Obsolete Pesticides
A “Burning” Question

A review of Super Critical Water Oxidation and Radicalplanet technologies for destruction of obsolete pesticides

Conference report
Obsolete pesticides-a „Burning” Question
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INTRODUCTION

Since 2005 a consortium of Milieukontakt International, the International HCH and Pesticides Association, engineering company Tauw BV and the Dutch NGO Natuur en Milieu (Nature and Environment) has been involved in the elimination of risks of obsolete pesticides in several countries in Eastern Europe and Central Asia.

In the past five years an international network has been established with international, national and local organisations that are active on this issue. Among them are NATO, UNEP, FAO, World Bank, the Dutch Ministries of Foreign Affairs and Environment, the Pesticides Action Network, IPEN, Green Cross, national and regional governments from Moldova, Georgia, Kyrgyzstan and Ukraine and many NGOs in these and other EECCA countries.

While working on the inventory and repacking of obsolete pesticides, the consortium realised that there is a strong need for locally applicable methods of destruction. A safe and environmentally sound method could prevent expensive long distance transport of pesticides to the incineration installations in Western Europe. An adequate local system in place could also prevent local governments from using their own installations -for example old cement factories- that can create severe environmental hazards.

The consortium believes that a locally applicable methodology could bring a new breakthrough in the destruction of obsolete pesticides. Therefore, it was decided to select two methodologies for further research and possible development. Due to the limit of the project budget, the number of methods had to be restricted. Based on earlier research and own inventory, we down selected two methodologies. This process was monitored by a group of experts on the basis of international developed criteria.

After an expert meeting in May 2008, a conference was organised in September 2008 to reflect with the main players in the field of obsolete pesticides on the two selected methodologies. This report presents the results of this conference, and also includes additional information on the two technologies under review.

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Goals and Expected Results

A technology that is locally applicable, sustainable and destroys obsolete pesticides at a reasonable cost would mean a breakthrough in the quest for a solution to this world wide problem.

Currently there are many ways of dealing with obsolete pesticides:

1. Although illegal, obsolete pesticides are still used and traded;
2. Obsolete pesticides are frequently destroyed at installations in developing countries, that do not work properly and/or are not permitted according to international standards;
3. Obsolete pesticides are often stored in deplorable conditions (and nothing is done to change the situation), with huge risks for people and environment;
4. Obsolete pesticides are repacked in controlled storages to prevent them from contaminating the environment. The environmental risks have temporarily been minimized, but this is not a long term solution. The obsolete pesticides are repacked and transported to Collection Centres, safeguarded and transported over long distances to large hazardous waste incinerators in the EU. The pesticides are then destroyed under controlled circumstances. The environmental risks in the selection of the location have been eliminated, except for the remains of the storage and the soil around it.

CURRENT PROCESS OF REPACKAGING AND DESTRUCTION OF OBSOLETE PESTICIDES:

1. Inception
2. Inventory of obsolete stockpiles for repackaging
3. Risk assessment and prioritization of sites
4. Selection and renovation of Intermediate Collection Centre
5. Planning and preparation repackaging campaign
6. Repackaging campaign
7. National transport of repacked waste to Intermediate Collection Centre
8. Safeguarding in Intermediate Collection Centre
9. International transport of repacked waste to Western Europe incineration/destruction plant
10. Incineration / destruction of repacked waste in Western Europe

DESIRABLE PROCESS OF REPACKAGING AND DESTRUCTION OF OBSOLETE PESTICIDES:

1. Inception
2. Inventory of obsolete stockpiles for repackaging
3. Risk assessment and prioritization of sites
4. Planning and preparation repackaging campaign
5. Repackaging campaign
6. National / regional transport of repacked waste to national / regional destruction plant
7. Destruction of repacked waste in the country / region

If obsolete pesticides could be destroyed under controlled and permitted conditions on location or in the region where they are found, this would prevent long term storage, expensive long distance transport and incineration, and avoid having authorities searching for local, cheaper unsustainable solutions. For this reason the consortium decided to look for an **appropriate, sustainable, locally applicable and controlled destruction technology for repacked obsolete pesticides.**

There were no expectations that one could start tomorrow with the selected technology, because until now none of the technologies have been tested sufficiently on location in order to assure application without major risk of failure. Our objective was to gain **insight into the possibilities of the most advanced technologies and perspectives for the establishment of a potential pilot project.**

In the following chapters, how far the goals set met these results is described.

Criteria for Locally Applicable (On Site) Methodologies

For the selection of destruction methodologies on location, a number of criteria are needed. The consortium follows the main criteria set in related conventions and the POPs Technology Specification and Data Sheet for the Secretariat of the Basel Convention (see appendix 2 and 3) and added specific criteria for starting a pilot project.

General criteria

The criteria used in the abovementioned Technology Specification and Data Sheets are a good base to start from and are briefly listed below (see also annex 1). The Sheets are built up in two main parts:

PART I: Criteria on the Adaptation of the Technology to the Country

PART II: Criteria on the Adaptation of the Country to the Technology

Part I deals solely with the performance of the technology itself, irrespective the location or country. However, Part II considers strongly all barriers and problems that can occur in „developing" countries, where many of the infrastructural facilities are frequently missing and create main barriers or so-called fatal flaws.

PART I: Criteria on the Adaptation of the Technology to the Country

There is one main criterion and that is the performance of each technology. The performance deals with virtually all ins and outs of the technology, such as:

- What kind of pre-treatment the waste needs in order to make sure that the technology will function properly for the designated waste streams;
- What toxic by-products will be generated;
- What is the appearance of the POPs and obsolete pesticides (empty packaging, liquids, granules, powders and solids), and;
- What is the capacity of the installation.

If the technology has only been working with very small capacities and we know that the amounts to be treated are huge, we have to know if it is a problem to scale up that technology to a much higher capacity.

The individual sub-criteria are based on the experience that the technology has had in the field and the measurements that have verified the functioning of the technology. The less experience the technology has, the less performance criteria are known. UNEP 2005 explains also in detail a large number of the criteria being briefly described in this chapter.

<u>Performance criteria</u>

1. Minimum pre-treatment;

2. Destruction Efficiency (DE);

3. Toxic By-products;

4. Uncontrolled releases;

5. Capacity to treat all POPs;

6. Throughput, and;

7. Wastes/Residuals.

PART II: Criteria on the Adaptation of the Country to the Technology

This part contains the individual technical requirements of the technology to function properly and one can then assess if the country can deliver these requirements/conditions, or if not, if the technology supplier must import additional materials to ensure proper functioning of the technology. If the requirements cannot be fulfilled, then this can lead then to a fatal flaw, which means that the application of the concerned technology is highly questionable and projects will be at high risk of failure. This part of the process is essential and cannot be overlooked in any assessment of the applicability of any technology to a country.

There are six main criteria that are used:

A. Resource needs (energy, water, reagents, buildings, sampling, communication systems, personnel required);

B. Costs (cost for installation, commissioning, site preparation, energy + telecom, monitoring, complying, reporting, running costs without and with waste, decommissioning, and transport of residues to landfill);

C. Impact (discharges for air, water and land and soil impact);

D. Risks (of reagents applied, technology, operational risks);

E. Constructability (ease of: installation/construction of plant, operation, shipping/transit, processing);

F. Output/generation waste (generated waste, deposited waste at landfill, waste quality properties).

All criteria that are mentioned in Part I and II have been used for this specific study.

