional recovery through the multifunctional treatment (off load and on load conditions) for life cycle management (LCM) of insulating liquids & transformers and includes the following key aims:

a) Dehalogenation & detoxification of PCBs in oil below the limits prescribed by local regulations or internal specifications (< 50; < 25; < 10; <2 mg/Kg of PCBs, determined with IEC 61619 Ed.1-1997). This process uses a solid reagent (S/CDP) consisting of a high molecular weight glycol mixture, a mixture of bases and radical promoter or other catalyst for chemical conversion of organic halogen to inert salts on a high surface area particulate support. This process normally runs typically at 80-100 °C and has the capability to decontaminate equipment on site, through continuous circulation of the oil in a closed system (without draining the oil or using auxiliary tanks), using the solvent capability of the oil for continuous extraction of PCBs from solid materials inside the equipment

(IEC 60422 Ed.4- 2012 art.11.4.3;CENELEC CLC/TR 50503 – 2010 art. 8.4.2.3; CIGRE 413 – 2010 art. 10.1.4.);

b) Selective depolarization of oil, with the reagents S/CDP & S/CHED, through elimination of oxidation by products, corrosive sulfur compounds-DBDS and organic-metal compounds with the improvement of oil properties (electrical, physical and chemical according IEC 60422 Ed. 4 2012; § Table 5);

c) Decontamination of transformers and electrical equipments (extraction of PCBs, DBDS, moisture, sediments and sludge from solid materials inside the equipment).

Main function	Physical decontamination	CHEDCOS depolarisation	CDP PROCESS® dehalogenation
Recovery of dielectric properties	●	●	●
Recovery of the chemical properties of the oil (acidity, delta tg, colour)		●	●
Elimination of **DBDS** (main responsible of **corrosive sulfur** problem)		●	●
Elimination of dissolved organo-metallic contaminants		●	●
Dehalogenation / Detoxification of **PCB**/PCT/PCBT, POPs, compounds etc.			●

DMU (Decontamination Mobile Unit) for Multifunctional Integrated Treatments & Process

CDP & DMU - Process Description

The performances of the CDP & DMU are the result of experience matured (since 1968), of the use of multi-function Decontamination Mobile Units (DMUs) developed (designed and made by Sea Marconi) and of the formulation of specific reagents (S/CDP and S/CHED etc.) used on the basis of different operational scenarios. The CDP Process® developed by Sea Marconi Technologies – Italy, since 1982 (first patent), has been successfully used for the for the complete dehalogenation /detoxification of the 2,3,7,8 TCDD (Dioxin of the "Seveso Case" in the 1983)

The CDP & DMU technique was classified as BAT/ BEP by the Italian Ministry of the Environment, the Territory and the Seas Decree 29/01/2007 – Published on the Official Gazette n.133 titled Guidelines for the identification and utilisation of the Best Available Techniques on Treatment of PCBs, apparatuses and wastes containing PCBs and stocking systems:

"E.3 General comparative evaluation

A comparative evaluation of the various technologies available for the decontamination of PCBs is proposed on the basis of the following factors:

a) safety of workers;

b) environmental safety ;

c) functional safety;

d) eco-balance and emissions;

e) cost/benefit ratio.

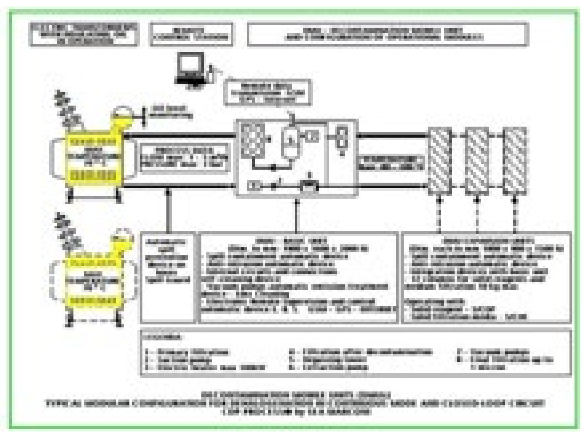
METHODS	Functional Safety	Environmental safety	Operator Safety	Eco-balance and Emissions	Global Cost/Benefit Ratio
Retrofilling	***	**	***	*	**
Sodium, Lithium and Derivates	*	*	*	**	*
KPEG	**	***	***	**	**
Continuous Closed-Loop Dehalogenation (CDP Process®)	***	***	***	****	****

CDP and DMU- BATCH mode diagram

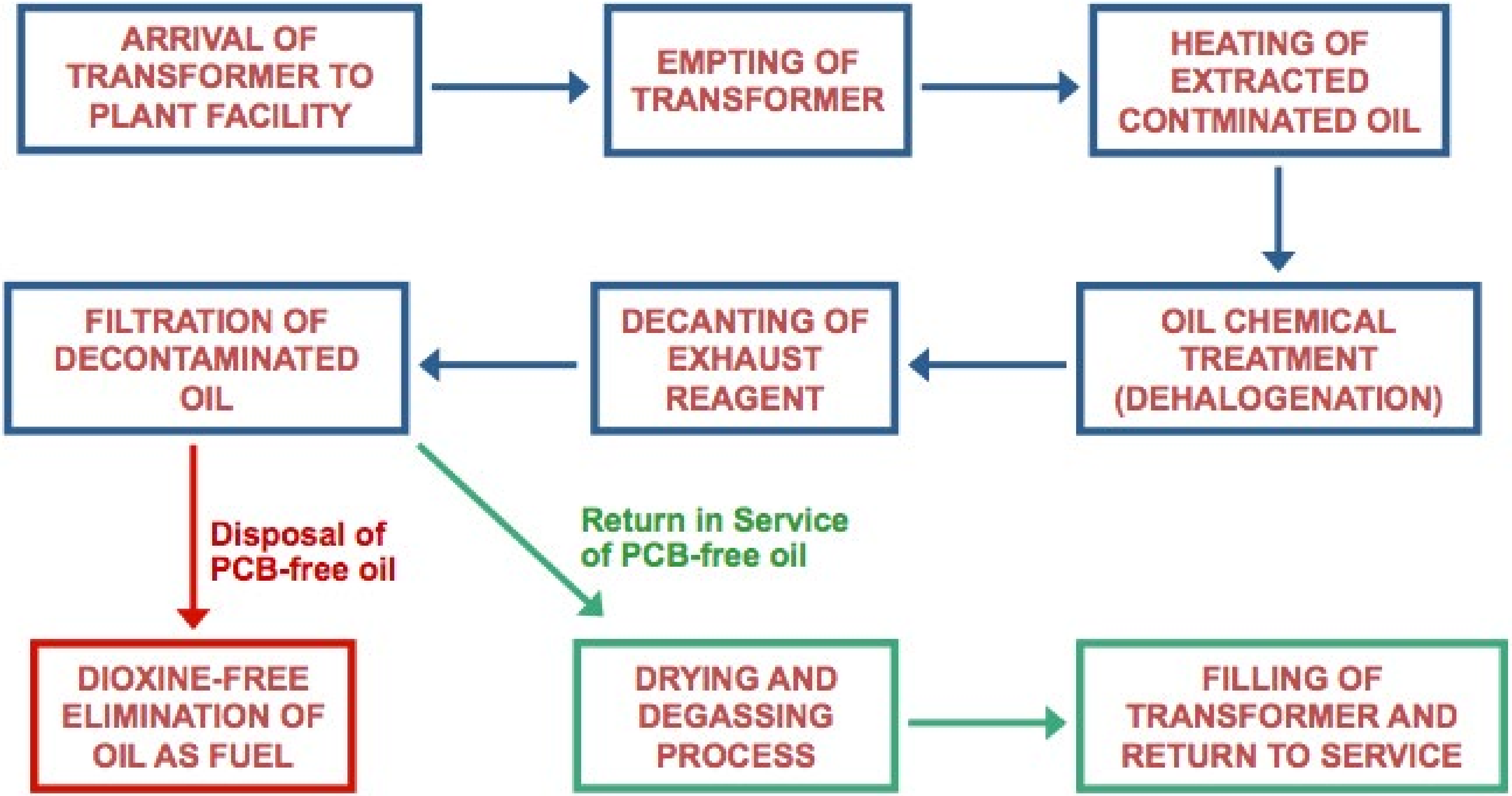
**** = OPTIMUM;   *** = GOOD;   ** = AVERAGE;   * = CRITICAL
Table E3 – Decisional matrix for the various available techniques

CDP and DMU – Generic scheme

DMU of multifunctional process is performed in a continuous manner by the closed-loop circulation of the oil, without draining the contaminated equipment; the latter is simply connected to a decontamination mobile unit (DMU), with a variable flow from 500 through 5.000 l/h. These mobile units are modular systems with compact dimensions equipped with automatic safety and process control systems capable of operating under all operational conditions (power generating stations, primary and transformation cabins, bunkerised substations etc.).

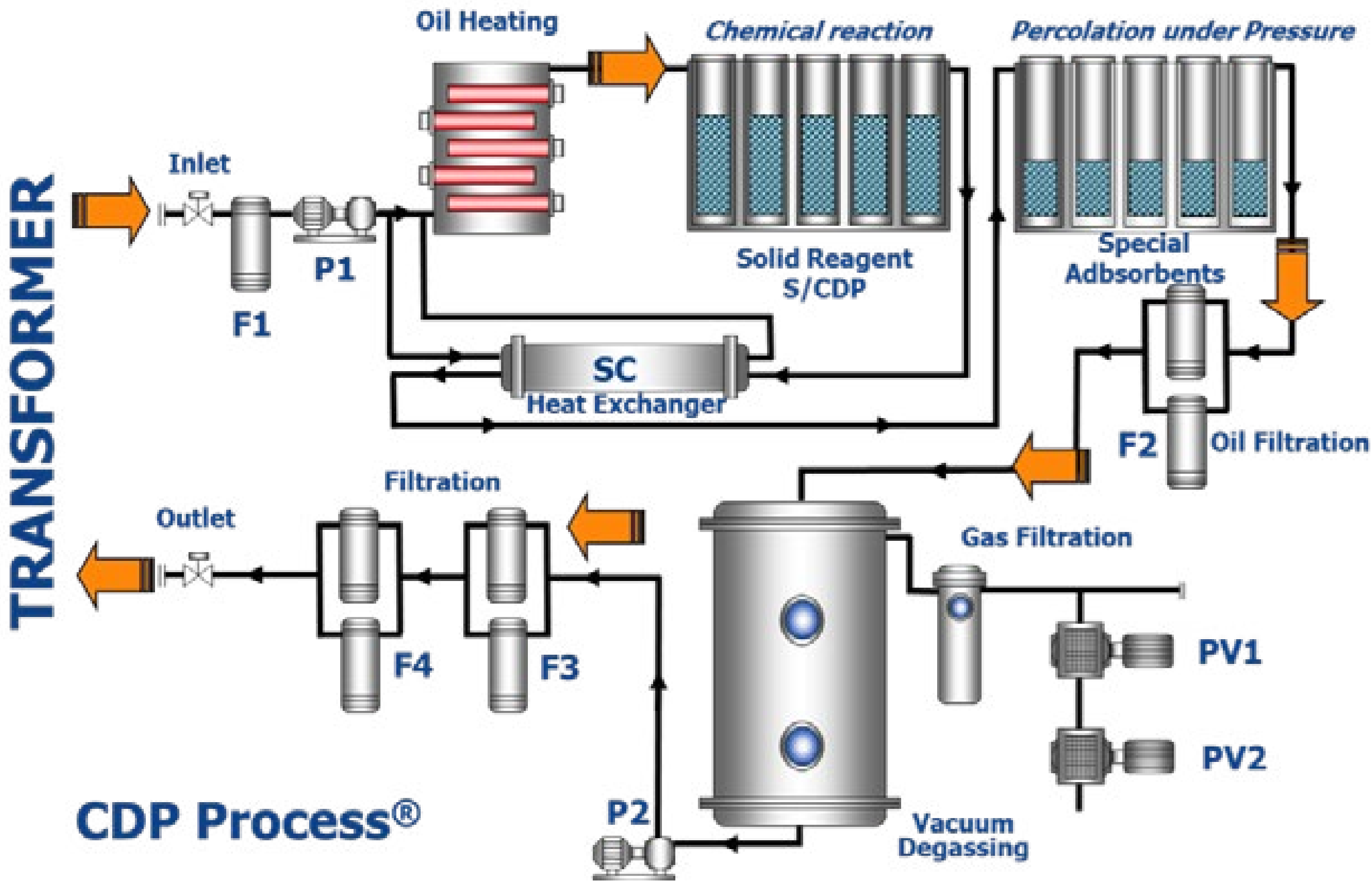


CDP and DMU - Dehalogenation in continuous mode diagram

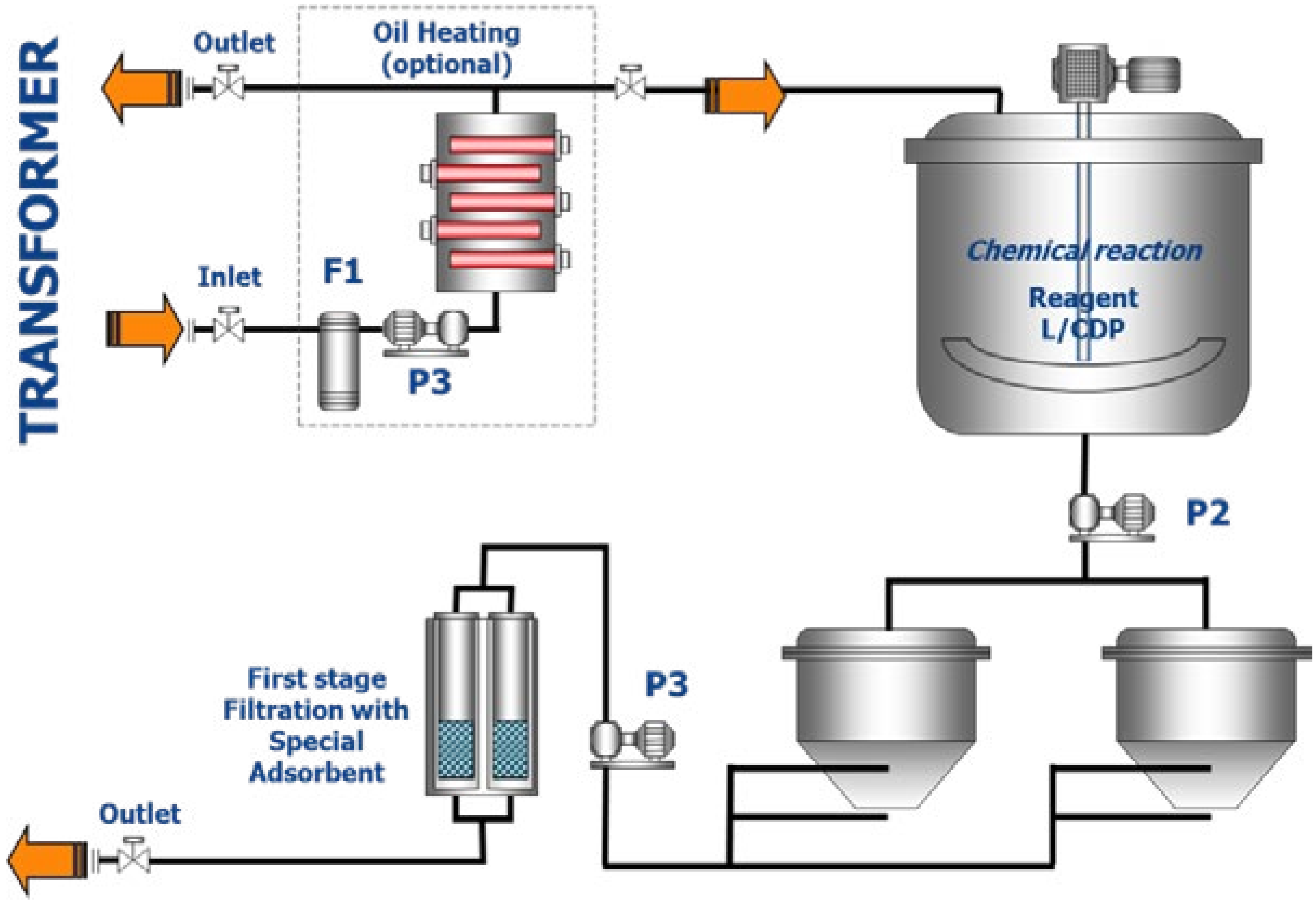


For the non-continuous technique (Batch process) the reagent is mixed with the oil in a reactor, the mixture is heated at 100 °C and stirred during the chemical reaction.

Typical configuration and pictures



CDP and DMU-Plant flow diagram



CDP and DMU -Typical configuration rendering and pictures

Typical Configuration and Pictures

CDP and DMU- Containerized unit connected with shunt reactor (500 kV) on-load treatment (Brazil 2010)

CDP and DMU- BATCH Typical Modular configuration rendering and picture

Sea Marconi Integrated Treatments" vs "Replacement of Oil"

Key Factors	Sea Marconi Closed loop treatment*	Replacement of Oil
On-Load Operation	Yes ✔	✖ **No** Off-Load for Draining and Refilling
Requirement of Unused Oil	No ✔	✖ **Yes** 125%/150% of original mass of oil**
Compatibility of Unused Oil vs original	Safety ✔	⚠ **Warning** base Oil, additives, others**
Recovery: Physical Properties KV, DGA, H_2O	Yes ✔	⚠ **Warning***** only after reconditioning of Unused Oil in closed loop §11.2.3 (IEC 60422 Ed. 4 2013)
Recovery: Chemical Properties TAN, DF, IFT	Yes ✔	⚠ **Warning***** only after reconditioning + reclamation treatments of Unused oil in closed loop §11.3 (IEC 60422 Ed. 4 2013)
Removal: DBDS & Corrosive Sulfur	Yes ✔	⚠ **Warning***** only if initial DBDS is < 80 mg/Kg or reclamation with special adsorbent
Desludging & Dehydration Solid Insulation	Yes ✔	⚠ **Warning***** only after reconditioning + reclamation of Unused oil in closed loop §11.3 (IEC 60422 Ed. 4 2013)

Sea Marconi Integrated Treatments" vs "Replacement of Oil"

Removal: DBDS & Corrosive Sulfur	Yes ✔	⚠ Warning*** only if initial DBDS is < 80 mg/Kg or reclamation with special adsorbent
Desludging & Dehydration Solid Insulation	Yes ✔	⚠ Warning*** only after reconditioning + reclamation of Unused oil in closed loop §11.3 (IEC 60422 Ed. 4 2013)
Decontamination: Dissolved Metals	Yes ✔	⚠ Warning*** only after reclamation with special adsorbent if initial value is 8/10 times higher than the target limit
Dehalogenation: PCBSs/POPs in Oils	Yes ✔	⚠ Warning*** only if initial PCBs is 8/10 times higher than the target limit
Self-cleaning unit from: DBDS, PCBs/POPs	Yes ✔	✖ No cross contamination***
Cross contamination by DBDS, PCBs/POPs	Safety ✔	⚠ Warning depending upon the used oil impregnated mainly in the solid insulation
Partial Discharges: bubble air & moisture inlet	Safety ✔	⚠ Warning especially for wet insulation
Environmental Risks for Oil handling	Safety ✔	⚠ Warning high logistical impact
Oil & PCBs Waste disposal	No ✔	✖ Yes especially if PCBs is higher than limit

SM Integrated Treatments" vs "Fuller Earth treatments

Key Factors	DMU & Integrated Treatments* Sea Marconi Patented	Treatment with typical Fuller Earth	Treatment with typical Fuller Earth and regeneration > 600-700 °C
Recovery: Physical Properties KV, DGA, H_2O	Yes	Yes	Yes
Recovery: Chemical Properties TAN, DF, IFT	Yes	Yes	Yes
Removal: DBDS & Corrosive Sulfur	Yes	No	No
Decontamination: Dissolved Metals	Yes	No	No
Dehalogenation: PCBs/POPs in Oils	Yes	No	No
Classification: BAT/BEP - Best Available Techniques/Best Environmental Practices (PCBs/POPs)	Yes	No	No
Self-cleaning unit from: DBDS, PCBs/POPs	Yes	No	No
Cross contamination by DBDS, PCBs/POPs	Safety	Danger	Danger
Corrosion by Sulfur Degradation byProducts (SDBP) as H_2S, Mercaptans, etc. due to high temperature (> 370 °C – typical 600-700 °C)	Safety	Safety	Danger
Dioxins Emissions (PCDDs, PCDFs) due to high temperature degradation byproducts from PCBs/POPs and halogenated contaminants in Oils	Safety	Safety	Danger

TYPICAL CASE HISTORY:

PCBs/POPs Free & Environmental Protection CYPRUS 1997

Elimination of PCBs from the insulating oil of distribution transformers - Electricity Authority of Cyprus

Total Transformers = 520

Solutions: DMU & PCBs Dehalogenation (CDP Process®)

Power max [KVA]: 10 - 1000
Voltage max [KV]:
Mass of contaminated oil [Kg]: 94,000
PCBs max [mg/Kg]: **15,000**
PCBs target [mg/Kg]: **< 10**

Result: **saving of 2 million USD**
(avoided transformer replacement and waste disposal)

CDP and DMU- Typical applications for distribution transformers on-site (Case History Cyprus - 1997)

TYPICAL CASE HISTORY:

PCBs/POPs Free & Environmental Protection
FRANCE 2004-2012

Utility – Power transformer of generation (nuclear, thermal, hydro), transmission and distribution

Total Transformers = 1,093

Solutions: DMU & PCBs Dehalogenation (CDP Process®) + Selective Depolarisation (Chedcos®) On Load/ Off Load

Power max [MVA]: 760
Voltage max [KV]: 400
Oil Mass [Kg]: 75,000 each
PCBs max [mg/Kg] = **5,000**
PCBs target [mg/Kg] = **<20** (after 90 days)

CDP and DMU- Typical applications for power transformers on-site (Case History France - 2004/2012)

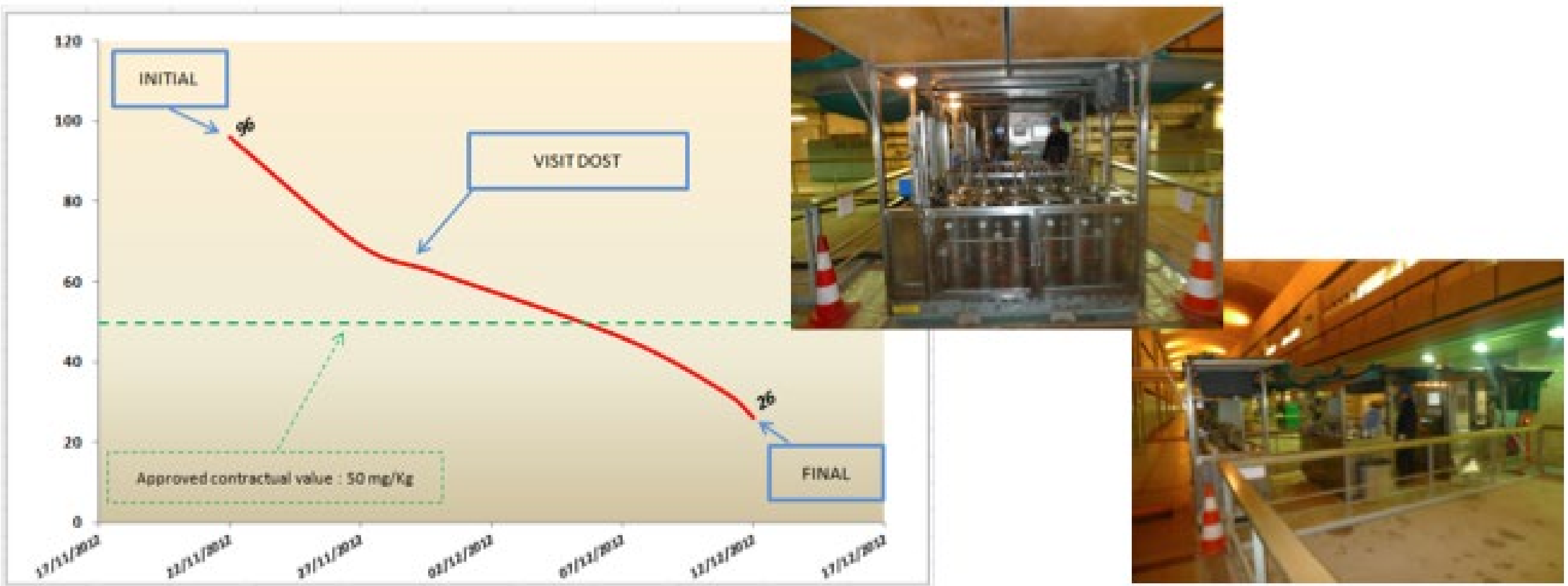
TYPICAL CASE HISTORY:

PCB + «C2 - NON DBDS & Corrosive Sulfur»

FRANCE 2012

Hydro Power Plant: 3 GSU Transformers

Solutions: DMU & PCBs Dehalogenation (CDP Process®) + Selective Depolarisation (Chedcos®) On Load



CDP and DMU- Typical applications for power transformers on-site and on-load (Case History France - 2012)

TYPICAL CASE HISTORY:
PCBs + «C1 - DBDS & Corrosive Sulfur» SWEDEN 2012

Primary alluminiun factory: 8 Rectifier Transformers

Solutions: DMU & PCBs Dehalogenation (CDP Process®) + Selective Depolarisation (Chedcos®) On Load

Manuf.: Brown Boveri
Year: 1930
Power [MVA]: 19
Voltage [KV]: 13
Oil Mass [Kg]: 15,000
Oil type: mineral blended

	PCBs [mg/Kg]	DBDS	IFT [mN/m]	CCD test	TAN [mg KOH/g]	DF
Before treatment	29	18	24	corrosive	0,34	0,230
After treatment	0,37	< 5	42	non corrosive	0,01	0,002

GUARANTEE: PCBs < 2 mg/Kg

CDP and DMU- Typical applications for power transformers on-site and on-load (Case History Sweden - 2012)

Manufactures	Jeumont Schneider
Year	1969
Power	105 MVA
Voltage	225 KV
Oil Mass	29.000 Kg
Total Mass	126.000 Kg
Oil Type	Mineral

OIL PROPERTY (IEC 60422 ed. 4 2013-01)	BEFORE	AFTER
Colour (ASTM D1500-07)	> 8	2,7
Breakdown Voltage (kV)	73,1	75
Water content (mg/Kg)	6	2
Acidity (mg KOH/g)	0,294	< 0,01
Dielectric Dissipation Factor at 90°C	1,023	0,09211
TCS - Total Corrosive Sulfur - DBDS equivalent (mg/Kg)	69	8
Interfacial tension (mN/m)	18,8	33,3
2-FAL (mg/Kg)	0,583	< 0,05
Total PCB content (mg/Kg)	71	25
Copper dissolved (mg/Kg)	64	2
Particles (ISO 4406:1999)	23 / 20 / 14	17 / 15 / 10
Note: PCBs Garantee < 50mg/Kg		

CDP & DMU-FIELD SCREENING TEST & DIAGNOSTIC IN LABORATORY

The CDP & DMU use the preliminary determination of the content of total chlorine, trough SM-TCPs KIT ; SM-TCPS test kit by Colorimetric; SM-TCS Test Kit; Sea Marconi and total acid number SM-TAN KIT by Sea Marconi.

Some representative samples of insulating liquids to be taken before, during and after the treatments to be analyzed in accredited Laboratory (SEA MARCONI has the accreditation N. 0899 by ACCREDIA). Test for total PBSs, Acid number, gases, breakdown voltage, dissipation factor, particles, moisture, DBDS, additives content, etc. according to IEC 60422 and diagnostic reports to be reclassified “NO PCBs Oil & Transformer”.

Kit for Total Chlorine/PCB

The scope of this SM - TCPs - Colorimetric kit is to provide, a quantitative Smart Field Test (SFT) for non-chemist, for the Life Cycle Management (LCM) and the related activities of inventory, control, management, decontamination and/or disposal of electrical equipments and containers with insulating liquids (such as mineral insulating oils) containing PCBs, in compliance with the European Council Directives (96/59/EC) using Best Available Techniques – BAT – (96/61/EC), Best Environmental Practices (BEP), Commission Decision (2001/68/EC), according to Stockholm Convention on Persistent Organic Pollutants (POPs)-2001, IEC 60422 Ed.4-2013, CENELEC CLC/TR 50503 February 2010, CIGRE 413 April 2010, other technical standards and/or national or local regulations.

Conclusion

The Sea Marconi solutions for Loss Prevention LCM O&T can prevent and/or mitigate the potential losses and unreasonable risks for the asset, workers, public health and environment.

These solutions are targeted for protection of specific fleet of strategic electrical equipment filled with insulating fluids.

This approach guarantees knowledge added value for Customers, Holders and Partners in terms of best innovative technologies, reliability, quality control, traceability, economics, environmental protection, social and stakeholders’ relationship.

