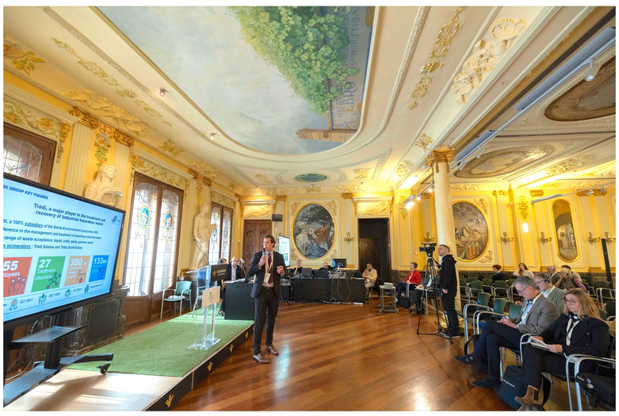
Block 3

WASTE AND SOIL TECHNOLOGIES. WASTE MANAGEMENT EXPERIENCES, DESTRUCTION TECHNOLOGIES




CAJA RURAL
DE ARAGÓN
NICK MORGAN


TREDI SAINT-VULBAS
12
Trédi Saint-Vulbas : HCH & other POPs
Recovery of hazardous waste
1 static kiln & 1 rotary kiln
Capacity : 50 000 T / year
9 treatment channels for solid, liquid
• 1 dedicated gas department
Added value : high percentage of chlorine, sulfur, and bromine treated
Regeneration of brominated brines
Séché


TREDI International Projects
International Projects :
Bangladesh (2022) → 550 t Pesticides - HCH
Macedonia (2022) → 750 t Pesticides
Ukraine (2018-2020) → 10 000 t Pesticides
Bulgaria (2018-2020) → 3500 t Pesticides
Egypt (2018) → 650 t Pesticides
Turkey (2018) → 730 t Pesticides
Belize (2018) → 35 t Pesticides
Belarus (2015) → 310 t Pesticides
Séché


CAJA RURAL
DE ARAGÓN

TREATMENT AND RECOVERY OF HAZARDOUS WASTE MANAGEMENT

Grégoire Hamon, Antoine Cunin

Séché Environnement / Trédi Global Solutions, Saint-Vulbas, France

Summary

Séché Environnement is the benchmark player in the treatment and recovery of all types of waste, including the most complex and hazardous, and in pollution control operations, serving the environment and health.
Séché Environnement is a French industrial group that has been working for more than 35 years in the field of industrial and territorial ecology. Its unique know-how is deployed in the heart of territories in more than 15 countries, including some fifty (54) industrial sites in France.
Thanks to its expertise in creating circular economy loops, decarbonization, and the treatment of pollutants and greenhouse gases, the Group contributes directly to the protection of life and biodiversity - a field in which it has been strongly committed since its creation.
Trédi, a wholly owned subsidiary of the Séché Environnement group since 2002, is a reference in the management and treatment of hazardous industrial waste. Specialized in the elimination of hazardous waste, and also in the recovery of materials, particularly high-added value materials such as solvents, chlorine or bromine.
Offering global management solution for hazardous waste disposal, our industrial sites of Trédi Salaise and Trédi Saint-Vulbas aim to process all types of waste in complete safety, whatever their volume and packaging.

Keywords

POP`s, HCH, PCB, Bromine, Obsolete Pesticides, Hazardous waste, Disposal

Trédi Saint Vulbas

Trédi Saint Vulbas is mainly dedicated to the treatment of organic wastes like obsoletes pesticides and PCB, which were historically mass-produced in the region. Facility is equipped of 1 static kiln and 1 rotary kiln, the 9 treatment channels treat **50,000** tons of waste per year, including a high percentage of chlorine, sulfur and bromine. The regeneration of brominated brines is a real unique added value.
Before the treatment, the content is analyzed beforehand to ensure its compliance. Then, the waste (liquid, solid, or gas) will be injected and burned in our rotative or static kiln at a temperature of 1200°C. All the fumes and the water used for the cooling are collected, treated and continuously monitored. Besides, as additional security protocol, we burn the empty cylinders and vessel in a grilled kiln up to 800°C to eliminate the remaining molecules of contaminated liquid or gas.

Trédi Salaise

Trédi Salaise is the most important thermal treatment facility with energy recovery of industrial waste. Ranked among the leading French and European facilities in terms of authorized tonnages and versatility of treatment methods. Origins of waste are mainly local coming from industrial areas (52%), but also from other french region (21%) and from abroad (27%). Three incineration units have a capacity of treatment of **294,000** tons per year.
The site's activity is divided into 18 treatment lines, which offers the possibility of extending our acceptance capacity.

They are designed to treat waste with very different physical and chemical characteristics, whether it is packaged in bulk, in road trays or in bulk tanks. Each unit has secure channels for receiving waste requiring specific treatment. The two types of kilns used (rotary kilns or grills) are complemented by gaseous and aqueous effluent treatment equipment using the best available technologies.

International Activities

Séché Environnement's international activity consists of answering supranational or specific customers' demands and implementing a ***global management solution for hazardous waste disposal***. Our approach is to find and develop the most appropriate and efficient solution for the disposal of the customer's waste. By knowing the location and complexity of the collection, we will be able to establish a transportation plan, from the country of origin to our facilities for final disposal.

Our international presence has grown in recent years, particularly in Africa, Central America and East-Europe, regarding hazardous waste projects. Collaborating with local governments and our trusted subcontractors allow us to successfully execute our missions in compliance with the Basel Convention.

Hazardous wastes are handled, packed and transported in compliance with ADR, IMDG, and IATA regulations and besides The European Agreement. All equipment and packaging are certified and approved by the UN. Drivers and staff passed specialized training and get permit to deal with hazardous waste.

Initially focused on the decontamination and disposal of contaminated PCB equipment and oils since its creation, Séché and Trédi have expanded their range of specifications in recent years. These include the mass treatment of pesticides and gases.

2018:

- **730 t** of obsolete pesticides (HCH) from all over *Turkey*
- **232 t** of obsolete pesticides (HCH) from all over *Egypt*

2019/2020:

- **10 000 t** of polluted soil with obsolete pesticides in *Ukraine*
- **3 500 t** of obsolete pesticides (POPs) from all over *Bulgaria*

2022:

- **900 t** of obsolete liquid & solid pesticides (HCH, 70% Cl) from *Macedonia*
- **450 t** of obsolete pesticides (DDT) from *Bangladesh*

Each year, thousands of tons of hazardous waste has been exported and disposed from around the world, thus reducing further increase and pollution of the environment, reducing transboundary spread of pollution

and reducing the harm to environment and human health.

ORGANIC AND PFAS WASTE DESTRUCTION USING SUPERCRITICAL WATER OXIDATION

John Follin

SCWO Organic Waste Destruction, General Atomics, Director

Summary

Supercritical water oxidation (SCWO) is an excellent process for the destruction of old or obsolete pesticides, obsolete paints, petroleum product manufacturing waste streams, solvents, biosolids, leachates, pharmaceutical waste, energetic materials (explosives or propellants), flame retardants (containing BTBPE, TBECH, PEBE, TBBPA, and TCEP), Per- and polyfluoroalkyl substances / Perfluorooctanoic acids (PFAS/ PFOA) and contaminated waste waters.

As described in the abstract, GA uses SCWO as 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.

Based on experiences with destruction of chemical agents, GA has developed a simplified, small and compact version of SCWO called Industrial SCWO (iSCWO) that operates at 650°C at 27MPa for increased reaction rates for excellent organic waste destruction. The iSCWO process flow diagram is illustrated in Figure 1 and an operational system is shown in Figure 2.

High pressure air is combined with water, fuel (if required by the specific application) and the waste liquid/slurry is pumped into the iSCWO reactor where high temperature and pressure will destroy the organic compounds via oxidation reactions. The reaction by-products exit the reactor through a pressure letdown system and discharge into a gas-liquid separator.

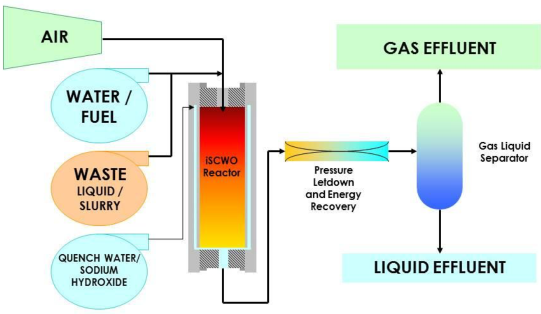


FIGURE 1 – ISCWO PROCESS FLOW DIAGRAM

The gases (CO_2, excess O_2, and steam) are exhausted through a stack and the liquids (water, dissolved salts from halogens in the waste, oxidized inorganics) are discharged either into a holding tank or into a commercial sewer system (Public Owned Treatment Works).

FIGURE 2 – ISCWO SYSTEM EQUIPMENT SKID

These simplified iSCWO systems have been supplied to US Government entities as well as commercial users since 2013 for the destruction of various chemical and hazardous wastes. The iSCWO system is available as a commercial 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 treatment (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 and compounds containing flame retardants (Figures 5 and 6) at GA's test facility (Figure 7) located in San Diego, California, which utilizes a 3gpm iSCWO system.

This system is used to test customer wastes in order to demonstrate operability and waste destruction. Effluent analyses (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 8 shows a transportable system undergoing final acceptance testing for a European commercial client.

FIGURE 3 – TRANSPORTABLE ISCWO SYSTEM

FIGURE 4 – EMBEDDED ISCWO SYSTEM

Recent tests funded by the US EPA and private entities using GA's test equipment for the destruction of PFAS/PFOA have shown that iSCWO destroys the organics to non-detect and mineralize the fluorine materials (salt matrix, NaF). The EPA has released a report documenting both the gas and liquid effluent results from the PFAS tests performed at GA.

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, 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 an 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).

Organic Chemicals		
Acetic Acid	Dichlorobenzene	Nitrobenzene*
Acetone	4,4-Dichlorobiphenyl	2-nitrophenol
Acetylsalicylic acid(aspirin)	Dichloroethylene	4-nitrophenol
Adumbran	Dichlorophenol	Nitrotoluene
4[(2-Amino-3, 5-dibromophenyl)-	Diethanolamine*	Octachlorostyrene
methylamino]cyclohexanol	Dimethylformamide*	Octadecanoic acid magnesium salt
Ammonium acetate*	Dimethyl methyl phosphonate	Paracetamol
Ammonium formate*	(DMMP)*	Pentachlorobenzene
Ammonium oxalate*	Dimethyl sulfoxide*	Pentachlorobenzonitrile
Benzene	4,6-denitro-o-cresol	Pentachlorophenol*
Biphenyl	2,4-Dinitrophenol	Pentachloropyridine
Butanol*	Dinitrotoluene	Phenol
Calcium acetate*	Dipyridamole	Polychlorinated biphenyls (PCB*)
Carbon tetrachloride*	Diisopropyl ethanolamine	Polychlorotrifluoroethylene*
Carboxylic acids	Diisopropyl ethylamine	Sodium acetate
Carboxymethyl cellulose	Ethanol	Sodium formate
Cellulose	Ethyl acetate*	Sodium hexanoate
Cerium Acetate*	Ethylene chlorohydrin	Sodium isethionate*
Chlorinated dibenzo-p-dioxins	Ethylenediamine tetraacetic acid	Sodium propionate
6-chloro-2,3,4,5-tetrahydro-3-	Ethylene glycol	Sucrose
methyl-1H-3-benzazepine	Fluorescein*	Surfactant
hydrochloride	Freon 22	Tetrachlorobenzene
Chlorobenzene*	Glycerol	Tetrachloroethylene*
Chloroform*	Hexachlorobenzene	Tetrapropylene H
2-Chlororphenol*	Hexachlorocyclohexane	Thiodiglycol*
o-Chlorotoluene*	Hexachlorocyclopentadiene	Toluene
Cobalt acetate	Iron acetate*	Tributyl phosphate
m-Cresol*	Isooctane	Trlchlorobenzenes
Cyanide*	Isopropanol*	1,1,1-Trichloroethane*
Cyclohexane	Lead acetate*	1,1,2-Trichloroethane*
DDT	Mercaptans	Trichloroethylene
Decachlorobiphenyl	Mercaptoethanol	Trichlorophenol
Dextrose	Methanol*	Trifluoroacetic acid
Dibenzofurans	Methyl acetate*	1,3,7-Trymethylxanthine
3,5-dibromo-N0cyclohexyl-N-	Methyl cellosolve	Unsymmetrical dimethyl
methyltoluene-,2-diamine	Methylene chloride*	hydrazine
Dibutyl phosphate	Methyl ethyl ketone	Urea
Dichloroacetic acid	Methylphosphonic acid (MPA)	o-Xylene*
Dichloroanisole	Monoethanolamine*	Zinc acetate*

FIGURE 5 – CHEMICALS SUCCESSFULLY TREATED BY ISCWO

To adequately treat powdered pesticides, flame retardants, biosolids, thick leachates, resin beads and granulated activated carbon, 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.