CHAPTER 3

Two Technologies Reviewed

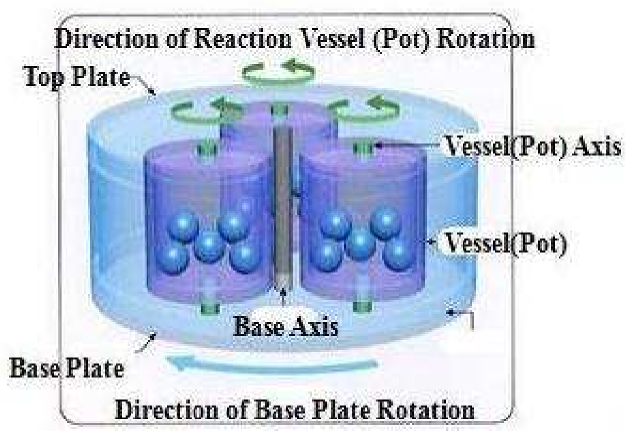
Based upon the selection done by the experts, and based upon available literature, two technologies were found that met a number of basic criteria mentioned in the previous chapter. During the conference, the technologies were intensively debated. After the conference, the methodologies were put to further examination.

First a short description of both technologies by Dr. Kaoru Shimme and Mr. Kevin Downey:

3.1 Radicalplanet Technology ("Ball Mill Technology")

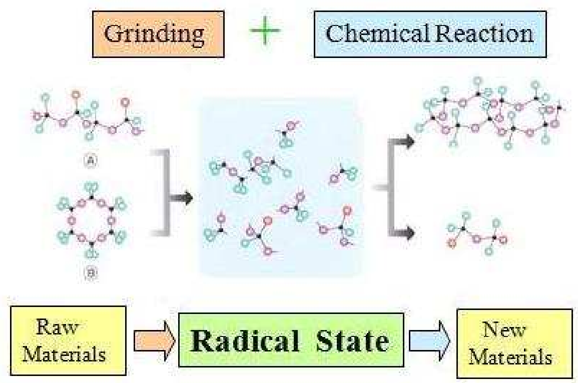
Dr Kaoru Shimme from Japan presented the Ball Mill technology. The ball mill provides a novel and interesting way of destroying pesticides on location.

Technology (by Kaoru Shimme): the aim of "Radicalplanet Technology" is the complete detoxification of harmful compounds (e.g. chlorinated organic compounds), into safe compounds under non-heating, atmospheric conditions and in a closed system, by the Mechanochemical principle. While the pesticides, PCBs, and related POPs wastes are treated, no exhaust gas and effluents are generated. There is no danger of secondary pollution due to transportation of the harmful compounds, because the system can be moved and can treat the pollutant on site. In addition, this process guarantees clean conditions because the reaction is created by mechanical energy without producing combustion gasses. In concrete, steel balls crush each other hard under non-heating conditions. The bonds in a molecule are cut by mechanical energy. The molecules are decomposed into an activated state, called the radical state, so that chemical reaction is accelerated.



In the case of chlorinated organic compounds, when a physical energy greater than a specific strength is exerted, the compounds containing chlorine will be chemically activated (as chlorine and carbon bonding is weaker, chlorine and carbon will be separate from each other). The de-chlorination reaction takes place without heating the harmful compounds. Additives such as CaO may be added depending on the desired end products (commercial products). In any case, safe and less expensive additives are selected for specific purposes. The chlorines in radical state combine with CaO in the vessel and produced chlorinated inorganic compounds, $CaCl_2$, Ca(OH)Cl, which are stable compounds. The organic compounds become harmless compounds which do not contain organochlorine compounds.

"Radicalplanet Technology" process means that the technical method can decompose the molecules into "radical" state by use of the "Planetary mill" and simultaneously change the harmful compounds entirely into substances of different molecular structures (target substances) by causing chemical reaction with non-harmful substances introduced in the closed system without heating the materials.



See also appendix 2:

Radicalplanet Technology(Mechanochemical Principle)- POPs Technology Specification and Data Sheet for the Secretariat of the Basel Convention, provisional Version (date 07.06.2008) and Radicalplanet Technology (Mechanochemical Principle) – Annex to POPs Technology Specification and Data Sheet, provisional version (date 07.06.08).

Applicable Pesticides and related POPs wastes:

Materials

- PCP, Chlordane, BHC, DDT, Endrin, PCB, DXNs;
- Mixture of pesticides and related POPs wastes;
- Admixture (soil, stones, concrete, glass, metal, plastics) polluted by PCB oils and POPs wastes;
- Fly ash and Incineration ash polluted by DXNs.

Form and conditions

- Solid and Powder;
- Liquid and Emulsion;
- Contaminated Materials (Fluorescent Stabilizer, Paper);
- Admixture of POPs Wastes.

Status: Pilot Commercial Treatment plant Operation (200kg/charge by the use of E-200 Type) 1999: Detoxification of Soil and Ash contaminated by DXNs; 2000: Detoxification of Pesticides and POPs wastes; 2001: Decomposition and detoxification of PCB oil, mixture and contaminated soil and stabilizers.

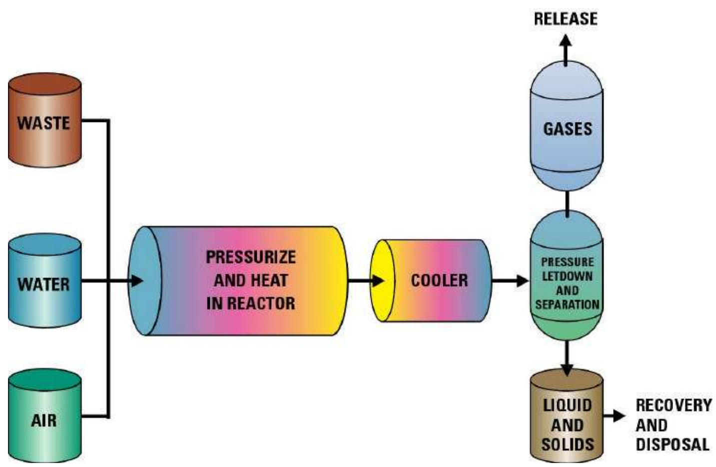
The commercial system was planned to begin in September, 1999, and was operated in January, 2000. Full scale operation began in February, 2000, in order to detoxify the POPs wastes delivered by the Japanese Government. The technical system was named "Radicalplanet technology" in April, 2003. Permission to apply the "Radicalplanet Technology" was officially granted by the Notification No.25 (April 1, 2004) from the

Environment Ministry in the name of the "kikai kagaku bunkai hoho" (mechanochemical decomposition method) under the law for Special Measures in relation with the law for PCB (and POPs) waste disposal. In 2006, A-500 type was designed for doubling the capacity of the E-200 type in order to operate on a larger scale. The commercial system (E-200: demonstration machine) is planned to re-start in 2008 at a new location.

