

**Macedonian Ministry of  
Environment and Physical Planning  
(MEPP)  
Skopje, Republic of Macedonia**

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**OHIS Site Remediation Project**

**Conceptual Design**



# Macedonian Ministry of Environment and Physical Planning (MEPP) Skopje, Republic of Macedonia

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Conceptual Design

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## **LIST OF ACRONYMS**

ACM	Asbestos Containing Material
AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
BAT	Best Available Technique
PCB	Polychlorinated Biphenyl
BWM	Backward Mode
CD	Conceptual Design
CHC	Chlorinated Hydrocarbons
COC	Contaminant of Concern
DCE	Dichloroethene
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DIV	Dutch Intervention Value
EC	European Community
EU	European Union
FWM	Forward Mode



**LIST OF ACRONYMS  
(Continuation)**

GEF	Global Environment Facility
HCH	Hexachlorocyclohexane
HDPE	High Density Polyethylene
HEPA	High Efficiency Particulate Arrestors
HHRA	Human Health Risk Assessment
IMELS	Italian Ministry of Environment, Land and Sea
ISTD	<i>In Situ</i> Thermal Desorption
LDPE	Low Density Polyethylene
MCD	Mechanochemical Dehalogenation
MDL	Method Detection Limit
MEPP	(Macedonian) Ministry of Environment and Physical Planning
MoU	Memorandum of Understanding
NIP	National Implementation Plan
OHIS	Organic Chemical Industry Skopje
OSHA	Occupational Safety and Health Organization
PAH	Polycyclic Aromatic Compound
PCA	1,1,2,2-Tetrachloroethane
PCE	Tetrachloroethene
PE	Polyethylene
PPE	Personal Protective Equipment
POP	Persistent Organic Pollutant
RBCA	Risk-Based Corrective Actions
RPE	Respiratory Protective Equipment
RTA	Rotary Thermal Apparatus
SSTL	Site Specific Target Level
SVOC	Semi-Volatile Organic Compound
TCE	Trichloroethylene
TD	Thermal Desorption
UNIDO	United Nations Industrial Development Organization
VOC	Volatile Organic Compound
WWTP	Waste Water Treatment Plant



## **REPORT OHIS SITE REMEDIATION PROJECT CONCEPTUAL DESIGN**

### **1 INTRODUCTION**

#### **1.1 PROJECT BACKGROUND**

The OHIS (Organic Chemical Industry Skopje) Site Remediation Project (or 'the Project') was developed in the frame of a Memorandum of Understanding (MoU) on the "Cooperation in the field of Environment and Sustainable Development", signed between the Italian Ministry of Environment, Land and Sea (IMELS) and the Macedonian Ministry of Environment and Physical Planning (MEPP). Based on the MoU, IMELS agreed to provide financial assistance to the MEPP for the preparation of a detailed feasibility study for the lindane and other Persistent Organic Pollutants (POPs) contamination of the OHIS site in Skopje (Macedonia) and for the development of a Conceptual Design (CD) of the applicable remedial technologies. Within this context, D'Appolonia has been selected, through an open tender procedure, to provide technical services for the review of the existing feasibility studies, the development of the CD of the applicable remedial technologies and the development of the necessary tender documentation for the procurement of design and implementation of the identified remedial interventions.

The Project has been developed within the framework of the National Implementation Plan (NIP) for the reduction and elimination of the POPs in the Republic of Macedonia (MEPP, 2004), prepared by the MEPP with the fund from the Global Environment Facility (GEF) and with the assistance of the United Nations Industrial Development Organization (UNIDO). The NIP, implemented with the coordination of the National POPs Unit, was aimed at creating a first baseline inventory of the POPs contaminated sites in Macedonia as well as at detailing the actions foreseen for the implementation of the obligations of the Stockholm Convention, signed by Macedonia on 23<sup>rd</sup> May 2001, and further ratified on March 19<sup>th</sup> 2004. Among the thirteen major priority areas identified in the NIP, becoming later on the basis for the proposed actions, the following concern was highlighted: "*Control of PAHs (In Macedonia large quantities of technical waste (technical mixture of hexachlorocyclohexane isomers) are stored which need to be solved in a proper manner. Although HCH is not listed in the Stockholm Convention, it is set as the 13<sup>th</sup> priority in order to find a prompt solution for this waste)*".

#### **1.2 PROJECT SCOPE OF WORK**

Within the above described IMELS-MEPP cooperation project, D'Appolonia was entrusted with the following activities:

- review of background data and feasibility studies already available for the OHIS site and preliminary technologies selection;
- execution of a new Human Health Risk Assessment (HHRA) to better define the remediation goals needed for the contaminated environmental matrices;
- final technology selection for contaminated matrices at the site based on final HHRA outcomes and a cost and market investigation, and development of the CD of the selected technologies; and



- support MEPP for the preparation of Tender documents required for the procurement of design and implementation of the remedial options identified under the Project.