Complex Feeds		
Activated carbon (spent)*	Explosives/energetics/propellants (hydrolyzed RDX, TNT, Tetryl, NG, NC)*	Paraffin oil
Adhesives*	Fermentation byproducts*	Pesticide manufacturing wastewater
Aqueous Cleaning Solution*	Fuel oil	Pharmaceutical waste*
AFFF	GB chemical agent (neat, hydrolyzed*)	Photographic developer paste
Antifreeze*	Gray water*	Photographic developer solutions*
Aroclor 1242	Greases (mixed)*	Polychlorotrifluoroethylene (PCTFE)*
Aroclor 1254	Human waste	Pig manure
Aroclor 1260*	Hydraulic fluid*	Propellants (hydrolyzed)*
Bacillus stearothermophilus (heat resistant spores)	Industrial biosludge	Protein
Brake fluid*	Ion exchange resins (styrene - divinyl benzene)	Pulp/paper mill sludge
Bran cereal	Kerosene*	Sewage sludge (black water)*
Caprolactam wastewater	Lube oil (molybdenum disulfide oil)*	Soil contaminated with organics
Casein	Malaria antigen	Soybean plants
Chlorinated plastics (shredded)*	Motor oil*	Sulfolobus acidocaldarius
Class 1.1 solid propellant*	Mustard chemical agent (neat, hydrolyzed*)	Transformer oil*
Class 1.3 AP-depleted solid propellant	Navy shore-based wastes*	Trimsol cutting oil*
Coal	Olive oil	VX chemical agent (neat, hydrolyzed*)
Coal waste	Organic salts (complex mixtures)'	Waste oils (chlorinated and non-chlorinated)*
Corn flakes*	Paint, paint sludges*	Wheat straw*
Corn oil	Paper	Wood fibers
Corn starch		Yeast
Diesel fuel		
E. coli		
Endotoxin (pyrogen)		

Inorganic Substances		
Aluminum hydroxide*	Fluorides	Potassium chloride
Aluminum metal	Hydrochloric acid*	Potassium hydroxide
Aluminum oxide sodium	Hydrofluoric acid	Potassium sulfate
Ammonia*	Iron chloride	Silica
Ammonium chloride	Iron oxide*	Sodium bicarbonate*
Ammonium nitrate*	Lead chloride*	Sodium carbonate
Ammonium nitrite*	Lead sulfate*	Sodium chloride*
Ammonium perchlorate*	Lithium hydroxide	Sodium fluoride*
Ammonium sulfate	Lithium sulfate	Sodium hydroxide*
Ammonium sulfite*	Magnesium nitrate	Sodium nitrate
Boric acid	Magnesium oxide	Sodium nitrite
Bromides	Magnesium phosphate	Sodium phosphate*
Calcium carbonate	Magnesium sulfate	Sodium sulfate*
Calcium chloride	Mercuric chloride	Sodium sulfite·
Calcium oxide	Molybdenum disulfide lube oil*	Sulfur, elemental
Calcium phosphate	Nitric acid*	Sulfuric acid*
Calcium sulfate	Phosphoric acid	Titanium dioxide
Cerium chloride*	Potassium bicarbonate	Zinc chloride*
Copper chloride	Potassium carbonate	Zinc sulfate*

FIGURE 6 – CHEMICALS SUCCESSFULLY TREATED BY ISCWO

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.

FIGURE 7 – ISCWO WASTE TEST SYSTEM

FIGURE 8 – FINAL ACCEPTANCE TEST

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 destroying all classes of hazardous and nonhazardous wastes including pesticides and PFAS/PFOA waste. SCWO systems can provide onsite waste treatment at an affordable cost.

CAN LOW TEMPERATURE THERMAL DESORPTION BE CONVERTED TO DESTRUCTION AND BE MORE SUSTAINABLE THAN TRADITIONAL INCINERATION

Eriksen, S.[1], Ploug, N.[1], Nielsen, S. G.[2]

[1]Krüger A/S, Soeborg, Denmark; [2]TerraTherm, Gardner, MA, US

Summary

High temperature thermal conductive heating (TCH) remediation at 300-350˚C has been utilised for decades to remediate contaminated soils both in situ and ex situ. TCH has a documented effect for a range of persistent organic pollutants like Dioxin, PCBs, Lindane and PFAS as well as mercury and PAHs. Literature study also suggests that DDT can be treated successfully using this approach.

Thermal remediation can be designed to be more than a simple separation of contaminants from soil. By tailoring the heating process it is possible to favour thermal degradation instead of evaporation and thereby potentially reduce health risks for site operators, simplify the treatment system and reduce consumables like activated carbon.

This approach has been used for a pilot scale remediation test of heavily parathion contaminated soils where it was possible to achieve +99.9% in-situ destruction.

Recent lab scale studies has implemented a similar approach to PFOS remediation and has demonstrated near complete conversion of PFOS to inorganic (water soluble) fluoride 25% and insoluble species (75%) with only 0.05% left as PFOS in the soil.

Complex mixture of pesticides, mercury, sulphur and HC

During a pilot scale TCH thermal remediation test conducted on soil from a chemical waste landfill, containing pesticides, mercury and hydrocarbons as well as elemental sulfur, the handling of parathion was a major health and safety concern. The conventional thermal remediation concept is evaporation from the soil followed by condensation in the treatment plant where the 50 kg of phosphate ester pesticides present in the pilot test would constitute a significant hazard. Furthermore the extraction of mercury bound as mercury sulfide required a design allowing controlled oxidation of the sulfide to form elemental mercury, which is the only volatile species.

By adopting a differentiated heating strategy in the soil as well as heating the extraction lines and assuring a reasonable residence time of the extracted gases at elevated temperature a +99.9% destruction of parathion was achieved meaning that 10 g rather than 50 kg was present in the 10 m^3 of condensate collected during the pilot test.

Other organic agricultural chemicals, primarily the phenoxy herbicide MCPA, as well as chlorophenol and p-nitrophenol degradation products from herbicides and pesticides were removed as the soil reached 200˚C. Degradation and removal pathways have not been investigated. The presence of chlorophenols raised a general concern about dioxin formation. The scrubber liquid was analysed, but no dioxins were found.

At a later stage when solid sulfur condensate was causing problems by blocking the treatment plant, the differentiated heating setup enabled oxidation of the sulfur within the soil volume and neutralise the acidic sulfur dioxide easily oxidising the sulfuric acid in aerated condensate rather than manage solid deposits.

Finally chemical conversion of mercury sulfide by oxidation was required to meet the mercury remediation requirements.

The safe and successful completion of the pilot test was only possible by carefully planning the chemical conversion steps to be completed in the soil and extraction lines in different stages of the heating process.

PFAS

In the past, incineration has been considered as the only efficient thermal PFAS remediation treatment. However the thermal stability of PFAS compounds is limited [1] and significant reduction of PFAS concentrations in solid matrices by thermal remediation at 350-500°C has been reported in a number of tests [2]. The traditional thermal remediation is focussed on desorption and volatilization of contaminants subsequently to be managed in the off gas and condensate treatment plant.

However for PFAS the treatment plant is challenged by:

- Chemical conversion during desorption challenges sorbents and monitoring program
- The lack of a universally accepted method of destruction for the PFAS waste (some territories have a ban on incineration of some PFAS waste types.

- Low contaminant mass makes a thermal oxidizer difficult to justify (and it is not even universally accepted)

In this perspective, in situ complete mineralization must be the ultimate objective to minimise the amount of PFAS to be captured by the treatment plant and the associated waste generation and disposal.

In a recent lab scale test series PFOS spiked sand was heat treated at 350°C for 7 days. The off gas was sent through three different catalysts at 600°C (residence time 5-20 min). The test resulted in up to 25% conversion of the total fluorine added as PFOS to water soluble fluoride, remaining fluorine being bound in the sand and catalysts as insoluble compounds. Only 0.05% of the fluorine was still bound in PFAS, mainly PFOS but chemical conversion had given rise to other PFAS compounds as well. The water soluble fluorine was partly found in the heat treated sand and partly in the off gas (collected in an alkaline impinger). The non soluble fluorine was partly found in the sand and partly in the catalysts. XPS analysis suggests that the insoluble fluorine fraction consists of inorganic minerals, but this remains to be proven.

The result obtained on degradation and mineralization at 600°C may be applicable to pyrolysis of sewer sludge biosolids.

Dioxin

Dioxins are very recalcitrant compounds that can stay in the soil for ages with no or very little degradation. Due to the toxicity they also require quite some measures when treated. A number of pilot scale tests as well as a large scale in pile thermal remediation project have been completed. The latter consisted of two batches. The first batch of 43.000 m³ reached 8,9 ppt as (2,3,7,8- TCDD)-TEQ and the second batch of 49.000 m³ reached 0,199 ppt TEQ. These soils were treated with target temperatures of 335°C with a designed holding time of three weeks.

During the full scale project in soil destruction was observed in both phases. The destruction was estimated to range from 68-97% and 60-75%, the first slower heating phase achieving the largest degree of destruction.

Lindane

Lindane has been studied in lab scale using DNAPL spiked rock cores from a lindane landfill in Spain. The as spiked Lindane concentration was 310 mg/kg

Thermal desorption was tested by heating the specimens to 100, 200 and 325°C for 7 days in a 10 mL/min air flow (residence time 40 min). No reduction of the contaminant level was achieved at 100°C, whereas the Lindane concentration of specimens heated to 200°C and 325°C for 7 days was reduced to 0.140 mg/kg and 0.004 mg/kg respectively.

The mass balance was investigated in this study, hence no information on the potential for thermal degradation was obtained..

DDT

DDT has been addressed in a brief literature study only. A number of degradation reactions in the presence of iron, iron salts and alkali have been reported. Also degradation at 260°C is stated as boiling point information in some tables.

In order to prepare a thermal conductive remediation of DDT a lab study would be needed to investigate the degradation reaction and whether iron or alkali or both amendments would be beneficial for in pile treatment. It is very important to verify that any chemical reactions are actually beneficial in terms of decontaminating the soil and reducing the overall toxicity of the chemicals.

"Low" temperature desorption vs. traditional incineration

So why look at "lower" temperature desorption when soils can be incinerated and treated within hours? It is important to differentiate more or less pure substances or mixtures from contaminated soils. Unlike the pure substances that are suited for incineration, soils have no calorific value and the heat required has to be supplied by adding fuel. Incineration of soil consumes 5-8 times the energy required for TCH thermal desorption processes.

Outlook

Doing thermal desorption in e.g. a pile we can utilise different temperature profiles over time in the same batch. This means we can control evaporation and breakdown of products in a much more controlled way. This will ease the requirements for the off gas treatment and also make it possible to treat the contamination in-situ or on-site with very little transport and handling. Continuous work is required to understand the degradation reactions and potentially result in optimised processes with complete degradation or even mineralization if sufficient reaction time at elevated temperature is obtained.

The need for off site destruction of concentrated waste products e.g. free phases and spent active carbon filter material cannot be eliminated by in situ or in pile destruction, but by introducing the use of controlled thermal degradation, the amount of waste could be reduced and possibly free up incineration capacity and reduce transportation of hazardous waste.

It is important to always evaluate the chemical reactions and reaction products to assure that the reactions reduce overall toxicity and facilitate remediation to prevent making things worse.

Conclusion

Tailoring the remediation process to favour thermal degradation of contaminants can greatly reduce the risk of operation, simplify the treatment system and associated costs and reduce the need for disposal of waste products like spent activated carbon.

In soil destruction has been documented for dioxins, parathion and PFAS in full, pilot and lab scale respectively.

During a pilot test remediation of a complex mixed chemicals contamination controlled chemical degradation and conversion proved instrumental in safely operating the test and achieving the remediation targets.

The in soil mineralization of PFAS observed could be a viable route to address PFAS soil remediation and destruction in a single process.

A common feature of the high temperature processes is that the thermal degradation forms more volatile degradation by products, that more easily can be removed by simple evaporation. The chemical reactions need to be controlled and monitored, to ensure that all reaction products are accounted for and included in the monitoring program. The degradation reactions can potentially be optimised to result in complete degradation or even mineralization if sufficient reaction time at elevated temperature is obtained.

References

1. Fei Wang et al.: Environ. Sci. Technol. 2015, 49, 5672−5680
DOI: 10.1021/es506234b
Paul J. Krusic et al.: Journal of Fluorine Chemistry 126 (2005) 1510–1516 (DOI:10.1016/j.jfluchem.2005.08.016)
J. A. Conesa, R. Font: Polymer Engineering & Science, Volume 41, Issue 12 December 2001 Pages 2137–2147
Lucia Odochian et al.: Thermochimica Acta 598 (2014) 28–35 (DOI: 10.1016/j.tca.2014.10.023)
2. The Military Engineer, No 719 Jan-Feb 2019, p.52-53 http://online.fliphtml5.com/fedq/sdoo/#p=55
3. Krüger-TerraTherm PFAS webinar
https://www.thermalrs.com/pfas-remediation/thermal-remediation-of-pfas-impacted-soil/
Paul G. Koster van Groos: SERDP Project ER18-1556

HYDROGEN REDUCTION OF HCH, PCBS AND PLASTIC

Douglas J. Hallett, PhD.

Chairman and CEO, Founder, True Energy Incorporated, Kingston, Ontario, Canada.

Summary

Gas Phase Chemical Reduction of PCBs was presented by ELI Eco Logic International Inc., at the 1998 conference in Bilbao, Spain. I was the founder of that company, and inventor of the GPCR process.
In 2023, **True Energy Incorporated** presented Hydrogen Reduction of Organic waste Molecules which was published under the Patent Convention Treaty in 2020.
This work reflects the continual development of a chemical process using hydrogen to destroy toxic organic molecules such as HCH and PCBs, breaking them down into methane and halogenated salts. Non-halogenated molecules and particularly polyethylene or plastic produce even higher volumes of methane and hydrogen. The overall mass and energy balance of this process is positive due to the release of energy during hydrogenolysis. This is an efficient, low-cost process. The methane produced is saleable as Renewable Natural Gas. There is a considerable quantity of this gas produced which more than offsets the operating cost and Capex of the plant. The process still operates with **no direct atmospheric emission** and the aquatic effluents have met Surface Water Discharge Criteria in Canada which are equivalent to WHO drinking water standards.
In recent years we have discovered that hydrogen can also be produced by catalysis of the methane produced, reacting with water or steam in our reactor. More than half of the hydrogen is produced from the water added making this a carbon neutral net producer of hydrogen at low cost. Carbon is converted to primarily CO and elemental carbon which are collected. The amount of hydrogen that is produced is much higher than the amount of methane. The production of this hydrogen meets the specification recently published by the US DOE. Production of methane or hydrogen from waste organic molecules using Hydrogen Reduction has finally achieved **Cyclic Management** of plastics, halogenated pesticides, still bottoms, solid municipal and commercial waste and sewage, providing a local source of fuel and energy.

Gas Phase Chemical Reduction (GPCR) of PCBs was presented by ELI Eco Logic International Inc., at this conference, in 1998, in Bilbao, Spain. Table 1 below provides a complete list of contaminants treated.
True Energy will also supply plants to process these materials using the Hydrogen Reduction process as described in our new patent.
This table was compiled for John Vijgen and is published by NATO.
I was the founder of ELI Eco Logic international Inc., and the inventor of the GPCR process. ELI Eco Logic International ceased operations in 2004.
In 2023, **True Energy Incorporated (TEI)** presents **Hydrogen Reduction of Organic Waste Molecules**. Our patent application was published under the Patent Convention Treaty in 2020 and was examined at that time. This work reflects the continual development of a chemical process using hydrogen to destroy toxic organic molecules such as HCH (See Figure 1) and PCBs, breaking them down into methane and halogenated salts.
Non-halogenated molecules and particularly polyethylene or plastic produce even higher volumes of methane and hydrogen.
The overall mass and energy balance of this process is positive due to the release of energy during hydrogenolysis (See Figure 2). This is an efficient, low-cost process.