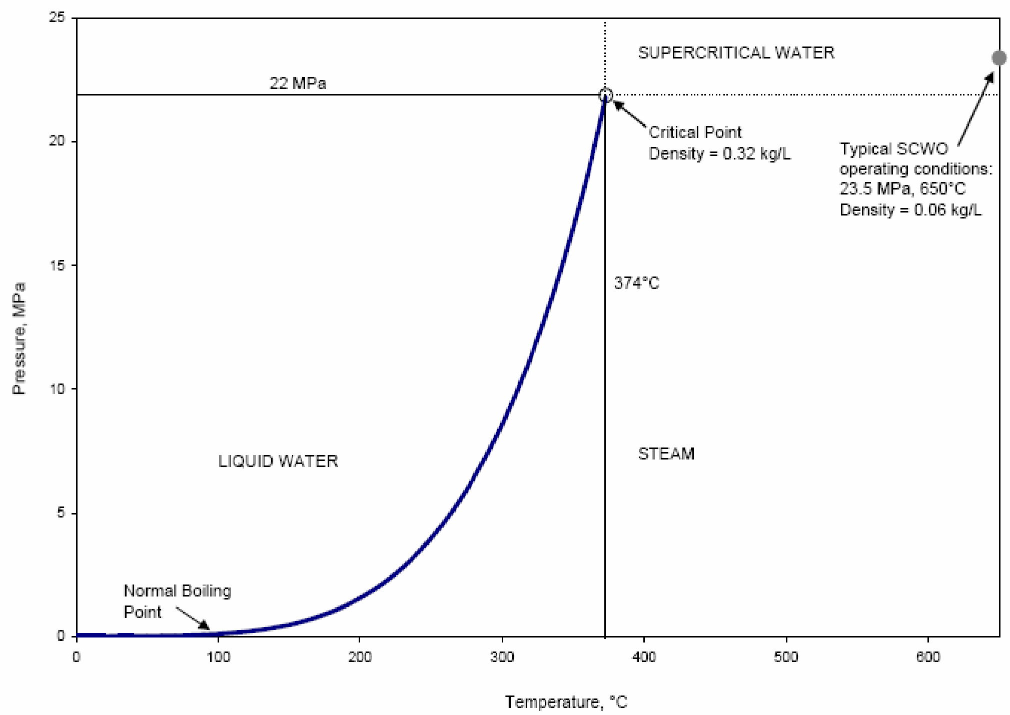
3.2 Supercritical Water Oxidation (SCWO)

The second technology presented was the Super Critical Water Oxidation Technology, presented by Kevin Downey from General Atomics USA

Technology (by Kevin Downey): Supercritical water oxidation (SCWO) is the 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 600-650°C and 23.5 MPa, respectively. The oxidant is typically high-pressure air, but pure oxygen, nitric acid, and other oxidizing agents can also be used. In supercritical water, organic materials are quickly destroyed to yield carbon dioxide and water. Heteroatoms such as chlorine, fluorine, and sulphur, 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.



Supercritical water (SCW) is one of the states of water which has higher temperatures and pressures than those at critical point. At this state, water is not condensed under any high pressure and SCW has intermediate properties between liquid and vapour. When SCW is used for the decomposition of organics, the organics and oxidant are miscible with SCW, creating a good condition for oxidation with no mass transport limitations. SCW has good fluidity and there is no diffusion rate determining step in reactions involving SCW. Therefore, SCWO is a high-rate reaction which has high-decomposition efficiency.



General Atomics is part of the Bechtel Parsons team responsible for design, construction, operation, and closure of a facility to dispose of the chemical munitions inventory at the Blue Grass Army Depot. Agent/energetic destruction technology being implemented is neutralization followed by SCWO. Three SCWO units rated at 1,000 lb/hr (450 kg/hr) to be supplied for treatment of the neutralized agent and neutralized energetic waste streams.

Applicable POPs wastes: BHC, Chlordane, PCB, mixtures of tetra- and octachlorinated dibenzop- dioxins and tetra- and octachlorinated dibenzofurans, Kelthane, permithrin and mixtures of 2,4 D and 2,4,5 T

Status: Commercial SCWO systems are operated in Japan, the US, the UK, Korea, and France. At present in Japan, 3 companies are working with SCWO systems. A joint venture of 2 companies is using the basic technology of a US company for the further development of the SCWO technology. In Japan, a plant is currently operating processing university laboratory wastewater. In the US, one company is continuing to develop the SCWO technology for Government and Commercial markets. Since 1992, this company has built approximately 20 SCWO units for various Government and Commercial programs. As of summer 2007, 3 additional SCWO units are under fabrication. Units are generally small with capacities from some hundreds of kg to max 15 tonnes/day in Japan. Another SCWO plant consisting of 3 individual SCWO units will be fabricated at the Blue Grass Army Depot as part of the ACWA Program for the destruction of chemical warfare agents. This plant will have a total capacity of ~12.000 tonnes per year. In Korea, one SCWO unit is processing dinitrotoluene (DNT) production wastewater at a capacity of 1800 kg/hr. In France, one company is processing food industry wastewater at a rate of ~100 kg/hr. Also PCB destruction has been tested successfully.

For details see appendix 3:

Supercritical Water Oxidation (SCWO)- POPs Technology Specification and Data Sheet for the Secretariat of the Basel Convention, provisional Version (date 09.06 2008) and SCWO – Annex to POPs Technology Specification and Data Sheet, provisional version.

Review

A review with all criteria and the two technologies can be found in annex 1, 2 and 3.

CHAPTER 4

Comparison of the Two Technologies

Comparison of technologies is not just the collection of data, giving scores to the various positive and negative factors and thereafter making a total list of points for each technology ending with the best or second best. It is more complex, and what is more difficult, one can hardly generalize such comparisons, so in principle case by case, depending on specific circumstances of the "waste encountered" and the "situation in the concerned country and the specific region(s)" will give the best possible and most realistic evaluation.

In our case the "waste encountered" is not yet known, but we expect that the situation will be similar to the situation in many countries of the EECCA region and we will find many small sites with relatively small amounts of mixed OP waste and sometimes a limited number of bigger sites and in a number of countries one or two large "polygons" or former landfill sites that have been used as official collection places of "outdated" pesticides.

One can expect to find regions with relatively bad infrastructure, lack of electricity and other necessary supply services, and often quite far away from towns with such services.

However, only real field demonstration tests in such regions can proof the feasibility and durability of the technologies.

Please note that the texts in the table do not consist of long explanatory sentences but texts have been formulated as short as possible to highlight certain issues.