Life Cycle Management (LCM) for insulating liquids and electrical equipment PCBs contaminated based on state of the art, IEC & CENELEC standards, Best Available Techniques (BAT) & Best Environmental Practice (BEP):

- PCBS INVENTORY
- PCBS CONTROL
- PCBS DECONTAMINATION AND/OR DISPOSAL

References

[1] EN 12766-1 Petroleum products and used oils - Determination of PCBs and related products - Part 1: Separation and determination of selected PCB congeners by gas chromatography (GC) using an electron capture detector (ECD);

[2] EN 12766-2:2001 Petroleum products and used oils - Determination of PCBs and related products - Part 2: Calculation of polychlorinated biphenyl (PCB) content EN 12766-3 Petroleum products and used oils - Determination of PCBs and related products - Part 3: Determination and quantification of polychlorinated terphenyls (PCT) and polychlorinated benzyl toluenes (PCBT) content by gas chromatography (GC) using an electron capture detector (ECD);

[3] EN 50195 Code of practice for the safe use of fully enclosed askarel-filled electrical equipment;

[4] EN 50225 Code of practice for the safe use of fully enclosed oil-filled electrical equipment which may be contaminated with PCBs;

[5] EN 60567 Oil-filled electrical equipment - Sampling of gases and of oil for analysis of free and dissolved gases - Guidance (IEC 60567);

[6] EN 60599 Mineral oil-impregnated electrical equipment in service - Guide to the interpretation of dissolved and free gases analysis (IEC 60599);

[7] EN 61198 Mineral insulating oils - Methods for the determination of 2-furfural and related compounds (IEC 61198);

[8] EN 61619 Insulating liquids - Contamination by polychlorinated biphenyls (PCBs) - Method of determination of PCBs by capillary column gas chromatography (IEC 61619);

EN 62535 Insulating liquids - Test method for detection of potentially corrosive sulphur in used and unused insulating oil (IEC 62535);

[9] EN 60296 Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear (IEC 60296);

[10] EN 60422 Ed.4 -2013 Mineral insulating oils in electrical equipment - Supervision and maintenance guidance;

[11] EN ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025);

[12] EN 60666 1) Detection and determination of specified anti-oxidant additives in insulating oils (IEC 60666);

[13] EN ISO 12185:1996 Crude petroleum and petroleum products - Determination of density - Oscillating U-tube method (ISO 12185:1996);

[14] ISO 3016 Petroleum products - Determination of pour point;

[15] EN ISO 9001 Quality management systems - Requirements (ISO 9001);

[16] CENELEC CLC/TR 50503 Guidelines for the inventory, control, management, decontamination and/or disposal of electrical equipment and insulating liquids containing PCBs;

[17] IEC 60475 Methods of sampling liquid dielectrics;

[18] IEC 60588 series Askarels for transformers and capacitors;

[19] IEC Test methods for quantitative determination of corrosive sulfur compounds in used and used insulating liquids- Part 1:Test method for quantitative determination of dibenzilsulfide (DBDS);

[20] ASTM D 971 Standard test method for interfacial tension of oil against water by the ring method;

[21] ASTM D 7151 Standard test method for determination of elements in insulating oils by inductively coupled plasma and atom emission spectrometry (ICP-AES);

[22] CIGRE Insulting oil regeneration and dehalogenation Brochure 413 Working Group D.1.01 (TF 12);

[23] CIGRE Copper sulphide in transformer insulation Brochure 378 Working Group A2.32;

[24] Italian Ministry of the Environment, the Territory and the Seas Decree 29/01/2007 – Published on the Official Gazette n.133 titled Guidelines for the identification and utilisation of the Best Available Techniques on Treatment of PCBs, apparatuses and wastes containing PCBs and stocking systems;

[25] Council Directive 75/442/EEC of 15 July 1975 on waste - Official Journal L 194, 25/07/1975 P. 39 – 41;

[26] Directive 96/56/EC of the European Parliament and the Council of 3 September 1996 amending Directive 67/548/EEC on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances - Official Journal L 236, 18/09/1996 P. 35 – 35;

[27] Council Directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT) - Official Journal L 243, 24/09/1996 P. 31 – 35;

[28] Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control - Official Journal L 257, 10/10/1996 P. 26 – 40;

[29] 2001/68/EC: Commission Decision of 16 January 2001 establishing two reference methods of measurement for PCBs pursuant to Article 10(a) of Council Directive 96/59/EC on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCBs/PCTs) (notified under document number C(2001) 107) - Official Journal L 023, 25/01/2001 P. 31 – 31;

[30] Stockholm Convention on Persistent Organic Pollutants. Stockholm, 22 May 2001 entry into force 17 May 2004 in accordance with article 26;

[31] Conference of the Parties to the Basel Convention on the Control of Transboundary Movements Of Hazardous Wastes and Their Disposal - Eighth meeting, Nairobi, 27 November–1 December 2006;

[32] UNEP (United Nations Environment Programme) - October 2002;

[33] Destruction and Decontamination Technologies for PCBs and other POPs Wastes under the Basel Convention. A Training Manual for Hazardous Waste Project managers. Volume A, Volume B;

[34] UNEP (United Nations Environment Programme) -- March 2003;

[35] Preparation of a National Environmentally Sound Management Plan for PCBs and PCBs -Contaminated Equipment. Training Manual;

[36] UNEP (United Nations Environment Programme)--K0760107 260307 Technical guidelines on environmentally sound management of waste containing or contaminated with unintentionally produced polychlorinated dibenzo-p-dioxins (PCDDs) polychlorinated dibenzofurans (PCDFs), hexachlorobenzene (HCB) or polychlorinated biphenyls (PCBs);

[37] UNEP(United Nations Environment Programme)--K0760113 180607;

[38] Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs);

[39] UNEP(United Nations Environment Programme)--K0760119 230307;

[40] Updated technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with polychlorinated biphenyls (PCBs), polychlorinated terphenlyls PCTs) or polybrominated biphenyls (PBBs);

[41] UNEP - May 2007, Geneva, Switzerland;

[42] Guidelines on Best Available Techniques and provisional guidance on Best Environmental Practices relevant to Article 5 and Annex C of Stockholm Convention on Persistent Organic Pollutants.

HIGH VACUUM DESORPTION PROCESS FOR DECONTAMINATION OF EQUIPMENT AND MATERIAL CONTAMINATED BY PCBs

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Abstract

Vacuum Technology is the term applied to all processes and physical measurements carried out under conditions of below normal atmospheric pressure.

High vacuum desorption is a decontamination process which extracts the liquid phases, include PCBs, from contaminated materials.

In 2006, after 5 years of R&D, APROCHIM adapted the vacuum technology for its decontamination process of equipment and materials contaminated by PCBs.

It allows the treatment of full transformers without prior intervention, unlike other methods of decontamination. Thus, the contaminated transformers are not dismantled prior to treatment, which allows operators not to be in a direct contact with contaminants and to guarantee a better respect of strong requirements in the field of environment protection.

It is mainly applicable for transformers and other contaminated equipment and solid materials (including: electro magnets, breakers, relays, ballasts, cables, radiators, drums, piping, vessels, valves and debris).

Keywords

PCBs, oil contaminated, contaminated materials, decontamination process, high vacuum technology, working conditions.

A.General description:

APROCHIM is a French company created in 1988, which is specialized in management and treatment of wastes contaminated by PCBs.

APROCHIM is authorized by the French authorities to process PCBs contaminated equipment in his facility in France (capacity: 30 000 tons/year).

Figure 1: APROCHIM decontamination plant in France

Until 2006, like many of its competitors, APROCHIM used autoclaving technology with solvent (perchloroethylen - PER) for decontamination of electrical transformer and materials contaminated with PCBs.

Decontamination with solvent (PER) is an efficient decontamination though it has three drawbacks, i.e.:

• Implementation of a management plan for used solvent

• Control emission of volatile organic components due to the solvent use

• Risks of contact for operators with contaminated materials during phase of preliminary-dismantling of equipment

In order to respond to these drawbacks, the high vacuum technology has been exclusively adapted by APROCHIM for his decontamination process. The principle is to make the evaporation of PCBs from materials by vacuum and temperature easier.

This process has permitted to make a treatment without use of solvent (principle of "wash without detergent") and to avoid a preliminary partially dismantling of contaminated equipment (devatting) before the decontamination process.

B. Description of method:

Electrical transformers and equipments are usually delivered completely or partially filled with PCB liquid or mineral oil polluted by PCBs.

Preliminary phases:
The phases before the decontamination process are as follows:

- Control of weight;
- Pumping and draining of PCB liquid or oil contaminated from the equipment; and
- Dismantling of the electrical bushings (this phase permits a better extraction of PCBs from the transformers during the process).

6 high vacuum chambers are used for the decontamination process.

The duration of treatment on average accounts for 30 hours.

Figure 2: High vacuum chambers

The method for decontaminating polluted materials is divided into the following steps:

1) **Loading** the material to be treated into a chamber capable of being placed under high vacuum;

2) **Inerting**: the chamber is placed under a first vacuum of less than 20 mbar, and then an inerting gas is injected, particularly nitrogen, until the pressure in the chamber rises back up above approximately 950 mbar;

3) **Heating** the contents of the chamber under forced convection, to a temperature that is kept under or equal to approximately 200°C;

4) **High vacuum and pumping**: the chamber is again placed under vacuum, up to a residual pressure of approximately 0.1 mbar, and the heating is continued; then an inert gas, in particular nitrogen, is injected, until the pressure rises back up to approximately 950 mbar. During this phase, PCBs or oils contaminated move from liquid form to gaseous form. The gas is pumping outside and hand it in liquid form by condensation. The extracted polluting/contaminating substances are removed in the form of a distillate.

5) **Cooling the content** of the chamber by circulating glycol water at 5 ° C in a network of finned tubes.

6) **Unloading**: Polluted devices are PCB free and can be unloaded for being first analysed and dismantling.

After decontamination and control of PCB rate, transformers are totally dismantled and each material is recycled and has a second life (steel, copper, magnetic ferro-silicon plate, ceramic...). This step helps significantly to reduce the cost of treatment. Only, papers and woods are incinerated with energy recovery heat.

The extracted liquids are stored in tanks awaiting shipment toward authorized installation for material valorization (hydrochloric acid) or energy recovery (high temperature incineration).

The process enables the decontamination of solids contaminated with PCBs without producing dioxins or furans: Indeed, PCBs have a high thermal stability, and these latter increases as the chlorine content increases. They decompose at temperatures above 300°C. Pyrolysis of PCBs (between 300 ° C and 1000°C) in the presence of oxygen leads to the formation of small quantities of Polychlorinated dibenzofurans (PCDFs) and Polychlorinated dibenzodioxins (PCDDs) compounds.

Figure 3: High vacuum process adapted for materials contaminated by PCBs

To avoid degradation of PCB, treatment in high vacuum chambers is done without oxygen (nitrogen inerting) and is strictly limited to temperature of 250 ° C maximum.

C. summary characteristics of high vacuum technology (pros and cons):

Advantages of the technology:

- Technology adapted for materials contaminated with pure PCBs or high rate of PCBs.

- PCB rate in recovery products is always under 20ppm after decontamination.

- Drop in waste generation after treatment (no used solvent).

- Energy costs have been reduced.

- Improved working conditions: operators don't have contact with contaminated materials because equipments are completely dismantled after decontamination.

	Limit values	Average analyzes on two years (May 2011-May 2013)
Magnetic plates in ferrosilicon	< 50ppm (indicator PCB - PCBi)	6.9 ppm
Scrap metal	< 50ppm (PCB_i)	5.7 ppm
Crushed copper	< 50ppm (PCB_i)	3.5 ppm
Ceramic	< 50ppm (PCB_i)	4.1 ppm
Aluminium	< 50ppm (PCB_i)	5.9 ppm
Red copper	< 50ppm (PCB_i)	7.0 ppm
Alloy (brass etc..)	< 50ppm (PCB_i)	14.8 ppm
Recovered oil	< 50ppm (PCB_i)	19.2 ppm

Table 1: Results of an analysis of recovery products

Figure 4: Air filtration system and wastewater treatment plant on site of APROCHIM

Drawbacks of the technology:

- No mobility: the high level of requirements in the field of environmental protection doesn't allow to this technology to be implemented in mobile processing units.

• To meet the limits of gas emissions values, a set of processing devices has to be established like absorption of gaseous component on activated carbon and capture of dust.

• To meet the limits of wastewater emissions (storm waters), a water treatment plant is needed.

In order to respond to this drawback, APROCHIM has developed a full service from administrative support to logistic solutions in accordance with Basel convention, international and national regulations for the transportation of hazardous goods (ADR – IMDG- RID and European regulations).

- Strong technical training for operators and maintenance workers due to the technicity of the process.

Other applications for this technology: This decontamination technology is adapted for decontamination of waste contaminated by pure PCBs and by oil contaminated by PCBs.

It isn't a destruction method, but it permits to extract pollutants from organic and inorganic wastes and allows reused of decontaminated materials (copper, steel..).

It should be noted that all other pollutants and/or contaminants with similar volatility or comparable to PCBs can also be extracted and collected by the process. As non-limiting examples of such pollutants / contaminants: complexes halogenated or non-halogenated vacuum distillable compounds; chlorinated and/or brominated volatile.

References

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Wikipedia: Vacuum http://en.wikipedia.org/wiki/Vacuum

CO-PROCESSING PCB & OTHER POP'S IN CEMENT KILNS

- A LOCAL SOLUTION

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The Netherlands

About ARP

The main priority of Alternate Resource Partners is to aid industry and government in their effort to efficiently recover valuable resources from their waste guided by the Waste Hierarchy using strict environmental and safe practices.

A growing attention of the public over the effects of climate change, the search for alternative energy sources and the drive towards sustainable development has led to great improvements in the recycling of waste materials. However, there are numerous sources of residual waste from fabrication processes that await transformation into useful energy and materials which will allow for a significant reduction in the requirement of fossil fuels and other raw materials.

To allow this transformation to happen, it is essential that a different approach is taken towards waste. Instead of thinking of waste as useless and disposable material, there should be a mindset of investigating possible uses of waste and application of found possibilities.

To accommodate such a re-setting of minds, it imperative that a three layered approach is used:

- Education of the government, industry and investors;
- Identification of the opportunities for possible reuse or recycling of waste; and
- Implementation of the identified opportunities with or for the customer.

As a consultant, coach or sparring partner Alternate Resource Partners is well-positioned and experienced to provide you with the right approach and tools.

Manufacturing of cement

Manufacturing of cement has 3 different phases:

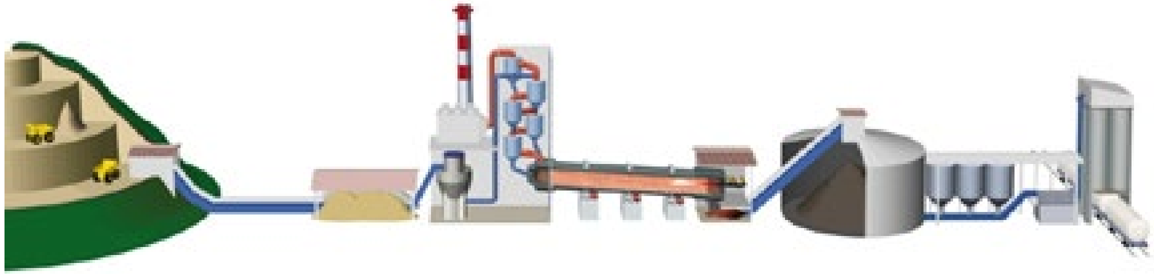
- Preparation of raw materials into raw meal
Extraction – Crushing – Pre-homogenisation - Dosing – Grinding - Homogenisation

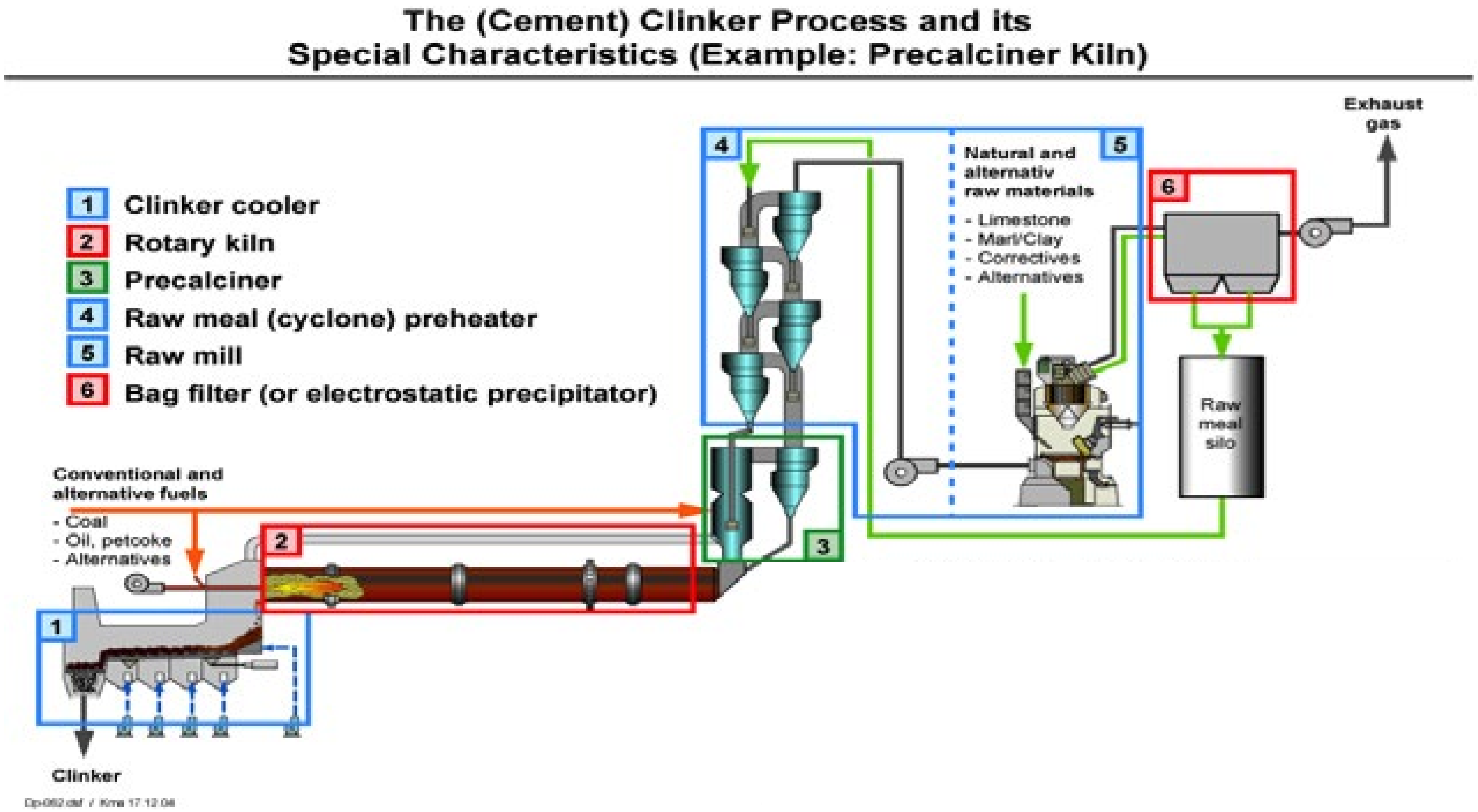
- Clinker production – pyro-processing of raw materials
Calcination of the raw meal into the rotary kiln – energy supplied by burning fuels

- Cement production
Grinding of clinker and mineral components to obtain cement

In the figure represented below, you can see the different components of a cement kiln and the introduction points for raw materials and Alternative fuels. The table contains the various temperatures in the different stages of the manufacturing process.

Schematic picture of the 3 phases of cement manufacturing





Equipm.	Temperatures Gas	Temperatures Mat.	Resid. Times Gas [sec]	Resid. Times Mat.[min]	Remarks
1	20-1000	1200-100	3-5	10	
2	2000-1050	850-1450	3-5	20	All organics burnt, Ash=raw mat.,incorporated in cli
3	1200-880	750-850	2-6	0.1-0.2	SO_2 and HCl trap due to presence of CaO
4	880-350	80-750	10-15	0.2-0.3	Acts as a 5 -stage dry scrubber for combustion gases
5	350-100	20-80	5-10	0.2-0.3	
6	100	100	10-15	0.2-0.3	99.999 % dedusting efficiency

Co-processing in cement kilns

What is co-processing?

Co-processing is the use of waste or by-products from one industrial process, as fuel or raw material substitutes in another manufacturing process.

In the cement community, these materials are referred to as alternative fuels and raw materials or AFR.

In the following industries, co-processing could be applied:

- Cement manufacturing
- Thermal power industry
- Steel industry
- Lime production
- Ceramics, bricks, glass
- Chemical industry
- Petroleum industry

What are the benefits of co-processing?

Benefits of co-processing are as follows:

- Provides a permanent solution to waste management problems
- Lessens reliance on fossil fuels
- Preserves natural resources
- Reduces emissions and greenhouse gases
- Saves on fuel costs

In short . . .

Co-processing is the environmentally-friendly alternative for responsible industries and communities

Co-processing (treatment) of POP's in cement kilns

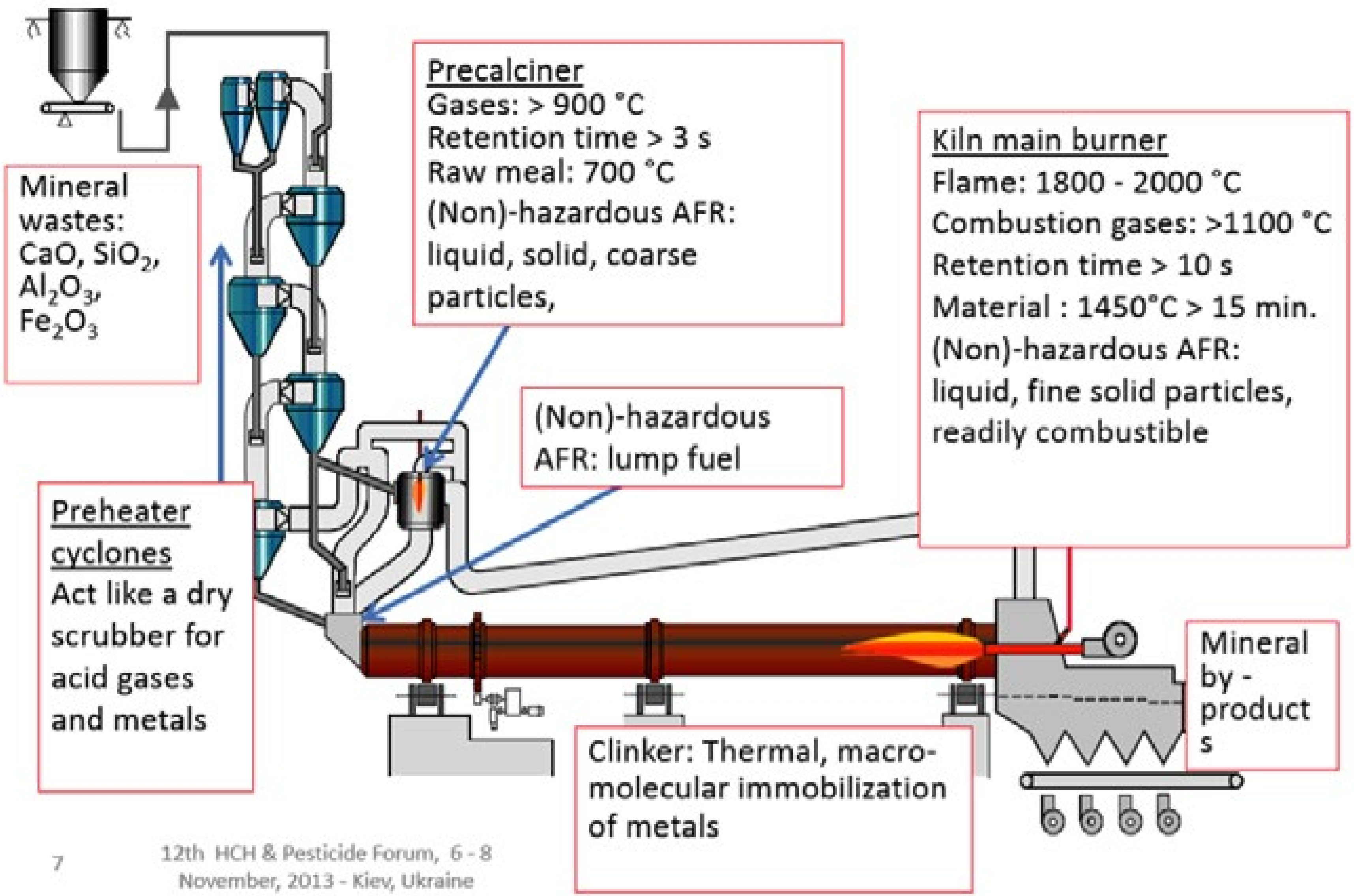
Technical characteristics of cement kiln

In the figure illustrated on the next page, you find the details on characteristics and feeding points of the various AFR – hazardous and non-hazardous, lump and fine, fuels and raw materials of :

- Pre-calciner
- Pre-heater
- Kiln main burner
- Feeding of nonhazardous lump fuels
- Feeding of (non) Hazardous liquids, solids

Furthermore, you will find the temperatures of gas and materials in the kiln stages as well as be able to understand what is actually happening in these parts of the kiln.

POP's, depending on their chemical and physical properties, will be fed to the kiln at the appropriate feeding points.


Mineral wastes: CaO, SiO_2, Al_2O_3, Fe_2O_3
Precalciner
Gases: > 900 °C
Retention time > 3 s
Raw meal: 700 °C
(Non)-hazardous AFR: liquid, solid, coarse particles,
Kiln main burner
Flame: 1800 - 2000 °C
Combustion gases: >1100 °C
Retention time > 10 s
Material : 1450°C > 15 min.
(Non)-hazardous AFR: liquid, fine solid particles, readily combustible
(Non)-hazardous AFR: lump fuel
Preheater cyclones
Act like a dry scrubber for acid gases and metals
Mineral by - product s
Clinker: Thermal, macro-molecular immobilization of metals
7
12th HCH & Pesticide Forum, 6 - 8 November, 2013 - Kiev, Ukraine

In the acceptance procedures for the AFR, the necessary analyses are made on both chemical and physical properties to have enough information to judge which feeding point to use, in the next part of this paper we will also explain more on the trial burns which might be part of the acceptance procedures if not enough information is available on the destruction behavior in the specific kiln where the POP's are being treated.

Main test results of co-processing PCB's

When PCB's are treated in a cement kiln for the first time and not enough data on the destruction efficiency is available, trial burns will be made.

In all kilns that co-process AFR an Emission monitoring and reporting scheme(EMR) has to be installed, the EMR should, at a minimum, contain the following components:

- **Implementation of continuous emission measuring equipment** for dust, SO2, NOx and VOC (and O2) on all cement kiln stacks

- At least a **once per year measurement** of HCl, NH3, C6H6, PCDD/DF and heavy metal emissions

- At least a **once per year calibration** of the CEM equipment

- The **yearly report** of results in a CSR report in a standardized form (Normal conditions, 10% O2, dry)

PCB Trial burn

A (PCB) trial burn testing scheme takes typically 3 days.

Day 1 Baseline emission testing in Compound mode of operation (with raw mill on) & no PCB
Day 2 AFR trial burn emission testing in Compound mode of operation (with raw mill on) and Burning of PCB, 2 ton/h (approx.10% fuel replacement) at main kiln burner
Day 3 Baseline emission testing, Direct mode of operation (with raw mill off) and no PCB.

During the trial, burn the following parameters need to be collected:

Besides the abovementioned parameters, the following operational parameters need to be collected:

- Temperature in kiln inlet
- CO content in kiln inlet
- O_2 content in kiln inlet
- Waste feed rate, energy and chlorine content
- Energy efficiency
- Primary combustion air flow rate
- Total fuel feed rate
- Raw meal consumption, clinker production, quantity and quality

Parameter	Unit	How the value is obtained
Mass flow rate concentration of PCB	g/min	Measured during test & calculated from flow and density
Flow volume of PCB	l/min	Measured during test
Density of PCB	g/ml	Density analysis from lab
Concentration of compound in stack sample	Nm3	Calculation from sample train
Stack flow volume	Nm3/h	Normative and current values

With respect to the Baseline emission testing, the table depicted below is giving the necessary information on the parameters.

Parameter	Mode of Operation	Note
Heavy Metals	Direct & Compound	
HCl, NH3, C6H6	Direct & Compound	(1)
PCDD/PCDF	Direct & Compound	(2)

Notes:

(1) Generally the emission of these substances is higher in direct operation.

(2) The PCDD/PCDF emission of a dry kiln is very low.

Sampling solids during PCB trial burn:

The following solid materials samples need to be taken during the trail brum

• Raw meal

• Clinker

• Coal (fine)

• EP dust

• Cement (from bag filter)

These samples have to be analyzed on the following parameters:

• PCB's

• Heavy metals (As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Sb, Sn, Tl, V, Zn)

• Cl, F, K, Na, NH3

The samples have to be taken during

• Baseline testing 1 – No PCB, raw mill on

• Trial burn – With PCB, raw mill on

• Baseline testing 2 – No PCB, raw mill off

Some pictures on a trial burn at a cement plant & Results in local plant

Emptying PCB drums for trial burn

Emission testing facility on kiln stack

Trial burn of PCBs -Pyralene oil with 56-62% of PCB's, 33-38% tri-chloro-benzene, 5-6% tetra-chloro-benzene

Results of trial burn
DRE
>99.99999998% & 99.999999995%
In 2 different scenarios
Emissions not effected by PCB

Notes: these results respect BAT/BEP guidelines of Stockholm Convention and Basel Convention, i.e. a DRE of 99.9999%.

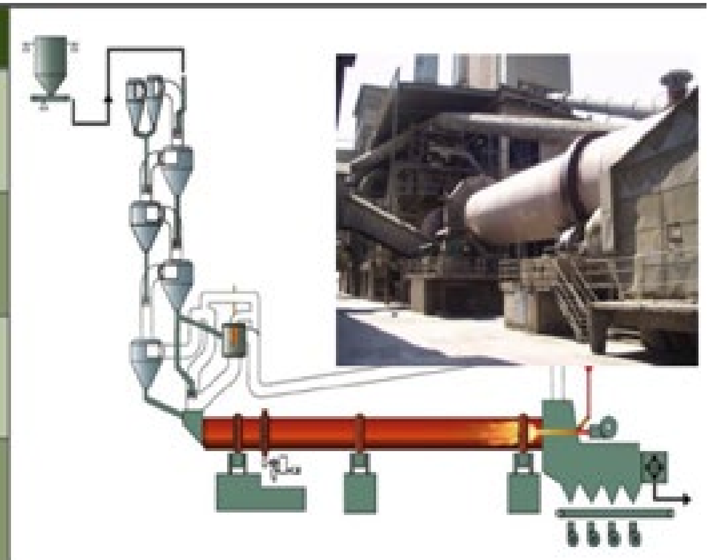
Main Conclusions

- Burning of AFR does not significantly affect the emission of the cement kiln
- The hazardous wastes destructed well in the kiln
- No additional pollution generated with burning of AFR
- Quality of clinker and cement products not changed

International development & recognition of solution

- GTZ – Holcim Alliance : Co-processing Guidelines, more info on www.coprocem.org

Characteristics	Temperature and time
Temperature at main burner	>1450°C: material >1800°C: flame temperature.
Residence time at main burner	>12-15 sec and >1200°C >5-6 sec and >1800°C
Temperature at precalciner	>850°C: material >1000°C: flame temperature
Residence time at precalciner	>2 - 6 sec and >800°C



International Technical Guidelines
- Basel Convention


UNITED NATIONS

UNEP

BC

UNEP/CHW.10/6/Add.3/Rev.1

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11 November 2011

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BASEL CONVENTION

Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal
Tenth meeting
Cartagena, Colombia, 17–21 October 2011
Item 3 (b) (i) of the provisional agenda*
Matters related to the implementation of the Convention: scientific and technical matters: technical guidelines

Technical guidelines

Note by the Secretariat

Addendum

Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns

At its tenth meeting, the Conference of the Parties adopted, as amended, the technical guidelines on the environmentally sound management co-processing of hazardous wastes in cement kilns on the basis of the draft contained in document UNEP/CHW.10/6/Add.3, which was prepared by the Government of Chile. The text of the final version of the technical guidelines is set out in the annex to the present document.