FIGURE 1 – DRUMS OF SOLID HCB CRYSTALS INSIDE AN SBV AT A GPCR PLANT

The methane produced is saleable as Renewable Natural Gas (RNG). There is a considerable quantity of this gas produced which more than offsets the operating cost and CapEx of the plant. The process still operates with **no direct atmospheric emission** and the aquatic effluents have met Surface Water Discharge Criteria in Canada which are equivalent to WHO drinking water standards.

TABLE 1. COMPOUNDS TREATED BY GPCR-1

Industrial Chemicals and Manufacturing By-products			
PCBs	Dioxin and Furans	Hexachlorinated Wastes	Pentachlorophenol
Polyaromatic Hydrocarbons			
Acenaphthene Acenaphthylene Anthracene Benzo(a)Anthracene	Benzo(a)Pyrene Benzo(b)Fluoranthene Benzo(ghi)Perylene Benzo(k)Fluoranthene	Chrysene Dibenzo(ah)Anthracene Fluoranthene Fluorene	Indeno(123-cd)Pyrene Naphthalene Phenanthrene Pyrene

Organochlorine Pesticides				
o,p'-DDE	Chlorodimeform	Endosulfan I	Mecoprop	Pirimphos ethyl
p,p'-DDE	Chlorofenviphos	Endosulphan	Metalaxyl	Procymidone
o,p'-DDD	Chloropropham	Endosulphan II	Methiocarb	Procynidone
p,p'-DDT	Chloropyrifos	Endrin	Methomyl	Propachlor
p,p'-DDD	cis-Chlordane	Endrin Ketone	Methoxychlor	Propargite
o,p'-DDT	Coumoiphos	Ethephon	Metoxuron	Propazine
2,4,5-T	Crotoxyphos	Ethion	Metribuzin	Propoxur
a-BHC	Dieldrin	Fenamiphos	Mevinphos	Quinomethionate
a-chlordane	Diazinon	Fenitrothion	Naproamide	Quintozene
Alachlor	Dicambamethyl	Fenoprop	Nicotine	Rotenone
Aldrin	Cyanthoate	Fenthion	Nornicotine	Secbumeton
Atrazine	Dacthal	Folpet	Oxydisulfoton	Simazine
Azinphos ethyl	d-BHC	g-BHC	Parathion	SWEP
b-BHC	DCPA	g-chlordane	Pendimethalin	Technazene
Bendiocarb	DDMU	Glyphosate	Permethrin I	Terbufos
Bis-2-chloroethylether	Dichlorfuanid	Heptachlor	Phenolthiazine	Terbutryn
Bupirimate	Dichlorobenil	Heptachlor Epoxide	Phorate	Tetrachloro-m-xylene
Captan	di-Chlorovos	Hexachloroethane	Phorate Sulfone	Thiabendazole
Carbaryl	Dicloran	Lindane	Phosmet	Trans-chlordane
Carbofenthion	Dicofol	Linuron	Phosphorodithioic Acid	Triadimefon
Carbophenothion	Dimethoate	Malathion	Piperonyl butoxide	Triallate
Carboxin	Disulfoton	Manoczeb	Pirimicarb	Tridimefon

Chemical Warfare Agents and other Military Wastes			
VX Napalm	HD (Distilled Sulphur Mustard) Chemical Agent Neutralents	GB (Sarin)	DPE Suit Material (Plastic, Teflon)
Other Compounds Treated			
Benzene	Toluene	Mineral oil	Vegetable oil

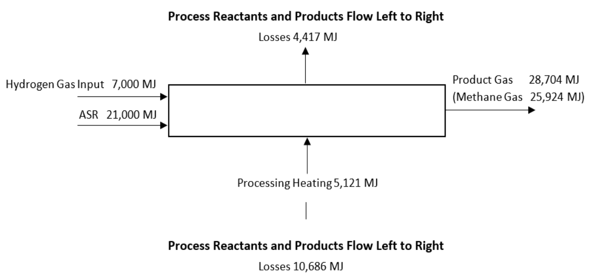


FIGURE 2. ENERGY BALANCE FOR ONE TONNE OF DRIED SOLID ASR (POLYETHYLENE PLASTIC) INTO METHANE

In recent years we have discovered that hydrogen can also be produced by catalysis of the methane produced, reacting with water or steam in our reactor. More than half of the hydrogen is produced from the water added making this a carbon neutral net producer of hydrogen at low cost. Carbon is converted to primarily CO and elemental carbon which are collected. The amount of hydrogen that is produced is much higher than the amount of methane. The production of this hydrogen meets the specification recently published by the US DOE. Production of methane (RNG) or hydrogen from waste organic molecules using Hydrogen Reduction has finally achieved **Cyclic Management** of plastics, halogenated pesticides, still bottoms, solid municipal and commercial waste and sewage, providing a local source of fuel and energy. The overall flow diagram as published is shown in Figure 3.

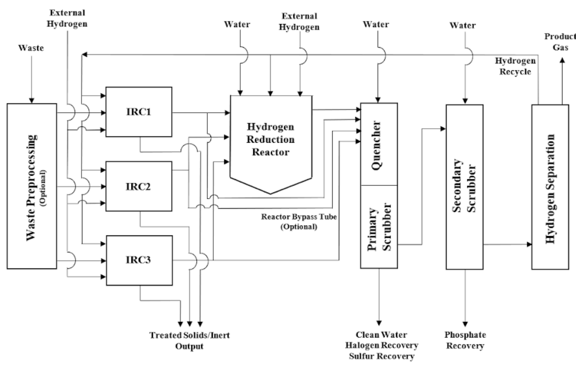


FIGURE 3. FLOW DIAGRAM FOR HYDROGEN REDUCTION

PROGRESS IN ENVIRONMENTALLY SOUND MANAGEMENT AND DISPOSAL OF PESTICIDE POPS WASTES IN CHINA

Zheng Peng

Foreign Environmental Cooperation Center of the Ministry of Ecology and Environment, People's Republic of China, Beijing, 100035

Summary

China, the largest developing country in the world, had widely used pesticides containing persistent organic pollutants for the pesticides and disease prevention and control in the fields of agriculture, sanitary and epidemic control, termite prevention and antifouling. Such POPs pesticides include DDT, HCB, toxaphene, chlordane and mirex. Pesticide POPs wastes are mainly original production process wastes, pesticide stockpiles and contaminated matters. In China, pesticide POPs wastes were mainly distributed in original manufacture plants and original sales, use and distribution areas; pesticide POPs wastes were mainly concentrated in the area of agricultural area, with the DDT wastes in largest percentage. As Chinese life-cycle management system of hazardous wastes is gradually improved, corresponding environmental management and disposal requirements are established for pesticide POPs wastes. Nowadays, Chinese government has disposed of pesticide POPs wastes left over historically, including environmentally sound disposal of 4147.93 t pesticide POPs wastes via cement kilns co-incineration, which provides experiences and references for the management and disposal of pesticide POPs wastes in various developing countries.

Keywords

POPs pesticide wastes; status quo; environmentally sound; co-incineration in cement kiln.

Information of Pesticide POPs Wastes in China

In the past, China produced and used pesticide POPs in large scale. By 2004, the total accumulative output of pesticide POPs had reached about 574,000t [1], mainly including DDT, HCB, chlordane, mirex, toxaphene and heptachlor, and excluding 3 POPs pesticides, i.e., aldrin, dieldrin and endrin, which have never been used in China. On May 17, 2009, the Ministry of Environmental Protection of the People's Republic of China, together with other nine ministries and commissions, had issued Announcement No. 23/2009, banning the production, distribution, use, import and export of DDT, chlordane, mirex and HCB in China (unless DDT is used for acceptable purposes), fulfilling the commitment to Convention implementation of banning the use of POPs pesticides to the world.

Now, pesticide POPs wastes in China mainly include POPs pesticide stockpiles not used after May 17, 2009, and intermediate wastes generated during production of POPs pesticides and wastes contaminated by POPs pesticides. They mainly exist in the obsolete stockpiles in the fields of original production, distribution and use and relevant contaminated wastes. In the field of production, the pesticide POPs wastes are mainly the sludge, residues, and intermediate by-products generated during production, in addition to some contaminated residual equipment and construction waste. In China, totally more than 50 enterprises had been produced pesticide POPs, and they are mainly distributed in 18 provinces, cities and autonomous regions, including Tianjin, Jiangsu, Zhejiang and Hebei. In the field of distribution, the pesticide POPs wastes feature as follows: (1) they are mainly concentrated in agricultural sectors and mainly come from agricultural materials companies, pesticide and fertilizer store, plant protection institutes, as well as pesticide sales points etc., with little wastes in the industries of termite prevention and control, garden, forestry and health; (2) DDT wastes are the largest in the quantity, followed by POPs mixture. According to the investigation during the development of National Implementation Plan for Stockholm Convention and on POPs pollution over China, it is expected that the total quantity of pesticide POPs wastes all over China is about 4,000-6,000t.

Environmental Management Concerning Pesticide POPs Wastes in China

Pesticide POPs wastes are hazardous wastes, of which, the environmentally sound management and disposal system initially established in China has involved the identification, reporting, and import and export management, packaging, transportation, storage, treatment and disposal and any other aspects, forming an environmentally sound management system of pesticide POPs wastes [2-4].

TABLE 1 OUTPUT OF POPS PESTICIDES IN CHINA [1]

Type	Condition	Accumulative output (t)	Use field
DDT	Out of production in 2009	About 464,000	Agriculture, health, marine antifouling paints
HCB	Out of production in 2004	>79,278	Raw material of sodium pentachlorophenate (Na-PCP)
Toxaphene	Out of production in 1980s	20,660	Agriculture (mainly for grain and cotton production)
Chlordane	Out of production in 2004	>9,000	Termite prevention
Mirex	Out of production in 2004s	160	Termite control
Heptachlor	Out of production in 1980s	<100	Railway crossties

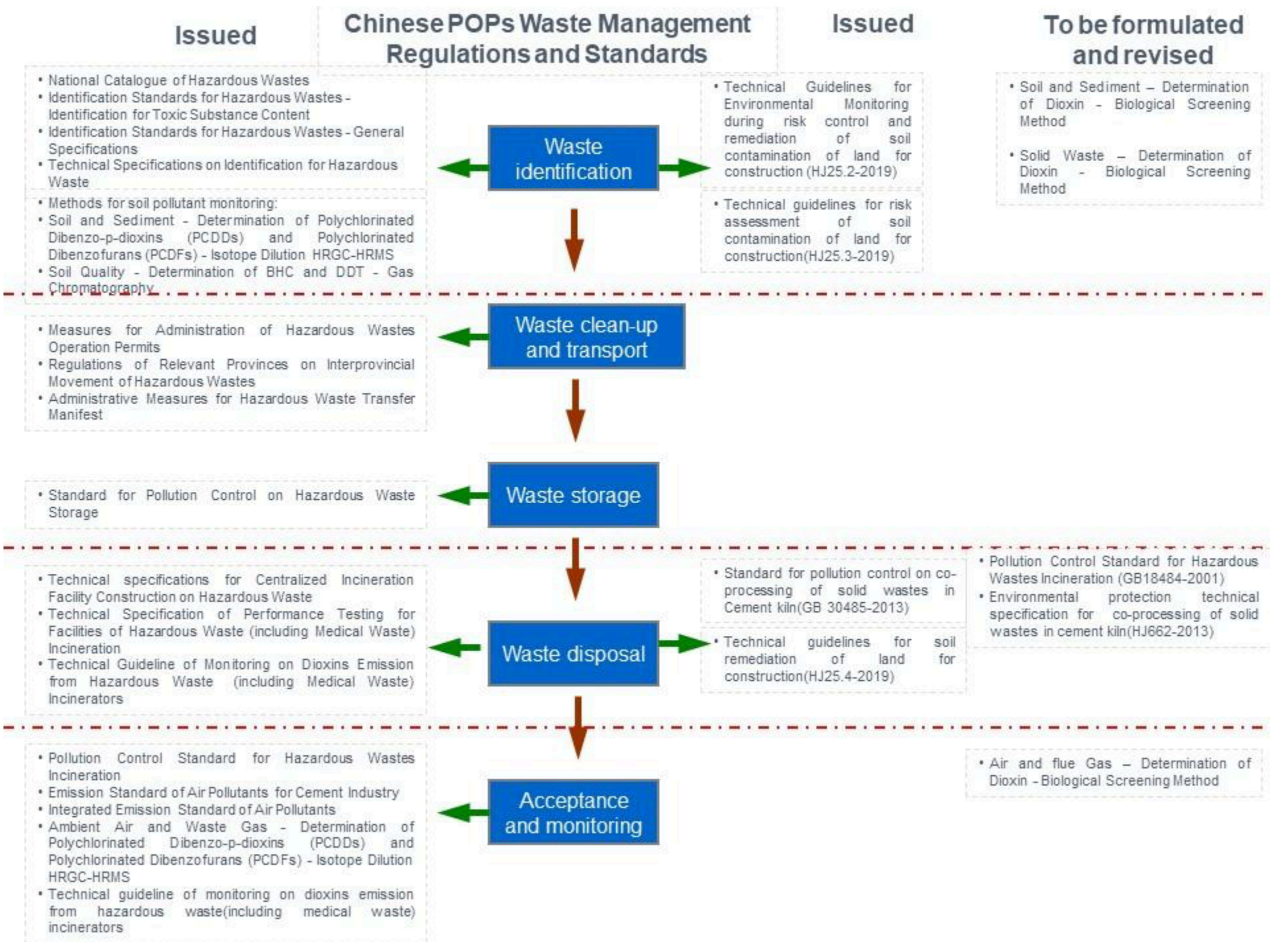


FIGURE 1. CHINESE POPS WASTE MANAGEMENT REGULATIONS AND STANDARDS

(1) In 2007, the Identification Standard for Hazardous Wastes - Identification for leaching Toxicity (GB 5080.3) listed the test methods for DDT, HCH, chlordane, HCB, toxaphene and mirex. The Identification Standards for Hazardous Wastes - Identification for Toxic Substance Content (GB 5085.6) specifies that pesticide POPs shall be disposed of as hazardous wastes in case the toxic substance content is equal to or larger than 50 mg/kg. (2) In 2008, the National Catalogue of Hazardous Wastes included the pesticide POPs, PCB wastes and dioxin wastes. (3) POPs wastes are hazardous wastes. According to the provisions in Article 53 of the Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste, the generators producing hazardous wastes are obligated to develop the hazardous wastes management plan in accordance with relevant regulations of the State, and report the type, output, flow, storage, disposal and other relevant information of hazardous wastes to administrative departments in charge of environmental protection under local people's governments above the county level. The declaration and registration system for POPs wastes has been established. (4) The Technology Policy for the Prevention and Control of Pollution Caused by Hazardous Wastes has expressly specified that POPs wastes should not be recovered, recycled, reclaimed or directly reused.