Criteria	Amount of requirements to be clarified in a Pilot Project									
Part I: Performance criteria	**Large**			**Medium**			**Little/none**			**Remarks**
1. Minimum pre-treatment										
SCWO				X						Need to convert solid waste into liquid or slurry wastes, so that feed can be pumped into SCWO, with an organic content of less than 20% and a particle size less than 200 Um. As we are confronted with a mix of various pesticides wastes, soil, building materials, packages, containers etc, the design of a proper pre-treatment device is vital to make the technology successful. With chemical agents in the ACWA program, everything was pulverized from wood pallets to rubber suits, which worked very well. Also for a heterogeneous feed stock.
Radicalplanet				X						No pre-treatment needed, only limits on size of drums or bags 20 l/20 kg. This means that the ball mill will strictly require the use of small size packaging materials as indicated as acceptance criterion. Calcium oxide will have to be added in a ratio following from the type of substance and the required destruction time.
2. Destruction Efficiency (DE)										
SCWO							X			DE of 6 to 8 9s for pesticides tests in Japan, however for very low concentrations. DE for high concentrations to be proven
Radicalplanet						X				DE of 4 and 5 9s are indicated and for DRE's 7 and 8 9s have been listed. It has to be clarified how DE is calculated as larger amounts of agencies are added?

3. Toxic By-products										
SCWO								X		None for POPS.
Radicalplanet				X						After treatment a final product powder is produced, that may require further treatment (see further under 7).
4. Uncontrolled releases										
SCWO								X		None with standard incorporation of pressure relief vessel.
Radicalplanet								X		No exhaust gas and no uncontrolled releases of effluents.
5. Capacity to treat all POPs										
SCWO					X					In principal a high potential to treat a wide range of POPs and other substances. Although proven in pilot studies at General Atomics and elsewhere, POPs treatment has been performed at very small scale only and needs to be performed in the pilot project. Specifically the difference between treatment of chemical weapons with clearly defined input varies considerably from the OPs, with a strong variety of materials and extremely variable concentrations. Therefore it is stressed that an independent verification of the chemical reaction path for the treatment of obsolete and POPs pesticides is essential.
Radicalplanet					X					A large spectrum of organochlorine POPs and OPs has been treated. The amounts have been very small and larger amounts need to be tested on an appropriate scale in the pilot test. Emphasis was mainly on dehalogenation of substances. However, as many pesticides are not organo-halogen compounds, the technology should also be proven with other classes of substances such as organophosphorous, carbamates and organo nitro compounds.

6. Throughput										
SCWO								X		In principle one has to reckon that throughput for mobile installations will be small, but that is inherent to mobile plants. 2 - 3 tonnes per day. In Japan at Kurita $10m^3$ per day was reached. Not clear if this is a stationary or mobile plant.
Radicalplanet	X									Max 2 tonnes per day. In principle one has to reckon that throughput for mobile installations will be small, but that is inherent to mobile plants. More detailed information is needed on the exact throughput. According to the fact sheet, the max volume of one treatment vessel is 1.5 m^3. For treatment of 1 ton BHC, 1.5 ton of CaO is needed plus a substantial volume is used by the steel balls. The question is how much the effective volume is for the BHC to be treated? The test results as listed in the fact sheet in Part I (plus presentation slide 15) show that for the destruction of 0.7 kg chlordane with unknown concentration, 69.3 kg of CaO are needed. This is much more than indicated. If for a treatment of certain pesticides 100 times the original weight of the pesticides agencies has to be applied, it has to be questioned if the process works more like a diffusion process and the throughput will be extremely low. Similar applies for 0.7 kg BHC with unknown concentration for which in total 65.5 kg agent (55.2 kg CaO +11.3 kg SiO2) was needed. These issues have to be clarified during the pilot project. Throughput for high concentrated waste has to be proven during pilot. How many tonnes of agent would be necessary to treat for example 1,000 tonnes of pure HCH?
7.Wastes/Residuals										
SCWO								X		In Japanese tests on BHC, chlordane and PCB it is stated that the treatment effluent contains harmless salt, such as NaCl, $NaHCO_3$. Exhaust gas is mainly composed of CO_2, N_2, O_2.

Radicalplanet	**X**									The main product after treatment is a powder, which contains the various components • Inorganic compounds like NaCl, $CaCl_2$ • Organic compounds like hydrocarbons or CO_2 • Non-chloric organic compounds like benzene, toluene and ethyl-benzene (C6H5C2H5). Independent detailed research should be conducted to see if there are other unknown intermediate breakdown products. In order to identify re-use of powder, the necessary leaching tests for these components have to be implemented, and based on the results, limited or free usage can be defined. In case the powder does not fulfil such criteria, the use of powder into concrete structures, as indicated in the Fact Sheet, has to be investigated with Leaching tests as described before. The results of these tests and possibilities of application/re-use will determine the feasibility of this technology. Additionally, the permission to apply the "Radicalplanet Technology" - which was officially granted by Notification No.25 (April 1, 2004) from the Environment Ministry in the name of the "kikai kagaku bunkai hoho" (mechano-chemical decomposition method) under the law for special Measures in relation with the law for PCB (and POPs) waste disposal - should be available in English in order to verify the specific conditions on application of the technology and the use of the powder.

Part II: Criteria	Amount of requirements to be clarified in a Pilot Project									
Resource needs:	**large**			**Medium**			**Little/none**			
SCWO								X		All data for SCWO are based on 3 gpm feed of a 2,000 Btu/lb feed. 440 V (550 kw) for high-pressure air compressor and 40 HP (30 kw) for remaining components. A diesel-powered air compressor can be used if desired to reduce the site electrical requirements, depending on site capabilities. Diesel Fuel: 1.3 kg/min (less for higher heat value feeds, and not required for feeds with heat content in excess of 2000 Btu/lb). Natural gas: 42 scfm (Startup only, i.e., <1 hour per week). Other resource needs are low.
Radicalplanet							X			Radicalplanet Treatment Process consists of three parts: The main machine (A-500 type), electric motor and powder collecting equipment with a power source of AC440V (550 kw), 3φ, 60Hz. Electric motor is equipped with AC500kw ×1000 rpm, and decelerator (deceleration ratio is 1/14.29). Powder collection equipment consists of a cyclone type and a bag filter type. with a power source of AC 220V, 30kw. In case no power source is available or power is unreliable in the concerned country, one can operate the treatment plant by a diesel generator. Resource needs are higher than resource needs of SCWO.

Costs:										**Note:** *no validation of the costs have been made here, as the costs indicated are estimated to be considerably higher when implementing the pilot tests*
SCWO										Capital costs: \$1.2-1.5M (3 gpm feed of a 2000 Btu/lb feed). Approx. 230-540 EURO per ton. Although indicated by the presenters, a specific cost evaluation based on the pilot and extrapolated to production conditions have to be made and these costs are site dependent. It is not clear if the costs include the costs for fuel and the investment for a generator.
Radicalplanet										A-500 (one machine with 210 tonnes/y) approx: 3.3 million EURO. Approx 420 EURO per ton, Although indicated by the presenters, a specific cost evaluation based on the pilot and extrapolated to production conditions has to be made. Treatment costs per ton and the electrical costs for the 2 different ball mills are: E-200:1,800kwh/ton=540kw×1.4h/107kg. A-500:3,600kwh/ton=540kw×1.4h/214kg. Annual maintenance cost is included in "Operating & Maintenance Cost 1.5 EURO per kg for Schedule Wastes", except expendables (parts) of the main machine. Important is that the technology supplier clarifies conditions for licence applicants fees, rights, and areas that cover the patent, so that costs related to the total costs can be budgeted.