For full tekst of guidelines visit website
www.basel.int/TheConvention/Publications/TechnicalGuidelines/tabid/2362/Default.aspx

Observations & Conclusions on way forward

- The cement kiln offers a highly advantageous system for co-processing because…..
• high gas and material temperatures in addition to long residence times in the kiln, virtually destroy all organic materials potentially present in alternate fuels, and
• alternative raw materials supply necessary chemical constituents of cement (calcium carbonate, silica, alumina, and iron).
- Cement companies have a local sustainable solution for PCB containing liquids & contaminated solids like PPM's, cleaning materials etc.),
- No long transport routes with these waste materials lower risk and lower cost or bigger volumes for same budget
- No investments needed in waste disposal infrastructure so budget can be used for other also much needed infrastructure in emerging countries materials.

Take home messages

- There is a great and urgent global need for the services of the cement industry based on general sustainability principles but in particular for hazardous waste co-processing in emerging countries

- The principles and philosophy/policy developed & adopted by Holcim on AFR practices are currently among the most responsible and advanced in the industry

- The "only" way forward is to document and publish the performance and practice, especially from well-designed studies in emerging countries.


Pre-processing
Liquids
Solids
Social
Co-processing
Economic
Environmental

PCB TREATMENT IN THE FUTURE

J. Ledure & T. Dawance
SITA Decontamination

Abstract

2 different problems will have to be tackled in the future:

- PCB containing equipment

- PCB light contaminated equipment

This paper has as objective to highlight the challenges the society are being faced with with regard to those problems. Proven technologies exist. No one solution can cover all aspects. Combination solutions have to be offered to be at the same time environmentally friendly and economically viable for the holders of contaminated equipment.

Indeed, different approaches and philosophies have to be adopted, maximizing local content and involvement.

SITA Decontamination has developed a cooperative approach with partners to offer those global solutions including local content.

Keywords

PCB; future challenges; cooperative approach; local content.

Article

The aim of this paper is to share some thoughts about the development of the PCB elimination into the future.

Europe is almost done with to the final elimination of its PCB waste, with a deadline for most countries to the end of 2010. Existing facilities have been used up to now to decontaminate not only PCB filled equipment, but also equipment filled with light contaminated oil.

Previously, because land transport was the cheapest and easiest way, most of the equipments to be decontaminated were shipped in drip trays, but filled with liquid. Thus, all of the operations were done on a single location. By now, these existing facilities need to use sea transport which requires equipment to be shipped drained and liquids to be shipped in UN approved containers following strictly the IMDG norms (containers well labelled, the material attached, absorbent, etc.).

The world of PCB is evolving. In the future, we will have to focus on the three following themes:

1. There is a significant difference in the approach between PCB containing equipment and PCB light contaminated equipment.

2. Local content and possibilities have to be developed, taking into account sometimes limited tonnages to be found in some countries.

3. Respect of a Quality Chart about the health of the workers, the emissions of PCB and the quality of the recycled material.

Let me now develop these themes.

1. PCB equipment

The source of all the troubles we are facing is at the start of the filling of electrical equipment with what at the time seemed to be a wonderful synthetic fluid: PCB sold with various compositions under a variety of nice commercial names: Askarel, Chlorophen, etc…

For those equipments filled at the origin with that type of liquid, whatever has been said or will be said at this conference, there is no other ecological, economical, respectful of human health way to dispose of those equipments, and recycle the valuable materials in those, than what has been done up to now: thorough decontamination of the equipment in closed vessels, dismantling of the equipment and thermal treatment of the liquid and solid residues.

Chemical treatment of the residue is both very expensive (cost of the consumables) and produces residues, which have to be disposed of.

There is no oil to recycle, and the paper/wood fraction is expensive and difficult to treat, as well as non-recyclable.

There is also no possibility (and it is forbidden by the Stockholm convention) to flush clean PCB filled electrical equipment and to reuse it afterwards.

2. PCB light contaminated equipment

The situation is totally different with equipment filled with mineral oil, which has been accidentally contaminated with PCB.

The reasons are as follows:

- Effective and environmentally sound techniques do exist for flushing the electrical equipments. They could even be utilized while transformers are in operation (mainly for big power transformers). For smaller ones, workshops could be installed where those operations take place.

- Equipments such as transformers could be reused after flushing and close monitoring of the oil quality.
- After decontamination, the oil can be recycled (or used as substitute fuel) locally. There is no need for export to dangerous waste incinerators.

3. Development of local capabilities

In the light of what was said before, we could see local developments in two directions:

- For PCB filled equipment, except for very large tonnages, the objective should be to prepare on site the equipments for disposal in existing facilities in Europe or elsewhere, provided the necessary guarantees are given (See further Quality Chart).

The main reason is the cost of the necessary investments to reach the required quality level.

To illustrate, we will give you some examples. A PCB decontamination plant, with a Year capacity of 8 – 10 kT/year would require an investment of +/- 10 M €. For an incineration plant for dangerous waste, with a plant capacity of 50 kT/year, the investment would probably be in the range of 100 M €.

- For equipment filled with light contaminated oil, alternative and affordable techniques do exist. Some have been presented here. The main advantages are the following:

- The needed investments are much lower than the figures mentioned above
- Many equipments could be reused after adequate treatment, minimizing replacement cost.
- The shop could be linked to e.g.. a transformer repair shop, maximizing local content and using local skilled labor.
- The treated oil could be reused or recycled locally.

4. Quality Chart

The treatment of PCB filled equipment is a tricky business. The quality of this molecule : its stability. Furthermore the long presence of the fluid in the equipment makes it difficult and costly to decontaminate the recyclable materials.

All this has to be done respecting closely the three aspects which are critical in all respects:

- The health of the workers should be protected. They should not be unduly exposed to PCB or other health dangerous substances;
- The emissions of PCB to the environment should be limited to the minimum and closely monitored;
- The quality of the recycled material should be such as to guarantee a concentration of max 50ppm (lower for some countries) on the metal.

To guarantee this, a few years ago, SITA Decontamination undertook to follow this way to work as if it was part of a "Quality Chart" to be complied so that we demonstrate that we respect all the necessary norms to guarantee the safeguarding of the Environment and the Health of the Workers. This is our daily work and our desire to move in that direction. This allows us to display today a triple certification (ISO 9001, ISO 14001 and OHSAS 18001).

This is a clear sign to all authorities and customers that a strict control is needed, that it is implemented, and that it gives confidence to everyone that the treatment is done correctly, safeguarding Human Health and Environment.

PACKAGING, TRANSPORT AND DISPOSAL OF PCB AND PCB CONTAINING EQUIPMENT

C. Rittersberger & T. Vandenbroucque
Tredi, Groupe Séché Environnement

Tredi is a hazardous waste operator from France (part of Séché Environnement) with ample experience in international POP projects since around twenty years. Regularly, Tredi executes projects on a worldwide basis with partners such as various UN agencies or government bodies.

Tredi covers the whole possible project range:

- training local teams,
- sampling & analyzing,
- packaging & conditioning,
- pre-treatment at site if suitable,
- notifications, documentation,
- transport by road and sea/rivers,
- disposal in own dedicated plants in France (Tredi Salaise & Tredi St Vulbas).

In 2010, Tredi participated in a tender by the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus (in Minsk) for the packaging, transport and disposal of PCB and PCB containing equipment. The tender was financed by GEF and supervised by the World Bank.

After a long and diligent selection process, Tredi was awarded the contract at the end of 2011 and started operations in 2012.

820 tons of PCB and PCB containing equipment were to be collected and packaged at 14 industrial sites in 9 towns of Belarus, than transported to France and decontaminated/incinerated.

Administrative tasks were heavy, as 14 notification files were necessary, meaning a total of over 2000 pages of documents and translations into English and Polish languages.

At the beginning of 2012, special packaging material was sent from Tredi St Vulbas/France to Belarus. Here, two Tredi field teams already present in the country received it. They had prepared the coming works together with the coordinators at the Ministry in Minsk and with the directors of the industrial sites where the PCB waste was stored.

The two teams consisted of specialized and experienced Tredi experts. They were supported by personnel from the PCB owners. Training the personnel on safety and technical issues was part of the tender. They started in parallel at different industrial sites the works called 'field services':

- training personnel from the industrial site (PCB owners) on safety
- training on technical issues
- designing a PCB works area
- packaging PCB waste
- loading to transport trucks
- organising customs and transport

After finishing at one PCB-site, a team would move to the next site according to a works plan agreed upon before with the Ministry in Minsk. Field services were finished within 6 months, keeping well below the project time frame of 15 months. They left behind clean sites where before dangerous PCB-waste was stored.

All PCB waste was transported for disposal in 2012 to the Tredi St Vulbas site in France. Here, the waste was either decontaminated or incinerated.

Decontamination by dismantling (for transformers) and autoclaving was applied to metal parts which, once cleaned, were recycled.

High-temperature incineration (1200°C) was applied for all liquid PCB-waste (including the PCB collected in the autoclaves) and for the porous parts (wood for example) from dismantling.

Tredi St Vulbas exceeds as well 99,9999% DRE (Destruction Removal Efficiency) as 99,99% DE (Destruction Efficiency). This was a requirement set out by contract conditions in the qualifying phase of the tender.

DECONTAMINATION OF PCBS (POLYCHLORINATED BIPHENYLS) - THE ITALIAN EXPERIENCE OF DELCO : THE COMBINED USE OF ASD (AUTOCLAVE SOLVENT DECONTAMINATION) AND ODR (OIL DECONTAMINATION & REGENERATION) FOR THE TREATMENT OF CONTAMINATED ELECTRICAL CAPACITORS.

M. Tonani

From an article written by Mario Coppo – Engineer and founder of D.E.L. CO. – Inveruno (MI) Italy

D.E.L.CO was the brainchild of Mario Coppo, an engineer with great experience in the field of circulating fluids such as hydraulic, quenching and heat exchangers, who in 1982 designed and patented the first prototype of Autoclave (ASD) able to extract from electrical equipment such as transformers and capacitors, PCBs (polychlorinated biphenyls and mixtures therein).

Figure 1: Mario Coppo

The innovative technology made it possible to extract and then decontaminate totally, regardless of concentration levels, the PCBs content in all parts of transformers and capacitors. This treatment has allowed the equipment contaminated with hazardous waste such as precious commodity to recycle.

In fact, the ASD method allows the total recovery of copper, iron, magnetic iron and ceramics present in transformers and capacitors. The principle of this operation is based on an intensive cleaning solvent, with Perchloroethylene or Trichloroethylene, solvents which in a controlled indoor environment and under vacuum, allow abstraction from the materials that make up transformers or capacitors around the PCB, allowing an optimal efficiency also for waste contaminated with pure PCBs.

The ASD system has evolved over the years coming now to its fifth generation and going from an average treatment time of one full day (24 hours) per wash cycle to the current time (4hours) in today's current period.

Figure 2: Global D.E.L.CO presence

Due to its effectiveness, the ASD technology quickly spread throughout the world, first in Italy then in France at the Saint Voulbas TREDI plant, Mexico, Argentina, Canada, Taiwan etc., allowing the recovery of thousands of tons of materials.

From the technological development of Signor Coppo's invention, ASD has also become an effective means for the regeneration of transformers contaminated by PCBs, allowing not only the recovery of the materials but a real and immediate reuse of the same. In fact the latest generation of ASD allow, in the event of transformers being contaminated by PCBs but still in good conditions, to recover the total transformer, reusing it perfectly decontaminated. The sophisticated process of vacuum decontamination with solvent vapours, does not damage the transformer and also allows re-use after decontamination.

Figure 3: Decontamination materials contained in transformers and capacitors

A regeneration transformers plant, based on ASD technology, has recently been built in Iseauz, France.

Figure 4: ASD

To be borne in mind at all times is the fact that the ASD technology has a considerable environmental advantage due not only to the absence of emissions into the atmosphere during the decontamination but also thanks to the continuous reuse in the solvent which is in turn regenerated and recovered, allowing use for many years without suffering any deterioration.

The particularity of the D.E.L.CO. experience in the decontamination from PCB, is not then limited only to the porous and non porous solid materials with the use of ASD, but in the 1990s has also evolved with the development of the new ODR technology, that allows the recovery and also the complete decontamination of insulating fluids in transformer content. In fact, before that the ASD technology allowed the decontamination of solids but the liquids were all sent for incineration, with a significant environmental impact and waste of energy and resources. This new idea of Signor Coppo, has allowed us to recover and regenerate even the dielectric oil contaminated.

Figure 5: Decontaminated and regenerated oil

The ODR patent can completely destroy the PCB content in the mineral oils for transformers, with concentrations of up to 10,000 ppm, but simultaneously also to regenerate the oils themselves. The regeneration level is so efficient that the organoleptic characteristic of decontaminated and treated with ODR are similar to those of the new dielectric oil.

Figure 6: Fixed ODR

ODR is designed and made in fixed and mobile versions allowing continuous treatment up to 2,000 litres per hour and with the use of different reagents.

Figure 7: Mobile ODR

The operation principle is based on the destruction of PCBs, with the aid of alkali metals such as sodium metal or sodium hydride, chemically transforming the PCBs as sodium chloride or NaCl (the general food salt) and biphenyl.

Thanks to the efficiency of its technology, it expands quickly around the world with mobile or fixed installations in Italy, France, Romania and Brazil.
D.E.L.CO. has managed over the years, thanks to the combined use of the two technologies ASD & ODR, to fulfil for its customers real centres of decontamination, with complete solutions that allow the decontamination of transformers, capacitors, cables seafood contaminated by PCBs and ballasts allowing recovery of solid materials and contaminated fluids.

The ballasts are capacitors and small transformers for neon lamps and other which are normally contaminated by PCBs. In Canada, we decontaminated by crushing after being cooled with liquid nitrogen and then sifting the crumbs of frozen PCB. This has enabled a remarkable reduction of the environmental impact of decontamination from PCBs, but at the same time, has also allowed a considerable reduction in materials intended for incineration allowing their immediate reuse in the production chain.

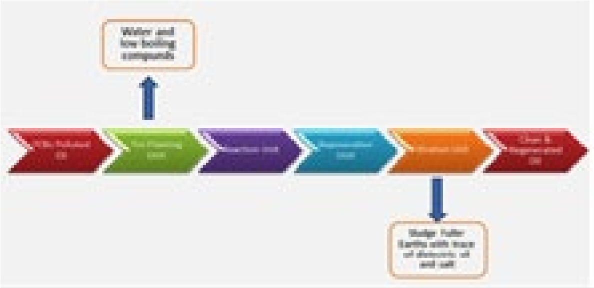

Figure 8: ODR Process

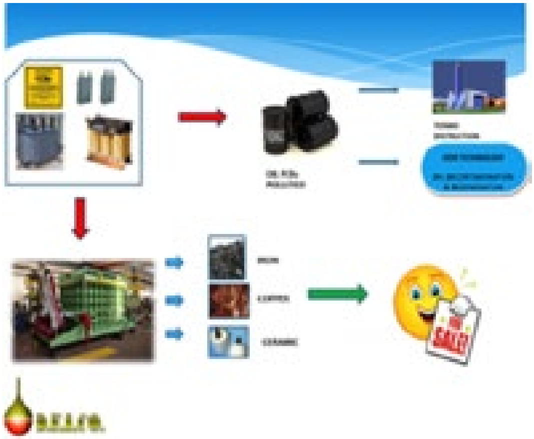

Figure 9: ASD Process of Decontamination and recycling materials

Not to be underestimated is the significant economic benefit to the end customer, that has reaped the benefit of a significant reduction of the costs of decontamination, but also a strong increase in business profitability due to the total recovery of valuable materials such as copper, iron and insulating dielectric oil.
// www.delcosrl.com

SUMMERY: PCB TREATMENT

D. J. Hoogendoorn
Orion b.v., the Netherlands

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ETI Environmental Technology Int. Ltd.,
Chur, Switzerland

Summary

1) Using existing local capacity for licenced high temperature treatment of liquid PCB's and POP's in emerging economies 80% to 95% of the PCB problem can be treated locally in many countries, with only 5% of the remaining PCB waste to be exported for treatment abroad.

2) Life cycle management and product reuse can be an important additional positive effect if inventory and sampling programs allow for additional oil quality analyses apart from PCB in oil testing. First of all, in this way, PCB free transformers may also benefit from the sampling efforts. Secondly, the stability and the reliability of the electric distribution grid can be assessed and, if necessary, improved. Thirdly, the low-PCB contaminated transformers with otherwise good technical conditions can be cleaned and re-used, thus, moving the PCB treatment up on the Waste Hierarchy.

3) Based on local and country specific needs, the general preference for 100% local treatment of PCB waste is usually not the economic and environmentally sound solution. However, an important part of available budgets is spend on (studying and coordinating) these projects without always achieving the desired outcome. Best practices and bench marks are available for feasibility scans for organizations wishing to use the available budgets effectively and efficiently.

Introduction

The session PCB treatment consists of presentations for all technologies available in the EU and in the emerging economies for PCB waste treatment and transformer decontamination. After an overview of the PCB waste related issues by Urs Wagner to set the context for a complete understanding of the subject, the following was presented: (next page)

INTERNATIONAL STATUS OF PCB REMOVAL TOWARDS 2028 & IDENTIFICATION, ENVIRONMENTALLY SOUND MANAGEMENT OF PCBS FROM OPEN APPLICATIONS	**Urs K. Wagner** ETI Environmental Technology Int. Ltd. Switzerland
PCB PROJECTS IN EMERGING ECONOMIES: ENVIRONMENTAL AND ECONOMIC BALANCE BASED ON CORPORATE SOCIAL RESPONSIBLE INNOVATIONS	**Dirk Jan Hoogendoorn** Orion b.v, the Netherlands
SODIUM TECHNOLOGY - THE CHOICE FOR TREATMENT OF POPS	**Edgar Bilger,** Klaus Seikel, Susanne Butorac Dr. Bilger Umweltconsulting GmbH, Freigericht, Germany
OILS & PCBS FREE PROGRAM 2013:BAT/ BEP-LCM FOR INVENTORY, CONTROL, MANAGEMENT AND DECONTAMINATION OF PCBS – POWER TRANSFORMERS AND CASE HISTORIES	**Vander Tumiatti**, M. Tumiatti, C. Roggero, R. Actis, R.Maina Sea Marconi Technologies S.a.s.Italy
HIGH VACUUM DESORPTION PROCESS FOR DECONTAMINATION OF EQUIPMENT AND MATERIAL CONTAMINATED BY PCBs	**Guillaume BARRIET** APROCHIM SA, France
CO-PROCESSING OF PCB AND OTHER POP'S IN CEMENT KILNS. A LOCAL SOLUTION FOR A WORLDWIDE PROBLEM	**Ed Verhamme** Alternate Resource Partners – The Netherlands
DECONTAMINATION PROCESS USING AUTOCLAVE (ASD) AND DE-CHLORINATION TECHNOLOGIES (ODR) – WORLDWIDE PAST EXPERIENCE AND FUTURE VISION.	**Michele Tonani,** Mario Coppo DELCO Srl – Italy
PCB TREATMENT IN THE FUTURE. SITA DECONTAMINATION	Jacques Ledure, **Thomas Dawance** Sita Decontamination
POPs IN IRAN - TREATMENT AND LIFE CYCLE MANAGEMENT FOR THE 21ST CENTURY: CURRENT EXPERIENCES AND SOLUTIONS	**Christoph Rittersberger** Séché Environment

It

The presentation of Urs K. Wagner gave an insight view of the status of international PCB assessment and removal activities towards the 2028 target of the Stockholm Convention, addressing both achievements and gaps.

It was concluded that countries prefer local treatment/disposal capacity and infrastructure (for example local or mobile PCB treatment plants). Local availability, however, cannot generally be considered the best solution for a country. Country-specific needs must be carefully evaluated in the frame of a PCB assessment; and treatment/disposal options can only be defined if and when a reliable PCB inventory is available! Some minimum criteria to be considered for tenders are amongst others:

Type of PCB waste	☐ transformer ☐ capacitor ☐ oil (pure or contaminated) ☐ soil ☐ solids waste (e.g. concrete, metal parts etc.) ☐ etc.
Contamination of PCB waste	☐ < 50 mg/kg ☐ > 500 to e.g. 3'000 mg/kg ☐ pure PCB
Total quantity of PCB waste	*Local treatment should only be envisaged with quantities exceeding certain limits (depending on technology/size of plant)*
Condition of PCB containing equipment	☐ in use ☐ to be reused after treatment ☐ phased out in good condition ☐ phased out and leaking/defect ☐ immediate actions necessary ☐ phased out and drained

Various environmentally sound PCB non combustion treatment and disposal technologies are available today. Local waste treatment in high temperature incinerators or approved co-processing in cement kilns can be evaluated. Treatment costs seem to be generally transparent and fair nowadays. The transport (and export) of PCB wastes to a treatment/disposal facilities, however, can be costly and risky. If ecologically and economically feasible, waste exports should be minimised and re-use of equipment/material maximised.

Current actions in the countries should focus on updating the existing PCB inventories. Only reliable and complete PCB assessments can be regarded a sufficient base for evaluating treatment/disposal options. During NIP Updates, open applications of PCBs (for example caulks, paints, anti-corrosion coatings, etc.) should be considered when inspecting buildings and sites for closed applications, and included in the PCB inventory.

The countries and the responsible Ministries and Steering Committees must take responsibility and ensure their homework is done professionally. It is vital that practical related and country specific PCB Guidelines are developed and implemented. Furthermore, PCB awareness raising and capacity building activities must be scheduled and workshops held in order to inform and train all relevant stakeholders.

Finally, PCB cross-contamination and unintentional formation of PCDD/PCDF must be prevented.

The other presentations and subjects are self-evident. Presentations and available papers may be accessed through the IHPA website.

SILENT LAND

SILENT LAND
AT THE 12TH INTERNATIONAL HCH AND PESTICIDES FORUM

J. Van den Berg
drsFILM

In September 2011, I travelled to Gabala, Azerbaijan, to show my documentary Silent Snow to the important audience of the 11th International HCH and Pesticide Forum. The film, about the consequences of pollution caused by the use of dangerous pesticides like DDT, was successfully received and later shown in over 35 countries at cinemas and international film festivals. Most importantly, it succeeded to inspire many people to take action and organize local initiatives to inform each other on a healthier way of producing food.

This fall I was therefore happy to return to the now 12th edition of the Forum in Kiev, Ukraine, which would host a preview of my first short film under the new Silent Land project: When elephants dance, the grass gets beaten. The project is a sequel to the Silent Land documentaries and has the objective to inform people about the effects of land grabbing for small local farms. In 'When elephants dance' we see how local farmers in Cambodia are losing their land to large multinationals and are faced with forced migration and food insecurity. Almost three quarter of the available land for agriculture in Cambodia has been sold to companies that produce for export only. As this is disastrous for the local food production, the World Food Program supports vulnerable parts of the population with food supplies. In the meantime, the exile of farmers continues. Since 2003, more than 400.000 Cambodians have been chased off their lands as a result of land grabbing. The stories I've heard about being an illegal migrant, the exploitation and having to work with dangerous pesticides are heart-breaking.

As I discovered on my journey to Kiev, in the Ukraine there's also still a lot of dangerous poison just lying out in the open. Often these toxic materials are located just next to children's playgrounds and it is very difficult to get rid of it in a safe way. It was again a great honor to be able to show my film to an audience of experts on this topic and I received very valuable feedback. The screening was held up a bit as the Communist Party held a demonstration outside the building against capitalism, while inside we discussed the dangerous left overs from Soviet Union's development aid. Main character 'Moon' attended the conference through a Skype-call and was very pleased with the compliments for the film.

As for the Silent Land project as a whole; after the premiere of the first short film we will continue working on the feature length documentary, which will offer a more worldwide perspective on the same issues. Early January, 'When elephants dance' will be screened on a Conference for Biology teachers in the Netherlands and the official world premiere will take in Antwerp on January 22nd, in combination with an expert panel discussion on land grabbing and food security. Furthermore, the film was part of the IDFA Docs for Sale selection last fall and will be screened on international film festivals like Parnu in Estonia, Cinemambiente in Italy and Festival du Film d' Environment in France this year. The project's educational material will also be soon available for schools, as part of the OXFAM GROW campaign.

More info on www.silentland.org
Trailer of 'When elephants dance, the grass gets beaten'

http://vimeo.com/79869713



PROGRESS AND EXPERIENCE ON POPS AND OBSOLETE PESTICIDES WASTE MANAGEMENT


EXPERIENCE IN THE IMPLEMENTATION OF GOVERNMENT CONTRACTS FOR WASTE FROM DETERIORATED PLANT PROTECTION PRODUCTS AND THEIR PACKAGING

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Tomsk, Russia

In recent years, the OAO "Polygon", which is operating the Tomsk hazardous waste landfill, is one of the main organizations in Russia engaged in the disposal of obsolete pesticides.

• For industrial wastes, the Tomsk landfill is one of the best sites in the Russian Federation. In a resolution by the Government of the Russian Federation, the Tomsk landfill was included in the federal priority programme "Waste" (1996 to 2000) as a"pilot project" for Russia on waste management;

• In a resolution by the Government of the Russian Federation, the construction of the Tomsk landfill was included in the federal program "Ecology and Natural Resources of Russia" (2002-2010)

• Funding for construction of the Tomsk landfill was included in the Federal Law № 204- FZ of 24.11.2008, № 308- FZ of 02.12.2009, and number № 357 of 13.02.2010 "On the federal budget ... " for financial years 2009, 2010, 2011 and 2012, respectively.

• At present, the share of the Russian Federation in the authorized capital of the company is more than 60 %.

• The analysis of work done under federal and municipal contracts for the disposal of obsolete pesticides showed following features :

1. Disposed pesticides are dating mostly from the Soviet era

2. 90 % of the pesticides are mixtures of chemicals of various origins

3. Pesticides are usually stored in unsuitable premises and facilities - often in the open air.

4. Information on the amount of pesticides that are passed on to the Federal Ministry of Natural Resources, underestimates the amounts on average by 30 %. Transmitted information also lacks information on the pesticides burial sites (mainly DDT) dating from the 1960-1970s.

• The current disposal option (burial) of pesticides makes its subsequent destruction very difficult.

• It is proposed - in terms of the implementation of the Stockholm Convention - to declare as a priority the establishment of waste disposal sites (landfills), where it is possible to carry out long-term, controlled storage until Russia has certified technology to destroy them.

Region	Number of contracts	Volume in tonnes
Tomsk region	6	37
Kemerovo region	1	14
Omsk region	10	132
Republic of Tyva	1	4,8
Total:	18	187,7

Table 1: Overview of contracts for disposal of pesticides implemented at the "OAO landfill in 2011

Photo 1: Overview of the Tomsk landfill facility with main installations and at the top 3 storage buildings filled with pesticides waste

Photo 2: One of the 3 storage buildings filleds with pesticides waste as indicated in photo 1

Photo 3: Waste containers for hazard class I.
These are used for storage of pesticides waste

Photo 4: Removal of chemicals from the warehouse of the Costumor

Photo 5 & 6: Obsolete Pesticides at another location were formerly stored in metal tanks and are now permanently removed, repacked and brought to one of the stores at the Tomsk Landfill

ECORESURS LLC EXPERIENCES IN MANAGEMENT OF WASTES OF I-V HAZARD CLASS ON THE TERRITORY OF KRASNOYARSK CITY AND KRASNOYARSK REGION

E. Shepelev
Director General

Ecoresurs LLC has been providing services in collecting, transporting, using, decontaminating and disposing the wastes of I-V hazard class on the territory of Krasnoyarsk city and Krasnoyarsk region for already 23 years. The Company's activity is licensed (License No 024 00101 dated 22.06.2012).

The Company's priority is to provide for the environmental safety on the territory of Krasnoyarsk city and Krasnoyarsk region.

Ecoresurs LLC owns modern production base, which includes the following:

– facilities for industrial and household wastes disposal;

– section for decontamination of mercury containing lamps;

– section for decontamination of hazardous and highly hazardous wastes;

– rapid response team to liquidate emergency situations related to mercury spillage;

– Environmental Consulting Department.

The following projects are successfully realized:

– Development of system of collecting, transportation and neutralization of the medical waste in the territory of the city of Krasnoyarsk. Work with medical institutions and the private organizations in Krasnoyarsk and nearby district of Krasnoyarsk region;

– Improvement of waste management from the territory in Krasnoyarsk and nearby cities;

– Construction of waste treatment plant for class I-IV danger class including re-use of energy. The most modern in Russia. It is put into operation of 05.06.2013. Allows to treat more than 250 types of waste;

– Development and deployment of selective waste collection system together with Head department of formation of the city of Krasnoyarsk (more than 335 establishments of Krasnoyarsk are included);

Thus, LLC Ecoresurs introduces complex system of total waste management collection at a source, packaging transportation, sorting, treatment and collection of residuals (ashes and slags).

This presentation summarizes the information on the certified waste treatment plant at high temperature. The plant is located in the existing premises on the territory of the Ecoresurs industrial wastes, located in Krasnoyarsk.

The technology is compliant with International Standards EC 2000/76.

The production facilities employ the advanced technologies of wastes incineration (optimal combination of pyrolysis incineration and wastes oxidation at the temperature of 850-900 C° in the combustion chamber; and at 1100-1200 C° in the afterburner - photo 1, 2, 3), gases filtration, which guarantees the environmental safety of the technological process.

The complex for thermal treatment of waste is intended for high-temperature treatment of the waste which as a result of operation of various infrastructures.

The technology of thermal treatment of waste in the incinerator is applied as unconditional alternative to the treatment of waste of the I-IV class of danger.

Technology advantages:

– epidemiological safety: there are no the viruses, capable to survive at t 850-900 C°;

– the ashes and slags generated belong to the IV class of danger;

– value of the maximum ground concentration of harmful substances on borders of established SZZ (sanitary protection zones) no more than 0,1 maximum concentration limits on all ingredients which are emitted at operation of installation.

High ecological safety of a complex is reached due to application of operated 2-zonal burning of waste; temperature maintenance in the first zone (the drum furnace) 900-1 000 C°и t 1 100-1 200 C°in the second zone (camera reburning), and also at the expense of the multistage system of gas purification of reactionary combustion gases including two scrubbers for cleaning of fly-ashes and from acid-forming secondary pollutants and frictional cleaning by coal nano-dispersions (photo 4,5);

– the complex works without smoke and a smell.

The Russian manufactured Processing Unit allows to decontaminate a wide range of wastes on the basis of the high temperature process: chemical, medical, biological, pesticides, herbicides, and other toxic chemicals (including unidentified), highly toxic wastes, “tails” of solid household and industrial wastes, oil slurries, contaminated soils and etc, except for the banned types of wastes.

Complex productivity:

– solid waste: more than 2 000 kg/h;

– liquid waste: more than 300 kg/h.

At thermal neutralization of waste surplus of heat which in winter time will be used for heating of all production base of LLC Ecoresurs is formed.

Since 2011, the Company commenced implementing its own project “Wastes Sorting Complex Construction” allowing for the advanced processing of solid household wastes resulting in the end product. Commissioning is planned for 2014.