The Standard for Pollution Control for Hazardous Waste Incineration and the Standard for Pollution Control on Hazardous Waste Storage is being revised by the Ministry of Environmental Protection of the People's Republic of China, in which the incineration and disposal requirements for pesticide POPs wastes are the same as those for common hazardous wastes before revision, that is, the temperature of the incinerator is equal to or greater than 1100°C, the destruction and removal efficiency is equal to or greater than 99.99% and dioxin concentration in flue gas is less than 0.5 ng-TEQ/Nm^3. The Guides for Co-disposal of Hazardous Wastes in Cement Kilns (for comments) has been drafted in China and puts forward specific disposal and environmental protection requirements for POPs wastes [5,6].

Disposal of Pesticide POPs Wastes in China

In 2009, the Chinese government applied for the "Project for Environmentally Sound Management and Disposal of Pesticide POPs Wastes and Other POPs Wastes in China funded by Global Environment Facility", which aims to promote the perfection of management system on pesticide POPs wastes in China, carry out environmentally sound disposal of pesticide POPs wastes, and completely eliminate the environmental risk of pesticide POPs wastes remaining in China. Under the support of the Project, a series of disposal activities were carried out from place to place through the co-processing in new dry-process and rotary cement precalciner kiln, including the disposal of 160t DDT pesticide wastes in Jiangsu Province in 2009 and the disposal of totally about 13t disused DDT stockpile in partial health and anti-epidemic agencies in Hunan Province and Sichuan Province, etc. In 2011, 2,228t pesticide POPs wastes were disposed in Hubei Province, and 637t in Hebei Province. Until the end of 2018, the environmentally sound disposal of 4147.93 t pesticide POPs wastes has been completed in China.

The detection results of POPs in conventional pollutants and raw meal, clinker and flue gas during disposal show that the emission concentration of dust, NOx, SO_2, HF, HCl, TOC, heavy metal, dioxin/furan and other air pollutants during co-disposal of DDT pesticide meets the emission standards of the wastes incinerated in cement kiln in our existing Emission Standard of Air Pollutants for Cement Industry (GB4915-2004) [7, 8], Standard for Pollution Control for Hazardous Waste Incineration (GB 18484-2001) and Directive of EU on Incineration of Wastes (2000/76/EC), with the DRE more than 99.9999%, and the average emission concentration of dioxin at 0.01ng-TEQ/Nm^3. This shows that the co-processing of pesticide POPs wastes causes no adverse effect on flue gas emission under the condition of appropriate feeding rate of pesticide POPs wastes. Meanwhile, the coal consumption, power consumption, clinker output record data, clinker quality analysis data and other data during conventional cement production and co-processing of pesticide POPs wastes indicate that it causes no adverse effect on the production process of clinker, clinker output and clinker quality under a proper feeding rate.

The detection has shown that the DDT concentration in clinker during co-disposal of DDT waste pesticide is lower than the instrument detection limit, and there is minute amount of DDT (49-73ng/m^3) in the released flue gas, with DRE changing within the range of 99.9999984% - 99.9999996%. This indicates that DDT has been effectively decomposed in the cement kiln.

Currently, the hazardous wastes are still disposed of by high-temperature incineration and safe landfill in China, and the co-disposal in cement kiln are carried out for POPs wastes containing pesticide on a large scale, but on the whole, the treatment and disposal technology is relatively simple and reliable in economic and technical respect. The secondary emission of dioxin exists in the incineration technology, while the landfill technology does not really achieve the destruction of POPs, and large quantity of land resources are occupied, furthermore, there are potential environmental risks.

Main Problems in Newly-added POPs Wastes in China

In May 2009, the 4th Conference of the Parties of the Convention was held, formally listing the α-HCH, β-HCH, chlordecone and silvanol into the Convention to be controlled. In April 2011, the 5th Conference of the Parties of the Convention was held, formally listing the endosulfen into the Convention to be controlled. The newly-listed pesticide POPs pollution has become one of the important environmental issues, so the related research and inventory investigation are in urgent need.

Conclusion

(1) There are about 4,000-6,000t pesticide POPs wastes in China, in addition to some contaminated residual equipment and construction waste. The pesticide POPs wastes in the distribution field are mainly concentrated in the agricultural sectors, with the DDT wastes most abundant.

(2) In the environmentally sound management system of hazardous wastes, China has initially established and perfected the management requirements for pesticide POPs wastes.

(3) Through the support of Project for Environmentally Sound Management and Disposal of Pesticide POPs Wastes and Other POPs Wastes in China supported by Global Environment Facility, the research on co-processing of pesticide POPs

wastes in rotary cement kiln shows that it is a cost-effective and environmentally sound disposal method under the condition of controlling the feeding rate of pesticide POPs wastes. By utilizing this disposal method, China has completed the disposal of nearly 3,000t pesticide POPs wastes.

(4) China shall carry out the related research and inventory investigation urgently for the Convention implementation of newly-added pesticide POPs.

References

1. Aihua Yi, Qifei Huang, Nana Zhao, et al. Management on pesticide POPs in China. Journal of Agro-Environment Science, 2006, 25 (Supplement), 783-786.

2. Nana Zhao, Li Li, Qifei Huang, et al. A study on the selection of POPs wastes disposal technologies in China. Research of Environmental Sciences, 2007, 20(3), 164-164

3. Aihua Yi, Qifei Huang, Zengqiang Zhang, et al. Analysis on types and pollution control countermeasures of pesticide POPs contaminated site in China. Environmental Protection Science, 2007, 34(1), 57-60.

4. Huabo Duan, Qifei Huang, Qi Wang, et al. Hazardous waste generation and management in China: A review. Journal of Hazardous Materials, 2008, 158(2-3), 221-227.

5. Lu Li, Qifei Huang, Zengqiang Zhang, et al. Emission research on co-disposal of contaminated soil in cement kiln. 2009, 3(5), 891-896.

6. Lu Li, Qifei Huang, Dahai Yan, et al. Analysis on co-disposal of waste pesticide in cement kiln based on life-cycle assessment EI 99 method. Journal of Agro-Environment Sciences, 2010.30(7), 1527-1536.

7. Yang Li, Ying Wang, Qifei Huang, et al. *Thermal treatment residue characteristics of DDT pesticide*. Research of Environmental Sciences, 2011, 24(7), 781-787.

8. Yang Li, Ying Wang, Qifei Huang, et al. *Study on reporting mechanism of pesticide POPs dynamics*. The Administration and Technique of Environmental Monitoring, 2011, 23(1) 8-12

9. Dahai Yan, Zheng Peng*, Kåre Helge Karstensen, Qiong Ding, Kaixiang Wang, Zuguang Wang, Destruction of DDT wastes in two preheater/precalciner cement kilns in China. Science of the Total Environment, 476-477(2014)250-257

HIGH TEMPERATURE INCINERATION OF POPS AND HAZARDOUS WASTE IS THE PROPER TREATMENT TO DESTROY THEM

Montse Papiol

SARPI Spain

Summary

Nowadays, there is a revolution to change from a linear economy to a circular economy. We have to reuse waste as many times as possible and we have to develop technologies to increase the circularity of the waste, following the action plan of the Green Deal. But taking into account this legislative package, we cannot reintroduce the pollutants into the economy to avoid any dispersion of hazards into the environment to ensure that the public health is protected. According to this, on 4th October 2022 the European Parliament voted to reduce the concentration limit values for POPs in the waste, existing in the previous POPs Regulation.

The high temperature rotary kiln is the best tool for hazardous waste. This treatment is based on a rotary kiln and post combustion chamber that incinerates at temperatures around 1.100°C or higher. And it is possible to incinerate different types of wastes: liquids with a wide range of viscosity, solids, gases, drums, IBC, etc. and different calorific values.

According to the waste there are different ways to feed it into the kiln, in addition to the burners for liquid and sludge waste, it is possible to feed the kiln directly from the truck (like toxic, corrosive, mutagenic or other extremely dangerous waste streams) . It is also possible to put in whole or crushed drums and crushed big bags or IBCs.

Sarpi Constantí in Spain is one of the most reliable incinerators for treating POPs and is the only HWI that exists in Spain with these features. It can provide a service not only to Spain but also to European and International Markets.

Introduction

From 1970 to 2015, there is a lot of literature on the environmental advantages of rotary kiln technology, because hazardous waste with complex components needs environmentally friendly treatments.

There are different technologies (eg. grade furnaces, fluidised beds, rotary kilns) and different kind of waste (eg. hazardous waste, non-haz waste). Each technology is specialised for a particular waste stream and the high temperature rotary kiln is the best tool for hazardous waste.

Nowadays, there is a revolution to change from a linear economy to a circular economy. We have to reuse waste as many times as possible and we have to develop technologies to increase the circularity of the waste, following the action plan of the Green Deal. But taking into account this legislative package, we cannot reintroduce the pollutants into the economy to avoid any dispersion of hazards into the environment to ensure that the public health is protected. According to this, on 4th October 2022 the European Parliament voted to reduce the concentration limit values for POPs in the waste, existing in the previous POPs Regulation.

What is important in Hazardous Waste Incinerators

The treatment is based on a rotary kiln and post combustion chamber that incinerates at temperatures around 1.100o C or higher. And it is possible to incinerate different types of wastes: liquids with a wide range of viscosity, solids, gases, drums, IBC, etc and different calorific values.

According to the waste there are different ways to feed it into the kiln, in addition to the burners for liquid and sludge waste, it is possible to feed the kiln directly from the truck (like toxic, corrosive, mutagenic or other extremely dangerous waste streams) . It is also possible to put in whole or crushed drums and crushed big bags or IBCs.

The target is to destroy hazardous components and 5 drivers are used: temperature, turbulence, residence time, type of waste and throughput. People with specific knowledge, manage these drivers with all the requirements in a safe way to protect the workers but also the environment and the health of the people.

Our experience is not only based on the handling of pesticides, herbicides, fungicides, and insecticides, but also on waste from chemical formulation industries, waste containing heavy metals and PCBs.

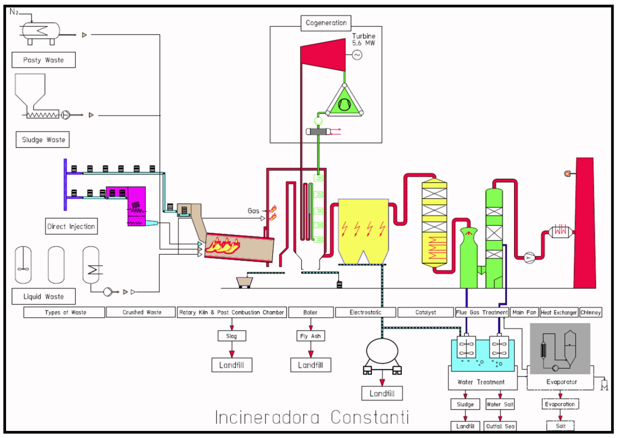
After the combustion, the incinerator can precipitate, capture or absorbed heavy metals, volatile metals like mercury, arsenic, and other compounds like halogens and sulphur

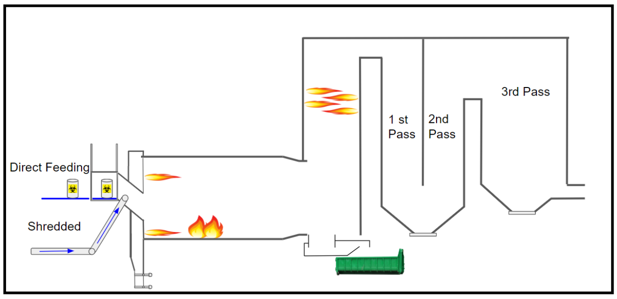
The plants have a very well equipped laboratory that can carry out an exhaustive analysis of the waste. With these values it is possible to decide the

best place to store the waste and the best way to introduce it into the kiln.
Some incinerators can recover the heat, because after the post combustion chamber, there is a boiler. The gases flow through the boiler to achieve steam for electricity or other uses.
The gas cleaning can be dry or wet. in Constantí (Tarragona, Spain) there are a wet treatment performed by four different equipment:
- Electrostatic precipitator: This High voltage filter holds and precipitates the fly ash with an efficiency higher than 99,99%.
- DeNOx Catalyst: The gas free of ash exits the Electrostatic precipitator and passes through a three layer Dioxin Catalyst, in order to destroy the dioxins and NOx.
- Quench: After the catalyst, gases pass through a Saturate Venturi, where most of the chlorine is dissolved in a water solution, and the temperature decreases to 68 degrees.
- Scrubber: A three stage scrubbing tower removes hydrochloric acid, oxides of sulphur, bromine, heavy metals and the traces of solid particles that could remain in flue gas.

What is special in Sarpi Constantí

Our incineration plant is one of the most reliable incinerators for treating POPs and is the only HWI that exists in Spain with these features. It can provide a service not only to Spain but also to European and International Markets.
This plant can treat packed waste:
- the whole drum or box etc.
- shredded drum or shredded IBC etc without prior manipulation





Both possibilities allow treating many different physical states of waste, as liquid, solid, powder, pasty, metal etc in order to get an optimal consistency to be transported. Nitrogen blanketing is used to avoid any risk and there are devices to measure also the concentration of oxygen to avoid flammability.

DISPOSAL OF DDT FROM BANGLADESH

Saso Martinov

Senior Technical Advisor and Project Manager Pesticides Risk Reduction in Bangladesh, FAO Bangladesh

The Food and Agriculture Organization of the United Nations (FAO) has supported the Government of Bangladesh in safely disposing Dichlorodiphenyltrichloroethane (DDT) through a complex international operation. What is thought to be the world's largest remaining stockpile of the now-banned pesticide DDT, left in Chattogram city for 37 years, has finally been removed.