Impact:										
SCWO								X		Minimal: Air discharges: approximately 50 kg/min. Exhaust gas is mainly composed of N_2, CO_2, O_2, and water vapour. Approximately 12 kg/min. Product is a brine solution, with the salt concentration dependent on the feed composition. Neither NO_2^- nor NO_3^- remains in the water after the oxidation reactions. Therefore, as long as there are no significant heavy metals in the feed, there is no need to further treat the SCWO effluent. Discharges to land: discharge contains harmless salt, such as NaCl, $NaHCO_3$.
Radicalplanet								X		Minimal: No air emissions during the process, however emission during opening should be measured during pilot. No water is generated in the process and no discharges to land. Low noise, and no vibration, because the direction of rotation and revolution is horizontal.
Risks:										
SCWO								X		None so far.
Radicalplanet								X		Process is a closed system and never generates exhaust gas and effluents during detoxification reaction. It is doubtful that if chlorinated benzenes are produced that emissions into the atmosphere are taking place. Independent verification of emissions during the opening of the pots should be made. **Risks of reagents:** very safe agents are applied in this technology, such as CaO, SiO_2 and A_2lO3, which are popular materials in the soil or the earth. No operational risks: in an emergency, the system can be shut down completely.

Constructability: 1. Ease of installation/ construction of plant 2. Ease of shipping/ transit 3. Ease of operation 4. Ease of processing										
SCWO								X		All parts easily be packed and shipped in containers. Easily operable. Mobility specifically for the objective of the pilot is of vital importance but seems relatively simple and is unproblematic. Specific attention has to be paid to the number of movements in a country or region per year, say per 100 or 150 tonnes treated. Cost-benefit analysis has to be made during the pilot project.
Radicalplanet						X				In general, easy construction that takes about 4 weeks. Shipping not possible in containers, but as a whole easily shipped and transported overland. Transport overland could eventually have some problems related to heights under bridges and also for bad and narrow roads, so certain care and preparation has to be made. Specific attention has to be paid to a number of movements in a country or region per year, say per 100 or 150 tonnes treated. Cost-benefit analysis has to be conducted during the pilot project.
Output/generation waste:										
SCWO				X						Japanese tests on BHC, chlordane and PCB stated that the treatment effluent contains harmless salt, such as NaCl, $NaHCO_3$. Exhaust gas is mainly composed of CO_2, N_2, O_2. The waste quality properties (pH, TCLP) analyses performed to date are reported to have passed TCLP. Main issue which has to be dealt with is the lack of substantial experience with the treatment of pesticides. That has to be proven to be working and is expected, due to its large variety of input materials, to be significantly different than the chemical warfare agents, which are clearly defined. The pilot test needs to deal with this. See also Part I, under 5.

Radicalplanet	**x**									According to the supplier, no waste is generated. See also Part I, 7. under Wastes/Residuals. The final product is a powder consisting of: • Inorganic compounds like NaCl, $CaCl_2$ • Organic compounds like hydrocarbons or CO_2 • Non-chloric organic compounds like benzene, toluene and ethyl-benzene (C6H5C2H5) No waste is deposited at landfills. All material can be re-used (possibility to use non-chloric organic compounds as energy source could be considered). On the waste quality properties (pH, TCLP) the supplier indicated that no liquid effluent was generated. However, it will be necessary that the results of independent leaching tests (specifically, results of benzenes, toluenes and ethyl-benzene have to be verified and assessed to determine if they are in accordance with acceptable levels) be provided. Specifically, during pilot test this issue has to be thoroughly investigated. Same issues as raised in Part I, item 7 have to be dealt with.

Conclusions and ranking of the technologies

Both technologies offer extremely interesting and innovative processes and if one or two pilot projects can clearly prove the technical and economical feasibility of the processes, it would mean a huge step forward for new sustainable approaches for local/on site treatment of obsolete pesticides and POPs.

The analysis can be summarized in a number of issues that have to be seriously dealt with by both technologies during the pilot project and/or before the start up of such a pilot project. The issues for each technique are summarized below.

SCWO

Pre-treatment: The SCWO reactor will be confronted with a mix of various pesticides wastes, soil, building materials, packages, containers etc. Therefore the design of a proper pre-treatment device is vital to make the technology successful. Eventually it is a good idea to combine SCWO with other technologies that have already sufficient experience with specific devices for the pre-treatment of obsolete pesticides. It must be stated, however, that with chemical agents in the ACWA program, everything was pulverized from wood pallets to rubber suits, and this worked very well. It also worked for a heterogeneous feed stock.

Capacity to treat all POPs needs clarification and large scale treatment data: SCWO has in principle the capacity to treat all POPs, but has very limited experience on a small scale, which cannot yet justify installation of a SCWO treatment plant to deal with obsolete pesticides. So here the need for results on how to deal with the mix of all kinds of different pesticides, in a different way than the chemicals weapons, will form the main task to prove SCWOs feasibility for the obsolete pesticides and POPs market.

Throughput and waste residuals: The technology provider has reported that a non-toxic output, eventually small amounts of metals and minor amounts of solid waste will have to be disposed of at landfills. However discharge of strong brine is a problem. Solving it by dilution is not a good alternative. The situation in the weapons programme cannot be compared with this. Therefore during the pilot test this issue should be dealt with.

Costs: With the requirements for SCWO on pre-treatment and on inclusion of a diesel generator and new results from testing obsolete pesticides instead of chemical agents, it is expected that the cost factors will modify considerably. Operating costs being presented during the workshop, 230-540 Euro per metric tonne, are estimated far too low. Even for formulations with low active ingredients, a price of 230 Euro per tonne seems unlikely. The SCWO capital costs refer only to the core unit itself. Real capital costs for a site will certainly be far higher. Note also that SCWO has been extensively tested only for the upmarket model for chemical Warfare agents. There is much less data for the interesting cheaper version for civilian usage for possible pesticides treatment.

Also, the additional costs for:

-Personnel Protective Equipment requirements can become an issue if the work needs to be performed in full protective clothing and breathing gear, and have to be seriously be taken into account during the pilot project.

-Building requirements for mobile treatment plants are often completely neglected, especially the proximity of housing, work places etc. Containment is often a requirement. Then additional costs of (temporary) buildings can occur and have to be considered as well.

Radical Planet

Pre-treatment: The Radicalplanet technology has a number of uncertainties that have to be clarified before a pilot can be implemented. One of these uncertainties is the pre-treatment program, the necessity of analyzing the waste to assess the amount of additives needed, and the volume of the final product.

Post-treatment: Another uncertainty is the post-treatment to separate the organic solvents from the $CaCl_2$ when the waste is treated in the Ball Mill. Considering the calculated volume of additives, the after treatment will be a significant step in the process cycle of Radicalplanet.

Throughput and waste residuals:

1. What is the effective use of the Ball Mill Vessels (Pots)?

According to fact sheet, the max volume is 1.5 m^3. For the treatment of 1 t BHC 1.5 t of CaO is needed. Besides that a substantial volume is used by the steel balls. The question is, how much the effective volume is for the BHC to be treated? This would mean that 60% of the available volume is occupied by the CaO and that additional volume will be occupied by the steel balls.