LLC Ecoresurs realized the project on construction and commissioning of a waste-processing complex.

The first stage is now realized: construction and commissioning of a waste sorting complex.

Design capacity waste sorting complex – 350 thousand tons of solid household waste per year (more than 1 million m^3 of Municipal Solid Waste (MSW).

Sorting type: the semi-automatic.

The second stage construction of plant on processing of secondary raw materials and production of the final product.

It is the new project of the company which allows to reduce the saved-up ecological damage, to reduce negative impact on environment and health of the person.

Photo 1-5: Overview of different situations of the dedicated hazardous waste treatment plant

MECHANICAL CHEMICAL DESTRUCTION (MCD) OF CONTAMINANTS IN SOILS

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Auckland, New Zealand

EDL Company Background

New Zealand based Environmental Decontamination Ltd was founded 1998 and backed by collaboration with the Government of New Zealand through the Ministry of the Environment, and The Foundation for Research, Science and Technology, EDL has pioneered a continuous process in the area of on-site ex-situ soil remediation through its development and commercialisation of Mechano-Chemical Destruction (MCD™) technology.

Mechano Chemical Destruction (MCD™)

The mechano-chemical destruction (MCD™) of PCBs, dioxins, pesticides and other organic contaminants in soil or soil-like mixtures is accomplished using EDL's patented multi-tube rotary ball-mill reactor. The principles of the MCD technology is based on the provision of impact energy created due to the velocity of special high wear resistant steel balls being in constant collision with each other. During this volatile activity, in a controlled environment, soil crystals rupture at the point of contact between the balls, with the resultant formation of reactive free radicals on the ruptured surface (for ex-

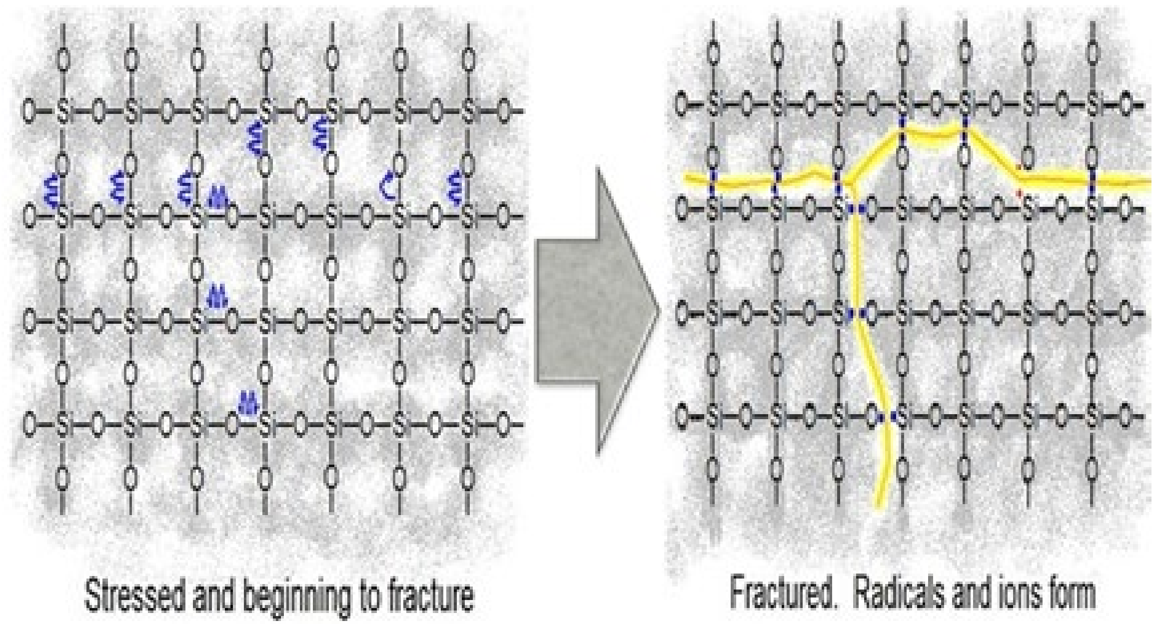


Figure 1: Radicals and ions forming

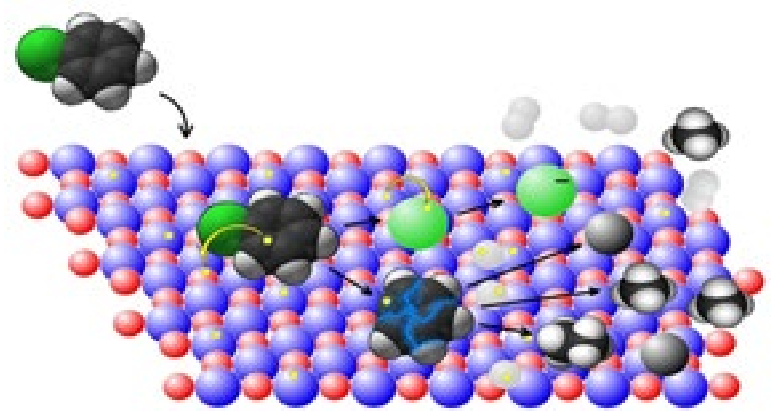


Figure 2: Chemical reaction diagram

ample 0-Si-0→≡Si· and ≡Si-0·). This rupturing of the crystals is accompanied by the emissions of electrons and protons, and the generation of electrostatic charges. This mix is often referred to as a “tribo-plasma”. Any organic pollutant, which is present within the tribo-plasma zone becomes excited and reacts with the highly reactive free radicals, with the resultant formation of inorganic halides and graphite carbon.

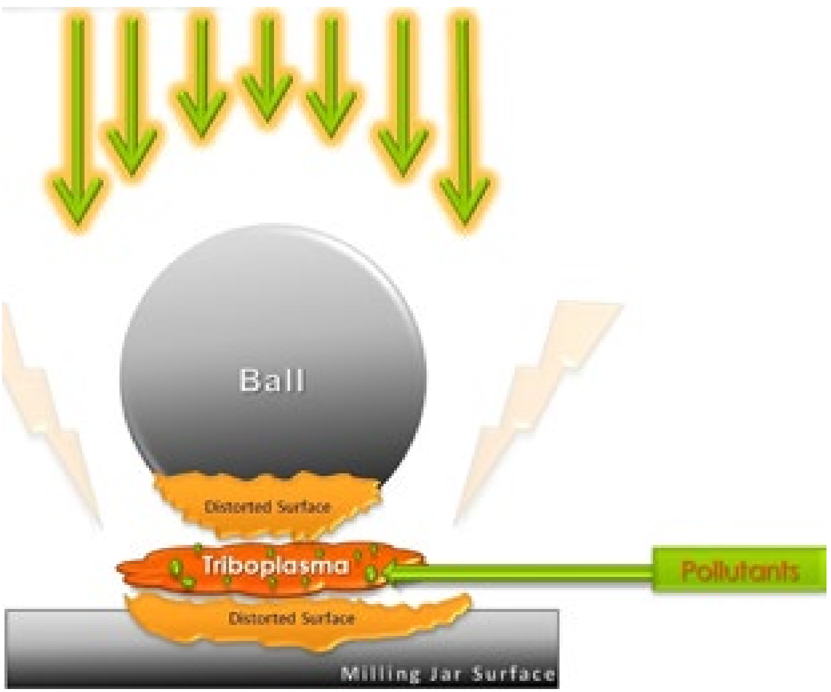


Figure 3: Tribo-plasma reaction within reactor

The MCD™ reactor adds significant amounts of energy to the milled material creating a fluidised reactive cloud of mineral particles with a large number of electrons (inorganic free radicals) and ions on their surfaces.

Since the basis of the process is fracturing solids, it works best (i.e. fastest) when the matrix is rich in hard brittle minerals. In real soils, these are mixtures of silicates such as feldspars, quartzites and the like. When a crystal fractures, the chemicalbonds may break in a number of ways. Thus, the Si-O bond can break heterolytically to give ions, or homolytically to give free radicals. Both processes leave the fracture surface rich either in charges or free electrons. Ions, radicals and neutral molecules themselves bind to the reactive fracture surfaces and undergo similar fragmentations to those undergone by the parent substrate.

The final products are small neutral molecules including ethane, methane, carbon dioxide, hydrogen, water and carbon.

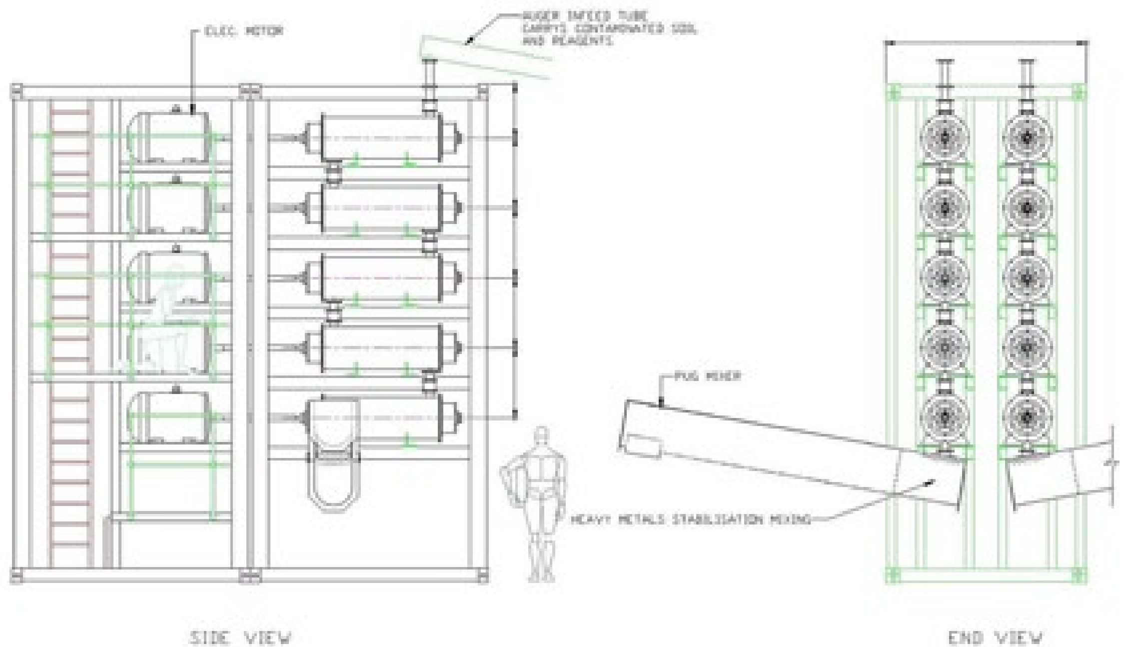
The use of mechanical energy to initiate chemical reactions is not new. Over the past few years, scientists around the world have conducted laboratory and pilot plant experiments using the fundamental principle of mechanical reaction to achieve the destruction of toxic chemicals. Various levels of Destruction Efficiency (DE) have been achieved, but the commercial application of this emerging technology has, up to now, never been accomplished.

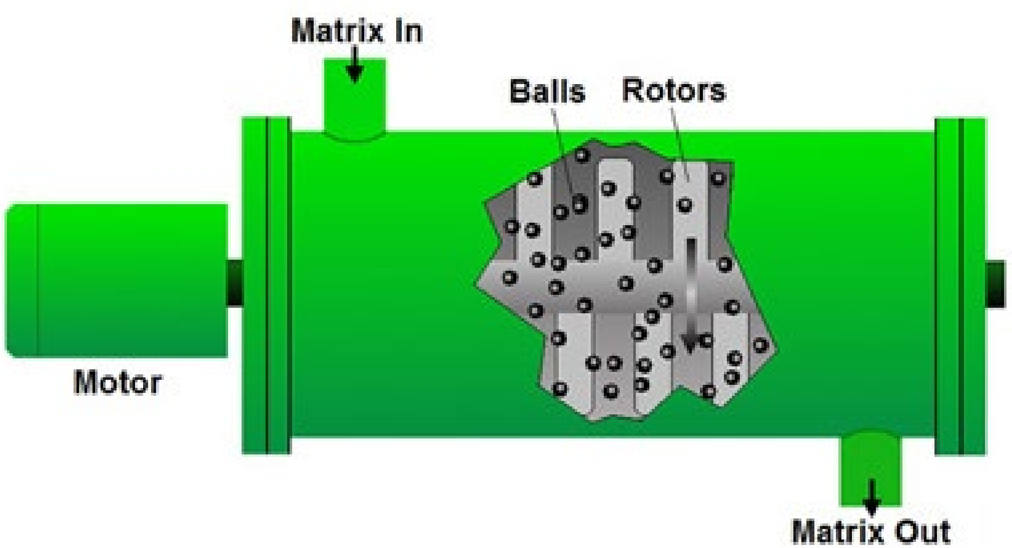
The MCD installation

Series V MCD™ plant is a non-combustion technology for the remediation of soils and soil like matrixes e.g. spent activated carbon. Operating at low temperatures, it is essentially a closed process with no risk of uncontrolled release of contaminants. The compact and containerised equipment makes transportation, deployment and maintenance of the plant straightforward. Plant throughputs and contaminant destruction efficiencies are controlled through variable retention times, additional MCD™ reactors can be linked in series for large scale remediation projects.

Prior to entering the drum, the soil is screened and dried to <2% moisture, which is facilitated by the use of a passive drying system with controlled temperatures less than 80 degrees Celsius. The soil travels from the dryer through EDL's patented, vertically stacked horizontal MCD ball mill array, then completes its process by traveling through a developed pug mill with incorporated water jets, to help cool and add moisture. In principle, the soil can be directly backfilled onto the location.

A typical plant layout looks like the diagram represented above with a relatively small plant footprint. Below a typical MCD reactor is illustrated:





Project Experience

EDL has successfully completed a number of full scale and pilot trials applying the MCD technology at different POP's contaminated sites, summarized in the chart to the right.

Date	Project	Volume of Soil	Machine	Contamination
2004	Mapua, NZ	8,650m3 full scale	Vibratory mill	DDT, aldrin, dieldrin, lindane
2006	USA, HP 1	9x10kg batch trials	1 drum	PCBs, dioxins, pesticides
2007	USA, HP 2	12x20kg batch trials	1 drum	PCBs, dioxins, heavy metals
2006	Hong Kong	4x10kg batch trials	1 drum	TPH, heavy metals
2007	China/Philippines	4x10kg batch trials	1 drum	Pesticides
2009	Japan Ministry Trial	14x10kg batch trials	1 drum	Dioxin, PCB's, BHC
2009	Alaska, USA	140m2 full scale	4 drum	PCB's
2010	Japan Osaka Trial	200 kg	2 drum pilot	Dioxins
2012	The Netherlands	1x10kg batch trial Activated Carbon	1 drum	Dioxins
2012	Vietnam UNDP	100 tons full scale	4 drum	Dioxins

Project showcases

Mapua, New Zealand

The technology was in full scale operation from 2004 - 2007 at New Zealand's worst contaminated site. This contract for the Ministry of the Environment was completed in June 2007. Over 65,000 m3 of soil contaminated with DDT, DDD, DDE, aldrin, dieldrin and lindane was excavated and screened with 7,300 m3 being successfully treated to the soil acceptance criteria defined in the EIA.

Picture 1: Landfill prior excavated during operations

Picture 2: Contract completed and site regressed

Photo 1-3: Granite Mountain, Alaska

Granite Mountain, Alaska

PCB contamination at a former radio transformer station at Granite Mountain, in partnership with the US Air force. EDL completed the project by using a fully portable 4 drum plant which was flown in by an Hercules C140 aircraft. The PCB concentrations in the soil ranged from 500 to 1,200ppm, with a target acceptance criteria of <1ppm. The destruction levels up to 99% were achieved, the treated soil was backfilled to the site.

Bein Hoa, Vietnam

EDL most recent successful project was in Vietnam 2012, undertaking the project called “Environmental Remediation of Dioxin Contaminated Hotspots in Vietnam” funded by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP), for the treatment of 100 tons of highly contaminated soils at the Bein Hoa airbase. This project was awarded to EDL following

Photo 1-2: Bein Hoa, Vietnam

an international tender and expert review of over 20 different technologies by environmental experts.

The site containing extensive dioxin contamination remaining from the use of various defoliant herbicides during the period of armed conflict. The most common of these herbicides was known as Agent Orange, whose production was associated with dioxin by-products. Dioxin contamination levels in soil of 2,000 to 30,000 ppt TEQ.

The MCD technology has demonstrated the capability of destroying the PCDD/F contaminated in soils representative of the hotspot contaminated sites at Bein Hoa in the “bare bones” configuration 4 reactor pilot installation.

The target criteria for dioxin contamination was <1,000 ppt TEQ, but levels of <300 ppt TEQ were successfully achieved.

Quoted from the independent evaluation UNDP Report (Environmental remediation of dioxin hotspots in Vietnam. by Rick Cooke)

“ As an overall conclusion, the MCD technology has now been demonstrated and evaluated to a significantly greater level than any other candidate technology, and, with limitations and conditions noted, is judged as generally qualified for commercial consideration in future large scale dioxin contaminated site remediation projects in Vietnam and elsewhere.”

Why EDL’s MCD™ Technology

• A reliable remediation solution backed by research and development in collaboration with the New Zealand Government, Universities and extensively independently evaluated by international specialists.

• Eco efficient, and cost efficient with rapid deployment, erection and decommissioning.

• A company totally focused on and committed to the ongoing refinement of MCD™ technology in soils, sediments and soil like matrixes.

• Relatively simple process is very flexible and can be tuned to the circumstances of each site

• Reactors are highly modular and very easy to service or replace. This is necessary when working in super critical situations.

• No hazardous or expensive reagents or conditions are needed.

• Soil can be in principle directly back filled onto the location.

• A wide range of organic contaminates and POP's can be successfully treated with one installation.

• A genuine alternative to incineration, thermal desorption and bioremediation.

Acknowledgements: Bryan Black and Mike Bulley
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PROGRESS & EXPERIENCE OF POPS TREATMENT SOLUTIONS IN THE FIELD

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Abstract

As a World leader in environmental services, VEOLIA has a wealth of experience in the environmentally sound treatment of hazardous waste including POPs. Our specialist International Field Services business unit based in the UK has >20 years of direct experience in handling POPs in field conditions throughout the world.

Having worked in Africa, Asia, Latin America and Eastern Europe, we have developed a successful model for the safe and effective management of POPs including safeguarding, removal, transportation and effective treatment through a network of state of the art treatment facilities. Our project model is based on a sustainable, collaborative approach, working with waste producers/holders, countries and international organisations to remove POPs safely and to provide a lasting skills legacy for the country.

Using this approach a POPs disposal project can provide an excellent opportunity to contribute to capacity building and prevention.

Background to Veolia Environmental Services

Environmental issues are a concern throughout the world, but even more so where there are no local resources or infrastructures in place to effectively manage these concerns. At Veolia Environmental Services, we are committed to delivering sustainable, responsible and economically viable waste management solutions and services, whilst protecting and caring for the welfare and development of the environment and local communities in which we operate.

Offering a truly worldwide service in specialist hazardous waste and clean-up solutions, Veolia Environmental Services has an unrivalled reputation for practical and economical solutions, with a dedicated international team to advise on the best practical environmental options and an enviable track record in the responsible handling of hazardous materials.

Our operations are delivered in the field with the utmost care for the environment, the law and the health and safety of those directly or indirectly involved.

With extensive project management experience, a range of treatment technologies and full logistical support, we provide turnkey solutions for the removal, treatment and disposal of all hazardous substances, including PCBs and pesticides, plus land and building remediation, clean up and decommissioning.

Introduction

Over a period extending back to the early 1990s, Veolia Field Services has undertaken POPs clean-up projects throughout the world including extensively in Africa, Latin America, the Far East and across the entire European area. Over this time, we have worked together with other stakeholders including waste producers, international organisations, governments and partners to foster and promote a sustainable added value solution for POPs destruction projects. Central to this approach has been a partnering strategy to ensure that as well as ensuring the safe destruction of POPs materials that there is a legacy of skills transferred from Veolia to the country from which the waste has been removed. These two aspects, i.e. destruction and skills transfer, are central to the aims and requirement of the Stockholm Convention. They are also fundamental to the strategy of Veolia Field Services in relation to POPs clean-up.

This paper will set out a basic review of POPs destruction using Rotary Kiln High Temperature Incineration and provide an insight of how a POPs clean-up project can be used as an opportunity to develop national capacity for chemical management via technical assistance.

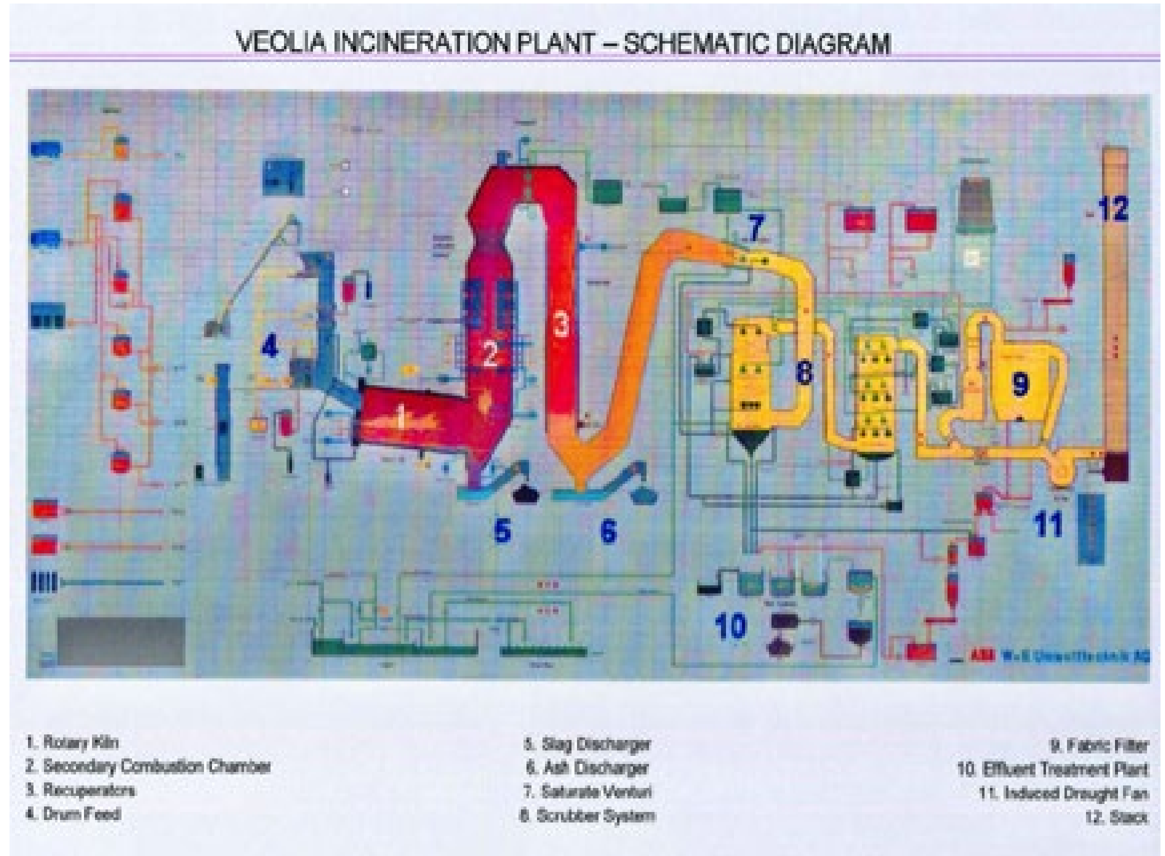

Figure 1: Schematic Diagram of HTI Facility

High Temperature Incineration (HTI)

For certain categories of waste including Persistent Organic Pollutants (POPS) and confidential materials, only the highest levels of secure destruction are appropriate in order to satisfy both commercial and legislative requirements. In these cases, High Temperature Incineration is frequently the most cost-effective solution. As a proven solution for the safe disposal of persistent hazardous organic chemicals HTI is widely regarded as the best practical environmental option (BPEO) for many chemical wastes.

The process, which involves heating to temperatures in excess of 1100°C, delivers a destruction efficiency of 99.999996% and is ideally suited to the secure disposal of hazardous by-products, redundant or obsolete products, laboratory waste and agents, contaminated electrical equipment and contaminated soils. The exceptionally high efficiency of this process is matched by outstanding performance in the environmental arena. HTI uses the latest technology at every stage in order to achieve legislative conformity. Meeting all authorisations and legislative requirements whilst offering maximum flexibility for the handling and receiving of a wide range of materials, including all POPs.

Rotary Kiln

Veolia Environmental Services operates HTI plants throughout Europe and also in the USA and China. In the UK the Ellesmere Port facility uses an advanced, water-cooled rotary kiln which achieves temperatures of up to 1,200°C, ensuring complete combustion of all waste materials. It is fully automated; operational parameters and waste feed mechanisms are under computer control and safety interlocks can prevent operation where necessary. The kiln rotates between 1 and 6 revolutions per hour, allowing a waste residence time of 30 – 90 minutes and ensuring maximum burnout and volatilisation of organic materials. The resultant inert slag flows continuously into a water quench in the base of the secondary combustion chamber (SCC), where it immediately cools to form an inert glass-like solid. This can be reused or disposed of at licensed landfill sites.

Secondary Combustion Chamber (SCC)

Exhaust gases from the kiln pass into the 25m high SCC where further liquid wastes and air enter tangentially, providing a vortex. Separate lances inject aqueous, gaseous and non-compatible wastes. With a residence time after the last injection of air in excess of 2 seconds, turbulence, excess oxygen and temperature maintained at greater than 1100°C a high destruction and removal efficiency for all wastes is achieved.

Gas Cleaning

Combustion gases exit the SCC and pass through a pair of parallel gas-gas heat exchangers which reduce the temperature to around 800°C before being quenched instantaneously in a Saturate Venturi to less than 80°C. This rapid cooling to below the critical band of 250-400°C where dioxins can reform is a major design feature and accounts for the plant's outstanding environmental performance. The saturated gases are then passed through 2 scrubbing towers, these towers remove hydrochloric acid, oxides of sulphur, bromine and some of the inert particulate matter. The gases then enter a fabric filter where, with the addition of lime to aid filtration, the final particulates together with any residual acidity are removed.

Effluent Treatment

Liquid effluent from the scrubbing towers flows to the automated, computer controlled acid neutralisation plant. The fully neutralised effluent is mixed with a flocculent and discharged to settlement tanks. Clarified supernatant water is discharged to the estuary within prescribed consent standards. Sludge from the settlement tanks is thickened in a consolidation tank before dewatering, and the cake is discharged to skips for disposal off-site.

Operating to strict environmental standards

The facility's central computer monitors every aspect of the operation, providing continuous readouts of operational parameters and emissions. Additional testing for specific stack and effluent emissions is carried out to maintain efficiency. Stringent management controls together with regular monitoring carried out by the UK Environment Agency ensure the highest environmental performance standards are maintained. The facility has been authorised by the Environment Agency under the Integrated Pollution Control (IPC) provisions of the UK 1990 Environmental Protection Act. Operations are certificated to the international standards for Quality and Environment, ISO 9001 and ISO 14001. The plant consistently beats the limits for gaseous emissions under the EA and IPC procedures, now including the rigorous standards imposed by the Hazardous Waste Incineration Directive 94/67/EC.

Collaborative Project Management

Veolia Field Services has over more than 20 years worked with stakeholders including waste producers and trade organisation such as Croplife International, International Organisations such as FAO and other partners to develop and promote a collaborative approach to delivery of POPs clean-up projects. A key strategy has been to use local staff as part of the core project team at all levels including project management, technical, administrative and operational roles.

Particulate matter	0.67 mg/m3
Total organic carbon	<5 mg/m3
Carbon monoxide	<20 mg/m3
HCl	<1 mg/m3
SOx as SO2	<5 mg/m3
NOx as NO2	205 mg/m3
Hg	0.004 mg/m3
Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn	0.096 mg/m3 (total)
Dioxin TEQ	<0.016 ng/m3
Destruction Removal Efficiency (DRE) for PCBs	99.999996%

Table 1: Typical emissions to atmosphere

Skills Legacy

In order to ensure that local inputs contribute fully to the safe and successful outcome of the project extensive training and on-going supervision and support is provided by Veolia. This ensures that all staff working on the project do so safely and effectively. In addition it ensures that following completion of the specific disposal operation that there is a legacy of trained, skilled and experienced national staff. This retained resource can contribute to or even act as a national focal point for responsible chemical management going forward.

The strategy of assigning local staff to active project roles ensures that they can apply the training provided in a "real world" situation which allows skills to be practiced and developed with expert support and supervision to ensure safe operations. Only by combining training with practical experience in a controlled environment can competency be achieved in the key areas of project management, administration, handling, storage and transport of hazardous chemicals including wastes.

Conclusion

Whilst Rotary Kiln High Temperature Incineration provides a proven, cost effective and environmentally sound solution for the destruction of POPs, a disposal project also provides a great opportunity to ensure a legacy of local competence in chemical management. If projects are designed and delivered applying a collaborative project management approach between key stakeholders from the private, public and international sectors they can deliver a sustainable outcome combined with secure POPs destruction. Accordingly this approach ensures that the key aims of the Stockholm Convention can be cost effectively achieved in practice.

HCB
THE DISAPPEARING POISON

D. Liszkiewicz & M. Kuciel
TVN television journalists
Poland

Introduction

The most dangerous waste in the world…

Taken from the Ukraine to prevent ecological disaster…

Brought to Gdansk in Poland by 2 ships and 500 hundred trucks...

They were meant to be irreversibly destroyed…

But they polluted the natural environment again…

Pollution transferred from the Ukraine to Poland

In the beginning, everything looked just like a legal transport of dangerous waste. However, after first transports reached it's destination and cargo was unloaded at Port Service incinerator, it became obvious that this situation was poorly handled by both polish environmental authorities and the company chosen as partner for waste disposal. Due to the lack of proper supervision, Poland has encountered serious HCB and pesticide pollution problems. Overloaded incineration plant was not capable of destroying HCB waste in a proper way. In effect, thousands of tons of partially incinerated waste were dumped illegally into a gravel pit 20 km from Gdansk and the Baltic Sea.

Luckily, one man decided to tell us the truth, though those facts that he described were really hard for us to believe in. With help and suggestions from Plant Protection Institute in Poland, we managed to confirm those serious allegations. Instructed by Mr Tomasz Stobiecki from Plant Protection Institute, we decided to take samples of water and soil from the place. The results were shocking. Many obsolete pesticides were found in those samples: HCH (alpha), HCH (gamma), HCB, DDT, and Atrazine. Concentrations of these compounds exceeded the standards for soil and water up to 550 times!

This story might not have been revealed. Year after year pollution might be spreading consequently to the environment, reaching the ground waters and poisoning water wells. It is a story of people of good will, who were brave enough to confront the dirty reality and helped us change it.