Background

In 1985 the Government of Bangladesh, through the Asian Development Bank (ADB) financed project implemented by the World Health Organization (WHO), imported around 500 tonnes of the notoriously toxic and currently illegal pesticide DDT, which were, however, considered not in compliance with the technical requirements and therefore, were stored in Chattogram Government Medical Sub-depot (MSD). The stockpile has remained there since, where due to the adverse effect of a humid tropical climate on DDT molecular stability, the stock has become severely degraded and largely obsolete. In addition, after 1991, the area was exposed to several events of heavy rainfall and floods that greatly exacerbated the problem by flushing DDT into the surrounding environment. DDT persists in soil and water and bio-accumulates in organisms through the food chain. Eventual consumption by humans has toxic and likely carcinogenic effects. Bangladesh has one of the highest population densities of any country in the world, and the port city of Chattogram is the second largest city in Bangladesh. DDT stockpile is in the center of the city. People living in slums surrounding the depot until recently will very likely have been exposed to DDT. The stockpile poses a very high risk to human health and ecosystem function. The increased frequency of flooding in the area driven by climate change makes action to prevent further release very urgent.

In 2015 and 2017, respectively, following g the request from the Ministry of Environment Forest and Climate Change of Bangladesh, FAO consultants reassessed the site and estimated the stockpile volume equivalent to 500 cubic meters. Subsequently, FAO formulated a project, secured funding from Global Environmental Facility (GEF), and initiated the Pesticide Risk Reduction in Bangladesh project from 2019. The project received government approval in August 2021.

Pesticide Risk Reduction in Bangladesh project

The project's development objective is to increase food security by eliminating POPs pesticides stockpiles and implementing safe alternatives for food preservation and agricultural practices. The project aims to reduce risk to human and animal health and the environment from Stockpiles of POPs and other obsolete pesticides and from excessive use of new POPs and other Highly Hazardous Pesticides. More specifically, the project aims to reduce the risk to human and animal health and the environment through the environmentally sound elimination of 525 tons (approx.) of POPs pesticides, including DDT, and the reduction of exposure to POPs pesticides.

The Department of Environment (DoE) under the Ministry of Environment, Forest and Climate Change (MoEFCC) became the lead government executing and coordinating agency for this project. In light of this, DoE has played the overall leading role in the execution of project activities as well as the overall coordination and monitoring at the national level.

The project is built around four components. The first component addresses the disposal of legacy stockpiles of POPs (FAO/DoE/Directorate General of Health Services). The second component aims to strengthen governance and enforcement with respect to pesticide laws and regulations. The third component will create alternatives for pesticide usage, and the fourth will focus on building awareness and communication.

The disposal of DDT

The DDT disposal is a complex and highly technical operation that took considerable expertise and planning and was the first of its kind in Bangladesh. This involved evacuating premises where the DDT waste was stored, packing the waste by employing an international technical team, obtaining approval from countries through which the waste shipment crossed ports, and finally executing the shipment of the packed waste through a waste facility in France.

1. During the initial phase, several queries were made to verify the existence of additional stockpiles of obsolete POPs or POPs pesticides. A reassessment of the existence of other obsolete pesticide stockpiles in Bangladesh was carried out with the support of the DAE and Plant Protection Wing (PPW) of DAE and Public Health Department verified that the MSD contains the last remaining stockpile of DDT.

2. FAO then procured safeguarding, packaging and disposal services. This procurement was done through international bidding of services, and selection was made in compliance with GEF standards and ensuring that the selected company had certified experience of safeguarding and destruction of POPs pesticides in an environmentally sound manner.
3. The appointed contractor, in close cooperation with GoB and FAO, prepared an Environmental Management Plan (EMP) that specified all the measures that will be put in place to protect people and the environment during the clean-up. This included barriers and early warning systems and was put in place as soon as the operation was confirmed. It also specified the Personal Protection Equipment (PPE) for the workers and measures for protecting local people during operations.
4. An **Environmental and Social Impact Assessment (ESIA)** was carried out for the safeguarding, packaging, transportation and environmentally sound disposal activities based on the FAO Environmental and Social Management guidelines, including disclosure requirements. The ESIA was prepared and submitted by the Disposal Service Contractor.
5. Alternative offices and storage facilities for DGHS staff stationed at the MSD were identified. The need for them to be evacuated during operations was due in part to the health hazard of DDT airborne dust release, making it necessary to relocate the staff and storage to alternative office space duration of the operations. In addition, medical and other goods that are also on site were moved to alternative storage space for the duration.
6. Establishing a hazardous waste (HW) manifest system for the mobilisation of the DDT waste. In Bangladesh there is currently no HW manifest system for keeping track of the generation, transportation, storage and disposal of hazardous waste. The establishment of this system for project purposes allowed piloting an HW manifest system for hazardous waste in general.
7. An exhaustive classroom and on-field training covering all the aspects of the safeguarding, repackaging and storing and transport operation was held for staff from DoE, Chattogram Fire Service, Chattogram Metropolitan Police and Civil Surgeon. The training was particularly important as it is envisaged to involve staff hired from the local population.
8. Safeguarding the entire DDT stockpile of the Chattogram MSD storage facility was then carried-out in phases considering the available space for storing repackaged DDT, other necessary resources and human capacity. Sixteen workers were hired by the disposal company and trained in the packaging process. The workers were closely supervised the technical team of the disposal company that took over the disposal operations in MSD.
9. Before the DDT shipment process began, fourteen countries had to give permission for the ship carrying the waste to transit through their territorial waters. France being one of only a handful of countries that has the capacity to dispose of DDT safely and having the provision to allow the import of hazardous waste from other countries according to international guidelines (Stockholm Convention), was selected for the destruction of the DDT.
10. Since the DDT shipment was a highly bureaucratic process, a disposal committee was formed chaired by the Ministry of Environment Forest and Climate Change and encompassing representatives from the following agencies:
    - Divisional Commissioner Chattogram
    - Deputy Commissioner Chattogram
    - Port Clearance (Chittagong Medical Sub Depot)
    - Chittagong Civil Surgeon
    - Dangerous Cargo Inspection Office, Bangladesh Navy
    - Chattogram City Corporation
    - Chattogram Metropolitan Police (CMP)
    - Fire Service and Civil Defense Chittagong
    - Chittagong Port Authority (CPA)
    - Bangladesh Bank Chittagong
    - Customs, Excise & VAT Commissionerate Chattogram
    - Office of the Chief Controller of Imports and Exports, Chittagong
    - Customs House Chittagong
    - Bangladesh Food Safety Authority (BFSA)
    - Bangladesh Agricultural Research Institute (BARI)
    - Bangladesh Freight Forwarders Association (BAFFA)
    - Transworld Logistics & Distribution
    - Polyeco S.A.

The DDT shipment took place in 3 phases; currently, all three shipments are on the way to France. The final weight of DDT being shipped off stood at 525 tons. A closing workshop was formally organized to conclude field operations of DDT. In this workshop, all relevant government institutions, non-governmental organizations and workers are recognized for their contributions. A press release was held by the Ministry of Environment Forest and Climate Change on 8 January 2022 where the country was declared DDT free.

11. Currently, characterizing the site post-operations is being done through an assessment that has been outsourced to a technical team from leading academic institution with expertise and experience of working with pesticide analysis. Samples have been taken from inside each storage building, including

wipe tests on the walls; soil sampling outside the buildings, inside and outside the storage facility, have been taken for the analysis. Surface water and groundwater quality testing is also being conducted. A detailed characterization of the site post-operations will be presented to FAO.

Next steps

The government and FAO are currently waiting for the certificate will be issued upon completion of the destruction of the DDT in France. This will formally conclude the DDT disposal operations.

The project team has not shifted focus on completing other components of the project that will aim to strengthen risk reduction activities related to harmful pesticide application practices in the country.

References

1. EPA. The hazardous waste electronic manifest (E-Manifest) system. United States Environmental Protection Agency, 2018 (also available at https://www.epa.gov/e-manifest).

OBSOLETE PESTICIDES MANAGEMENT AND DESTRUCTION IN MOLDOVA

Cupcea, L., Barbarasa, I., Plesca, V., Iordanov, I.-R.

Chisinau, Republic of Moldova

Summary

This communication presents the results of the actions undertaken in the Republic of Moldova during the last 20 years in the management of obsolete and prohibited pesticides, including POP pesticides, and elimination of the risks caused by them in relation to the environment and human health.

Concrete measures to solve this problem began in the early 2000s, following a special decision of the Government, and carried out in accordance with the NIP of the Stockholm Convention on Persistent Organic Pollutants ratified by the Moldovan Parliament in 2004. These actions have been funded by the Government and substantially supported by international organizations and Governments of development partner countries.

As a result, to date all known obsolete pesticides stockpiles, including POP pesticides, which constitute 4,220 tons, were collected, evacuated abroad, and disposed of. Parallel to these actions the national inventory and mapping of OP and POPs contaminated areas (around 1,600 sites) were conducted.

Progress is being made in the modernization of the legal framework on chemicals and waste management. As a result of extensive information and awareness campaigns on POPs, the level of education and awareness at all scales increased substantially.

In achieving these objectives, the Ministry of Environment, Ministry of Agriculture and Food Industry, Ministry of Defense, Ministry of Economy, local authorities, research institutes, international and local consulting companies and experts, NGOs were involved. Over 20 projects funded from various sources have been implemented in this area.

The main next steps to be taken in reducing the impact of OP and POPs waste are to ensure a sustainable management of chemicals in agriculture and industry, to find and eliminate any unknown stocks of pesticide waste and remediation of contaminated sites.

Keywords

Obsolete pesticides (OP), Persistent organic pollutants (POPs), Regulatory framework, POPs management, OP inventory, Contaminated sites, Stockholm Convention on POPs.

Introduction

Moldova has never produced pesticides, including POP pesticides, but has a long tradition in agricultural production and hence used large amounts of pesticides in the past. It is estimated that between the 1950s and 1990s about 560,000 tons of pesticides were used in the Moldovan agricultural sector, including 22,000 tons of organochlorine pesticides. In the absence of an adequate pesticides management strategy, like the prevention of new stockpiles accumulation, more than 3,000 tons of now banned and useless pesticides have been accumulated over the years in storage facilities all over the country. The number of those facilities stood at about 1,000 in 1990. Subsequently, the warehouses have been dilapidated in many cases. Over time, due to the deterioration of the packaging, the stored chemicals have contaminated the sites and surrounding soils, and nearby surface waters. When obsolete pesticides were collected and placed in central warehouses, they were generally indiscriminately mixed with each other in bags and drums.

The bases of obsolete pesticides management

The Moldovan Government initiated a set of measures to address OP issues in 2002 based on its own financial and human resources by approving a special decision on additional measures for centralized storage and neutralization of obsolete pesticides [1]. After signing and ratification the Stockholm Convention on Persistent Organic Pollutants, the Republic of Moldova became eligible for international support in solving these problems. In the following period, all the actions in this area were based on cooperation with international institutions and experts, financed from the national budget, but with strong support from the international organizations. Over the last 20 years more than 20 projects in the area of management and disposal of POPs and other dangerous chemicals and wastes have been implemented.

The main objectives of these actions were to protect human health and the environment by safely managing and disposing of OP pesticides stockpiles, establishing of their sustainable management and strengthening the regulatory and institutional arrangements for long term control of POP and other toxic substances in line with the requirements of the Stockholm Convention and related other conventions and protocols ratified by

Moldova. The amount of funds used for these purposes up to now is more than US$20 million (equivalent).

The Ministry of Environment was the central national environmental authority designated as the Stockholm Convention competent authority and as such is responsible for coordinating the POPs-related activities of all government entities involved in chemicals management issues. Such responsibilities are borne also the Ministry of Agriculture and Food Industry (MAFI), the Ministry of Economy, the Ministry of Defense (MoD), the Ministry of Health, the General Inspectorate for Emergency Situations, the Customs Service, other central public authorities, as well as the local authorities. All actions taken in the area of management and destruction of obsolete pesticide stockpiles can be divided in several stages.

Inventory of Obsolete Pesticide stockpiles and development of NIP for the Stockholm Convention

The first inventory of OP stocks in Moldova had been undertaken in the period of 2002 to 2004 with the support of a GEF/WB grant for enabling activities regarding the implementation of the Stockholm Convention and was based on the documents available at that time to the Ministry of Agriculture and Food Industry. The inventory results revealed 1,700 tons in 350 poorly equipped warehouses, and approx. 4,000 tons that were buried in a landfill in the South of the country near the Cismichioi community, most of them mixed or of unknown composition. After the completion of the repackaging and storage measures of OP, it was found out that the amount collected from the various warehouses was twice as large as expected because of their inadvertent mixing with fertilizers due to inadequate storage conditions and damaged packaging materials.

Also, within this project the National Strategy on the reduction and elimination of POPs and the National Implementation Plan for the Stockholm Convention on POPs was developed and approved by the Government in 2004. In 2005 the Moldovan Parliament ratified the Convention.

Repackaging and temporary storage of OP stockpiles

In 2003, the Ministry of Defense (MoD) and the Department of Emergency Situations started the repackaging and transportation of the obsolete pesticide stockpiles from about 350 warehouses scattered across the country to the newly selected centralized district storage facilities, one in each administrative district. These warehouses were chosen based on a number of criteria to ensure safe storage until a final solution would be chosen. Each of the warehouses was examined during the environmental assessment of the project to evaluate their integrity. While the system of centralizing the storage of obsolete stockpiles was an improvement, it was not a long term solution. Centralizing the hazardous matter allowed for improved security and monitoring and facilitated ultimate disposal, which was to remain the goal.

The expenditures for these measures were covered initially by the National Environmental Fund (NEF) and the national budget and starting from 2005, they have been funded within one NATO/OSCE project implemented by MoD. In one district, these activities have been carried out within the regional project implemented by Milieukontakt International (The Netherlands).

As a result, by the end of 2008, approx. 3,350 tons of obsolete pesticides had been relocated to 37 guarded central district warehouses.

Strengthening the regulatory framework and capacity building for POPs management

Between 2006 and 2010, a GEF/WB *"Persistent Organic Pollutants Stockpiles Management and Destruction Project"* was implemented by the Ministry of Environment in Moldova, based on a GEF grant and a counterpart contribution from the Moldovan state's budget and National Ecological Fund. The project was implemented using the World Bank procedures. To facilitate project implementation, a dedicated team of experts, POPs Sustainable Management Office, was established under the MoE, based on the team which was working in the field of POPs since 2002, ensuring that use is being made of capacity once it's built.