2. Independent detailed research is necessary to verify the presence of other unknown intermediate breakdown products.

During and after the Utrecht conference, intensive discussions have taken place in order to verify exactly what intermediate breakdown products are generated. Therefore, independent detailed research should be conducted to see if there are other unknown intermediate breakdown products.

3. The amounts of agents needed in the process seem to be extremely high and this has to be clarified.

The test results as listed in the fact sheet in Part I (plus presentation slide 15) show that for the destruction of 0.7 kg chlordane, with unknown concentration, 69.3 kg of CaO are needed. This is much more than indicated. If for a treatment of certain pesticides 100 times the original weight of the pesticides agents has to be applied, it has to be questioned if the process works more like a diffusion process and the throughput will be extremely low. Similar reasoning applies for 0.7 kg BHC with unknown concentration for which in total 65,5 kg agent (55.2 kg CaO +11.3 kg SiO2) was needed. These issues have to be clarified during the pilot project.

Throughput for highly concentrated waste has to be proven during the pilot test. For example, how many tonnes of agents would be necessary to treat 1,000 tonnes of pure HCH?

4. The final treatment product must be investigated and all details have to be clarified.

The main treatment product is a powder, which includes various components, such as:

- Inorganic compounds like NaCl, $CaCl_2$
- Organic compounds like hydrocarbons or CO_2
- Non-chloric organic compounds like benzene, toluene and ethyl-benzene(C6H5C2H5)

In order to identify re-use of powder, the necessary leaching tests for these components have to be implemented and, based on the results, limited or free usage can be defined. It is also important to test the toxicity of the organic phase. In case the powder does not fulfil the required criteria the use of powder into concrete structures, as indicated in the Fact Sheet, has to be investigated with leaching tests as described before. All necessary tests have to be conducted by an independent certified party.

The results of these tests and possibilities and restrictions of application/re-use will determine to a major extent the feasibility of this technology.

5. The Japanese permit is not accessible for parties that would like to work with Radical Planet Technology outside of Japan.

Additionally, the permission to apply the "Radicalplanet Technology" - which was officially granted by the Notification No.25 (April 1, 2004) of the Environment Ministry in the name of "kikai kagaku bunkai hoho" (mechano-chemical decomposition method) under the law for special Measures in relation with the law for PCB (and POPs) waste disposal- should be available in English in order to verify the specific conditions on application of the technology and the use of the powder.

Costs: Also, for the Radical Planet technology a similar cost-benefit analysis needs to be made during and after the pilot project. Specifically interesting is the issue about the fabrication of the Ball Mill. As this is one of the main costs, treatment costs could be considerably reduced if the technology supplier would give the licensee the right to construct a new plant in one of the countries in the EECCA region, especially if the manufacturing period is so short.

For Radical Planet technology, if all conditions are cleared, a similar cost-benefit analysis needs to be carried out. For example:

-license costs have not been taken into account;
-if there are restrictions on use of the final product, additional costs will occur;
-in case of unlimited use benefits could reduce the treatment price.

Such issues can play a major role in the final costs of the technology and should be taken into account.

Risks: It is doubtful that if chlorinated benzenes are produced, that emissions into the atmosphere would take place. Independent verification of emissions during the opening of the pots should be made.

Constructability plays a special role for both pilot plants

The factors considered in the data sheets include:
1. Ease of installation/ construction of plant
2. Ease of shipping/transit
3. Ease of operation
4. Ease of processing

The factor „Ease of shipping/transport" deals frequently with a single action of transporting the plant from the factory, often by sea transport to the respective country and then to a fixed location, and in some cases additional transport. However, the objective of the coming pilot project is „more frequent" transfers to various locations.

Here it is also important to establish a number of criteria that make the application of on site treatment feasible. This would mean that per location at least a kind of minimum amount of pesticides should be treated, say 100 tonnes. It is often seen that regional governments want to deal, or are forced to deal, with their own hazardous waste problems, so a plant could then clean up one region with 100 or 150 tonnes and then move to the next region. This would mean that at individual sites smaller amounts will be safely repacked and then transported over smaller distances and then treated at the temporary treatment sites.

However, on-site treatment of every small site with 500 kg or 3,5 tonnes should not be the objective of the on site treatment plant.

There are different ways that obsolete pesticides can be delivered to the treatment plant:
-They can be repacked in advance in a temporary store, or:
-The delivery/repacking can take place as a continuous process.

So during the pilot project, the mobility/ease of re-location is very important and has to be tested with at least one change of location after finishing of the first treatment site.

The Factor "Ease of operation" plays a specific role for SCWO, as SCWO is a very corrosive process, necessitating the change-out of the reactor liners, and it can clog with salts easily. In a pilot test specific attention to the latter has to be paid.

CHAPTER 4

Proposed Next Steps

As discussed, the consortium thinks that both methodologies offer interesting and novel possibilities for use in EECCA countries. However, questions remain regarding the process and economical sustainability of the methodologies. Therefore we propose the following steps:

Step1:

Based on the evaluation, the SWCO process does not need more explanation for chemical weapons, but does need it for the necessary demonstration works on the pre-treatment and treatment of OPs. Specifically, the difference between treatment of chemical weapons with clearly defined input varies considerably from the OPs, with a large variety of materials and extremely variable concentrations. Therefore it is stressed that an independent verification of the chemical reaction path for the treatment of obsolete and POPs pesticides is essential.

Therefore it is recommended that a pilot test for SCWO should be initiated to verify all the abovementioned concerns.

As mentioned previously, a pilot test will be relatively expensive. However, these costs have to be made in order to have a clear view of a larger scale SCWO for treatment and pre-treatment of OPs in EECCA countries. Also, it is important to gain a clearer picture of (operating) costs of SCWO when used in EECCA countries. IHPA, Milieukontakt and Tauw will discuss with partners and donors the possibilities and financing of such a pilot test.

Milieukontakt's programme (2009-2015) for obsolete pesticides can be downloaded from www.obsoletepesticides.net.

Step 2:

Clarifications of questions -as described in detail in the last chapter under *Conclusions and ranking of the technologies*- on Radical Planet are needed before any other field test shall take place. If these questions have been satisfactorily clarified, the next phase of a second pilot project can be discussed.

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During our conference on September 26th 2008 in Utrecht, The Netherlands, the following presentations were delivered:

- Michael Valentine (ISTC): *International Science and Technology Centre: Experience and Opportunities for Obsolete Pesticide destruction*
- Alan Watson (IPEN): *Introduction on obsolete pesticides-incineration and alternative technologies*
- Kaoru Shimme: *Radicalplanet Technology*
- Kevin Downey (GA): *SCWO of obsolete pesticides*
- Hans Muilerman (Natuur & Milieu): *And what happens with the „new" obsolete pesticides?*
- John Fairweather (BCD)/ Alan Watson (IPEN)/ John Vijgen (IHPA): *Monitoring and Validation of alternative technologies*

These presentations are available as PDF. Files upon request or can be downloaded from www.obsoletepesticides.net.

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ANNEXES

1. Information on criteria (taken from Disposal technology Options – review and update of technology, Under the ASP).

2. Radicalplanet Technology (Mechanochemical Principle POPs Technology Specification and Data Sheet for the Secretariat of the Basel Convention, Provisional Version, date 07.06.2008 and Radicalplanet Technology (Mechanochemical Principle) – Annex to POPs Technology Specification and Data Sheet, Provisional version, date 07.06.08.