The story begins

In January 2012, we received an e-mail from a concerned citizen of Gdansk.

We called this man "The Guardsman" since he was a person who wanted to protect the environment, and local inhabitants, that might have been affected by toxic waste.

"I live in New Port district in Gdansk. There is an incinerator there, that takes thousands of tons of waste from th Ukraine. Hundreds of trucks come there daily, dropping their loads in every spot in this facility"- he wrote.

The Watchman", and other people, who live in the vicinity of this plant kept wondering why waste from the Ukraine is transported for over 1000 kilometers to our city. They could not find any information about the transports. The piles of waste kept growing every day to an unprecedented size.

"There is so much of this waste, that it's stored all over the place. It's not sheltered in any way, nor protected from rain or wild animals. The odor is hard to describe. I tried to inform local authorities, but no one wants to help. They keep ensuring us, that everything is in order. For myself and the other inhabitants of our district, I'm asking you for help. I cannot reveal my

identity, because I'm afraid of possible consequences or even losing my employment" .

We contacted him, and after confirming the facts, we decided to travel 550 km to Gdansk where we met "The Watchman" in person. He told us a story of his fight, that begun long before he contacted us. But local authorities denied him any help or attention.

Doubts and Questions

During our first visit, we managed to film large bags stored, without any shelter, all around the facility. They were leaking, torn, and covered with snow. This was not "storage". It looked like a giant garbage dump! These bags were covering every available space of the incinerator.. We kept looking for any marks or signatures to identify what is inside them. Finally, we found a place just few meters from a fence. Hundreds of bags were piled there.

I walked there with my camera, covering my face with a scarf against the overwhelming odor. We found one of the bags marked with 2 letters and 4 numbers: "UN2729". Below we found a mark, "UA", indicating that it might be from the Ukraine.

The first internet search returned with a phrase **"Hexachlorobenzene [UN2729] [Poison]"**. Further research revealed: "Toxic, persistent organic pollutant, carcinogenic, especially dangerous to water organisms, banned within the Stockholm Convention."

How was it possible, to dump thousands of tons of such substances just a few meters from the sea, without any shelter, just in plastic wraps, without any protection? How was it possible to just dump it there like that? We could not find an answer over polish internet. Not a single article on HCB, not a word about its origins. We had thousands of tons of one of the world's most dangerous substances lying all around the incinerator in Gdansk, but not a single bit of information available on the matter. Finally, we found a short article about pesticides in leaky bags being returned from the Polish/Ukrainian border. Hexachlorobenzene was one of them.We confirmed that hundreds of trucks carrying HCB and Pesticides were coming, with permission granted by the Main Inspectorate of Environmental Protection.

Breakpoint

We were stuck. We could not prove any irregularities without a strong and reliable expert, who would make us sure that we are right. No one wanted to confirm to us, that what we saw in Port Service might be against the law.

Luckily, we came across Mr. Wiesław Stefan Kuc, an IHPA ambassador in Poland, who contacted us with Mr. Stanislaw Stobiecki, from the Institute of Plant Protection

in Sosnicowice. It was right at the point, where we could not move forward with our investigation, when Mr. Stobiecki invited me to a conference in Jaworzno, where I had pleasure of meeting John Vijgen. After a short conversation with John, I had no doubts, that pesticide waste is not treated properly. Together with Maciej Kuciel, we decided to go to Gdansk and enter Port-Service with our camera.

Incinerator Plant

The president of Port Service, Krzysztof Pusz, was so confident that he took us for a walk around the incinerator plant. What we saw there was shocking. At the end of this walk, we asked President Pusz if he knows what kind of waste he stores. He said that he is not precisely aware what it is. However, he kept claiming that he had all the necessary permissions from the proper authorities, making us sure that with proper supervision from environmental officials this situation wouldn't be possible. After further investigation we discovered that this facility wasn't capable of taking that much waste without harm to the environment. It's annual capacity was set for 6000 Mg of highly chlorinated compounds, but it was allowed to bring 12,000 Mg of HCB waste. The facility's storage capacity was set at 450 square meters. When HCB was already dumped there, it was increased to 4,500 square meters, but only on paper. The permission was changed in 11 days. Nobody even checked if this facility could ensure environmentally sound management of this type of waste. All the documents were signed to legalize something that was highly illegal already. We finished our work and aired 2 reports. However, what disappointed us was the fact that Polish environmental authorities, instead of initiating a solid control, claimed at first that there is no danger, due to the fact that this waste contained just 1.6% of HCB. Luckily, the prosecutor's office in Gdansk initiated an investigation and decided to check the facts. Their investigation proved that the Ukrainian waste consists of much higher percentages of HCB, reaching up to 30%.

We received serious support from Greenpeace. They did not trust the official statements, and wanted to check if the facility operated properly, and for pollution from the incinerator. Greenpeace sent their regional toxic expert Gergely Simon from Hungary, to judge the influence of those compounds on environment. John Vijgen's and Greenpeace's involvement in this case allowed us to receive international support. Journalists from Denmark, Sweden, and Germany contacted us, offering their help in disseminating this report in those countries. Thanks to their involvement, the governments of Denmark and Sweden put pressure on polish authorities. That changed everything. Local environmental authorities were removed, and finally, a serious investigation begun.

Blum Gruppe, German owners of the Port Service incinerator plant in Gdansk, decided to sever ties with former president Mr. Pusz, making Soren Blum the new president of the company. Changes were significant. Waste was covered with tarps, the area secured, and it stopped looking like a dumping site.

But new questions arose:

Where are the ashes from incineration?

Was the incinerator capable of decomposing those compounds?

Was it under proper supervision?

Letter from "The Woodsman"

At the time when officials tried to answer those questions, we received a very worrisome e-mail from a person who called himself "The Woodsman". He claimed that he was a witness to the dumping of partially incinerated waste from Port Service into a gravel pit.

We could not believe it at first, but after the first meeting, when "The Woodsman" took us to this place, we knew we had to prove it.

After a long conversation with Mr. Tomasz Stobiecki from the Plant Protection Institute, we received instructions on how to properly acquire soil and water samples. Equipped with special bottles and containers, we entered the gravel pit. Luckily, we got there unnoticed. At the bottom of the ridge, we smelled chemicals and saw partially burnt bags. We then took the samples of ashes and water as instructed.

The results were shocking. Many obsolete pesticides were found in the samples we delivered: HCH(alpha), HCH(gamma), HCB, DDT, and Atrazine. Concentrations of these compounds exceeded the standards for soil and water up to 550 times! We had no doubt where it came from, because those same compounds were found by Greenpeace, right at the Port Service fence.

We aired 2 new reports on this matter. Yet again, all the information we revealed were confirmed. The prosecutor's office and Inspectorates for Environmental Protection officials admitted that area in the gravel pit was polluted. The area was secured immediately.

Nearly one year has passed since we revealed this fact. In another 1,5 year pollution might start spreading into ground waters, in another 3 years it can show up in local wells. Everything happened under supervision of polish environmental authorities. They agreed to bring this waste to Gdansk, they confirmed that company is capable of it's destruction, they assured us, that there is no danger for the environment. We were meant to believe it, but as journalists we started asking questions. And though this investigation was completed, there are still questions that are pushing us to find the answers:

Is it possible that ashes from incineration of "softly" polluted soil (according to official documents HCB didn't exceed 1,6 % in total waste) would produce such a pollution all around dumping site? What happened to waste that originated from Kalush, that seemed to vapourize, but only on official documents. Is it possible, that authorities did not tell us the truth about HCB concentration in Kalush waste ?

Picture: (Ełganowo gravel pit- illegal dumping spot of incinerated HCB/pesticide waste)

ALTERNATIVE METHOD FOR THE CHEMICAL TREATMENT OF METHYL BROMIDE

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The Ministry of Environment of the Government of Nepal (MoEST) and the Chemical Safety Project of the "Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ)", Germany, planned and carried out a disposal operation in Nepal in October 2011. All 75 tons of obsolete pesticides mentioned in the National Implementation Plan (NIP) of the Government of Nepal from April 2007 were collected and shipped to Germany for final disposal.

The NIP also comprised 43 steel cylinders with 4 tons of methyl bromide, which had been stored for over 30 years in two stores in the Kathmandu Valley. Due to the bad storage conditions, two of the steel cylinders corroded and the highly toxic gas escaped into the environment in an uncontrolled manner. Corrosion was also visible on the metal surface of all steel cylinders and the valves were no longer functional.

According to the international ADR/RID and IMDG standards for the transportation of steel cylinders with compressed toxic gases, these cylinders were no longer fit for transportation by road, rail or sea to Europe for destruction. Due to these circumstances, the GIZ project worked out a technically and economically viable alternative for on-site elimination of the methyl bromide through a chemical treatment process.

Hydrolysis of methyl bromide

The hydrolysis of methyl bromide is a simple chemical reaction that transforms the toxic methyl bromide into non-toxic and bio-degradable methyl alcohol and sodium bromide – which can both be released into the environment without any risks.

$$CH_3\text{-}Br + NaOH \longrightarrow CH_3\text{-}OH + NaBr$$

Experts from GIZ and a specialist company designed an apparatus for the chemical treatment of the methyl bromide and adopted a proven technology to open the steel cylinders on-site without using the valve. The chemical apparatus was designed as a mobile unit based in a 20-ft sea container. It was shipped to Nepal.

Transfer of the methyl bromide into the reactors and the chemical process

The chemical process is a two-stage process in a closed system of specially designed steel vessels with a volume of 1,000 litres each. The high-pressure reactor system consists of two steel reactor vessels, with electric stirrers and a flow-control system so that the hydrolysis takes place under controlled conditions.

Considering the fact that the original valves could malfunction and to avoid the risk that the methyl bromide might escape into the atmosphere, the steel cylinders were opened on the side walls by applying a special spot drilling technique with an 'gas-tight system'. After drilling, the methyl bromide in the cylinder was transferred into the first reactor vessel via a connected Teflon tube, forced by the gas pressure in the cylinder, supported by nitrogen.

The reaction process

A volume of 500 litres of a 25% aqueous sodium hydroxide solution was pumped into reactor 1 prior to the hydrolysis in this reactor. After that the methyl bromide from a steel cylinder was transferred into reactor 1 via the Teflon tube. Simultaneously, the electric agitator stirred the mixture to support the hydrolysis process.

The dosage of the methyl bromide was controlled, so that the pressure inside reactor 1 did not exceed a pressure of 1.5 bar. The reaction temperature did not rise over 70 °C. After completion of the chemical process the reaction products were pumped into reactor vessel 2 for the after-reaction process and cooling down.

The chemical reaction was controlled by the pressure and the temperature and was monitored through the inspection window. This was an exothermic reaction and cooling was necessary. After cooling down, and the transformation of the methyl bromide into methyl alcohol and sodium bromide, the reaction product was neutralized with acetic acid. When the methyl bromide concentration reached a level lower than 10 mg/l and a pH of 6-7, the reaction products were transported by a tank truck directly to a local sewage system for discharge.

Scientific and technical background information

The hydrolysis of methyl bromide is a batch-by-batch process executed in a closed system. The reaction is very selective and fast; no other by-products are produced. The stoichiometric composition has to be calculated in a way that the quantity of the sodium hydroxide with a 10% excess corresponds exactly to the quantity of 200 kg of methyl bromide – or the quantity of 2 steel cylinders. Continuous chemical analyses were carried out at the end of each batch in order to control the completion of the chemical reaction.

Summary

The reaction products are eminently water-soluble and have no eco-toxic effects. Methanol is 100% biodegradable (eco-toxicity LC_{50} fish 96h 10.8 g/l). Sodium bromide has no impact on water. It is an integral part of seawater (toxicity LD_{50} rat 3.5 g/kg, oral). After the neutralization of the aqueous mixture of methanol and sodium bromide, the solution was directly disposed of in the local sewage plant.

The emptied steel cylinders were free of methyl bromide residues. After testing with Draeger test tubes, the valves of the steel cylinders were torn off. The steel cylinders were then ready for recycling by one of the local steel plants as scrapped metal.

The practical work on site was carried out by specialists from a German company and by GIZ experts and supported by Nepalese counterparts.

This method is an economical, technically proven and practical on-site approach for the environmentally sound elimination of the highly toxic gas methyl bromide and can be applied in any country with identical problems to those in Nepal.

Methyl bromide
Methyl bromide, also known as bromomethane, with formula CH_3Br is an odourless, colourless and non-flammable gas produced both industrially and particularly biologically. Methyl bromide has been used as a soil fumigant and structural fumigant to control pests (insects, termites, rodents, weeds, nematodes), and soil-borne diseases.

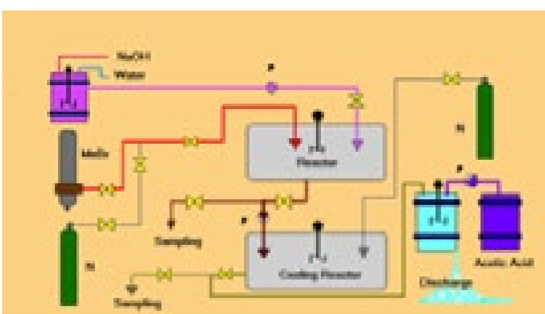
In 1999, an estimated 71,500 tons of synthetic methyl bromide were used annually worldwide (UNEP, 1 August 1999). 97% of this estimate was used extensively for fumigation purposes in the agriculture field, whilst 3% is used for the manufacture of other products, ex. as methylation agent, solvent and in fire extinguishers (halons).

Methyl bromide is an extremely toxic vapour. In humans, methyl bromide is readily absorbed through the lungs. Most problems occur as a result of inhalation and exposure effects from skin and eye irritation to death. Most fatalities and injuries occurred when methyl bromide was used as a fumigant.

Methyl bromide is recognized as an ozone-depleting chemical. As such, it is subject to phase-out requirements of the Montreal Protocol on Ozone Depleting Substances (1987).

Photo 2: The apparatus for the elimination of the methyl bromide

Photo.: W. Schimpf



Graphic: Diagram of the apparatus for treatment of the methyl bromide

Graph: W. Woywod

Photo 1: The steel cylinders with methyl bromide

Photo.: W. Schimpf

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PESTICIDE DESTRUCTION USING SUPERCRITICAL WATER OXIDATION

GENERAL ATOMICS

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Abstract

Supercritical water oxidation (SCWO) is a destruction technology for organic compounds and toxic wastes that makes use of the unique properties of water exhibited under supercritical conditions, that is, temperatures above 374°C and pressures above 22 MPa. Typical SCWO reactor operating temperatures and pressures are 600-700°C and 23.5 MPa, respectively. The oxidant is typically high-pressure air or oxygen. Organics and oxidant are miscible with SCW, creating good conditions for oxidation with minimal mass transport limitations, thus, even the most difficult to oxidize organic materials are quickly destroyed to yield carbon dioxide and water. Heteroatoms such as chlorine, fluorine, phosphorus and sulfur, are converted to inorganic acids or to salts if sufficient cations such as sodium or potassium are present. If present, metals such as iron and nickel will produce the metal oxides.

Typical SCWO gaseous discharge composition when oxidizing organic compounds consists of O_2 depleted and CO_2 enriched air. Oxidation of nitrogenous compounds produces primarily N_2 and in some cases small quantities of N_2O. Acid gases are largely eliminated from the SCWO gaseous effluent due to the self scrubbing nature of the aqueous reaction medium during pressure let down. Similarly, particulates are self scrubbed into the process liquid effluent.

Unlike incineration, SCWO does not produce NOx or SOx as exhaust gases. Electronegative elements such as S, Cl and P are converted to water soluble anions or oxyanions, and will appear in the liquid effluent as acids or salts depending on the cationic content of the feed or additives. In general there is little if any treatment required for discharge of the products.

Solid residue in the SCWO process effluent only occurs when the influent waste stream contains or produces water insoluble materials. For example, the liquid effluent produced from an influent slurry of organically contaminated soil would be a slurry of decontaminated soil. In essence, the soil would pass through the SCWO system unaffected because it is, primarily, mineral oxides with low water solubility levels.

These characteristics including reasonable capital and operational costs, and the highly portable nature of iSCWO systems make this processing approach ideal for the treatment of the lethal obsolete pesticide and persistent organic pollutants required by the various and relevant conventions and national implementation plans.

General Atomics (GA), a leading US defense contractor and developer of cutting edge technologies has been developing SCWO technologies and delivering SCWO/iSCWO systems to the US government and commercial clientele since 1991.

This paper will review how SCWO oper-

ates, GA's experience with SCWO with a variety of applications, and how SCWO technology can be applied for the destruction of obsolete pesticides and other organic materials.

Article

Supercritical water oxidation (SCWO) is excellent for the destruction of old or obsolete pesticides, obsolete paints, petroleum product manufacturing waste streams, pharmaceutical waste, energetic materials (explosives or propellants), and contaminated waste waters.

As described in the abstract, SCWO is a destruction technology for organic compounds and toxic wastes that makes use of the unique properties of water exhibited at supercritical conditions, that is, temperatures above 374°C and pressures above 22 MPa. Under these conditions, oxidation reactions occur rapidly and to completion with by-products consisting of clean water or brine, clean gases, and inorganic ash with essentially no airborne particulates.

GA has developed a simplified, small and compact version of SCWO called Industrial SCWO (iSCWO). The iSCWO process flow diagram is illustrated in Figure 1 and an operational system is shown in Figure 2.

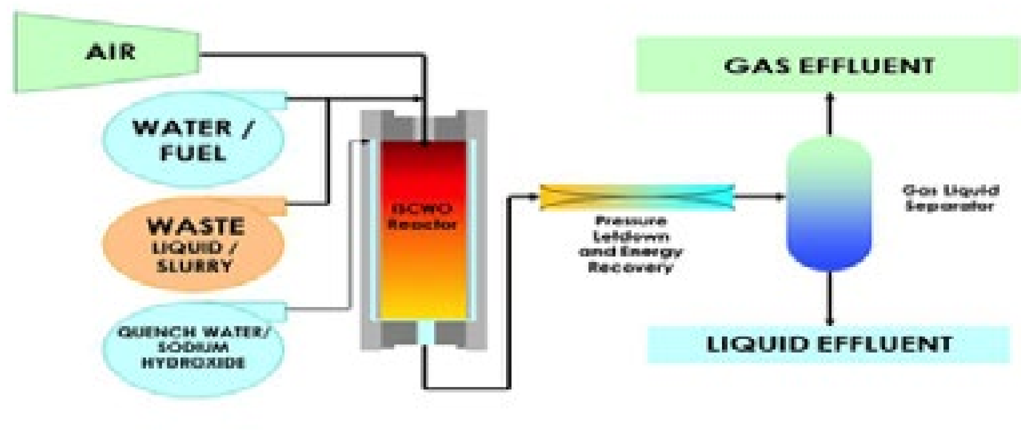

Figure 1: iSCWO Process Flow Diagram

Figure 2: iSCWO System Equipment Skid

Figure 3: Transportable iSCWO System

High pressure air along with water, fuel (if required by the specific application) and the waste liquid/slurry is pumped into the iSCWO reactor in which the high temperature and pressure will destroy the organic compounds via oxidation reactions.

Figure 4: Embedded iSCWO System

The reaction by-products exit the reactor through a pressure letdown system and discharge into a gas-liquid separator. The gases are exhausted through a stack and the liquids are discharged either into a holding tank or into a commercial sewer system.

A number of these simplified iSCWO systems have been supplied to US Government entities as well as commercial users for the destruction of various chemical and hazardous wastes. The iSCWO system is available as a compact, transportable unit (see Figure 3) or available to be installed in a new or existing facility as a final installation (see Figure 4). The benefits of utilizing SCWO far outweigh the use of alternative waste destruction approaches especially if onsite (or for transportable systems, multiple sites) use is desired. In addition, SCWO systems do not require pollution abatement systems for gaseous effluent cleanup.

GA has demonstrated the destruction of hundreds of organic compounds and mixtures with SCWO technology including pesticides. Shown below in Figure 5 is GA's test facility located in San Diego, California, which utilizes a 3gpm iSCWO system. This system can be used to test customer wastes in order to demonstrate operability and waste destruction. Effluent analysis (gas and liquid) are performed to confirm high waste destruction efficiencies. The systems built for our customers are put through rigorous acceptance tests prior to shipment. Figure 6 shows a transportable system undergoing final acceptance testing for a European commercial client.

The iSCWO system has a limited number of components which makes maintenance and operation very easy. The control system uses off-the-shelf computer components such as programmable logic controllers (PLC), variable frequency drives (VFD), gas and liquid monitors, and workstation graphic displays for automated operation (calibrate, startup, operation,

Figure 5: iSCWO Waste Test System

Figure 6: Final Acceptance Test

shutdown) complete with alarms and interlocks. The control system is highly intuitive and can be configured for English or Metric Units, and customized for specific languages.

The installed size of the iSCWO skid is 7.3 meters long by 4.5 meters high and 2.4 meters wide. For the transportable version, the iSCWO fits inside a ISO container that is 8.3 meters long by 2.9 meters high and 2.4 meters wide. Once the transportable unit is at the site, only a small number of equipment components need to be assembled before operation (e.g., heat exchanger).

To adequately treat powdered pesticides and other solid wastes, a front-end feed processing system would need to be incorporated. Preprocessing steps could include size reduction, slurrying, blending, filtering, and other waste preprocessing technologies to produce pumpable mixtures. Once in an acceptable form, the waste feed would be pumped into the iSCWO reactor as shown in Figure 1. The majority of iSCWO systems that GA supplies require some type of up-front pre-processing system to create mixtures that can be delivered to the process in a reliable manner.

Evaluating the implementation of iSCWO as either a transportable system or a fixed site system involves the identification and inventory of the pesticide and other wastes to be processed as well as logistical studies to determine the optimum remediation strategy. This includes performing a mass and energy balance evaluation along with economic, safety and feasibility studies.

The next step would be to perform tests to demonstrate that the iSCWO system can process and destroy the waste, and to collect the test data to support design and permitting activities. While SCWO destruction efficiencies typically exceed 99.999%, the actual requirement is driven by site specific needs especially if the liquid effluent is to be disposed of via the site sewer system. The collected test data will be used to characterize gas and liquid effluent compositions, determine operating conditions, and to quantify utility requirements (electrical power, water, fuel). Included in this analysis is the capital and operating costs of the iSCWO system for the specific waste(s) to be processed.

Once deemed acceptable, the final step would be the design and fabrication of an iSCWO system(s) based on the test results and specific customer requirements (e.g., safety and fabrication standards). Prior to shipment to the customer site, the system would be subjected to final acceptance tests to demonstrate operability and waste destruction efficiencies.

In summary, SCWO technology is an exceptionally clean waste destruction process suitable for processing all classes of hazardous and nonhazardous wastes especially pesticides. SCWO systems can provide onsite waste treatment at an affordable cost.

TREATMENT OF ORGANIC HAZARDOUS WASTES USING TETRONICS' PLASMA ARC TECHNOLOGY

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Tetronics DC plasma arc system can be used to treat a wide range of solid, liquid or gaseous waste streams to destroy or transform hazardous components and to recover valuable materials as by-products. To date, Tetronics has supplied more than 90 plasma systems globally, of which 27 have been for the treatment of hazardous wastes, including material containing Polychlorinated Biphenyls (PCBs), Persistent Bio-accumulative and Toxic (PBT) pollutants and Air Pollution Control residues (APCr), containing dioxins and furans alongside a range of other hazardous species, such as chlorine, sulphur and heavy metals.

This paper presents details of the application of Tetronics' DC arc technology for the destruction of persistent organic pollutants in a number of waste streams. The process develops a high temperature (>10,000 °C) plasma-arc, which is generated using either graphite electrodes or water-cooled torches, depending on the application. It results in an extremely high destruction and removal efficiency, with a performance of 99.9999% typically achieved as a result of the high temperatures and intense ultra-violet light generated by the arc, the close control of oxidation conditions and the residence time in the plasma furnace. The off gas treatment systems also ensure reformation of the organic pollutants does not occur, in order to ensure the high destruction efficiencies are achieved. In addition, the decontamination process for these wastes also produces an inert slag material (Plasmarok®), which has been approved for use by the UK Environment Agency as a secondary aggregate. Within this paper, further examples will be provided of other valuable by-products generated by the waste treatment process, such as the recovery of acid and valuable metals.

Keywords

- Tetronics International
- Organic waste destruction
- Plasma waste treatment
- Plasma technology
- Treatment of persistent organic pollutants
- Hazardous waste treatment
- Air pollution control residues

Technology Description

1.1 General description

Tetronics DC plasma arc system can be used to treat a range of waste streams to destroy and transform hazardous components and to recover valuable materials as by-products. One of the applications of the technology is the destruction of organic wastes including Polychlorinated Biphenyls (PCBs) and other types of Persistent Bio-accumulative and Toxic (PBT) pollutants at very high efficiencies across a wide range of concentrations. To date Tetronics has supplied >90 commercial plasma treatment facilities for a range of applications, of which 27 were for hazardous waste applications. These include organic wastes containing PBTs and APCr, containing dioxins and furans.

At the heart of any Tetronics plant is a DC plasma furnace shown schematically in Figure 1. The process develops a high temperature (>10 000 °C) plasma-arc by ionising a plasma forming gas, e.g. nitrogen. Tetronics' processes use either graphite electrodes or water-cooled torch systems (single or multiple torch systems) to generate plasma. Typically graphite electrodes are used for waste management applications.

A schematic process flow diagram of plasma hazardous waste treatment is shown in Figure 2.

The following points summarise the main features of the system:

- Feed material can be introduced as a solid, slurry, liquid or gas through the furnace feed port(s). The feed system is tailored to the nature of feed where possible.
- The intense temperature and ultra-violet light of the plasma is used to destroy hazardous organic components and melt the inorganic fractions of the waste material.

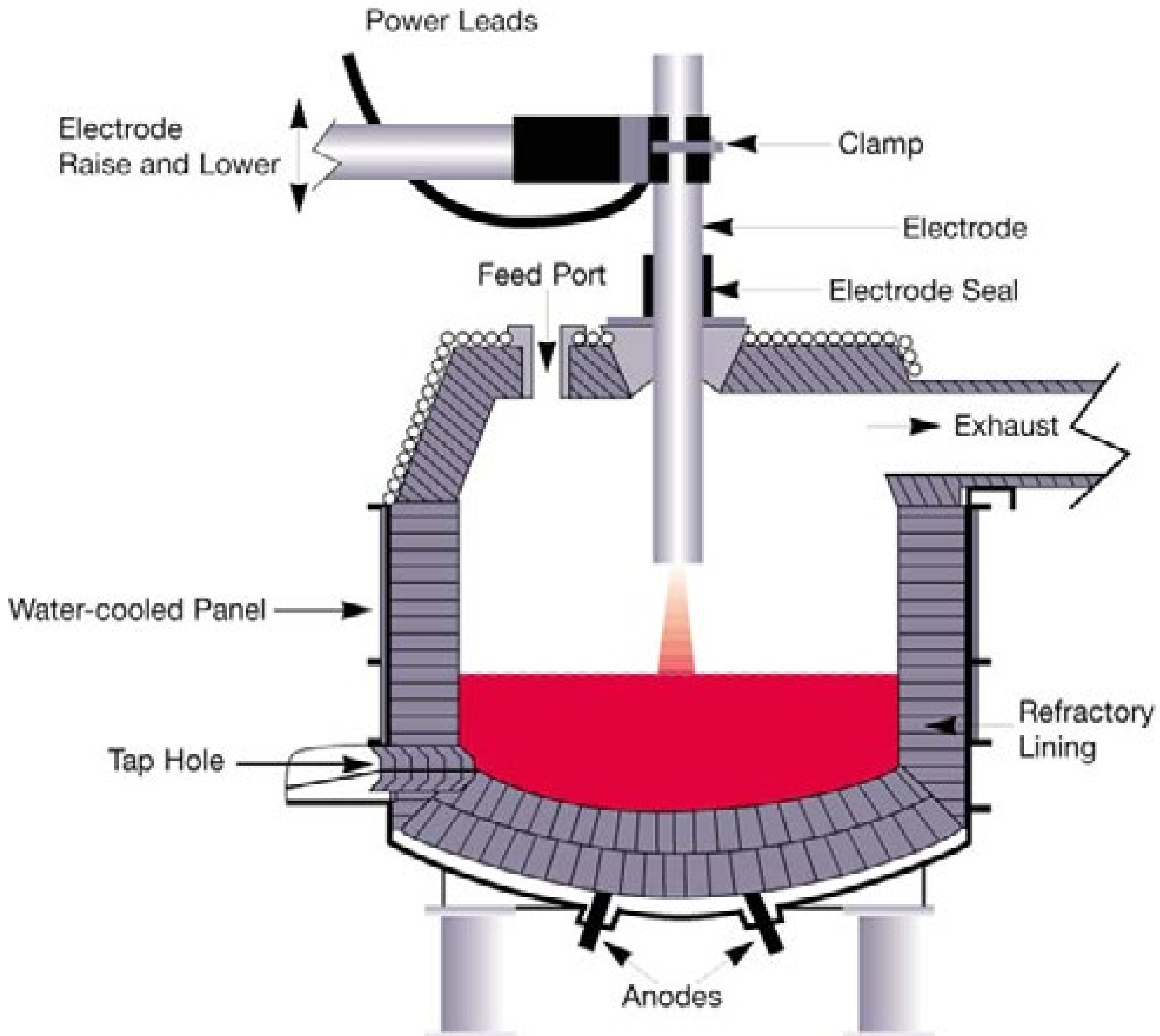

Figure 1: Main components of Tetronics' DC Plasma furnace (graphite electrode system)

- The inert slag produced from the process (Plasmarok®) can be employed in a range of applications, such as a simple construction aggregate and is officially qualified as a product in a number of territories.

- Fluxing reagents are added to ensure an inert (stable, non leaching) slag is produced and also to ensure low slag viscosity when molten. Where possible, fluxing material is sourced from waste material containing suitable fluxing agents to minimise operating costs and maximise environmental benefits.

- Valuable metals can be recovered using this process by adding, if required, suitable reducing agents and collector metal. The recovered metal segregates at the base and is tapped intermittently during operation.

- The high furnace temperatures, electromagnetic radiation (light) and oxidant injection (if required) ensure that any volatiles species are decomposed to a simple mixture of carbon dioxide, carbon monoxide, water vapour, and hydrogen gases.

- The steep thermal gradients and favourable temperature-time history also inhibits Persistent Organic Pollutants (POPs) reformation mechanisms.

- Depending on the feed chemistry, NOx and SOx may also be present. As part of the plasma treatment system and subject to project specifics, Tetronics offers an integrated off gas abatement system with energy recovery capabilities, provided the product gases have sufficient calorific value/sensible heat.