This project was the cornerstone in strengthening the policy and regulatory framework for POPs management and control in the Republic of Moldova. Through this project the main objectives of the NIP have been achieved. The project assisted the Government of Moldova in confining stockpiles of pesticides in such a way that harm to the environment or human health is largely prevented. Furthermore, the regulatory framework and institutional capacity to address POPs related issues has been strengthened.

The major results achieved in these activities are the following:

- New or revised national policies and regulations, like the *National Program on Sound Chemicals Management*, *Law on environmental protection, Law regarding the regime of harmful substances and products, Law on plant protection, Law on production and domestic waste, Law on payment for environmental pollution* as well as guidelines have been developed. Also the Handbook on inventory and mapping of POPs contaminated sites and the Handbook on remediation of POPs contaminated sites. Over 12 packages of draft legal and regulatory documents, including a *Law on Environment Protection*, *Law on Chemicals* and *Law on Waste*, have been promoted;

- A National Concept of the Information Management and Reporting System on POPs has been developed;
- Two modern laboratories have been equipped with high resolution equipment used for monitoring and identification of POPs in environment components;
- Environmental, plant protection and energetic inspectors have been trained in enforcement and compliance with the POPs convention requirements based on the new legal documents on POPs management;
- A public awareness and information campaign has been conducted through local, regional and national seminars and conferences, radio and TV programs, documentary movies and TV ads, articles in local and national newspapers, project website *www.moldovapops.md* etc. The special surveys showed a significant increase of public awareness in the field of POPs;
- The 9th International HCH and Pesticides Forum was organized in Moldova, during September 20-22, 2007;
- Results obtained have been presented within more than 70 local, national and international workshops and conferences, including the last seven International HCH and Pesticides Forums.

Elimination of obsolete pesticides stockpiles

Elimination of OP stockpiles in Moldova began in 2006 under the *POPs Stockpiles Management and Destruction Project*. At that time the priorities were established on the evacuation and disposal of over 3000 tons of waste from 37 central district warehouses.

In the following two years 1293 tons of pesticides and contaminated packaging were exported to France and incinerated. These activities have continued after 2011 within other projects implemented or coordinated by the MoE, MoD and MAFI, with financial support from the national budget and from international organizations such as Czech Development Agency (CzDA), NATO, OSCE, the European Commission (EC) and FAO. By 2018, all OP and waste collected and stored in the central district warehouses have been eliminated. The amount of pesticides exported and disposed in Germany and Poland stands at 4,220 tons. The details can be found in table below.

TABLE 1. ELIMINATION OF OP STOCKS IN MOLDOVA

Project	Financing Agency	Implementing/ coordinating Agency	Period of elimination works	Amount of OP eliminated, tons
POPs stockpiles management and destruction	GEF/WB, MD Gov, NEF	MoE (POPs PMT)	2007-2008	1293
Remediation of environmental burdens caused by pesticides in Moldova	CzDA	CzDA, MoE (POPs PMT)	2011-2015	452
Elimination of obsolete pesticides stocks with major risks (liquid OP)	NEF	MoE (POPs PMT)	2013-2014	200
Disposal of dangerous pesticides from the Transdniestrian Region of Moldova	OSCE	OSCE Mission to Moldova, MoE (POPs PMT)	2013-2022	565
Destruction of pesticides and hazardous chemicals in the Republic of Moldova	NATO, NEF	NATO, MoD	2013-2017	1350
Improving capacities to eliminate and prevent recurrence of OP as a model for tackling unused hazardous chemicals in the former Soviet Union	EC/FAO	FAO, MAFI, MoE (POPs PMT)	2013-2015	360

However, until now new quantities of pesticide waste and other chemicals are appearing in the country, either from previously unknown small deposits, or from those smuggled into the country, or from those left unused. The amount of this waste could be several hundred tons. Also, old pesticides from some warehouses in the Transdniestrian Region have not been evacuated. Regarding this waste, the Ministry of the Environment is currently initiating measures on inventory, collection and disposal, based on a new project.

Inventory and mapping of POP pesticide polluted areas

One of the tasks of the *POPs Stockpiles Management and Destruction Project* referred on a national inventory and mapping of POPs polluted sites. The objective of this study was to identify the POPs polluted areas posing the highest environmental and health risks, as well as mapping of those areas using a GIS tool. These activities were carried out in 2008-2010.

An original methodology of POPs pollution study and hazards assessment was developed aiming at: (i) identification and assessment of potentially POPs contaminated sites all over the country; (ii) creation and completing of the POPs database as well as mapping and visualisation of acquired data; and (iii) establishing common reporting formats and assuring database support.

All potentially contaminated sites identified, most of them contaminated with pesticides, were described based on a unified questionnaire; the coordinates of the POPs sites were determined using GPS; photo images and composite soil samples were taken at each site before being further analyzed for POPs in a certified laboratory. About 1600 contaminated sites were identified and described [3].

The Site Hazard Total Score was used for ranking the site hazard according to the five generic groups. According to this ranking scheme, the full set of investigated POPs sites were prioritized as follow (See Table 2).

TABLE 2. CLASSIFICATION OF POPS CONTAMINATED SITES ACCORDING TO HAZARD RISK

Site Hazard Total Score (as percentile value, based on the statistical data set)	Site hazard rank	Site priority for remediation strategy	Action needs	Number and % of contaminated sites	
> 95 %	I	Very high	Urgent	76	4.8 %
65 – 95 %	II	High	In short-term perspective	467	29.7 %
35 – 65 %	III	Medium	In medium-term perspective	513	32.7 %
5 – 35 %	IV	Low	In long-term perspective	440	28,0%
< 5 %	V	Negligible	General protective / low-cost measures required	76	4.8 %

An integrated GIS system for POPs data mapping and analysis has been developed allowing effective storing, managing and presenting of POPs-related information, such as the geographic locations of the sites, concentrations and other related parameters, as well as distribution of health and environmental hazards. With the POPs database, the central and local authorities got a new tool which significantly improved the management of contaminated sites. It effectively supported the policy and decision making process in the field of contaminated sites management. The database was available on the Ministry of Environment website, but, unfortunately, during the period of institutional restructuring the database was not properly managed and currently it requires a fundamental review and update.

In parallel with the inventory of contaminated sites, several pilot remediation activities had been carried out which have the following specific objectives: (i) to identify Best Available Technologies for of POP pesticide polluted areas, taking into account technical, financial and ecological aspects; (ii) to assess their potential environmental/health benefits and impacts; (iii) to implement appropriate remediation techniques at a few selected sites. Based on these practical experiences, Guidelines for local environmental authorities were compiled on how and when to carry out remediation measures on areas polluted with POP pesticides.

Conclusions and Lessons Learnt

The conclusions and lessons learnt over two decades of experience in the management and disposal of POPs in Moldova can be summarized as follows:

- A comprehensive strategy and action plans at the national level is the key for an efficient implementation of relevant policies and for providing the appropriate funding resources;
- A key to success is the cooperation and communication among the relevant stakeholders (ministries, agencies, control bodies, local authorities, retailers, private owners) involved in the hazardous waste management;
- The establishment of a reliable cooperation with the donors at an early stage was important. Due to this fact, transparency and better planning of projects activities in terms of finance and procurement have to be established;
- The approaches and decisions that led to successful achievement of the objectives were based on the fact that all initiated projects and measures carried out had continuity in time and trained personal. All parties have to respect their commitments and activities and complement each other and complete their tasks within the set time frame;
- A comprehensive assessment and establishment of a detailed inventory is essential to have a control over the OP stockpiles;
- Streamlining of the existing policies in the field of OP management and development of subsequent legislation is essential for ensuring the effectiveness of the implementation;
- From a practical implementation point of view, one of the important decisions was the establishment and maintenance of the project management team (e.g. POPs Sustainable Management PMT under the Ministry of Environment) that, once established, continued for 15 years to work in order to ensure the sustainability and effectiveness of OP and POPs stocks management and elimination activities;
- The selection and contracting of qualified consultants, both local and international, facilitated the successful implementation of planned activities and transferring knowledge to personnel;
- Compliance of and contribution from the government and the partners who have agreed to

support projects are non-negotiable for the successful implementation of activities.
- Awareness raising activities at all levels of society are crucial throughout the entire process of approaching and solving of POPs issues.

References

1. Government Decision no 1543 from 29.11.2002 on additional measures for centralized storage and disposal of obsolete pesticides.
2. V. Plesca et al, “Persistent organic pollutants stockpiles management and destruction in Moldova” // 11th International HCH and Pesticides Forum, Proceedings, 7-9 September 2011, Gabala, Republic of Azerbaijan.
3. V. Plesca et al, “Inventory of POP pesticides polluted areas in Moldova” //12th International HCH and Pesticides Forum. Proceedings. 6-8 November 2013, Kiev, Ukraine.

MANAGEMENT OF POPs CONTAMINATED SITES IN MOLDOVA: CISMICHIOI LANDFILL

Plesca, V.[1], Barbarasa, I.[1], Cupcea, L.[1], Kubricht, J.[2], Polak, M.[2]

[1]Chisinau, Republic of Moldova; [2]Dekonta a.s., Prague, Czech Republic

Summary

Here we present the evolution of the situation at the largest pesticide waste storage location in the Republic of Moldova – the Cismichioi landfill.

The Chismichioi burial site was built in 1977 and put into operation in 1978, according to a special decision of the Government, on the territory of Cismichioi [Chishmikioy] community in the south of Moldova. The operations of burial of obsolete pesticides under the Ministry of Agriculture supervision have been carried out in several stages. According to the available documents, by 1987 more than 4,000 tons of waste, including POP pesticides, were buried in 14 pits on an area of 2.3 ha.

The ecological situation at this landfill has been periodically evaluated with participation of different interested institutions from Moldova. Also, some repair and consolidation works on the site were carried out. The conclusions on the ecological situation was that over the years the impact of this object on the environment is minimal.

However, considering the age of the landfill and the uncertainty regarding the amount of buried obsolete pesticides and packaging materials, as well as the growing concerns of the residents of this area regarding the harmlessness of this object, it was considered necessary to carry out an extensive assessment of the situation at the site and to take measures in order to dispose of or conserve this wastes.

Consequently, in the period 2016-2018, with the support of the Government of the Czech Republic, a series of investigation activities, risk assessment and a feasibility study were carried out, followed by the execution of extensive reconstruction and consolidation of the landfill infrastructure, and establishing of a monitoring system of this site.

Currently, the Cismichioi landfill is under the management of the National Agency for Food Safety (ANSA).

Keywords

Cismichioi landfill, Obsolete Pesticides (OP), Persistent Organic Pollutants (POPs), Feasibility study, Risk assessment (RA), Site rehabilitation.

Introduction

During the second half of last century Moldova served practically as a large experimental field for use of chemicals in agriculture. Between 1950 and 1990 about 560 thousand tons of pesticides were imported in Moldova.

Due to the lack of an adequate management of pesticides, such as preventing the accumulation of unused stocks, more than 3,000 tons of pesticide wastes have been accumulated over the years in warehouses throughout the country. Others 4,000 tons (according to available documents) of obsolete or prohibited pesticides were collected during the period from 1978 to 1987 and stored in a specially constructed for this purpose landfill in the south the country near the village of Cismichioi.

Over the last years, the Government of Moldova with the support of international organizations removed more than 4,200 tons of pesticide wastes kept in warehouses.

After this, as one of the priority issues along with the contaminated areas became the Cismichioi landfill. This site is located on the border with Ukraine and not far from the border with Romania, and thereby represents a cross-border environmental problem.

The official data on the amount of pesticide stored in this landfill were incomplete. In fact, it was suspected that this amount could be more times higher. A study conducted in 2014 within a project financed by the National Ecological Fund, and according to information presented by plant protection specialists, who participated in the construction of the landfill, show that the total volume of 14 pits at this landfill is about 26 thousand cubic meters, which indicates a much higher amount of waste, estimated over 16 thousand tons.

In this situation, the initiation of activities on elimination the danger caused by this landfill had to be preceded by a feasibility study to determine more accurately the quantities and categories of waste stored, to determine the most appropriate method of remediation, to estimate costs, technical and equipment needs, etc.

Such investigations, as well as practical remedial works at the Cismichioi landfill, were carried out in the period 2016-2018 by the Czech Company Dekonta a.s. within a project financed by the Czech Development Agency. From the Moldovan side, the respective activities were coordinated by POPs Sustainable Management PMT within the Ministry of Environment and the National Agency for Food Safety.

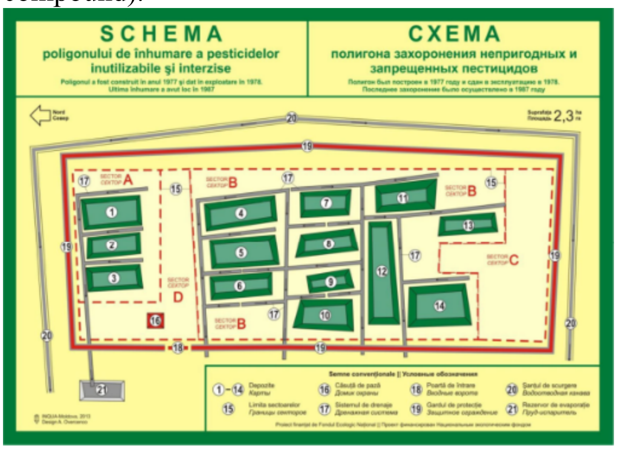
1. General description of the site until investigations

The Cismichioi landfill is located at the most Southern part of Moldova, approx. 5 km from Ukrainian border and approximately 10 km from the Danube river delta.

The compound of the landfill is protected by a fence made of concrete slabs with the height of approx. 2.5 m and it is guarded by security guards.

The nearest village of Cismichioi is approx. 7 km distant from the landfill.

The landfill forms an enclosed area of the size of approx. 2.3 ha with 14 waste storage sites (3 concrete pits and 11 ground repositories, lined with PE foils). The size of concrete pits is approx. 30m×10m×4m, the size of ground repositories is 29-43m×12.5m-16.5m×5m. There are filler blocks on the surface among individual storage sites, which serve for rain water drainage, which was accumulated in the non-drainage tank inside the fenced compound (approx. 50 m of the entry to the compound).