In particular, according to UNIDO suggestions and following MEPP expectations regarding project's applicability for GEF or other International funding, D'Appolonia has been developed the CD:

- considering, among the selected technologies to be developed within the CD both commercial and innovative technologies for lindane remediation; and
- following a phased approach for the different contaminated media, in order to allow for separate funding (if the case) of the different remedial interventions to be implemented at the OHIS site.

### **1.3 DOCUMENT ORGANIZATION**

The present Report is organized as follows.

Sections 2 to 5 summarize all the background information used for the development of the CD for the site including: the geological-hydrogeological setting, the National and International regulatory framework for the contaminated site management, all chemical-physical data gathered from past investigations and the outcomes of the site specific HHRA performed to obtain the remediation goals for the contaminated matrices.

Section 6 summarizes the proposed remediation approach, the estimated area/volumes for site remediation and the constraints to be adopted for the site and its surroundings following the proposed tiered approach for the site remediation.

Section 7 provides a description of the selected remediation options, the selection criteria and the application to the tiered approach.

Section 8 provides the detailed technologies description, the operative procedures and relevant process diagrams of each remediation phase.

Preliminary time schedule and overall costs estimation are provided in the conclusive Sections 9 and 10.



## **2 SITE SETTINGS**

### **2.1 ENVIRONMENTAL SETTINGS**

#### **2.1.1 Geographical Location**

The OHIS Factory is located about 5.5 km Southeast of the centre of Skopje. The Vadar River, the main water course of Macedonia, flows in the NW to SE direction at a distance of about 2-2.5 km Northeast of the plant. The nearest surface water is the Colemni Kamenj creek flowing in direction SW to NE at a distance of 400 m to the Northwest of the site. Another water course in the vicinity of the site is the Makova River, flowing in the South - North direction within a distance of 1.6 km to the East of the site.

The total area of the OHIS Plant is of about 90 hectares whereas the extension of the targeted site for the Project is about 10 hectares.

The nearest settlements are Lisice, Pintija, and Dracevo in a radius up to 2 till 5 km, with more than 50000 inhabitants in the surrounding area.

#### **2.1.2 Geology and Hydrogeology**

The regional geology of Skopje Valley is characterized by the Vardar Zone geo-tectonic unit. The valley contains Neogenic (Miocene and Pliocene) and Quaternary sediments. The bedrock beneath the site area is composed of Pliocene sediments comprising sandstone, marlstone, and conglomerate. The depth to bedrock rapidly increases in north-east direction from first tens of meters to more than 200 m along the Vardar River. The bedrock is overlain by Quaternary proluvial sediments comprising sandy, gravelly and silty loams. Quaternary proluvial sediments fill the depression eroded in Pliocene sediments. The thickness of Quaternary proluvial sediments is about 70 m at the site and increases in northern direction to approximately 90 m. The Quaternary proluvial sediments are overlain by alluvial sediments of the Vardar river comprising mainly gravels, sandy, silty and loamy gravels intercalated with thin layers (first tens of centimeters) of sandy gravelly clay and silt. The uppermost layers of alluvial sediments comprise clayey silt to silty clay. The thickness of these fine grained sediments varies at the site from 1.5 m to 5.2 m. The alluvial sediments are locally overlain by fill comprising mostly crushed aggregate, gravelly clay and gravel.

Phreatic aquifer is hosted in the alluvial sediments of the Vadar River. Permeability of the aquifer is of about  $10^{-2}$  to  $10^{-3}$  m/s in pure gravel formations. Also the underlying proluvial sediment can be considered as water bearing strata but with lower permeability. The saturated thickness of the aquifer is reported to be of about 60 m at the site and increases in the northern direction. The installation of the monitoring wells within the plant area revealed the presence of a relatively impermeable layer at a depth ranging from 10 to 12 m bgl which is considered the base of a shallow aquifer. Lateral continuity of this impervious layer at 10-12 m bgl is unknown. Groundwater flows generally in a northeast direction, towards the main discharge river Vardar, which is located approximately 2-2.5 km down gradient.

#### **2.1.3 Climate and Meteorological Data**

Annual average data on major meteorological parameters were mainly taken from the MEPP "Report on Second Communication on Climate and Climate Changes and Adaptation in the Republic of Macedonia" (MEPP, 2006).