- Tetronics' processes generally produce minimal amounts of secondary waste because the by-products generated (slag, metal, fly ash and/or APC residue from the off gas cleaning system) can be used for secondary applications.

1.2 Destruction of Persistent Organic Pollutants (POPs)

This paper describes the main applications relevant to the treatment of waste contaminated with hazardous organic wastes such as dioxins, furans, PCBs and other POPs. The decontamination process for these wastes is designed to separate and destroy the hazardous components leaving an inert material with a valuable secondary use. The process results in an extremely high Destruction and Removal Efficiency (DREs) with performance of 99.9999% typically achieved.

Tetronics has installed several plants for the treatment of waste material containing hazardous organic wastes. In addition, new projects are underway for installing further plants. Tetronics has also used its Arc lab, the onsite demonstration facility (the most sophisticated of its type in Europe), to treat hazardous wastes. The following points summarise the main details of these plants, projects, and demonstrations:

- A plasma system was supplied to the GEKA in Munster, Germany, to treat soil contaminated with arsenic and chemical weapons residues.

- A plasma treatment plant including feed system and off gas treatment was designed, installed and commissioned for Centro Sviluppo Materiali (CSM) in Rome, Italy to treat a range of solid and liquid waste streams including oils containing PCBs (polychlorinated biphenyls), contaminated soils containing heavy metals and POPs, sewage sludge, Municipal Solid Waste (MSW) incinerator fly ash containing dioxins and furans, and asbestos containing material. The plant throughput is 100 kg/h.

- Tetronics has installed and commissioned 18 plasma facilities in Japan for treating fly ash and bottom ash arising from the incineration of municipal solid waste (MSW) and sewage sludge, which also contain organic pollutants such as dioxins and furans, carbon and alkaline salts.

- Tetronics are currently in the process of supplying a similar plant for a UK customer to treat 33ktpa of APCr.
- Tetronics has delivered a plasma treatment facility in Brazil for the treatment of oily sludge waste material from refinery storage tanks at a throughput of 4000tpy. This waste contains polyaromatic hydrocarbons (PAH) and other organic wastes.
- Tetronics has used its Arc lab, the onsite plasma treatment demonstration facility, to treat a simulant contaminated soil waste material. The actual waste to be treated by the client contains PCBs, oil, soil and aggregate. However, due to regulatory reasons associated with trans-boundary movement of PCBs, a simulant material was used for these demonstrations. The simulant feed material contained 1 wt% 1,4 dichlorobenzene.

The main attributes of these applications are presented in this paper by broadly categorizing the use of DC arc plasma technology to treat three waste streams as follows:

Component	Oily Sludge from Refinery Storage Tanks, Vol %	PCB Contaminated Soil, Vol %	MSW derived APCr, vol%
H_2(g)	25.9	0.1	3.9
H_2O(g)	30.8	59.8	41.1
CO(g)	28.2	0.1	16.6
CO_2(g)	8.0	32.4	33.0
O_2(g)	0.0	1.0	0.0
N_2(g)	7.2	6.6	8.4
Offgas production (Nm3/tonne of waste)	*1657.23*	*526.08*	*224.82*

Table 1: Typical furnace off gas compositions for three different waste streams (before off gas cleaning)

- Oily sludge from refinery storage tanks
- PCB contaminated wastes
- APC residues from thermal waste MSW

1.3 Process gases

1.3.1 Products of the process

The gaseous products of Tetronics' processes are mainly carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2), water vapour (H_2O) and inert purge gas (N_2 or Ar). Other volatile components that may be present are alkali metal chlorides (KCl and NaCl), SOx and NOx depending on the feed composition. Table 1 presents typical off gas compositions at the furnace exit for the three main waste streams discussed in this paper i.e. oily sludge from refinery storage tanks, PCB contaminated soil and MSW derived APC residue. Treatment of PCB contaminated soil generally requires excess oxygen as an additional reagent to ensure complete destruction of POPs. Therefore, partially combusted products such as H_2 and CO are lower in concentration compared to the other two streams. Chloride salts present in the off gas (due to chlorine containing APC residues) can be recovered through scrubbing.

1.3.2 Occurrence of unintentionally generated pollutants

Upon exposure to the high intensity plasma arc, long chain hydrocarbons are broken down into simpler molecules. These processes are thermally and photo-catalytically driven and addition of oxidants leads to the destruction of these species. As a result, during steady state operation, the off-gas composition follows that shown in Table 1. To minimize emissions of unintentionally generated pollutants during transient periods of operation, the plasma system is coupled with an off gas abatement system tailored to the furnace exhaust gas specification as well as the feed material composition. This off gas system is brought to temperature independently before the waste stream is introduced into the process.

This ensures that atmospheric emissions of components such as volatile organic compounds (VOCs), halogenated species, dioxins/furans, SOx, and NOx are minimised and well below the limits set out by local regulatory bodies.

1.3.3 Secondary waste stream volumes and treatment

The "secondary waste" stream from the process is the particulate drop out from the thermal oxidizer and filtration system. This contains mainly KCl and NaCl, as well as oxides and salts of other volatile metals such as Zn, Pb, Cd, Hg etc and a small amount of physically carried over species. This waste stream can sometimes be recycled to the plasma furnace with, or without, further treatment.

	Oily Sludge from Refinery Storage Tanks	PCB Contaminated Soil	MSW APC residue*
SiO_2	187.54	-	Typically 100-300
Al_2O_3	-	33.87	
CaO	187.54	62.26	
$O_2(g)$	590.13	349.31	-

*Flux addition depends on ratio of bottom ash to fly ash. In most of the plants, cost of flux addition is minimized by using waste material containing suitable fluxing components.

Table 2: Flux and oxidant additions for three different waste streams (kg addition/tonne of waste)

1.4 Process Reagents

The process reagents depend on the feed stream chemistry. In comparison to other thermal operations, Tetronics' processes generally require lower levels of reagents such as flux, oxidants etc. for a specific application and scale of operation.

The required process reagents may include any of the following:

- Fluxing agents to provide a glassy matrix for the transformation and incorporation of the material within an inert non-leaching product while producing a low melting point phase with low viscosity when molten (typically achieved by adding SiO_2 and/or CaO and/or Al_2O_3)
- Oxidants to promote destruction of organic material and to provide additional reaction energy (typically oxygen and/or water) off-setting plasma energy requirements
- In applications involving metal recovery, reagents include reductants and collector metal in addition to fluxing agents (less applicable to hazardous waste applications)

The process is optimised to ensure such additions are minimised while achieving the required process outputs (i.e. destruction of hazardous components, vitrification of inorganic components, and recovery of valuable materials). The main additions relevant to the three processes discussed in this paper are fluxing agents and oxidants. Typical addition levels for these components, per tonne of waste treated, are given in Table 2.

Hazardous wastes with high organic fractions generally require more flux additions due to the low inorganic content and also require additional oxidants to complete the reaction with hydrocarbons. The oily sludge process is designed to produce syngas for energy recovery in a downstream process, while the PCB waste treatment process requires excess oxygen to ensure maximum destruction of the PCBs. Fluxing additions for MSW derived APC residue depend on the ratio of bottom ash to fly ash as the former is mainly inorganic material containing some fluxing properties i.e. feed streams with higher fractions of bottom ash require less fluxing. The plasma arc is more than sufficient to destroy the dioxins/furans and therefore oxygen additions are not required.

	Oily Sludge from Refinery Storage Tanks, wt %	PCB Contaminated Soil, wt %	MSW derived APCr wt%
SiO_2(l)	32.41	57.12	39.74
CaO(l)	35.23	22.14	31.36
Al_2O_3(l)	17.50	12.05	0.64
TiO_2(l)	-	-	0.16
FeO(l)	12.26	1.91	0.47
MgO(l)	1.78	4.68	0.86
Fe_2O_3(l)	0.06	0.21	0.00
Na_2O(l)	0.00	1.01	0.00
ZnO(l)	-	-	0.11
Cr_2O_3(l)	-	-	0.00
$CaCO_3$(l)	-	0.87	0.03
K_2O(l)	0.00	-	0.00
Fe_3O_4(l)	0.76	-	0.00
CuO(l)	-	-	0.06
NaCl(l)	-	-	6.27
KCl(l)	-	-	2.89
$CaCl_2$(l)	-	-	15.94
FeS(l)	-	-	0.01
CaS(l)	-	-	1.41
MnO(l)	-	-	0.04
Slag production (kg/tonne of waste)	*599.16*	*839.62*	*845.38*

Table 3: Typical composition of slag produced from Tetronics' DC Plasma technology to treat three different waste streams.

1.5 Process water

1.5.1 Secondary waste stream volumes and treatment

Water is used on a closed loop basis for cooling the furnace shell and deionised water is used for cooling the electrical components. Water is also used to cool the slag conveyor or to quench the slag if a granulation vessel is used. All cooling water is recirculated and thermally managed in a sealed system. Water is also used to quench the off-gas from the combustion chamber to below 250 °C to ensure that there is no De Novo formation of dioxins and furans. Any scrubber effluent is discharged after suitable treatment to meet compliance requirements.

Some APCr can contain high levels of chlorine. Analysis has shown that the chlorine in the feed partitions as chlorides of Na, K, and Ca in the slag and also as volatile species in the off gas. Chloride components that are present as particulates or which condense in the off gas system are collected in the baghouse, while any remaining in the gas phase if sufficient in quantity is recovered using conventional technology to produce HCl as a process credit.

	Oily Sludge from Refinery Storage Tanks	PCB Contaminated Soil	MSW derived APCr
Metal Production (kg/tonne waste)	43.80	-	3.10

Table 4: Typical metal production rate from Tetronics' DC Plasma techology to treat three different waste streams

1.6 Solid residues

1.6.1 Valuable residues

The solid residues are represented by the vitrified slag, any dust collected in the baghouse, and the recovered metal. The slag produced is an inert by-product called Plasmarok® and can be sold to be used in the construction industry or moulded into various product forms, e.g. tiles. The recovered metal fraction is generally low for the applications considered here, however any metal recovered may be resold. Dust collected in the baghouse containing KCl and NaCl may be reused. However, if scrubbing agents are used, further processing may be required. Otherwise, this stream is classified as secondary APC residue. Sometimes it is feasible to recycle the dust back to the plasma furnace.

Typical slag and metal compositions for the three applications discussed here are shown in Table 3 and Table 4 respectively along with the expected slag and metal production rates.

The metal phase consists mainly of iron with minor elements such as copper, phosphorous, silicon, manganese, chromium and zinc also being present.

1.6.2 Secondary waste stream volumes and treatment:

Secondary APC residues are produced in small quantities due to low particulate carry over with the furnace off gas. This may be as a result of physical carryover of the feed stream as well as condensation of volatile species (chemical carryover) in the cooler sections of the process downstream of the furnace. The partitioning mechanisms are complex. For solid feed streams crushed to a fine dust, physical carryover may be between 1 – 3 % of the

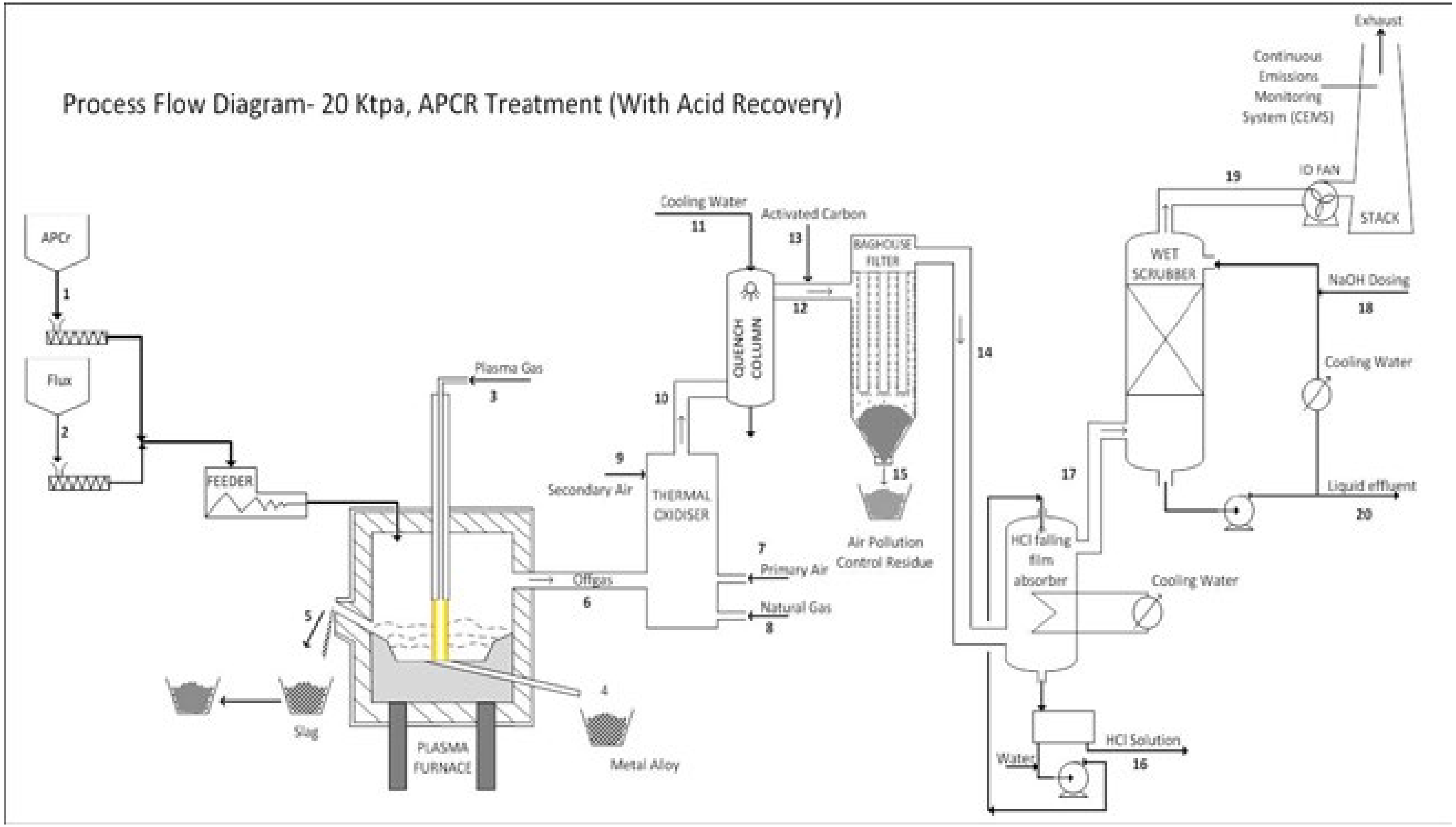

Figure 2: Schematic process flow diagram for plasme hazardous waste treatment.

total feed rate. In total, particulates collected in the off gas system amount to no more than 10% of the total feed rate which includes condensation of volatile species and spent sorbents.

The general approach is to minimize physical carryover by optimizing the furnace design. As this cannot be eliminated completely, where possible, secondary APC residue may be recycled back into the furnace. Depending on the chemistry of this particulate stream, scrubbing of the gas may be required also.

1.7 Pre-treatment

- For MSW ash, the use of a magnet and vibrating screen enables magnetic iron content to be removed prior to charging into the furnace. Drying of the feed material to <10% moisture is recommended to minimise energy consumption in the plasma process.
- Oily sludge waste material and contaminated soils may need some form of dewatering/drying and homogenization to minimise instabilities in feed.
- Liquids may also be fed into the process using a liquid/sludge injection lance system. Feed streams may require some form of pretreatment if not already of the required conveying consistency.

2. History

This section describes the history in relation to supplying the plasma systems for GEKA in Munster, Germany and Centro Sviluppo Materiali (CSM) in Rome, Italy.

2.1 GEKA

During the World Wars, Munster became the site of a testing and production facility for arsenical agents such as Clark II (DC), Mustard agent (HD) and Chloropicrin (PS). A fire broke out in a workshop; the chain of events that followed led to the explosion of a train fully loaded with shells, mines and chemical agents. In total, 48 buildings, in excess of 1 million shells, mines and tank wagons full of liquid agent were destroyed and an area of 3 km radius was contaminated. In 1956, with the take-over of the site by the Bundeswehr, the first ever systematic and controlled operation to clear the debris of both World Wars began. The site now houses Incineration plant, soil washing facilities and a plasma furnace. The system initially used a non-Tetronics plasma system; however, it was plagued by operational difficulties. Tetronics plasma systems were retrofitted to replace the original equipment, which resulted in improved reliability and process energy efficiency, enabling the facility to work as intended. This plant continues to operate successfully. Here the primary plant function is demilitarisation including destruction of chemical agents. The URL is http://www.geka-munster.de/.

The Tetronics installation provided for much improved reliability and energy efficiency, so greatly reducing the necessity for complementary fossil fuel heating of the plasma furnace previously required to supplement the original system provided by others.

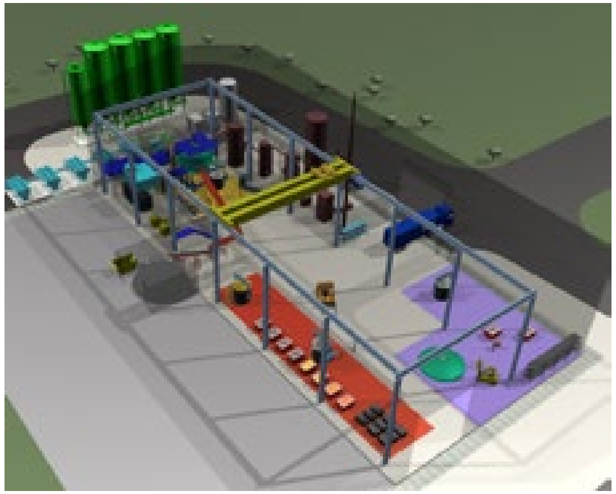

Figure 3: Plant layout for a Tetronics DC Plasma treatment facility

2.2 Centro Sviluppo Materiali (CSM)

Tetronics was approached by CSM for the treatment of hazardous solid and liquid waste with the requirement of a maximum level of flexibility including multi or single torch/electrode operation under a range of conditions, to feed both solid and liquid feed streams.

The scope of supply included the design, build, installation and commissioning of a twin 38 mm shrouded torches, 500 kW power supply, manipulation, furnace, water/gas manifolds, pump chiller unit, control system, liquid and solids feed system, off-gas treatment. The system was designed for the treatment of a wide range of waste materials including oily waste material classified as carcinongenic. This waste was sourced from cleaning of interceptor waste oil sumps and tank bottoms.

2.3 TSL Engenharia Ambiental (TSL)
TSL Engenharia Ambiental (TSL) is a multidisciplinary Brazilian based service / utility engineering company with core activities in the field of waste management. This company operates in close liaison with the state environmental authorities, CETESB (the Brazilian equivalent to the EA) and are responsible for the first commercial plasma references established in Brazil.

TSL approached Tetronics to use its DC Plasma Technology for PCBs destruction in Brazil. This technology focuses on converting contaminated soil to inert slag, a valuable construction material. Prior to establishing a commercial plant in Brazil, TSL and Tetronics carried out trials at Tetronics' Arclab facility to confirm the stability of the process in operation and the destruction and removal efficiency (DRE) of PCBs. The trials were undertaken using a series of simulants made with 1,4-dichlorobenzene, topsoil, aggregate, engine oil and water.

3. Infrastructural and organizational requirements

3.1 Infrastructure
Figure 3 shows a site layout of a typical plasma treatment facility. The controlroom, plasma power supply, feed system, cooling water pump set and manifolds services and utilities manifolds and furnace are enclosed inside a building. The furnace exhaust gas leaves the building through the exit duct and to the off gas system outside. This includes a thermal oxidizer, particulate removal system, gas monitoring system and stack as a minimum, with dry/wet scrubbing, waste heat boiler or other energy recovery system as further options.

- For a 40,000 tpy ash vitrification plant the typical building foot print of such a plant is 35m x 75m and 22m at the apex.

Parameter	Oily Sludge from Refinery Storage Tanks	PCB Contaminated Soil	MSW derived APCr
Waste Feed Rate (t/h)	0.5	0.7	2.5
Waste Calorific Value (kWh/t)	4586	4543	n/a
Heat of Reaction Released (kW)	559	785	n/a
Theoretical Electrical Energy Requirement (kWh/t waste)	47	244	400
Net Electrical Power Requirement (kW)	**24**	**180**	**1015**
Furnace Steady State Heat Losses (kW)	466	412	1000
Gross Electrical Power Requirement (kW)	**490**	**591**	**2015**
Furnace Energy Efficiency (%)	56	70	50

Table 5: Typical energy requirements to treat three different waste streams using Tetronics' DC plasma technology.

- For a 4000 tpy hazardous waste treatment plant, the typical building foot print is 25m x 48m and 11m at the apex.

3.2 Energy requirements
Table 5 summarises the energy requirements for the three different processes. Oily sludge and contaminated soil wastes both contain an organic fraction. The reaction of these components with oxidants releases energy into the process and therefore, compared to ash vitrification processes (such as MSW derived APCr treatment), the theoretical electrical energy requirement is less. The organic fraction for MSW derived APCr wastes is low compared to the other two processes and therefore any reaction energy released is considered negligible.

The furnace energy efficiency is defined as follows:

$$\text{Efficiency} = \frac{\text{Heat of reaction released + Net Plasma power requirement}}{\text{Heat of reaction released + Gross Plasma power requirement}} \times 100$$

The oily sludge process is based on a smaller furnace (4000tpy annual throughput) and hence the energy efficiency is lower than for the larger 6000tpy and 20000tpy furnaces modeled for PCB contaminated soil and MSW derived APCr

Name of city	Wastes treated	Furnace capacity (tonnes per day)	Number of furnaces
Munster, Germany	Contaminated soil	-	1
Rome, Italy	Range of organic wastes containing PCB and other POPs, asbestos and inorganic wastes	2.4	1
Chester, UK (EA Technology)	Asbestos Contaminated Material	5	1
St-Paul-Lez-Durance (CEA)	Assorted waste	2.5	1
Iwaki (MHI)	MSW incinerator ash treatment plants in Japan	40	1
Tushima (MHI)		28	2
Kouchi (MHI)		40	2
Nagoya (MHI)		35	2
Hiroshima (MHI)		48	2
Sendai (MHI)		80	2
Tochigi (MHI)		30	2
Sapporo (Takuma)		140	1
Hitachi city (Hitachi Zosen)		6	1
Kamo city (Hitachi Zosen)		30	1
Ichikawa (TSK)		5	1
Ichikawa (Takuma)		5	1
Takasago (Takuma)		24	1
Kobe (KOBE)		8	1
Fujisawa (Ebara Soken)		2.4	1

Table 6: Fixed plants for treating hazardous wastes

treatment respectively, i.e. there is an economy of scale.

3.3 Auxiliary materials/chemicals requirement
Depending on the sulphur and chlorine content of the ash, abatement additives such as lime/activated carbon injection or final wet scrubbing using sodium hydroxide may be required to remove acid gases.

4. Types of waste treated

Tetronics DC Plasma process has been implemented for a range of feed streams, including the following:

- Contaminated soils containing PCBs and other POPs
- Liquid waste streams containing PCBs and other POPs
- Air pollution control residues containing dioxins and furans
- Oily sludge from refinery storage tanks containing polyaromatic hydrocarbons (PAHs)
- Other hazardous organic and inorganic wastes eg. Wastes containing asbestos, arsenic.
- Gaseous feed streams containing long chain hydrocarbons
- Asbestos Contaminated Materials (ACM)
- Mixed bottom ash and APC residues

5. Status of commercialization

5.1 Fixed plants
Fixed plants for treating hazardous wastes have been supplied by Tetronics for several clients as shown in Table 6.

5.2 Portability
Portable facilities have not been supplied by Tetronics; however, a transportable unit is currently under development and may be supplied if required.

5.3 POPs throughput:
[POPs waste/total waste in %]
The plasma facilities supplied to GEKA in Germany and CSM in Italy are used to treat a range of waste materials. The proportion of wastes containing POPS as a percentage of total plant throughput is not publically available. The public information on the POPs concentration of wastes is also limited.

In the case of MSW fly ash treatment, where only fly ash is treated, it can be stated that all of the waste treated contains some contaminants in the form of dioxins and furans (1.1 -1.3 ng-TEQ/g). Tetronics' DC plasma technology destroys a large part of the dioxins/furans present in incinerator fly ash waste. Dioxin/furans in the slag from MHI plant were found to be between 0.0000018 – 0.0043 ng-TEQ/g. Any of these persistent organic pollutants that exit the furnace with the off gas are destroyed further in the thermal oxidizer. The combusted gas is then cooled rapidly via a quench column to prevent De Novo generation of dioxins.

POPs throughput and destruction efficiencies (slag based) are available from demonstration work conducted at Tetronics' Arclab facility as shown in Table 7.

Name of city	POP's throughput	POPs concentration in POPs waste	Units	Destruction efficiency (%)
Oily Sludge	100%	15-85	mg/kg waste	Unknowm
PCB contaminated waste	100%	5000	mg/kg waste	99.9999

Table 7: POP's throughput and destruction efficiency for oily sludge and contaminated soil waste material.

Utilities required for hazardous waste treatment

Table 8: Utilities required for a plant treating oily sludge from refinery storage tanks

Consumables	Units	Quantity per tonne of waste	Quantity per year (4000 t/y commercial plant)
Electrical Power	kWh	980	3,920,000
Electrical Power Auxiliary	kWh	121	482,352
Inert Gas (Argon)	Nm^3	118	472,231
Flux (CaO)	kg	190	760,000
Flux (SiO_2)	kg	190	760,000
Oxygen (O_2)	Nm^3	590	2,360,512
Plasmarok production	kg	342	1,367,200
Secondary APC	kg	11	45,200
Throughput of waste	kg/h	537.20	
	Tonnes/year	4000.00	
	Plant availability (%)	85%	

Table 9: Utilities required for a plant treating PCB contaminated soil

Consumables	Units	Quantity per tonne of waste	Quantity per year (5479 t/y commercial plant)
Electrical Power	kWh	804	4,404,285
Electrical Power Auxiliary	kWh	121	660,643
Inert Gas (Argon)	Nm^3	33	178,704
Flux (CaO)	kg	62	340,783
Flux (AI_2O_3)	kg	34	185,547
Oxygen (O_2)	Nm^3	249	1,362,730
Plasmarok production	kg	840	4,601,947
Secondary APC	kg	10.00	57,785
Throughput of waste	kg/h	735.77	
	Tonnes/year	5478.51	
	Plant availability (%)	85%	

Table 10: Utilities required for a plant treating APCr

Consumables	Units	Quantity per tonne of waste	Quantity per year (20,000 t/y commercial plant)
Electrical Power	kWh	794	15,885,200
Electrical Power Auxiliary	kWh	39	780,000
Inert Gas (Nitrogen)	Nm^3	24	473,000
Silicia Flux	kg	305	6,100,000
Plasmarok production	kg	664	13,280,000
Metal Alloy Production	kg	3	62,000
Secondary APC	kg	302	6,046,700
HCI Condensate Production	kg	556	11,315,220
Waste throughput	kg/h	2537	
	Tonnes/year	20000	
Plant Availability	%	90	

6. Conclusions

Tetronics DC Plasma process is an effective method of treating hazardous and organic waste materials from a range of industries. Commercial plants for the remediation of wastes and the simultaneous recovery of valuable materials have been supplied by Tetronics to companies around the world for many years. The process develops a high temperature (>10,000 °C) plasma-arc, which results in an extremely high destruction and removal efficiecy. Destruction efficiencies of typically 99.9999% are achieved as a result of the high temperatures and intense ultra-violet light generated by the arc, the close control of oxidation conditions and the residence time in the plasma furnace. The off gas treatment systems also ensure reformation of the organic pollutants does not occur, in order to ensure the high destruction efficiencies are achieved. In addition, the decontamination process for these wastes also produces an inert slag material (Plasmarok®), which has been approved for use by the UK Environment Agency as a secondary aggregate.

IMPROVEMENTS AT PORTSERVICE INCINERATION PLANT

S. Blum & D. Naumann
Portservice, Poland

Because of a wrong decision taken in 2011 there were brought 15.000 Mg of pesticides on Port Service's place, which caused many problems with environmental inspectorates due to a risk of inappropriate storage and probable dangerous fume emission.

From January 2012 to June 2013 Port Service had been working hard on modernization of the Incineration Plant to make all processes connected with thermal utilisation much more safe and environmentally friendly.

The company managed to improve and secure the storage system of different fractions of hazardous waste, including pesticides. There were made special lodgings, which make it possible to storage them properly and separately.

Port Service was also successful in the reduction of fume emission by using new technologies and renovation of some elements in the Incineration Plant like electrostatic precipitator, adsorption apparatus, steel structures, etc.

All factors which may cause any dangerous implications are constantly monitored by comprehensive system of measurement control.

The Incineration Plant is still developing.

GEOMELT VITRIFICATION TECHNOLOGY ELIMINATES PERSISTENT ORGANIC POLLUTANTS AND PESTICIDE CONTAMINATION

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Abstract
Kurion's GeoMelt® vitrification technologies have been used for thermal destruction of Persistent Organic Pollutants (POPs) and pesticide contamination. This paper presents several case studies based on prior treatment projects and summarizes recent technology development work.

Key Words
GeoMelt, Vitrification, Persistent Organic Pollutants, Thermal Treatment, Kurion,

Introduction
Kurion's GeoMelt vitrification technology is based on joule melting of glass-forming materials and wastes. The melting destroys organics though thermal processes and immobilizes toxic metals in a durable glassy wasteform. Wastes treated by GeoMelt have included a wide variety of Persistent Organic Pollutants (POPs), other organic wastes, radioactive wastes, and asbestos. GeoMelt has been proven to be ideal at treating large volumes of contaminated soil as well as contaminated debris, metals, wood, plastics, rubber, and concrete. The process is robust and flexible.

The GeoMelt technology is used in two configurations: 1) In-Situ Vitrification (ISV)™ and 2) In-Container Vitrification (ICV)™. ISV is a batch treatment process that uses electricity to melt contaminated soil. Electrical power is directed to the treatment zone between graphite electrodes embedded in buried wastes. As power is applied, resistive heat is produced which results in melting of the soil. The molten soil further propagates the electrical current and heat throughout the contaminated material between the electrodes. As the electrical power is continued, the melt grows resulting in a large molten mass defined in extent by the positing of the electrodes. Melt temperatures can reach as high as 1800 °C, depending mostly on soil chemistry. Destruction of organic wastes including POPs is achieved primarily through pyrolysis and catalytic dechlorination reactions. Off-gases that evolve from the melt are collected in a steel containment hood and directed to an off-gas treatment system. Typical ISV melts treat approximately 500 to 800 tonnes of soil and wastes in a single setting. Individual melts treat an area up to approximately 80 m2 to a depth normally ranging from 3 to 9 m. Multiple melts are performed in sequence to treat a larger overall area. ISV has been used to treat approximately 26,000 tonnes of contaminated materials throughout the world.