The landfill is settled at the top of a small hill and its area is locked in the planted acacia forest and surrounded with the fields and pastures. Westward from the landfill is a shallow valley. Altitude differences between the site at the top and the bottom of the valley is about 75 m. Valley is supposed to be a main drainage line for both, the surface and also the underground water.

2. Investigation activities

The investigation work at the first stage of the project aimed to determine the amount of waste stored, the nature of stored substances and degree of contamination and included the following activities:

- geophysical investigation,
- investigation of the unsaturated zone,
- investigation of the saturated zone,
- sampling of all the matrices,
- laboratory analyses of samples collected,
- waste identification and inventory,
- surveying,
- data evaluation.

The investigation program included studying and describing of geomorphological, geological, hydrogeological, hydrological, hydrochemical conditions of the site. The methodology of investigation, and analytical work included site reconnaissance; preparation of the site; and complex of geophysical works [1].

The main aim of the survey was to optimize the location of hydrogeological wells, monitoring quality of the underground water and its possible contamination by chemicals leaked from the landfill. The geophysical lines covered the area of about 1.3 km^2 around the landfill.

Sampling works included sampling of soil samples, surface water and bottom sediments samples, ground water samples, building structure samples, waste samples.

The *nature of stored substances* was considered, in order to identify substances of the priority interest. As far as pesticides are concerned, especially the substances from the group of organo-chlorinated, triazine and acidic pesticides, were monitored.

Also, *ambient air quality monitoring* has been carried out before commencement of the investigation works, during the investigation works and after their ending.

As a result of these investigations, the rate and extent of contamination of soil, waste material, groundwater and surface water, bottom sediments and building structures were determined.

Conclusions

Based on the described survey, following findings were achieved.

The material of the 14 mounds situated within the area of the landfill is, except one (mound 7), contaminated with heavy metals (As, Crtot, Cu, Zn), pesticides (2,4-D, atrazine, simazine), organochloride pesticides (4,4'-DDT; 4,4'-DDE; 4,4'-DDD; 2,4-DDT; 2,4-DDE; 2,4-DDD; HCH alpha, HCH beta, HCH gamma), oil products (C10-C40) and PAH's (naphthalene and benzo(a)anthracene). In the most of them the contaminated depth interval reaches up the depth 5-6 m (below to tops of the mounds). The top strata of the mounds (up to approx. 2,4 m b.t.) shows relatively low level of contamination. The rough estimation, based on the analyses results and the knowledge of the mounds dimensions, is that in the landfill there is approx. 37,600 m^3 of contaminated soil/waste.

The soil samples taken from boreholes were dominantly contaminated with organochloride pesticides 4,4'-DDT, 2,4-DDT and HCH beta. Based on these samples taken in the vicinity of the mounds, it can be concluded that there is probably only a very limited contaminant migration from the waste deposits. The contamination distribution beyond the mounds had dominantly a point character and it was almost exclusively related to the top soil strata (up to 1.2 m depth b.t.).

In case of all the building structure samples, bottom sediment samples and surface water samples no contamination was indicated.

1. Risk assessment

The Risk Assessment (RA) was prepared based on the results of the site investigation performed The scope and results of this investigation are in detail described in the separate report [1].

The main objective of the RA was to assess significant human health and environmental risks related to existing soil and groundwater impact and determine appropriate mitigation measures.

2. Hazard identification

Given the preliminary conceptual site model, the contaminants whose concentrations in the uppermost soil layer exceeded, to a statistically significant degree, the value of a given indicator of contamination were determined as priority contaminants. The following contaminants meet this criterion: 2,4-DDT, 4,4-DDE, 4,4-DDT, and β-HCH.

The following risk recipients were assumed in the preliminary conceptual site model:

- On-site workers (security guard) conducting routine passing of the site areas where can get into the contact with the impacted uppermost soil layer including inhalation of dust;
- Off-site farmers inhaling dust released from the landfill;

From an environmental perspective, no ecosystems are considered to be in the potential risk given the level of the groundwater contamination and estimated groundwater flow velocity.

3. Summary of Total Risk

The identified risks can be summarized as follows:

- The soil contamination beyond the waste mounds had dominantly a point character and it was almost exclusively related to the top soil strata. The soil beyond the waste mounds was found impacted mainly by organochlorine pesticides.
- The extent of soil impact indicates an inability of contaminants to significantly migrate through the unsaturated zone to groundwater due to the following aspects:
- the relatively low rainfall amount;
- grass coverage of the landfill area which eliminates the storm water seepage;
- lithological character of the subsurface strata with predominant clayey material;
- type of contaminants of concern (pesticides, heavy metals, PAHs) with moderate to high absorption potential on soil particles;
- thickness of the unsaturated zone up to 90 m at the landfill area.
- No groundwater contamination was detected. The groundwater flow velocity was estimated to be 10 m/year.
- Considering the site land use the conceptual site model has been developed resulting in selection of real exposure scenarios of potential contact with the impacted media (inhalation of dust by on-site workers and off-site farmers during their routine passage at/around the site, and contact of workers with the on-site contaminated soil also during their routine passage the site). No unacceptable risks were identified for on-site workers and off-site farmers for any quantified exposure scenario. The identified level of risk is approximately 3 to 10 times lower than the used acceptable level.
- Considering that the landfill in Cismichioi represents the potential serious contamination source which requires the permanent control.

4. *Recommendation of mitigation measures*

Definition of objectives of mitigation measures

The following findings form the baseline for the derivation of mitigation measures parameters:

- Roughly, there is approx. 37 600 m^3 of contaminated soil/waste containing pesticides, heavy metals, petroleum hydrocarbons, PAHs and PCBs at the 14 waste repositories of the landfill Cismichioi.
- On the other hand, only limited soil contamination of point character and relatively low level was detected beyond the waste repositories. Furthermore, no contamination of other media apart from soil (constructions, groundwater, sediments, surface water) was observed.
- Under the given geological and hydrogeological settings and the site character the potential for the off-site spreading of contamination is considered as low.

Taking the above stated into account the following objectives of the mitigation measures were defined:

- Permanent control of the landfill presenting a potential serious contamination source;
- To eliminate any potential for the release of the deposited material from the landfill to the surrounding environmental media;
- To complete the groundwater monitoring network by additional monitoring well located southwest the landfill in the anticipated groundwater flow direction;
- Monitoring of groundwater quality should be conducted with the aim to verify the results of the performed site investigation;
- No changes should be made to the current land use of the subject property.

Options of mitigation measures

Three options of mitigation measures for the Cismichioi landfill have been proposed: No action, Upgrade of containment and Removal of landfill.

Option 1. No action. This option presents no remedial action at the site, the site remains as it is. Even though no unacceptable risks were identified for on-site workers and off-site farmers no action variant does not meet the defined objectives of mitigation measures for the permanent control of the landfill as a serious potential contamination source and does not eliminate the potential any future release of the deposited material from the landfill to the surrounding environmental media. It was considered that No Action option is not acceptable for the Cismichioi landfill.

Option 2. Upgrade of landfill containment comprises a capping of a landfill as a complex or of the individual waste repositories with compacted landfill surface, geocomposite bentonite mat, covered with HDPE 2 mm thick foil, geotextile a granular drainage layer and a vegetative support layer, and further upgrade of the existing drainage system. Capping is considered as an adequate method for the wastes containing materials stored in this landfill and for the control of releases from the hazardous materials, meeting thus the defined objectives of the mitigation measures.

Option 3. Removal of landfill comprises the removal of topsoil and waste by excavation and further disposal of the excavated materials on the off-site landfill for hazardous waste or its treatment by one of the existing methods for this type of contamination. This option allows the complete removal of the landfill, but it also has negative sides, such as complicated technologies, large amounts of waste treated, requires a long time and high costs.

In conclusion, ***Option 2. Upgrade of Landfill Containment*** was considered as the most feasible method to meet the objectives of the mitigation measures defined based on the outputs of this Risk Assessment study. It was recommended to elaborate a feasibility study to specify the optimal solution for the improvement of the landfill containment including the precise estimate of the respective costs.

5. *Feasibility study*

The Feasibility Study (FS) proposes and assesses alternative remedial actions aiming at reducing and/or eliminating risks related to the existence of the hazardous waste landfill in Cismichioi.

Assessment of prospective technologies and identification of promising methods.

Identification of promising technologies was focused on selection of a feasible method(s) for clean-up of pesticides contaminated unsaturated zone (dump site) to ensure that the remedial goals will be met. The relationship between the general categories of remedial technologies and the remedial objectives is summarized in [3]. The list of general remedial response actions and technologies includes:

- Containment by Capping the waste;
- Removal by Excavation of waste;
- Disposal by Waste disposal at the incinerator; and
- Treatment by Waste or Soil treatment applying different chemical or mechanical methods.

During the *Screening of remedial technologies,* the following criteria were considered:

- Overall protection of human health and the environment;
- Regulatory compliance;
- Effectiveness and performance;
- Long term maintenance issues;
- Reductions in toxicity, mobility, and/or volume of contaminants;
- Implementability;
- Cost.

Assembly of remediation alternatives. The remedial technologies that were carried forward through the screening evaluation were combined to create several remediation alternatives for the remediation of hazardous landfill in Cismichioi. The development of the remediation alternatives was guided by the need for alternatives that will achieve the objectives of the remediation action and provide a range of remediation options. Four remediation alternatives, consistent with the scope of work of the Feasibility Study, were developed using this approach. The major components of each of the four remedial alternatives are summarized in [3]. The four alternatives are:

Alternative 1: Capping of hazardous landfill in Cismichioi;

Alternative 2: Excavation of dumped pesticides waste and contaminated soil with their disposal in an incinerator;

Alternative 3: Excavation of dumped pesticides waste and contaminated soil with on-site treatment of waste using Gas Phase Chemical Reduction and treatment of soil by biodegradation;

Alternative 4: Excavation of dumped pesticides waste and contaminated soil with on-site waste treatment using Base Catalysed Decomposition and treatment of soil by biodegradation.

The criteria for evaluating the remedial alternatives are technical, institutional, and economic considerations that decision-makers will take into account in selecting the remedial actions.

The following criteria were used to evaluate each remedial alternative:

- Protection of human health and the environment.
- Short-term Effectiveness,
- Long-term effectiveness,
- Implementability,
- Socioeconomics effects,
- Compliance with current environment laws and regulations,
- Costs.

Each of these evaluation criteria was described in [3].

Conclusions. After the comparative analysis of the remedial alternatives based on mentioned criteria it was concluded that there are no significant differences between individual alternatives with regards to protection of human health and the environment, and to long-term effectiveness. All alternatives were judged technically feasible. The difference was made by the costs.

Alternative 1 considering capping is relatively cheap (approx. 1 million Euro). Costs for alternatives considering removal of waste and contaminated soil range from about 20,6 million Euro *(Alternative 3)* to about 59,5 million Euro *(Alternative 2)*. Removal of waste and contaminated soil cannot be justified on an economic basis.

In sum, alternative 1 was recommended for further considerations mainly due to relatively short time needed for achieving acceptable reduction of existing risks, relatively low exposure to hazardous substances during remedial action and low cost in comparison to other alternatives.

6. Rehabilitation of Cismichioi hazardous waste landfill

Subsequently to the Feasibility study, the company has prepared a procedure for rehabilitation of the Cismichioi landfill under current Moldovan legislation. The purpose of this action was to terminate the operation of the landfill and to put its area in a state that allows its involvement in the environment, in order to eliminate the negative impacts of the landfill on the environment.

Rehabilitation works. The technical works of the landfill were carried out in 2018-2019.

The main purpose of the rehabilitated construction was to prevent the dump body from subsidizing the rainfall water and thus securing the material of the landfill before it is washed out by precipitation water and discharged into a landfill.

The condition for the fulfillment of the purpose of the construction was the implementation of such technical measures, which will ensure the elimination of the ingress of rainwater into the surface of the landfill, thereby minimizing the amount of landfill water that is currently bound in the landfill. Subsequently, the dump body has been reclaimed and incorporated into the landscape.

The technical solution of the project for the reclamation of the hazardous waste landfill in Cismichioi included several stages of construction works and facilities:

- Landscape design,
- Technical remediation,
- Drainage,
- Biological remediation,
- Monitoring.

The landscape design and reconstruction included works to strengthen the surface of the landfill (slope of about 3% in the east-west direction) and the circumferential slopes along the perimeter of the landfill in order to prepare for laying insulating layers and technical fleece. Pure soil was used to correct the shape of the polygon body. The total excavation area was 10,375 m^2 and 16,373 m^3 of soil was used.

Above the compacted leveling layer, consisting of clean soil, laid on the surface of the landfill body, there is a waterproof layer that prevents rainwater from entering and, as a result, washing pollutants into the environment.

The top sealing system of the reclaimed landfill consists of the following layers: insulating bentonite coating, HDPE foil layer 1 mm thick, and drainage layer based on geocomposite with geotextile protective layer.

A signal layer of sand 20 cm thick, a layer of technical soil 50 cm thick and a layer of fertile soil (without compaction) 30 cm thick were laid on top of the insulating layers.

The total area of technical rehabilitation is 11,830 m^2, during the work 2,372 m^3 of sand (signal layer), 5,915 m^3 of soil (technical) and 3,549 m^3 of fertile soil were used.

The drainage system is represented by a trench 800 mm deep and 1,000 mm wide, the bottom of the trench is covered with gravel, steel reinforcement was also fixed at the bottom of the trench, and the final correction to give the gutter a trapezoidal shape was made using liquid concrete. The dimensions of the concrete gutter are as follows: concrete thickness - 100 mm; upper chute width - 750 mm; bottom chute width - 200 mm; trough depth - 350 mm. The total length of the drainage system is 530 m. The total coverage area is 612 m^2.

The reclaimed surface of the landfill has a vegetative cover planted with a mixture of fast-growing grasses, which helps to improve the nitrogen balance in the soil, while at the same time preventing the expansion of ruderal grasses. In addition, the vegetative cover minimizes water and wind erosion of the entire slope. Moisture-resistant grasses were planted, mixed with dry-resistant clover species.

The system for monitoring groundwater and atmospheric air quality parameters was reconstructed.

Thanks to landfill rehabilitation, a significant improvement in the safety of stockpiled pesticides and other chemicals has been achieved in order to prevent environmental pollution (soil, groundwater) in the future. Ensuring the safety of the landfill will reduce public health risks.