Average annual air temperature over the period from 1961 to 2005 (time series of 45 years) is of 12.3°C from the meteorological station of Skopje-Petrovec. In the southern part of the country (Nov Dojran, Gevgelija) the annual average temperatures are higher whereas they strongly decrease in the mountain regions (Popova Sapka, Solunska Glava).

The distribution of the precipitation in Macedonia is timely and spatially uneven. Lowest amounts of precipitations are recorded in the central regions of Macedonia (Gradsko, Tikves and Ovce Pole) with average annual sum of precipitation in range of 400-500 mm. The highest precipitations are recorded on the high mountains (about 1.000 mm) in the western part of the country. In the remaining parts of Macedonia, the annual sums of precipitations are in the range of 600-1000 mm. Over the same time period as for the temperature data, the average annual sum of precipitation is of 498.4 mm for the meteorological station of Skopje-Petrovec, and the recorded minimum and maximum precipitation were of 300.4 mm (year 2000) and 714.0 mm (year 1999), respectively. Evaporation from the free water surface is within the range from 400 to 580 mm annually for Skopje. Distribution of the precipitations and temperatures in Macedonia classified the climate in the category of semi-arid climate.

## 2.2 SITE HISTORY AND BACKGROUND

The OHIS site is an organic chemical industrial factory nowadays partially dismissed and interested by old environmental burdens due to the historical production of pesticides, particularly lindane, monochloroacetic acid and chlorine.

The OHIS Plant was founded in 1964 through the union of two factories for production of synthetic textile fibers and acetylene products, i.e. the Naum Naumovski Borce and the Electro-Chemical Combine (UNEP, 2001). The first units in operation produced detergents and pesticides (including lindane or gamma-hexachlorocyclohexane). Later, a polyvinylchloride plant was built and put into operation. The complex grew to become one of the country's leading industrial manufacturers.

The Lindane complex was gradually put into function since 1964 and was functioning until 1977, when lindane production ceased due to changing market conditions and due to environmental reasons.

In the period of Plant operation the Hexachlorocyclohexane (HCH), whose gamma-isomer is the active component of the insecticide lindane, was produced by the process of photo-chlorination of benzene. The produced mixture contained also other HCH-isomers, i.e. alfa-, beta- and delta-HCH. The gamma isomer was separated by extraction in methanol and by further concentration process whereas the remaining HCH-isomers, forming the 86-88% of the batch mixture, were treated as a waste and about 30000 t were 'temporary' stockpiled in dumpsites (UNEP, 2001; Jordanov, 2008).

After site closure, in the 1980s the lindane plant's equipment was dismantled, leaving behind two empty buildings. In the same year, a wastewater treatment system was built.

## 2.3 PRESENT SITE CONDITIONS

The area object of the present CD is the North-western section of the 90 hectares-wide OHIS industrial plant (see Drawing 1). The targeted surface is about 10 hectares.

The site has been subdivided in the following Sectors in connection with their past functions:

- Sector A is the former Lindane production and storage area;
- Sector B includes the two HCH dumps;
- Sector C is the former Monochloroacetic Acid production and storage area;



- Sector D is the former Electrolysis plant; and
- Sector E is the outdoor storage of fuels/flammables and chemicals.

Sector subdivision and relevant buildings' code are reported in Drawing 2.

All buildings in the area of interest are semi-abandoned, apart from D4 and D5 buildings located in the former Electrolysis Plant sector, which are still in operation (production and storage of hydrochloric acid) and some of the warehouses present in Sector A, still used for products storage. All other buildings, even not in use, are not completely cleared of equipment and past production apparatus. Pipe racks and aerial flowlines connecting the different process buildings are still present on site.

Aboveground Storage Tanks (ASTs) for fuels and drums stored in Sector E show advanced degree of corrosion. According to the retrieved information ASTs should be empty.

Two separate dumpsites with different extension and aspect are present in Sector B. The widest one ( $\alpha+\beta$ -HCH isomers dump) is surrounded by a concrete sidewall (see Figure 2.1). The smaller dump, which should consist of five underground storage basins, extends beyond the basins perimeters, and their limits are almost completely hidden by the overlying soil (see Figure 2.2).



**Figure 2.1:  $\alpha+\beta$ -HCH Isomers Dump (North-western side)**



**Figure 2.2:  $\delta$ -HCH Isomer Dump**



## **2.4 FUTURE DESTINATION OF THE SITE**

The CD development is strictly related with the remedial targets calculated through the HHRA. However, computed remediation goals are connected to a given site use (i.e. commercial, residential, etc.) and different target levels will be applied according to the final site destination/s, affecting the remediation needs and related technological costs.

According to what jointly discussed, all possible future site use scenarios have been considered during HHRA development, and the relevant remedial targets have been calculated. In such way, the proposed phased approach, detailing possible applicable technologies, site use constraints and remediation costs for each phase, is the basis for any choice about future site development.