ICV is a treatment process similar to ISV but carried out in a refractory-lined container. GeoMelt ICV is essentially identical to ISV except that wastes are instead treated in a treatment vessel or melt container, enhancing process control and allowing for treatment of wastes that are not buried. The container either is reusable or single-use. When single-use the melt container also is the disposal container.

Larger batches of waste (up to 100 tonnes) have been processed in refractory lined concrete vaults from which glass is removed for disposal by heavy equipment between melts. Typical ICV melts generally range from 10 to 50 tonnes.

Case Study #1: Wasatch Pesticide Manufacturing Site, USA

Wasatch Chemical Superfund Site in Salt Lake City, Utah, was an industrial facility involved with packaging and distributing acids, caustics, organic solvents, pesticides, herbicides, fertilizers, and other agricultural chemicals. Site operations involved transferring contaminated liquids to a concrete evaporation pond filled with engineered layers of earthen materials. The site contained high levels of dioxin, other organics, and miscellaneous buried waste and debris (Figure 1). Soil moisture content in the pond varied from 9 wt% to fully saturated.

Thirty-six GeoMelt ISV melts were performed in a 6 m x 6 m array (the melt size was constrained by the pit pond depth; smaller melts are shallower), resulting in the contents of the evaporation pond to be completely treated into a single large contiguous monolith. A total of 5,440 tonnes of soil and debris was treated. In addition to the dioxin-contaminated soil, ~2,460 L

Figure 1: The Wasatch Pesticide Waste and Debris Before and After GeoMelt ISV Treatment

of dioxin-contaminated oily liquid waste was also treated, in a 37th melt located at the center of the pond. Analysis of post-treatment vitrified product indicated that all contaminants were detection limits for all contaminants and significantly below the regulatory limits established for the site (Table 1)[1]. Analyses of treated off-gas samples taken during treatment of the liquid dioxin waste materials and during another melt indicated that all analytes (dioxins, pesticides, herbicides, and various volatile organic compounds were below detection limits.

Case Study #2: Parsons Pesticide Manufacturing Site, USA

Parsons Chemical Works was used to manufacture herbicides and pesticides from 1945 to 1979. Site activities resulted in widespread soil contamination throughout the property. The soil at the site was silty clay with some sand and contained debris such as vegetation, concrete, drum lids, plastic sheeting, tires, and cobble rock. Soil and debris (4,350 tonnes) from around the site were excavated and placed into a 5-m-deep treatment trench. GeoMelt ISV was used to treat the contents of the trench, in a series of nine 8 m x 8 m melts. Figure 2 shows the mobile processing equipment used to treat the herbicide and pesticide contamination.

Analyses of the vitrified product confirmed the absence of organic contaminants and the secure immobilization of heavy metals. Off-gases were found to be free of pesticides and other organics. Soil sampling performed on adjacent soil indicated that no detectable contamination moved from the treatment volume into the adjacent soil during processing. Table 2 provides treatment results for analyzed pesticides and herbicides.[2]

Table 1. Pre-and Post-Treatment Contaminant Levels, Wasatch Site

Contaminant	Pre-Treatment (µg/kg)	Post-Treatment, TCLP (µg/kg)	Regulatory Limit (µg/kg)
TCDD-Dioxin	11	<0.12	20
2,4-D	34,793	<20	NA
2,4,5-T	1,137	<14	NA
Total Chlordanes	535,000	<80	7,000
Heptachlor	137.5	ND	2,000
Hexachlorobenzene	17,000	ND	7,000

µg/kg = micrograms per kilogram
TCLP = Toxicity Characteristics Leaching Procedure

Figure 2: GeoMelt ISV System during Parsons Pesticide Manufacturing Plant Remediation

Case Study #3: Orica HCB Treatment Site, Australia

From 1964 to 1991 the Orica Australia Pty. Ltd. plant near Sydney produced approximately 15,000 tonnes of hexachlorobenze (HCB) wastes which are currently stored onsite awaiting destruction. GeoMelt ICV was successfully demonstrated as an alternative to incineration because there is no incinerator in Australia capable of treating the HCB.

The objective of the demonstration, undertaken in 1999, was to evaluate the treatment effectiveness of a specially adapted version of GeoMelt for destruction of HCB. The demonstration involved three melts on mixtures of soil with HCB concentrations ranging from 16.5 to 33 wt%. The melting was performed aboveground in a refractory lined steel container in a batch plant (Figure 3). The tests provided an opportunity to vary equipment and operational parameters to determine the most effective treatment configuration for the HCB waste. Batch sizes of ~2 metric tons were treated. For Test 3, the waste mixture included scrap steel, wood chips, plastic drum liners, used protective clothing, and spent filters to simulate the expected waste mixture at full-scale.

Table 2. Pre-and Post-Treatment Contaminant Levels, Parsons Site

Contaminant	Pre-Treatment Average (µg/kg)	Pre-Treatment Maximum (µg/kg)	Post-Treatment, TCLP (µg/kg)	Regulatory Limit (µg/kg)
Chlordane	<80	89,000	<80	1,000
4,4'-DDT	13,000	340,000	<16	4,000
Dieldrin	4,600	87,000	<16	80

µg/kg = micrograms per kilogram
TCLP = Toxicity Characteristics Leaching Procedure

Alumina (Al2O3) and water were added to the waste mixture to enhance the dechlorination reactions that occur in the hot soil underneath the melt. In the heated soil environment, the alumina reacts with the HCB by removing the chlorine atoms, which then destroys the HCB and result in the formation of aluminum chloride (AlCl3), carbon monoxide (CO) and carbon (C).[3] The presence of water converts the AlCl3 into alumina and hydrochloric acid (removed by the off-gas treatment system), and C into CO2, and H2. The reactions are as follows:

$$C_6Cl_6 + Al_2O_3 \text{ (solid)} \rightarrow 2AlCl_3 \text{ (gas)} + 3CO \text{ (gas)} + 3C \text{ (solid)}$$
$$2AlCl_3 \text{ (gas)} + 3H2O \text{ (gas)} \rightarrow Al_2O_3 \text{ (solid)} + 6HCl \text{ (gas)}$$
$$C \text{ (solid)} + H_2O \text{ (gas)} \rightarrow CO \text{ (gas)} + H_2 \text{ (gas)}$$

Figure 3: Concrete ICV Treatment Container Used for HCB Treatability Demonstrations

The GeoMelt process was proven effective in treating HCB waste; no detectable traces of HCB or the other organochlorines were present in the vitrified product. For all three tests, the destruction efficiencies (DEs) for the melt alone, not accounting for the off-gas treatment system, were typically 97.5% to 99.7%, indicating that most of the waste was destroyed by the melt in the first step of the treatment process. Destruction and removal efficiencies (DREs) for HCB and other organochlorines were >99.9999% for the complete system including the melt and the off-gas treatment system.[4] Treated off-gas emissions typically satisfied regulatory criteria by a factor of 10 to 100. Samples of the vitrified product easily passed the TCLP test. As a result of this project, GeoMelt was selected as an alternative to incineration.

Although Geomelt was shown to be effective for treatment of HCB, and was approved for use by regional Regulators, a final site in New South Wales with suitable infrastructure and community endorsement has yet to be identified.[5]

Agricultural Chemical POPs Treatment Facility, Iga City, Japan

GeoMelt ICV is being used to treat a wide variety of POPs in Japan under sublicense to Kurion. A summary of relevant projects is provided in Table 4.[6]

GeoMelt ICV destroys agricultural chemical POPs in a plant near Iga City, Mie Prefecture, Japan (Figure 4). The main features of this plant are 1) a pre-treatment building used for mixing wastes and glass reagents, a crusher for size-reducing debris, and conveyance for loading the ICV container; 2) a reusable 10-tonne batch ICV container, off-gas containment hood and electrode support superstructure; 3) the off-gas treatment system including filtration, wet scrubbing, thermal oxidation, and on-site water treatment of scrubwater limiting effluent discharge. POPs are stored in an adjacent building, and process control is carried out in an onsite control room.

Table 3. Treatment Efficiencies for Organochlorines, Orica Site (33 wt% HCB)

Contaminant	Pre-Treatment Average (wt%)	Melt DE (%)	Process DRE (%)
Hexachlorobenzene (HCB)	80-90	99.57	>99.9999
Hexachlorobutadiene (HCBD)	4-13	98.68	>99.9999
Hexachloroethane	1-2	99.80	>99.9999

wt% = weight percent
DE = Destruction Efficiency
DRE = Destruction and Removal Efficiency

Table 4. List of POPs GeoMelt ICV Treatment Projects in Japan

Project	POPs Treated	Quantity (tonnes)
Hasimoto	Dioxins	20
Hashimoto	Dioxin-Contaminated Soil	1056
Nagano	Pesticides	161
Nose	Dioxin-Contaminated Soil	51
Hokkai-Sankyo	Pesticides	60
Akita	Pesticides	27
Niigata	Pesticides	425
Hukushima	Pesticides	6
Miyagi	Pesticides	71
Nose	Pesticides	6

The Iga City plant is approved to treat pesticides and herbicides, and also industrial wastes including sludges, waste acids and bases, oils, and asbestos. Processing rates are generally on the order of 200 kg/hr and melt temperatures are as high as 1600 °C, depending on waste composition. Figure 5 shows agrichemical POPs wastes (DDT and Lindane [BHC]) treated at the Iga City plant for a project.

This project involved the treatment of 20.85 tonnes of DDT and Lindane, 38.76 tonnes of contaminated concrete, and 101.09 tonnes of contaminated soil. The GeoMelt ICV station at Iga City is shown in Figure 6.

Figure 5: Lindane, DDT, Contaminated Concrete, and Soil Treated at Iga City, Japan

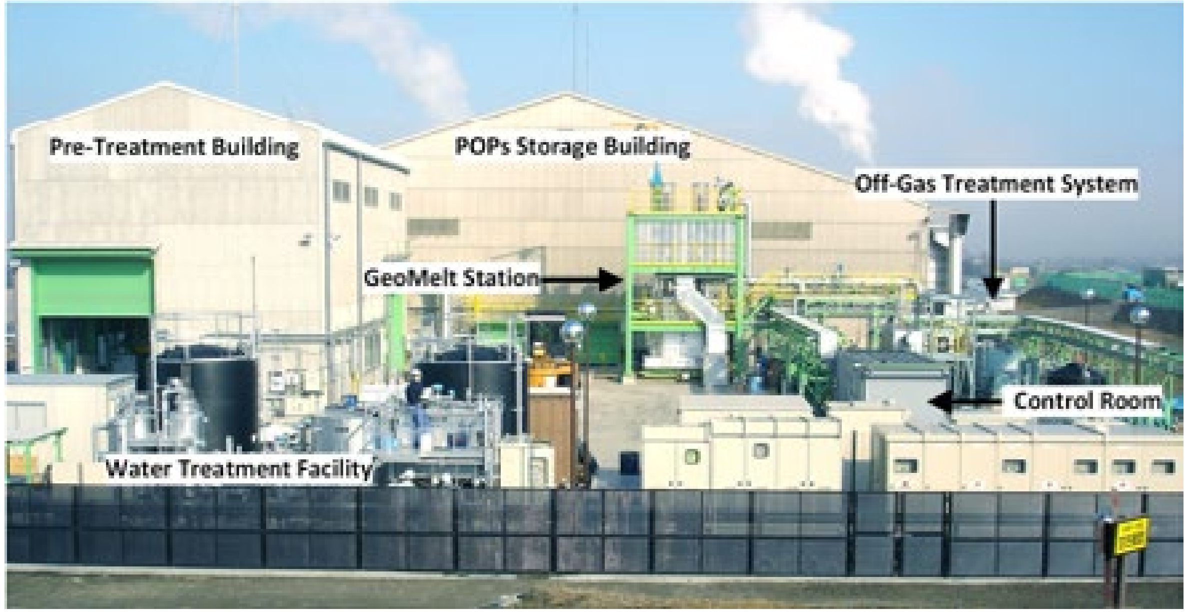

Figure 4: GeoMelt Agricultural Chemicals POPs Treatment Plant, Iga City, Japan

Figure 6: Iga City ICV Station with 10-tonne Melt Container

US EPA TSCA Permit Renewal PCB Demonstration

The GeoMelt technology has been authorized by the United States Environmental Protection Agency (EPA) for the treatment of polychlorinated biphenyls (PCBs) under the U.S. Toxic Substances Control Act (TSCA). Kurion is currently in the process of renewing this authorization as required under the regulation. Part of the permit renewal process involves conducting treatability testing every 10 years. The treatability test conducted by Kurion involved processing 68 liters of Pyranol (Aroclor 1260 in oil) at a concentration of 530,000 mg/L or 53 wt%. The Pyranol was absorbed onto soil resulting in an average of 40,000 mg/L or 4 wt% PCBs. The purpose of the soil was to adsorb the liquid PCBs and to provide glass-formers for the vitrification process. The three spiked layers were staged in a refractory-lined, 10-tonne batch ICV container at different elevations separated by clean soil layers above and below. Each layer constituted a separate test; as the melt progressed from the top of the ICV container downward, stack emissions were monitored in order to use analytical results representing treatment of individual layers to calculate DREs. The ICV container used for the demonstration is shown in Figure 7.

Figure 7: TSCA Permit Renewal PCB Demonstration ICV Container and Process Trailer

The demonstration was completed without operational difficulty. Melt temperatures up to 1400 °C were obtained from thermocouples located within the ICV container during processing. After completion of the tests and allowing time to allow the glass monolith to cool, glass samples were obtained for quantification of individual PCB congeners. Concentrations of all congeners were below the laboratory detection limits (ranging from 20 to 20 pg/g) except for several co-eluting isomers (indicating matrix interference rather than a true value). DRE values calculated using glass analytical data and isokinetic stack sampling results (Table 4) were well above the 99.9999 % permit requirement.

Table 4. Treatment Efficiencies for TSCA Permit Renewal PCB Demonstration	
Test	Process DRE (%) for PCBs
1	>99.999989
2	>99.999994
3	>99.999994
DRE = Destruction and Removal Efficiency	

The EPA has recently issued Kurion a draft permit which is in the process of finalization. The permit confirms the ability of GeoMelt ICV to meet the TSCA PCB performance standard of 99.9999% DRE equivalent to incineration and to a level below 2 parts per million (ppm), and authorizes the use of the technology to treat PCBs at the level demonstrated (i.e., 40,000 mg/L) in the United States.

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TREATMENT AND DESTRUCTION ON POPS SESSION

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The session provided the opportunity for presentations and discussion on a wide range of treatment technologies applicable to the destruction and stabilisation of POPs wastes. Various technologies were presented including thermal, chemical, physical options for the treatment of a wide range of liquid, solid, gases and contaminated materials. In each case, the technology was presented in the context of a Case Study demonstrating the practical application of the technology, its benefits and limitations.

In addition to presentations on specific technologies, a presentation was given by TVN Television, Poland in relation to issues relating to the importation of HCB wastes from Ukraine. The presentation highlighted concerns associated with controls surrounding the shipment, storage and disposal of waste exported from the Ukraine to the Port Services Incinerator in Poland. Subsequently Port Services made a statement and presented an update on the activities at the Port Services facility.

During the discussions, it was commented that with a wide range of technologies on offer it was crucial that monitoring and control of both the treatment facility and those stakeholders involved in the management chain were consistently and robustly applied. Specific issues included the following:

• Adequate and detailed characterisation of wastes prior to transport/treatment;

• Consistent online monitoring of emissions from treatment facilities;

• Accountability of regulators, waste producers, waste notifiers/brokers, transport and disposal organisations/companies involved in the treatment project lifecycle;

The session concluded that with a wide range of proven and commercially available treatment technologies there are viable solutions available now for POPs removal. There is also a responsibility amongst all stakeholders to ensure that projects are managed in order to ensure that POPs are treated to agreed and consistent standards, and that problems are not merely transferred from one location to another.


BREAKING THE INFINITE ASSESSMENT CYCLE OF POP PESTICIDES DUMPSITES


CLASSIFICATION OF POP PESTICIDE DUMPSITES

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Abstract

This paper presents a simple classification tool developed to present a holistic view on the status of a POP pesti-cides dump-site. The status ranges from uncontrolled to completely controlled or sustainable dumpsite. The sta-tus is determined by site environmental risks, awareness of stake-holders, availability of funds for sustain-able site management, and availability of remediation techniques.

Several dumpsites, such as The Volger-meer near Amsterdam in The Netherlands, The Vakhsh burial site in Ta-jikistan and Suzak B in Kyrgyzstan, are classified at different periods in site history. The Vol-germeer is an uncon-trolled dumpsite that shifted with time to a completely con-trolled dumpsite. The Vakhsh in Tajikistan and Suzak B in Kyrgyzstan, are dumpsites that were controlled in the past, but be-came uncontrolled.

POPs pesticide dumpsite classification demonstrates which initiatives should be taken to arrive at a sustainable dumpsite and presents lessons for developing and implementing sustainable dumpsite man-agement. An im-portant lesson learned is that a dumpsite needs a 'foster parent' who is aware of the environmental risks and has the power and willingness to actively develop and implement sustainable site management and is able to allocate funds for maintenance and monitoring.

Keywords

Uncontrolled and controlled dumpsite, classification, risk assessment, sustainable site management.

Introduction

To get rid of waste, four key modes of contaminant release in waste streams can be distinguished: discharge to landfills or dumpsites, discharge to aquatic systems, disposal via hazardous waste incinerators, and storage of chemical waste (Weber 2008). This also holds for obsolete and POPs pesticides disposed of in Europe, the for-mer Soviet Union republics and some countries of Indo China. In this paper, we focus on the classification of the environ-mental status of dumpsites with obsolete and POPs pesticides.

Often, dumping of obsolete and POPs pesticides into landfills started without adequate control measures to prevent mi-gration of (persistent) chemicals offsite. An exception is the dumpsites in the for-mer Soviet Union. The often construct-ed concrete bunkers for the permanent storage of obsolete, and POPs pesticides were moni-tored and maintained, but good care was aborted abruptly after the Soviet Union collapse. As a result, there are numerous landfills (all over the world) posing severe ecological and/or human risks now and in the future. These landfills are uncontrolled, which requires securing measures to prevent direct contact with on-site receptors and halt migration of chemicals offsite. Available risk reducing options for POPs pesticides dumpsite are to remove and destruct the waste, to contain in-site and treat waste on-site.

The status of a dumpsite can range from uncontrolled to completely controlled dumpsite. An uncontrolled dumpsite is a dumpsite where long-term storage is not possible without causing adverse effects on the environ-ment and human health. A completely controlled dumpsite fulfills the criteria of sustainability according to the Concept of Sustainable Development (World Commission on Environment and Development 1987). At a con-trolled dumpsite, permanent storage is possible with minimal long-term effect on the environment and human health. No direct and indirect risks are imposed to the natural environment or human health; i.e. all risk exposure pathways are intercepted. An uncontrolled dumpsite can become a completely controlled dumpsite by taking adequate remediation and control measures including maintenance and aftercare. Aftercare has to be as limited as possible.

To visualise the status of a dumpsite, a simple classification tool was developed. The tool addresses the complex-ity of remediation of uncontrolled dumpsite by summarizing the following four selected categories:

1. The status of the environmental site risks control;

2. The availability of funds to manage the site (remediation, monitoring and aftercare);

3. The awareness of all site stakeholders concerning the environmental risks;

4. The availability of techniques to control the environmental site risks.

The classification tool aims to assess why no initiatives are taken to control site risks and to raise awareness by visualizing in a simple way the constraints for stagnating remediation.

To demonstrate the use of the classification tool, the statuses of different dumpsites are assessed in this paper. One of them is The Volgermeer, a chemical landfill near Amsterdam (The Netherlands) where nowadays com-prehensive monitoring is undertaken and extensive funds are available for eventually cleaning leachates. The Volgermeer is an example of an uncontrolled dumpsite that has successfully been remediated to become a controlled dumpsite. In addition to the case of the Volgermeer, the tool is also applied to two other dumpsites: the POPs pesticide dumpsites Vakhsh (Tajikistan) and Suzak B (Kyrgyzstan), which are examples of controlled dumpsites that have become uncontrolled dumpsites because of lack of monitoring and maintenance.

Material and Methods

2.1 Methods

The input for the classification tool (see figure 2-1) is a complete site assessment that describes the site within its environment. The above four selected categories should be considered. By judging the level of the four features, an overview of the status of the dumpsite is visualised. As a result of the classification, it becomes clear which category is hampering implementation of site rehabilitation strategies, and thus why an uncontrolled dumpsite has not reached the class of a controlled dumpsite.

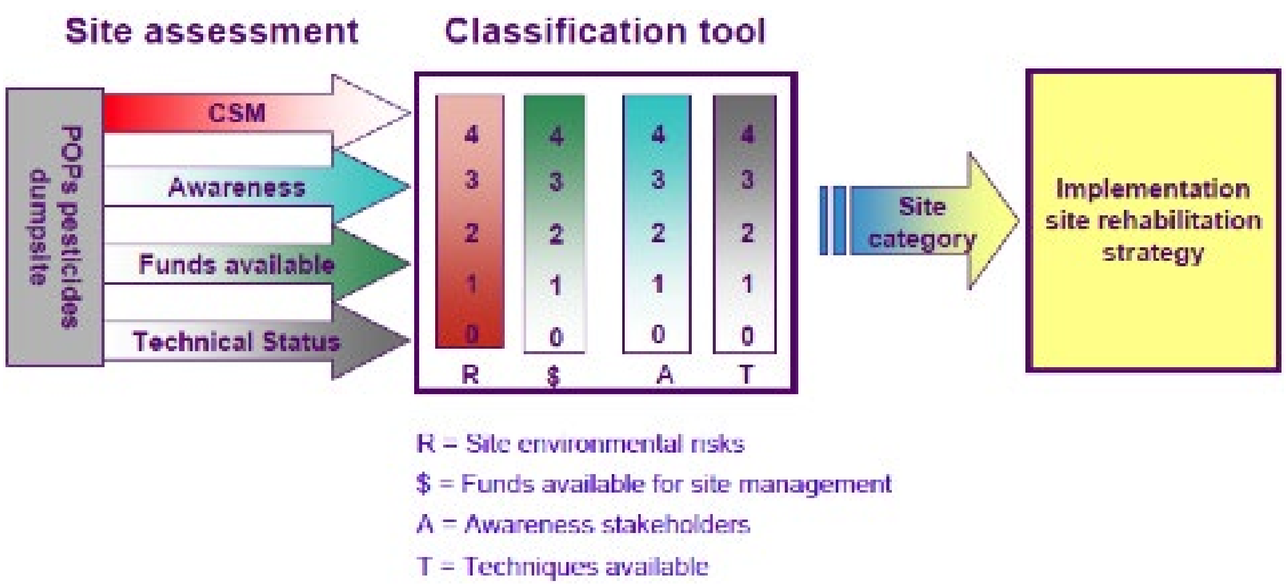

Figure 2-1: The status of a POPs pesticides dumpsite can be classified through a site assessment

2.2 Site assessment

A site assessment should be performed including the contaminant situation within the existing site topography, soils and hy-drology, along with other pertinent site in-formation such as climate and site history. An important part of the site assessment is the social description, starting site-wide and expanding to regional or country-wide analysis of involvement of stakeholders, economical status, and governmental form. The complete site assess-ment pro-vides all information about the four site categories that classify the dumpsite.

The environmental site risks can be screened by developing a Conceptual Site Model (CSM) picturing the source zone(s) of contamination, the migration pathway(s) and the (potential) receptor(s). Designing a complete CSM is a phased process. The initial phase is the prelimi-nary site assessment resulting in an initial CSM and a preliminary risk assessment. A gap analysis bridges the initial phase with the second phase of the site assessment. With a comprehensive site assessment the CSM can be improved or completed and relevant risks can be assessed. To define risks of the toxicological profile of the compounds at the site, and their effects on the receptor, the fol-low-ing exposure can be estimated or calculated. A complete CSM and a risk assessment are the deliverables of the second phase of the site as-sessment.

2.3 Classification tool

Each site feature in the classifica-tion tool has five classes: the un-controlled, minimum controlled, semi con-trolled, controlled, and completely controlled class. The classification depends on the before mentioned site fea-tures. If all four categories are at the highest level, the site can be considered as a completely con-trolled dumpsite. In this section and in table 2-1, an explanation of the different classes of each category is given.

Level	Class	Category			
		Risk control	Availability of funds	Awareness profile	Availability of technique
4	**Completely controlled**	Direct, potential and latent risks controlled	Funds available, including funds for monitoring and aftercare	All stakeholders take their responsibilities	All risk control measures are readily available and feasible
3	**Controlled**	Direct and potential risks controlled	Funds available on the short and mid-term	Receptors, local and national decision makers are aware of risks and responsibilities are allocated	Risk control measures can be designed site specific
2	**Semi controlled**	Direct risks controlled	Funds available on the short-term	Receptors and local decision makers are aware of risks	Direct risk control measures are available
1	**Minimum controlled**	Emergency measures implemented	Emergency block grant available	Receptors are aware of risks	Emergency measures are readily available
0	**Uncontrolled**	No risks controlled	No funds available	Stakeholders do not take their responsibility	Risk control measures are not available

Table 2-1: Classification of POPs pesticides dumpsite by categories risk, funds, awareness and technique

Environmental risks
The environmental site risks include human health risks, risks of off-site migration and ecological risks. These risks can be direct, potential or latent. The first risk class (level 0) is a dumpsite with uncontrolled risks. No site measures to mitigate the environmental risks are taken. The second class (level 1), minimum controlled risks and is allocated to dumpsites with emergency measures only. The third class (level 2), the semi controlled dumpsites, is for dumpsites with controlled direct risks. The dumpsites with controlled direct and the potential risks are classified in the fourth class (level 3). The fifth and last class (level 4), completely controlled, is used for the dumpsites with all direct risks mitigated, potential risks contained and latent risks monitored.

Availability of funds
Classification based on the availability of funds for site management uses the same five classes. In the lowest class, i.e. the uncontrolled dumpsites for this category, sites have no funds available for site management. This class is followed by the class used for the minimum controlled dumpsites, i.e. sites that have only funds for emergency measures. The third class in this category is used for dumpsites for which funds are available on the short-term for mitigating the direct risks. If dumpsite funds are available for mitigating the direct risks on the short-term and containing the potential risks on the mid-term, the dumpsite is classified as the fourth class. This class is called controlled. The last class, the completely controlled site, is used for dumpsites that have imple-mented all risk control measures while funds are being provided for containment of the potential risks, monitor-ing of the latent risks and aftercare.

Stakeholder's awareness
The first of the five classes used for category stakeholder's awareness, the uncontrolled class, includes the sites where stakeholders are not aware of the environmental risks or do not take their responsibilities. The second class is used for the dumpsites where only the receptors are aware of risks. These are the minimum controlled sites for this category. When receptors and the local decision makers are aware of the environmental risks, the dumpsite is seen as a semi controlled for this category. If the receptors, local and national decision makers are aware and the responsibilities are allocated, the site is a controlled dumpsite. If all stakeholders take their respon-sibility the dumpsite is classified as completely controlled dumpsites.

Availability of techniques
The five classes for the availability of the techniques for mitigating the direct risks, containing the potential risks and monitoring the latent risks, are also ranging from uncontrolled to completely controlled. If there are no techniques available to control the environmental risks the dumpsite is classified as uncontrolled. A site is minimum controlled if emergency measures are readily available. A dumpsite is semi controlled if direct risk control measures are available. The site is controlled when risk control measures can be designed site specific. If all risk control measures are readily available and feasible, the dumpsite is classified as the completely controlled.

At a completely controlled dumpsite, all the direct environmental risks have been mitigated, the potential envi-ronmental risks contained and the latent risks monitored. Funds for monitoring and aftercare have been allocat-ed. Site stakeholders take their responsibility and all risk control techniques are readily available.

3. Results and Discussion
To demonstrate the use of the classification tool, we have classified the Volgermeer, Vakhsh and Suzak B dumpsites at different periods in their site history. The

classification is discussed demonstrating the coherence between the different aspects and explaining shifts from one dumpsite class to the other.

3.1 Description of the Volgermeer dumpsite

The history of the Volgermeer is thoroughly known and described below in different distinctive periods. Based on the description of the dumpsite in these periods, a classification of the Volgermeer is presented and dis-cussed.

Description history Volgermeer until 1955

The peat bog lands of Holland were the main energy resources of the Netherlands from 1.000 AD till about the beginning of the twentieth century when coal and hydrocarbons became the main energy resources. The excava-tion of peat transformed the former peat bogs into large lakes and valuable land was lost in this process. Authori-ties counteracted the loss of valuable land by permitting peat exploitation under the condition that excavations were backfilled.

Growing cities and economic development were major drivers for increased municipal solid waste volumes at the beginning of the twentieth century. The operators of one of the last bogs, the Volgermeer, realized that the isolated position of the polder and its perfect connection to Amsterdam by existing waterways provided a suita-ble disposal site that could meet the backfilling obligation. Around 1955, the peat exploitation came to an end due to decreased margins. By then, about 110 hectares of peat bog were exploited and became available for the disposal of waste.

Volgermeer 1956 - 1979

Somewhere between 1955 and 1965, the barges which ferried the solid municipal waste to the Volgermeer also started to collect waste in various industrial zones of Amsterdam. Among others, this industrial hazardous waste originated from several chemical industries and the producer of organic pesticides. In particular, the disposal of residues from the organic pesticides production (among which Agent Orange), can be considered as a game changer. Hazardous waste was mixed with large volumes of solid municipal waste. From time to time, local pop-ulation complained about uncontrolled fires at the dumpsite.

Volgermeer 1980 - 1981

In the late 1970s, environmental awareness of the Dutch population increased significantly. The local population started to complain more and more about the uncontrolled fires at the Volgermeer dumpsite. In 1980, a local shovel operator working at the Volgermeer polder discovered drums with the skull warning sign. Just at that time, soil pollution in ‘Lekkerkerk’ made headlines in the Dutch news. The discovery of the drums was a confir-mation that a new ‘Lekkerkerk’ was potentially born at the Volgermeer. The news of the drums rapidly spread in the local community and increased the existing agitation about the uncontrolled fires. Local leaders of the nearby village of Broek in Waterland established a committee that was able to mobilize the local population and attract a lot of attention in the national news. As local authorities initially denied the presence of hazardous waste and environmental and human risks, the local population decided to barricade the entrance to the Volgermeer. With-in three months’ time, the City of Amsterdam was forced to cease further disposal of waste at the Volgermeer.

In the early 1980s, the Volgermeer continued to attract a lot of attention in the Netherlands, and the local com-mittee maintained its pressure on the local and national authorities. Local and national authorities realized that emergency measures had to be implemented. Drums at the surface of the dumpsite were collected and stored on-site. An attempt was made to isolate the surface water within the Volgermeer from the surrounding surface waters. The site was fenced and warning signs were posted.