3. Supercritical Water Oxidation (SCWO), POPs Technology Specification and Data Sheet for the Secretariat of the Basel Convention, Provisional Version, date 09.06 2008 and SCWO – Annex to POPs Technology Specification and Data Sheet, Provisional version.

Annex 1: Information on Criteria

This information on criteria is taken from WWF report Disposal technology Options – review and update of technology, under the ASP

> **This information has been included as it gives insight on what criteria are important for the technologies and describes also briefly how the** POPs Technology Specification and Data Sheets for the Secretariat of the Basel Convention are built up **and what the criteria used, actually mean.**
>
> **Please note that this part is specifically written for the ASP (African Stockpile Programme) and can include also parts that are not specifically applying for this report.**

- **General Description**
- **PART I: Criteria on the Adaptation of the Technology to the Country**
- **PART II: Criteria on the Adaptation of the Country to the Technology**

General Description

This section gives a short introduction on the technology and includes the following main items:

<u>Name of the technology:</u>

<u>Status of the technology:</u> Indicating for example how many plants on the market, and specific cases and newest developments

<u>Applicable Pesticide and related POP wastes:</u> Listing the components that have been treated by the technology

<u>Technology Description:</u> Short description of the process, individual steps, flow schedule or process diagram etc

PART I: Criteria on the Adaptation of the Technology to the Country

There is one main criterion that is the performance of each technology. The performance deals with virtually all ins and outs of the technology like what kind of pre-treatment the waste needs in order to make sure that the technology will function properly for the designated waste streams. But it must be able to tell what toxic by-products will be generated, or if all POPs or only a few can be treated, and the capacity. If the technology has only been working with very small capacities and the amounts to be dealt with are huge, then it can be a problem to scale up that technology to a much higher capacity. The individual sub-criteria are based on the experience that the technology has had in the field and the measurements made that have verified the functioning of the technology. The less experience the technology has, the fewer performance criteria.

UNEP 2005 explains also in detail a large number of the criteria being briefly described in this chapter.

A. Performance:

1. Minimum pre-treatment:

Mostly pre-treatment issues involve actions like grinding, blending, mixing and homogenization processes. Often also larger particles have to be removed by sifting and crushing to reduce their size; or in some processes pH and moisture content may need to be adjusted.

In order to release POPs from drums or packaging materials thermal desorption has often been used in conjunction with a number of processes prior to treatment (see further details in UNEP 2007, under pre-treatment).

2. Destruction Efficiency (DE):

In the early days for the treatment of pesticides waste the terminology Destruction and Removal Efficiency (DRE) was used. However, the DRE is defined as DRE = (Mi-Ms)/Mi x 100, where Mi is the mass of a chemical fed into the destruction system during a known period of time and Ms is the mass of the chemical released in stack gases during the same period of time. But this measurement does not take into consideration the releases of chemicals that might be present in residues and other releases.

A better measurement of overall destruction is the "Destruction Efficiency (DE)". The DE is defined as DE= (Mi –Mo)/Mi x 100, where Mi is the mass of a chemical fed into the destruction system during a known period of time and Mo is the mass of that same chemical released in stack gases, fly ash, scrubber water, bottom ash and any other residue stream.

(see also DANCEE, 2004, and Pat Costner, June 2004).

3. International Criteria

There are no general or international regulations that prescribe levels to be obtained for DEs and DREs. The Updated general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants (POPs), Basel Convention Technical Guidelines (UNEP, 2007) address two main criteria and the concerned levels to be applied:

A. Low POP content

Here is stated that the following provisional definitions for low POP content should be applied:

- PCDDs and PCDFs: 15 µg TEQ/kg;[1]
- Aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, mirex and toxaphene: 50 mg/kg for each.[2]

1 TEQ as referred to in annex C, part IV, paragraph 2, of the Stockholm Convention, but only for PCDDs and PCDFs.

2 Determined according to national or international methods and standards

and

B. Levels of destruction and irreversible transformation

The following provisional definition for levels of destruction and irreversible transformation, based upon absolute levels (i.e., waste output streams of treatment processes) should be applied:

(a) Atmospheric emissions:

PCDDs and PCDFs: 0.1 ng TEQ/Nm^3;[3]

All other POPs: pertinent national legislation and international rules, standards and guidelines, examples of pertinent national legislation can be found in annex II;

(b) Aqueous releases: pertinent national legislation and international rules, standards and guidelines, examples of pertinent national legislation can be found in annex II;

(c) Solid residues: POP contents should be below the low POP contents defined in section A above of this chapter. However, if the POP content of unintentionally produced PCDD/PCDFs is above the low POP content defined in section A, the solid residues should be treated in accordance with section IV.G.

In addition, technologies for destruction and irreversible transformation should be operated in accordance with BAT and BEP.

On the methods that constitute environmentally sound disposal, it refers to Section G of chapter IV that contains a description of methods that *are considered to constitute environmentally sound disposal of wastes consisting of, containing or contaminated with POPs*. It must be noted that this is a consideration only and reflects that status on the technologies in 2005. In this section experiences on DE's and DRE's are reported.

3. Toxic By-products:

Residue streams that may be toxic are identified.

4. Uncontrolled releases:

Any releases that are potentially uncontrolled are identified along with measures that are taken to ensure that such releases do not occur.

5. Capacity to treat all POPs:

Comments on the ability of the technology to treat all types of POPs noting any limitations.

3 TEQ as referred to in annex C, Part IV, paragraph 2 of the Stockholm Convention, but only for PCDDs and PCDFs. Nm3 refers to dry gas, 101.3 kPa and 273.15 K. Standardization at 11 per cent O_2.

6. Throughput:

Typical values for amounts of waste treated. For the various technologies there can be a big difference in the usual throughput of an installation. For example hazardous waste incinerators can treat between 30,000 and 100,000 tonnes total waste per year.

Plants dedicated solely to treating POPs and related wastes might typically have throughputs from hundreds to thousands of tonnes per year.

POPs throughput: [POPs waste/total waste in %] - The hazardous waste incinerators that can treat between 30,000 and 100,000 tonnes per year can treat max 10% chlorines or halogens. This means that the POPs throughput is effectively approximately a maximum of between 3,000 and 10,000 tonnes per year.

As a rule of thumb for cement kilns, chlorine should usually be limited to 300 to 500 g/t cement clinker for a kiln without by-pass and 400 to 750 g/t for a kiln with by-pass (the chlorine tolerance of the kiln most be known in each instance). For example a cement kiln with capacities between 300,000 and 1,000,000 tonnes cement clinker per year, this would theoretically mean the maximum POPs throughput would be 90 to 500 tonnes per year for a kiln without by-pass and 120 to 750 tonnes for a kiln with by-pass.

7. Wastes/Residuals

Here are included:

- Secondary waste stream volumes/masses:

For example, any residual ash, slag or other residue. The amounts, properties and proper treatment of these streams will vary considerably from one technology to another and safe handling, additional treatment required or ultimately safe disposal facilities should be considered for the technology under consideration.