It is considered that the main goal of rehabilitation to complete the operation of the landfill and limit its impact on the environment has been achieved.

References

1. Investigation Work Report // "Reduction of the risks related to hazardous waste landfill in Cismichioi" Project, Dekonta a.s., January 2017.
2. Risk Assessment Report // "Reduction of the risks related to hazardous waste landfill in Cismichioi" Project, Dekonta a.s., March 2017.
3. Feasibility study // "Reduction of the risks related to hazardous waste landfill in Cismichioi" Project, Dekonta a.s., June 2017.
4. Rekultivace skládky nebezpečných odpadů v Cismichioi závěrečná zpráva // Projekt "Omezení rizik souvisejících se skládkou nebezpečného odpadu v Cişmichioi", Dekonta a.s., Října 2019.

PESTICIDE INFORMATION SOURCES AND WASTE MANAGEMENT – SURVEY RESULTS FROM AZERBAIJAN COMPARED TO GEORGIA REFLECT DEVELOPMENTS IN WASTE MANAGEMENT REGULATIONS

Lud, D.[1], Schwemm, A.[2], Babaev, E.[3], Kalandadze, B.[4], Simon, M.P.[2], Weller, P.[5], Düring, R.A.[2]

[1]Rhein-Waal University of Applied Sciences, Faculty of Communication and Environment, Kamp-Lintfort, Germany; [2]Institute of Soil Science and Soil Conservation, Justus Liebig Universität Giessen, Germany; [3]Institute of Chemistry of Additives, Azerbaijan National Academy of Sciences, Baku, Azerbaijan; [4]Department of Soil Geography, Ivane Javakhishvili State University, Tbilisi, Georgia; [5]Institute of Instrumental Analytics and Bioanalytics, Mannheim University of Applied Sciences, Germany

Summary

Both Azerbaijan and Georgia inherited a legacy of obsolete pesticides like DDT and HCHs from Soviet times. In this contribution, results of a small survey (30 participants) with a standardized questionnaire conducted in Azerbaijan are compared to results obtained from a survey in Georgia with 100 participants living in the surroundings of a former pesticide store. Reported pesticide names show similarities and differences between both countries. The results show that both countries share similar challenges e.g. with regard to risk communication about pesticide use. An important issue is repackaging of pesticides into alternative containers without labels or reliable instructions on safe handling and disposal of pesticides. For Azerbaijan, prolonged use of pesticides is reported as disposal option, which is in line with a lack of adequate disposal options. The situation of environmental legislation and its implementation is reflected in the survey results regarding safe management options for hazardous waste for both countries. In addition, environmental legislation in both countries is still developing or weak. Especially in rural areas, safe waste management of hazardous waste needs further efforts in both countries in the future to reduce risks to human health and the environment and to enable better use of resources.

Keywords

Pesticide label, risk communication, pesticide use, waste management

Introduction

Azerbaijan and Georgia share similarities with respect to the legacy of persistent organic pollutants inherited from the former Soviet Union (Abbasov et al., 2019, Kalandadze and Matchavariani 2019). Environmental pollution with persistent organic pollutants in agricultural soil and water resources represent a challenge for sustainable development of the agricultural sector and the country, both in Azerbaijan and in Georgia (Mustafayeva et al., 2022, Fehr et al., 2020).

Waste management needs further attention in both countries; national regulations in both countries were set up and adapted in response to supranational legal instruments such as the Stockholm Convention and the Basel Convention. In Georgia a considerable number of regulations and by-laws were released since waste management code was set up in 2015 (Chachkhiani et al., 2022). However, the country still suffers from a lack of compliance and weakly developed infrastructure for waste management (Collin 2015; Fehr et al., 2020). This means that to date, in Georgia major targets with regard to improved waste management are not met (Kaza et al., 2021). In Azerbaijan, framework legislation in the form of the regulation on the protection of the environment and a law on environmental safety was set up in 1999 (Umudov 2021). In the following years more specific legislation was set up e.g. in the year 2000 on hazardous and industrial waste. Since then, legislation concerning waste management is developing slowly (Collin 2015). There is little progress in recent years, even though better waste management has the potential to yield immediate benefits, as outlined for Azerbaijan regarding greenhouse gas emissions and quality of environmental resources (World Bank 2022)

The aim of this contribution is to investigate whether the current development of environmental legislation and implementation are reflected in survey results on pesticide use and pesticide waste management from Azerbaijan and Georgia. The focus is on the comparison of the situation in Azerbaijan and Georgia in the light of recent developments in waste management regulation and implementation.

Material and Methods

A paper-based survey on knowledge about pesticides and waste management was conducted in Ganja (Azerbaijan) with a non-governmental organization. In Ganja, there was a large pesticide store in the past, where inadequate storage of obsolete pesticides resulted in contamination of building structures and the environment. This survey yielded completed questionnaires of 30 participants. The results from Azerbaijan were compared to a survey with 100 participants conducted in Georgia as reported in Lud et al. (2022). The participants from Georgia were inhabitants from the surroundings of a former pesticide store in a rural area.

Results and Discussion

Among the pesticides mentioned by participants of the surveys were no POPs pesticides regulated under the Stockholm Convention. In Azerbaijan, the most frequently mentioned pesticides were copper-containing products and a sulfonylurea-herbicide from a Turkish manufacturer. Other groups of pesticides reported from Azerbaijan include neonicotinoids and organophosphorus pesticides. The pesticides reported by participants from Georgia are mainly copper-containing products and pyrethroid pesticides (Lud et al., 2022). In both countries, pesticides are used for a long time (well beyond shelf life). The products mentioned are similar to pesticides reported from other countries in the region (Tadevosyan et al., 2013), in Azerbaijan, there is also some influence of Turkish products.

In Azerbaijan, two thirds of the respondents can name either an active ingredient, product or producer of the pesticides. This is similar to the survey from Georgia; there, more than two thirds report to know the active ingredients (Lud et al., 2022). In both countries, reported active ingredients and reported brand names often do not match, reflecting lack of knowledge about pesticides used in both countries. The results indicate that, even though legislation exists regarding the labelling of hazardous substances in Azerbaijan (IHPA 2017), the label does not play an important role as a source of information about pesticide use. In both countries, results show that direct contact to people is the preferred way of participants in rural areas of getting information about pesticide use: In Azerbaijan, friends and family are the most important source of information, followed by the retailer. Additionally, agricultural advisors are mentioned as important source of information in the survey from Azerbaijan. In Georgia, the retailer is the most important source of information, followed by friends and family (Lud et al., 2022).

Repackaging pesticides into alternative containers often means that the pesticide containers do not have proper labels anymore when used on the farms. This is common practice in both countries and increases the risk of incorrect handling, exposure or poisoning.

There is a high awareness regarding the use of personal protective equipment in both countries, the majority of the participants report that they use protective equipment in both countries: In Azerbaijan, masks (or more informally something to cover the face) are the most frequently reported protective equipment followed by special clothing. A considerable number of participants (13 %) in Azerbaijan reports informal measures such as eating yoghurt or drinking milk as protective measure. Labels on pesticide containers could help to inform users about adequate safety measures. In Georgia, gloves are the most frequently reported protective equipment, followed by mask, goggles and special clothing (Lud et al., 2022).

Reported disposal options of used pesticides reflect the current waste management situation in both countries. In Azerbaijan, the most frequently reported disposal option is domestic waste. The second most reported option is to keep remaining pesticides for the following season. In Georgia, disposal via domestic waste and burning of waste are the most frequently reported disposal options (Lud et al., 2022). Disposal via domestic waste is common, because in rural areas there is no separate collection of hazardous waste from households or farms. The reported share of hazardous waste in domestic waste in Georgia is low (0-1.8%, Chachkhiani et al., 2022), but it might be difficult to identify pesticides repacked in alternative containers as hazardous waste via occasional waste composition studies (Chachkhiani et al., 2022; A. Allesch, personal communication). Mixed disposal of unwanted pesticides in domestic waste represents an environmental health risk, e.g. to people involved in informal waste recycling. The practice of keeping remaining pesticides for the next season reported from Azerbaijan could also explain the use pattern described for Georgia, where the reported age of the pesticides used was very high (Lud et al., 2022).

The results from Azerbaijan indicate that a lack of disposal options favors prolonged use of old pesticides. This reflects a lack of disposal infrastructure for hazardous waste in both countries, especially in rural areas: waste collection rates in rural areas are lower than in the large cities. In rural areas in Georgia, Kaza et al. (2021) report waste collection rates of 64% (range 25%-95%), whereas the waste collection rate in Tbilisi is 100%. In both countries disposal in informal landfills was or is common practice. In Azerbaijan, 80% of the informal landfills are closed (Kaza et al., 2018), but waste is largely not managed adequately (World Bank 2022). Plans for new waste disposal infrastructure are implemented (OECD 2021). Also in Georgia, informal landfills are common (Kaza et al., 2021) and form an environmental risk (Buachidze et al., 2016). Projects for site closure of existing informal landfills are also under way in Georgia (https://geo.org.ge/waste). After closure, old informal landfills require adequate site management.

Conclusions

According to the National Environmental Action Plan of Azerbaijan, one of the main issues to be addressed is the loss of fertile agricultural land e.g. due to pollution with agrochemicals (Umudov 2021). Both countries address waste management with some priority as can be seen from legislatory actions and recent assessments (Chachkhiani et al., 2022, Kaza et al., 2021, World Bank 2022). Further challenges regarding waste e.g. in the Marneuli region include management, awareness and implementation (Fehr et al., 2020). In both countries the situation in rural areas, where waste management practices are simple, deserves special attention (Collin 2015, Kaza et al., 2021, World Bank 2022).

Landfilling is the predominant form of disposal, often at informal dumps rather than engineered landfills, the waste collected usually is not separated (Collin 2015, World Bank 2022). This means that hazardous waste collected with municipal waste is dumped together with municipal waste and thereby represents a risk to the environment (Buachidze et al., 2016) and humans, e.g. people involved in informal recycling (Chachkhiani et al., 2022). Additionally, the lack of separation hampers the reuse of resources (Fehr et al., 2020). This is reflected in the results presented.

Separation of waste and collection rate need to be improved in both countries to improve the environmental quality and to facilitate better use of resources. Infrastructure currently is and will be developed in the future. Additionally, the environmental pollution risks e.g. of existing informal landfills need to be addressed for sustainable development of agriculture. These measures will help to reduce pressure on environmental resources such as water and agricultural land in the face of climate change (Mustafayeva et al., 2022).

Acknowledgements

This research was funded by Bundesministerium für Bildung und Forschung (BMBF) under grant number 01DK17030B, which is gratefully acknowledged.

References

1. Abbasov, R., Cervantes de Blois, C. L., Sharov, P., Temnikova, A., Karimov, R., & Karimova, G. (2019). Toxic Site Identification Program in Azerbaijan. Environmental Management, 64(6), 794–808. https://doi.org/10.1007/s00267-019-01215-1
2. Buachidze, N., Chikviladze, K., Kordzakhia, G., Shubladze, E., Shavliashvili, L. (2016) Research of Uncontrolled Landfills Impact on Environment in Georgia, American Journal of Environmental Protection. 5(3), 65-70. https://doi:10.11648/j.ajep.20160503.14
3. Chachkhiani M., Allesch A., Reichenbach J., Huber-Humer M. (2022) Formal and informal solid waste management in Kutaisi, Georgia: A status quo report based on material flow analysis. Waste Management & Research. 2022;0(0). https://doi.org/10.1177/0734242X221135261
4. Collin, R.W. (2015). Trash Talk: An Encyclopedia of Garbage and Recycling Around the World. ISBN 978-1-61069-508-4
5. Fehr, A., Urushadze, T., Zöller, N., Knerr, B., Ploeger, A., Vogtmann, H. (2020). Establishing a Sustainable Waste Management System in a Transitional Economic Context: Analysis of the Socio-Economic Dynamics.Sustainability,12(9), 1.
6. IHPA (2017) Working Document Management of Obsolete Pesticides Republic of Azerbaijan http://www.ihpa.info/docs/library/other/improving/Azerbaijan-WD-ENG.pdf
7. Kalandadze, B., Matchavariani, L. (2019). Soil Pollution. In: Matchavariani, L. (eds) The Soils of Georgia. World Soils Book Series. Springer, Cham. https://doi.org/10.1007/978-3-030-18509-1_8
8. Kaza, S., Yao, L., Bhada-Tata, P., & Van Woerden, F. (2018). What a waste 2.0: A global snapshot of solid waste management to 2050. World Bank Publications. Urban Development Series. Washington, DC: World Bank. https://doi.org/10.1596/978-1-4648-1329-0
9. Kaza, S., Gogotishvili, T., Oe, N., Shotadze, M., Simonis, G. M., Anchabadze, A., Kobulia, I. (2021) Georgia – Solid Waste Sector: Assessment Report (English). Washington, D.C.: World Bank Group. https://doi.org/10.1596/35704
10. Lud, D., Schwemm, A., Kalandadze, B., Babaev, E., Simon, M.P., Weller, P., & Düring, R.-A. (2022). Pesticide handling and waste management: a case study on DDT and HCHs from the Southern Caucasus. SN Appl. Sci. 4, 112. https://doi.org/10.1007/s42452-022-04999-w
11. Mustafayeva R., Abbasova Y., Qambarova R. (2022). Ecological issues of ensuring sustainable development of agriculture in Azerbaijan. Management, Economic Engineering in Agriculture and rural development, 22(3), 439-450.
12. OECD (2021). Sustainable Infrastructure for Low-carbon Development in the EU Eastern Partnership: Hotspot Analysis and Needs Assessment, Green Finance and Investment. Paris: OECD Publishing. https://doi.org/10.1787/c1b2b68d-en
13. Tadevosyan, A., Tadevosyan, N., Kelly, K., Gibbs, S., Rautiainen, R. (2013). Pesticide Use Practices in Rural Armenia. Journal of Agromedicine, 18(4), 326-333. https://doi.org/10.1080/1059924X.2013.826118
14. Umudov, A. (2021). Overview of Environmental Governance in Azerbaijan. In: Asymmetric Environmental Governance in Azerbaijan. Societies and Political Orders in Transition. Springer, Cham. https://doi.org/10.1007/978-3-030-82116-6_2
15. World Bank. (2022). Azerbaijan: Towards Green Growth, Issues Note. Washington, DC: World Bank.