Volgermeer 1982 - 1998
After the implementation of the emergency measures, preliminary studies were conducted. Given the scale of the dumpsite (six million cubic meters of hazardous waste with significant concentrations of organic pesticide resi-dues and dioxins) and the available techniques at that time, it was concluded that remediation was almost impos-sible and too expensive. Attention shifted towards the question on liabilities. Communication between authori-ties and the local committee almost ceased and was best characterized by distrust.

Given the isolated position of the Volgermeer and the discovery of another, large-scale soil pollution nearer to the population centre of Amsterdam, the authorities lost their focus on the Volgermeer. It was also hard for the local committee to attract further attention of the broader public. The general idea was that with the implemen-tation of the emergency measures, the situation at the Volgermeer was safeguarded.

Volgermeer 1999 - 2000
In the late 1990s, local and national authorities put the remediation of the Volgermeer back on the agenda, due to the involvement of two political leaders who sincerely wanted to fulfil an old promise to the local committee and resumed responsibility of the former disposal activities. At that time, the regulations on soil remediation had also changed in the Netherlands, which made it possible to use new concepts such as monitored natural attenua-tion and risk based land management as viable remediation options. Finally, in 2000, a remediation plan was drafted, approved by the authorities and accepted by the local committee.

The objective of this final plan was to remove direct contact possibilities with the polluted material through the installation of a top cover and monitoring of the pollution pathways. Field investigations and model calculation had shown that off-site spreading of the pollution was not possible. The earlier emergency measures were rein-stalled, and previously collected drums were removed from the site.

Volgermeer 2000 – 2013
From 2001 to 2010 the actual design and implementation of the remediation works took place. During this peri-od, an extensive monitoring program was set up (involving over 350 observation wells around the Volgermeer and just less than 300 within). On the basis of the monitoring results, it was shown that over large areas of the Volgermeer, high concentrations of degradation products of organic pollutants and pesticides residues were pre-sent in the pore water of the landfill body. More surprisingly, the groundwater in most of the observation wells just outside the landfill did not contain any pollution during this period. Also, the original surface waters within the landfill showed practically no pollution.

Further in-depth assessment revealed that the existing peat soil surrounding the Volgermeer landfill and the or-ganic rich sediments effectively contained the contamination inside the landfill body itself. Given the importance of the peat layers, a surprisingly simple and effective concept, i.e. the ‘natural cap’, was developed.

The original aim was to cap the waste by multiple layers, i.e. vegetation, topsoil, drainage, geo-membrane (HDPE) and gas ventilation and to maintain this top layer for eternity. In the natural-cap concept, a peat layer is to be developed on top of the remediated landfill. Meanwhile, this peat layer will act as a natural barrier, reducing the eternal aftercare and maintenance program which was deemed necessary for the original multi-layer-top solu-tion.

Peat will prevent off-site migration of

pollutants. This approach was founded on the assumption that engineering solutions should not inhibit natural processes of risk mitigation. Rather, engineering should enhance and support natural biological processes. Conservation of existing peat layers around the Volgermeer and development of new peat layers on top of the Volgermeer are important corner stones of this approach. Development and con-servation of peat bogs, on the mid-term, can also earn the area a special protected status of a valuable wetland area.

During the implementation of the remediation project, the local committee and other stakeholders were actively involved in the rehabilitation and transformation of the landfill site and monitoring results were transparently shared and discussed with them. Since 2011, local citizens are actively involved in the transformation of the area into a natural peat bog. Distrust truly changed to common trust. Together with several universities, a research program was set up to assess and validate the concept of the natural cap and the potential for peat development. Local and national authorities made long-term commitments for funding of aftercare and monitoring. Fall-back scenarios are available to man age unexpected risks, and remediation techniques, which can be utilized to inter-cept polluted groundwater (if needed), have been identified.

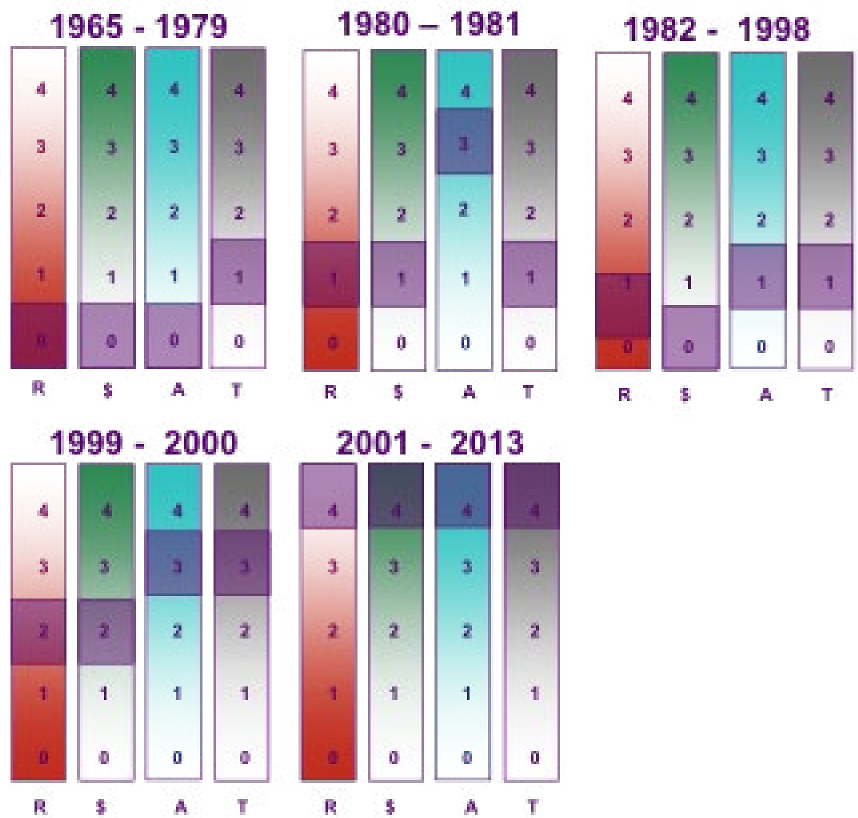

Figure 3-1: Classification Volgermeer in the Netherlands

3.2 Volgermeer Classification

Although, before 1955, large volumes of solid municipal waste had already been disposed at the Volgermeer, it cannot be considered as a hazardous waste dumpsite for that period of time because no hazardous waste was stored. After 1955, hazardous waste, mixed with large volumes of solid municipal waste, turned the Volgermeer into a hazardous waste dumpsite. Based on the above description of the Volgermeer, figure 3-1 visualizes the classification of the dumpsite from 1955 to date.

Volgermeer 1965 – 1979

The disposal of hazardous waste transformed the Volgermeer into an uncontrolled dumpsite. The large volumes of waste consisted of hazardous waste mixed with solid municipal waste. Although the local population was from time to time complaining about uncontrolled fires at the dumpsite, nobody was aware that a game change of hazardous waste disposal had taken place. Let alone anybody realized the increased risk profile of the Vol-germeer or the necessity to control risks.

Volgermeer 1980 - 1981
In 1980, the receptors were the first to become aware of the risks of the Volgermeer. By pressure of the local population further disposal of waste to the Volgermeer ceased. Shortly after, local and national authorities real-ized that emergency measures had to be implemented. Drums at the surface of the dumpsite were collected and stored on-site and the site was fenced and warning signs were installed. In this period, the Volgermeer can be considered a minimum controlled dumpsite.

Volgermeer 1982 – 1998
In this period, the authorities lost their focus on the Volgermeer. The installed emergency measures were not well maintained. The status of the dumpsite in this period is classified between a minimum and uncontrolled dumpsite.

Volgermeer 1999 - 2000
Due to the efforts of two political leaders, the awareness increased, and it was realized that new soil remediation concepts were available. On the basis of investigation results and model calculation, the state of the art remedia-tion concepts were applied as a design basis. Direct risks were controlled, funds were made available and respon-sibilities were allocated. In this period, the site can be classified as a semi-controlled dumpsite. Furthermore, the approved remediation plan for the Volgermeer ensured that potential risks would be controlled in a few years' time.

Volgermeer 2001 - 2013
From 2001 to 2010, remediation measures to control direct, potential and latent risks were designed and imple-mented. The waste was capped by multiple layers and, on top a peat layer is currently developing. Meanwhile, this peat layer will act as a natural barrier, reducing the aftercare program. Local and national authorities made long-term commitments for funding of aftercare and monitoring. In the year 2013 the Volgermeer was classified as a completely controlled dumpsite.

Future of the Volgermeer
The classification of a completely controlled dumpsite in 2013 cannot be taken as a guarantee for a bright future. Peat layers in Holland are under severe pressure due to dewatering, oxidation and excessive levels of nutrients in the environment (eutrophication). Nation-wide studies show evidence that peat layers might completely disap-pear within the next centuries. Since the current remediation concept is heavily dependent on the containment capacities of the peat layers, it may be clear that such a future disappearance can change the status of the Vol-germeer back to a less controlled dumpsite. Also a fainting focus at national, local or community level can threat-en the current status of a completely controlled dumpsite. Allocated budgets also need to be permanently secured, especially in times of severe budget constraints. In other words, the currently reached status of completely controlled sink is not automatically guaranteed for the future. To guarantee the status the Volgermeer, a dedicat-ed community of involved partners is required in the long-term.

3.3 Description dumpsite Vakhsh

The Vakhsh dumpsite history is divided into three distinctive periods: 1973 -1991, 1992 - 2008 and 2009 - 2013.

The conditions of the dumpsite will be described during each period. Based on these descriptions a classification for the Vakhsh dumpsite in these periods is presented and discussed. Specific attention is given to the effects of the disintegration of the Soviet Union.

Vakhsh 1973 - 1991
Huge amounts of pesticides, including POPs pesticides, were distributed across the Soviet Union almost free of charge to raise agricultural production back in the

1950s and 1960s. POPs pesticides were banned in the Soviet Union in the beginning of the 1970s. Polygons consisting of concrete sarcophagi were constructed to perma-nently store the banned POPs pesticides all over the Soviet Union. The banned solid pesticides and sometimes fluids were placed in the sarcophagi. Often fluids were burned to reduce the volume. The Vakhsh polygon, with around 30 sarcophagi, was constructed in a cattle-raising area a few kilometers upstream of an agricultural area with irrigation channels draining to the Vakhsh river system. The dumping started in 1973 and continued to 1990 when disposal was definitely stopped.

The site is situated approximately five kilometers east of the city of Vakhsh. The city of Vakhsh is one of the major cities in the Khatlon region in the southwestern part of Tajikistan. The city is situated about 40 kilometers north of the border with Afghanistan. Geographically the area is located in the valley of the Vakhsh River, one of the major boundary rivers of Tajikistan. The first aquifer is deeper than 50 meter below the surface of the poly-gon. The polygon was fenced and permanently guarded. To control erosion upslope areas were terraced and trees were planted. An irrigation system was installed to water the trees in the dry season. With the collapse of the Soviet Union, the agricultural system fell apart at the end of 1991. This left the Vakhsh polygon and others pesticide stocks unmanaged and many of these without designated owners.

Vakhsh 1992 – 2008

After the collapse of the Soviet Union, efforts to secure the site ended, the fences were stolen and local people (and their herds) could easily enter the polygon. The erosion-control terraces on the slopes above the burial site were still present. The trees were gone and erosion of the terraces had started. All efforts and inputs to start afforestation on these slopes ceased to exist.

The neglect of environmental concern, combined with poor environmental awareness and planning, created a major environmental hotspot at the polygon, making it a legacy of the past. This legacy could hardly be dealt with in the post-civil war devastation and economic hardships.

The originally well designed Vakhsh polygon was also targeted by ‘illegal waste miners’. Especially DDT was taken out to be sold at local markets. The degradation of the polygon and the illegal waste mining resulted in exposure and spreading of pesticides. Exposed POPs pesticides contaminated the topsoil, migrated off-site by surface run-off and wind erosion. Trespassers and herders, especially children and cattle were exposed to the toxic waste.

Vakhsh 2009 - 2013

The World Bank received financing from the Canada Persistent Organic Pollutants Fund, through the Canadian International Development Agency on behalf of the Government of Canada for the inventory of the POPs pes-ticides and risk assessment. The World Bank applied a portion of these funds for ‘The Obsolete pesticides tech-nical study in the Kyrgyz Republic, the Republic of Tajikistan and the Republic of Uzbekistan’.

The Vakhsh polygon was one of the top priority sites. Given the absence of monitoring and site management, a considerable potential was assumed to exist for contaminant spreading away from the designated area to the direct surroundings and inhabited areas. One of the objectives of the obsolete pesticides technical study was to assist Tajikistan in protecting the environment and human health by safely managing the Vakhsh polygon. To meet the objective a CSM was designed, and the environmental risks were assessed followed by a feasibility study for in-situ site remediation and or containment alternatives for the highly contaminated site.

The total estimated volume of POPs pesticides exposed was estimated to be around 1,500 tons. In addition, the quantity of POPs pesticides still buried in sarcophagi was estimated at 2,500 tons. Over the years, approximately 333,000 m2 of soil has been contaminated by POPs pesticides. The estimated volume of heavily contaminated soil is around 22,000 m3 (39,600 tons). The proposed and pre-design short-term measures to mitigate the direct environmental risks comprise gathering and containing the 1,500 tons of exposed POPs pesticides in the sar-cophagi, together with the still buried 2,500 tons, followed by final disposal as soon as possible.

In addition to the containment of the POPs pesticides and heavily contaminated soil awaiting final disposal, it is seen as crucial to install proper site management and install guards to prevent waste mining and to ensure proper containment of the remaining contaminated soil as long as needed. To keep trespassers and cattle safely away from the site and to reduce further risks, it will be necessary to fence the whole site. Very important additional short-term measures consist of reinstalling the old surface drainage and implementing erosion control measures. Last but not least, the awareness of all the stakeholders needs to be raised.

3.4 Vakhsh Classification

Based on the above description of the dumpsite, figure 3-2 visualizes the site classes for the four categories per period. The figure illustrates the stages of the Vakhsh dumpsite and can support the decision making process for the next steps necessary for proper site management.

Vakhsh 1973 - 1991

In the perspective of the site risk profile, the Vashkh dumpsite history has three distinct periods. The first period is from 1973 to 1991 when the site risks were limited to direct exposure of the site workers and the emissions (dioxin) from burning liquid pesticides. When dumping ceased, the environmental risks were contained by prop-er site management. Proper site management, guarding, monitoring and maintenance were guaranteed because funds were allocated by the Soviets. The site was a completely controlled dumpsite for nearly all categories. The fact that it was allowed to burn liquid pesticide demonstrates that the authorities were not fully aware of the en-vironmental risks.

Vakhsh 1992 – 2008

In the next period of 1992 - 2008, political instability, cut of funds and poverty led to further site destruction enlarging the environmental risks substantially. There was a decline in the awareness of the people using the site and its surroundings. The

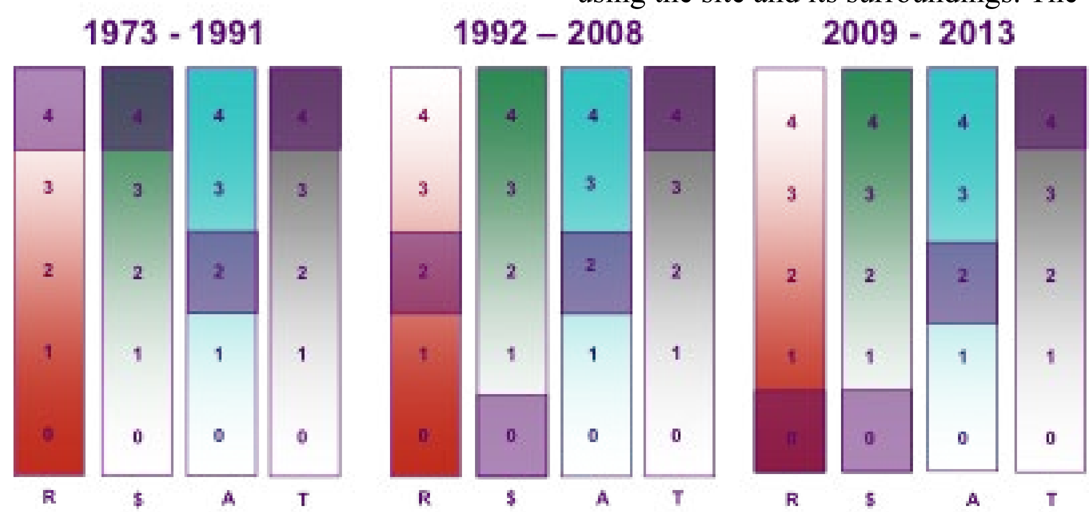

Figure 3-2: Classification Vakhsh in Tajikistan

status of the site fell back to an uncontrolled dumpsite. The remediation techniques to control all environmental risks were readily available and feasible in that period.

Vakhsh 2009 - 2013

The awareness of national stakeholders increased again through the results of the World Bank project after Ca-nadian funds became available in 2009. Until 2013, there was no follow up of this technical study because the Tajik national authorities had other priorities. The local authority's awareness was raised by training and partici-pation in the World Bank project, but they lack the means to implement proper site management. Waste miners, mostly young boys, are still active and will be active as long as there are POPs pesticides in the sarcophagi and there is market for these cheap alternatives for the expensive modern pesticides. The Vakhsh polygon can only become a completely controlled dumpsite again if the national stakeholders are aware that for implementing risk reducing measures, only limited investments are needed. Besides, the awareness of the waste miners should be raised. They should be told that their activities not only affect their own health, but also have a huge impact on the environment. The techniques to mitigate the direct risks on the short-term, to contain the potential risk and monitor the latent risks are available.

3.5 Description of Suzak B dumpsite

The Suzak B dumpsite history can be divided into three distinctive periods: 1973 -1991, 1992 – 2005 and 2005 – 2013. The boundary between the second and third period is not exactly known and was set to 2005. The next sections describe the dumpsite during each period and discuss its classification.

Suzak 1973 - 1991

The Suzak B dumpsite is located Kyrgyzstan. Kyrgyzstan is a former Soviet Union member and was therefore also subjected to the agricultural policy of the 1950s and 1960s. The Suzak B polygon was constructed and filled somewhere between 1970 and 1990. The Polygon consisted of around 5 - 10 sarcophagi filled with pesticides. The polygon was constructed in the vicinity of a settlement on the summit of a hill. The area was also a cattle-raising area. The first aquifer is deeper than 50 meter below the surface of the polygon. The polygon was fenced and permanently guarded. A site drainage system was installed to control erosion. The Suzak B polygon was left unmanaged and without designated owner after the collapse of the Soviet Union.

Suzak 1992 - 2005

After the collapse of the Soviet Union, the same happened at Suzak B as at Vakhsh in Tajikistan. The neglect of environmental concern, combined with poor environmental awareness and planning, created an environmental hotspot at the polygon, making it a legacy of the past. The originally well designed polygon was not so much targeted by 'illegal waste miners' compare to Vakhsh because the site was within the vicinity of the growing set-tlement. The degradation of the polygon and the illegal waste mining resulted in exposure and off-site migration of pesticides and also created nuisance to the people living nearby.

Suzak 2005 - 2013

The land pressure around the Suzak B dumpsite increased, and people were directly confronted with the negative environmental impact of the substandard condition of the polygon. To be able to use the surrounding land for horticulture and to eliminate the nuisances, the people living nearby the polygon organized and implemented risk reduction measures themselves. In the beginning of this century, they managed to fence the site and closed the waste miner's pits. In 2010, the site fence was still intact; a healthy looking grass and shrub cover was present preventing wind erosion. Warning signs were installed making people well aware of the dangers involved in case their attention would weaken.

3.6 Suzak B Classification

Figure 3-3 visualizes the categories, which are further described in the next sections.

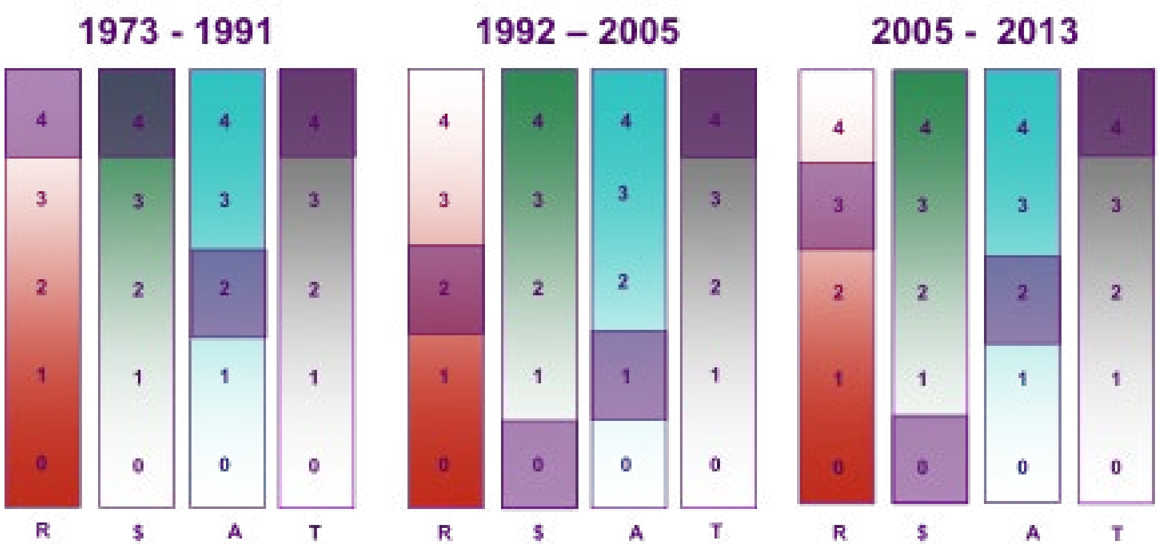

Figure 3-3: Classification Suzak B in Kyrgyzstan

Suzak 1973 - 1991

In the perspective of the site risk profile, the Suzak B dumpsite history has three distinct periods. In the first period, which lasted from 1973 to 1991, the site risks were limited to direct exposure of the site workers. When dumping ceased, the environmental risks were contained by proper site management. The site was a completely controlled dumpsite for nearly all categories. For the same reason as Vakhsh, the awareness category is not com-pletely controlled.

Suzak 1992 – 2005

In the next period, the cut of funds for proper site management and poverty led to the first steps in the direction of an uncontrolled dumpsite. This period was short because the people living close to the site experienced a negative impact. This led to an increase in awareness, and the status of the site fell back to a semi controlled dumpsite for the risk category only for a short period.

Suzak 2005 - 2013

Due to the collective initiatives, the direct risks were mitigated and the potential risks were contained. The dumpsite is now classified as controlled dumpsite for risk category. It is not a completely controlled dumpsite because the latent risks are not being monitored. The current status has been reached although there are hardly any funds available.

3.7 Discussion

In developing economies, we often see that the infinite assessment circle of Harmsen et al. (2009) is valid. The infinite circle (see figure 3-4) commences with site assessment. When the assessment reveals that the environ-mental problem is too big, the assessment report is often shelved and nothing is done. But the environmental risks remain. After some time, new initiatives are taken because of the remaining sense of urgency. Scarce funds are spent again on updating the earlier site assessment. Again the new site assessment reveals that the problem is too big and has often grown even bigger. The site assessment report is shelved again because the means are in-adequate to implement miti-gation measures. The environmental prob-lem is still too big. The proposed classifi-ca-tion introduced in this paper can help to achieve a breakthrough of this infinite assessment circle by:

• Assessing the dumpsite.

• Making a CSM.

• Assessing the environmental risks.

• Classifying the dumpsite.

• Identifying the hurdles for sustainable site management.

• Focussing only on removing these hurdles.

The success of the remediation of the Vol-germeer provides important lessons for remediation of uncontrolled dumpsites elsewhere in the world. The Volgermeer problem seemed also too big and from 1980 to 1999 nothing was done, except for some emergency measures. But this changed at end of the 1990s and classifica-tion of the Volgermeer in different periods demonstrates the causes of these changes. The Volgermeer has taught the fol-lowing lessons:

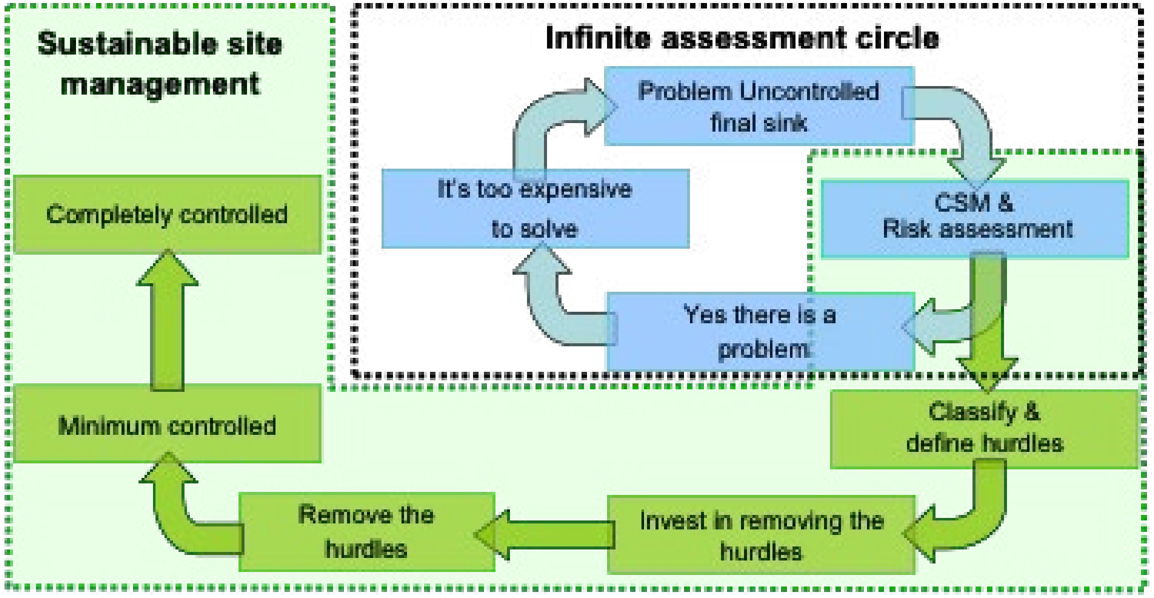

Figure 3-4: Breaking the infinite assessment circle (modified from Harmsen et al, 2009)

• It is crucial that the rehabilitation of the dumpsite is fostered by a person or a group with the power and willingness to do so (Kips et al, 2011).

• Make sure there is a socio-economic incentive. Let improvement of the so-cio-economic situation be a pow-erful driving force, for any chosen solution.

• Apply simple and effective solutions us-ing natural processes and locally available resources that add value to the future sur rounding land use. The concept preferably builds with nature instead of being against nature.

• Balance civil engineering and green re-habilitation. Recognise that it is essential to exchange knowledge (bio-geo-chem-ical-civil engineering) within the project setting and also at a broader scale.

When classifying Vakhsh, it becomes clear that the hurdle for implementing sustain-able site management is the awareness of the local and national decision makers.

They should be convinced that implementing mitigation measures to reduce the direct risks on the short-term can be simple and not costly by using locally available re-sources.

The classification of the current situation at Suzak B illustrates that an important driving force is the awareness of the local stakeholders. The people living nearby the polygon Suzak B are aware of the environmental risks and therefore implemented simple, but effective, risk reduction measures themselves.

The classifications of Vakhsh and Suzak B clearly demonstrate that even when the status of a controlled dumpsite was reached, relapse of the status may occur due to unforeseen circumstances. Although a dumpsite may be completely controlled, proper site management, monitoring and aftercare should be secured perpetually.

Using the classification tool provides a holistic view of the main features of the dumpsite that influence the pro-cess to go from an uncontrolled to a more controlled and finally to a sustainably managed dumpsite. The classifi-cations show at a single glance which initiatives should be deployed to implement sustainable site management. The classification also supports the decision making process for rehabilitation of the dumpsite with sustainable mitigation measures, turning the dumpsite into a completely controlled dumpsite.

4 Conclusions

Classifying dumpsites:

1. Helps to achieve a breakthrough of the infinite assessment circle.

2. Reveals the hurdles for implementing sustainable dumpsite management.

Using the proposed classification tool:

1. Provides a holistic view of the main features of the dumpsite that influence the process to go from an un-controlled to a more controlled and finally to a sustainably managed dumpsite.

2. Supports the decision making process for implementation of sustainable dumpsite management.

Classification of the Volgermeer, Vakhsh and Suzak B dumpsites shows that successful implementation of sus-tainable dumpsite management needs to:

1. Be fostered by a person or group with the power and willingness to do so.

2. Create socio-economic incentive with the future site.

3. Make as much as possible use of natural processes and locally available resources.

4. Secure proper site management, monitoring and aftercare perpetually.

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CLASSIFICATION OF POP PESTICIDE DUMPSITES

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This session was used to present and demonstrate the use of a simple classification tool. This tool is developed to present a holistic view on the status of a POP pesticides dumpsite, to explain the current status of a site and facilitate the identification of the gap(s) to break the infinite site assessment circle (Joop Harmsen et al., 2009) and to sustainably manage the dumpsite.

The introduction of this session was given by Boudewijn Fokke (Tauw, the Netherlands). The fact that the status of a dumpsite can vary from uncontrolled to controlled and the dumpsite characteristics describing the status were discussed. The chosen dumpsite characteristics are environmental risks, awareness of stakeholders, the availability of funds for sustainable site management, and availability of site remediation techniques.

The next part of the session was used to demonstrate the application of the tool. The first case was presented by Ingrid Rijk (Witteveen+Bos, the Netherlands). She used the tool to demonstrate the development of the 100 hectare hazardous waste dumpsite of Volgermeer the Netherlands from an uncontrolled to a completely controlled site over the last 60 years.

Tomasz Stobiecki (Institute of Plant Protection, National Research Institute Sosnicowice Branch, Poland) gave a presentation on the status of the Rudna Góra, a POPs pesticide dumpsite near Jarworzno in Poland, over the last 100 years. Matthijs Bouwknegt and Boudewijn Fokke (Tauw), the Netherlands) characterized respectively the POPs pesticide dumpsite Suzak A in Kyrgyzstan and the Nubarashen dumpsite in Armenia. The last presentation of the session was by Joop Harmsen (Alterra Wageningen, the Netherlands) on his experiences in the 'Risk Reduction of Soil Contaminated by Obsolete Pesticides in Africa' project.

After the presentations of the cases, the usefulness of the tool was discussed with the audience. It was concluded that POPs pesticide dumpsite classification demonstrates which initiatives should be taken to arrive at a sustainable dumpsite management. It was also concluded that the tool should be improved by including the legal status of the site and the willingness to allocate funds for sustainable site management.

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