- Off gas treatment:

This section describes any flue gas treatment systems that are required. These vary from technology to technology and may be simple (thermal oxidiser) or complex and multistage with wet and dry scrubbing and specific modules for treatment of metals or dioxins.

Many of the details of the treatment data can be found in the Annexes of the TSDS, where one can find four tables:

Table 1: Technology overview - Summary - Technical Details

Table 2: Overview project experience per technology supplier

Table 3: Overview detailed project information per project - Project name (from Table 2)

Table 4: Client References for certain Plants if available from the technology providers

PART II: Criteria on the Adaptation of the Country to the Technology

This part contains the individual technical requirements of the technology to function properly and one can assess then if the country can deliver these requirements/conditions or if not if the technology supplier must import additional materials to ensure proper functioning of technology. If the requirements cannot be fulfilled, then this can lead then to a fatal flaw, which means that the application of the concerned technology is highly questionable and projects will be at high risk of failure. This part of the process is essential and cannot be overlooked in any assessment of the applicability of any technology to a country.

There are six main criteria that are used:

A. Resource needs:
B. Costs:
C. Impact:
D. Risks:
E. Constructability:
F. Output/generation waste:

Each of the criteria includes then a number of key components that have been dealt with and are briefly indicated in the following section. Details can be also found in UNEP, 2005.

A. Resource needs:

Under resource needs fall a large number of vital criteria listed that can be decisive if the technology is, as it is, able to survive in a number of African countries and below some examples are given:

- Power requirements
  Lack of reliable power is one of the major barriers in Africa, as frequently the public supply fails. For plants that are connected to the grid, this brings additional insecurities on the continuity of their production and mostly a back-up or stand alone generator is chosen. Another factor is the height of the power demand. Many of the smaller plants have only a demand of some hundreds of kW but some with higher capacity pass easily a couple of MW. For plants with a very high demand, even then the supply of a large stand-alone generator could create an additional problem. For standalone generation a reliable supply of fuel is required. On the other hand, large power demanding plants like cement kilns have already an infrastructure that is often completely independent from the existing grid. Additionally one has to consider higher power consumption for offices, living quarters, laboratory equipment, storage facilities that can only function with air-conditioners.

- Water requirements
  There are a lot of arid countries in Africa, and lack of water is there a common problem as water is likely to be essential and the volumes required are often underestimated. Special care has to be taken on this issue. Not only for the process purposes but also for supply of the crew members drinking and washing

purposes and here the quality of the water plays an important role. Often wells, when the first aquifers are polluted or dried out, or special deep wells have to be drilled and the establishment of an additional water reservoir is needed in order to secure the supply. Sometimes water has to be transported regularly from outside the site and arrangements made with water supply companies in the major cities. In case that material has to be mixed for the treatment process, then the quality of the water has to be examined in order to test its suitability for that purpose.

- Fuel volumes
  Fuel supply can be problematic in some countries. If these are permanent problems it is very questionable if any technology can survive. Of course one can look for a complete autonomic supply from outside of the country, but even though such situations can put any technology at high risk. Most of the installations make use of oil, natural gas or propane.

- Reagent volumes
  Some processes need specific reagents which may be not available in the concerned country and in the surrounding countries. For example, special hydrogen donor oil, specific catalysts, caustic, nitrogen or hydrogen etc. It is obvious that a special supply or enough of such materials for a long production period has to be secured.

- Water tight buildings
  As we have often to deal with intensive rainfalls in the tropical zones, these requirements have to be considered thoroughly. A typical case can also be where and what location the repacked pesticides have to be stored. If stored at low area, during the rainy season, the storage place can even be inundated and additional dangers can occur. Also the proper selection of the location of the plant, and the access should be ensured at all times.

- Hazardous waste personnel requirement

- Sampling requirements/facilities

- Peer sampling and external audit/review
  In principle, sampling can be done by trained personnel from the contractor, but in general an independent organisation is needed. If no "competent" independent local companies are available, special arrangements with specialists outside the country then have to be made.

- Laboratory requirements
  Many of the plants are at present provided with basic laboratory equipment, in order to control their own process. Often the analysis needs quite some time and too much time for the contractor and therefore most contractors have analytical equipment installed at the plant, so one is able to adjust faster to certain situations

- Communication systems
  Most of the installations are automatically controlled, but also here specific precautions have to be taken into consideration with climatic conditions like high

humidity, dust and intermittent power can cause many failures. Networks are at present frequently mobile, specifically in Africa where fixed networks are problematic

- *Number of personnel required*
  Here it is important to distinguish between the number of skilled labour (technicians) and the number of unskilled labour. Depending on the availability of local skilled personnel, the possibility of training and capacity-building, the inclusion of international skilled labour can be decreased or increased accordingly.

B. Costs

These individual costs are rather specific and can often only be considered in detail when contractors make their offer to the client and depend further on the tender documents, often containing specific country information, that are supplied by the client to the contractors. Additionally before a bid will be made, contractors will send their representatives for a special mission to the country in order to assess the below mentioned facts seriously. Therefore they are not described but only listed here.

- Installation and commissioning costs
- Site preparation costs
- Energy & Telecom installation costs
- Monitoring costs
- Compliance costs
- Reporting costs
- Running costs with no waste (testing and dry runs on functionality before waste treatment)
- Running costs operating with waste
- Decommissioning costs (Site remediation and project completion costs – at end of project lifetime including any necessary site clean up dismantling and removal of equipment and restoration of site as required.
- Landfill costs
- Transport costs of residues

C. Impact

Typically a detailed environmental impact assessment will be required along with on-going monitoring and evaluation of releases to the environment to ensure that damage is not being caused. Clean up systems for releases to air, water and land may be needed and will require attention throughout the project operation. Discharges will need to be monitored and residues appropriately and safely handled and disposed of.

- Discharges to air
- Discharges to water
- Discharges to land
- Soil impact
- Noise and local impacts (not included in the TSDS)

D. Risks

- Risks of reagents applied

Various technologies apply reagents that have various risks and each technology has to develop the necessary safety procedures to deal with such risks.

- Risk of technology

Here one deals with risks of occurrence of for example fires or explosions.

For hazardous waste incinerators, the risks are well-known and many safety reports have been made conform to the Seveso II Directive. For other technologies full assessments may need to be developed.

- Operational risks

Operational risks are identified and measures required noted.

In general these risks are minimized by the process control system. The process control system that forms part of the general system safety and control. Most of the technologies have such process control system described in the TSDS.

E. <u>Constructability</u>

- Ease of installation/construction of plant

The ease of installation/construction will vary considerably from technology to technology. Some come mounted on one or more skids and delivered by container for easy assembly, others would require larger scale engineering for site works.

- Ease of Shipping/transport

- Ease of operation

Including notes of automation or start up and shut down or whether considerable operator intervention is required.

- Ease of Processing

Including available information on process availability or up-time.

F. <u>Output/generation waste</u>

- Generated waste (% of input)

Most significant where non-recyclable/usable products are produced.

- Deposited waste at landfill (% of input)

Residue/waste streams that would usually or always be disposed of by landfill.

- Waste properties (pH, TCLP)

Properties of the residual wastes/by products.