The CD described in the following Sections has been developed considering the future commercial use of the OHIS site. Technologies selection, remediation operations and cost estimation are based on this hypothesis and the relevant remedial targets calculated through HHRA. However, the same approach could be followed in case the selected future scenario would be the residential site use. Of course, both operating times and remediation costs will noticeably increase, due to the greater soil volumes to be remediated and the more stringent remediation goals to be achieved.



### **3 APPLICABLE REGULATORY FRAMEWORK**

#### **3.1 MACEDONIAN ENVIRONMENTAL LEGISLATIVE FRAMEWORK**

Macedonia's environmental legislative framework is based on the Constitution Law, which determines the protection of the environment as a basic principle, and the Law on the Environment. The Macedonian environmental legislation framework is further developed by the Law on the Quality of the Ambient Air, the Law on Waters and subsequent Regulations and the Law on Waste Management.

##### **3.1.1 Law on the Environment**

The main objectives of the Law on the Environment are: i) preservation, protection, restoration and improvement of the quality of the environment; ii) protection of human life and health; iii) protection of biological diversity; iv) rational and sustainable utilization of natural resources; v) implementation and improvement of measures aimed at addressing regional and global environmental problems.

The Law establishes a permitting system which covers both the major industrial installations identified by the European Union (EU) Integrated Pollution Prevention and Control Directive and the industrial installations with lower capacity of environmental pollution. The Law also prescribes the establishment of the register of dangerous substances, cadastre of polluters and contains issues on planning, monitoring, informing, supervision and enforcement. It contains provisions which give the public extensive rights to participate in the planning and permitting process and stipulates their right to complain. The Law transposes the Aarhus Convention and European Community (EC) Directives on access to environmental information.

##### **3.1.2 Law on the Quality of Ambient Air**

The Law on the Quality of Ambient Air identifies the main sources of air pollution (stationary sources – industrial and energy installations, mobile sources of pollution) and prescribes threshold values (limit values for the quality of the ambient air and alert thresholds, limit values for emissions from stationary sources, limit values for emissions from mobile sources and the maximum allowed content of the dangerous substances in fuels). The Law defines the needs of management of ambient air quality through regular assessments. The EU Council Directive 96/62/EC and subsequent modifications are fully transposed in this law.

##### **3.1.3 Law on Waters**

The Law on Waters is a general framework law intended to regulate the basic water management principles. The water management refers to all measures and activities for rational and effective use of waters and sustainable development of water resources. This Law focuses on three major areas: i) use of waters; ii) protection of waters and control of pollution; and iii) protection from adverse effects. The law provisions are completed by the Regulation for Classification of Water (which defines the classification of water including underground water and gives the maximum allowed concentrations for the different classes) and the Regulation for Categorization of Watercourses, Lakes, Water Accumulations and Underground waters (which defines the categorization of surface and underground waters according to Regulation for Classification of Water).



### **3.1.4 Law on Waste Management**

The Law on Waste Management focuses on the institutionalization of instruments supporting the sustainable development by promoting the rational use of natural resources and preventing and eliminating the dangers to human health and the environment from wastes. The Law provides for the creation of a prevention-oriented hierarchy of obligations (minimization of waste before processing, disposal is the last final solution). It encourages the prevention or reduction of waste generation. It aims to reduce the harmful effects of wastes by encouraging clean technologies, technical developments and new products on the market, which were produced by waste recycling.

This Law focuses on the modalities of waste management, disposal, collection and recycling, as well as on the obligations of the generators and holders of waste. The Law requires that waste management be carried out based on a system of permits issued in accordance with planning documents. The Law also stipulates an obligation for recording and reporting all phases of waste management.

The Law contains separate parts concerning:

- Hazardous Wastes, which aims to provide legal basis for implementing a controlled management;
- Import, export and transit of wastes, which aims to reduce the amounts of transboundary movement of wastes by implementing efficient control at the international level;
- Landfilling, which aims to prescribe basic provisions on the requirements for disposal of certain type of waste in certain classes of landfills;
- Incineration and co-incineration, which aims to set requirements of these installations and their operation;
- Special waste streams including exhausted oils, Polychlorinated Biphenyls (PCBs), end of life-vehicles, electric and electronic equipment waste, etc.

Finally, a National Waste Management Plan was prepared in 2005 and adopted in 2006, giving the basics for future waste management activities, setting the strategic objectives and specifying the short term actions / measures.

### **3.1.5 Persistent Organic Pollutants**

Macedonia has signed (May 2001) and ratified (March 2004) the Stockholm Convention on POPs. In order to fulfill the obligations, the Government of the Republic of Macedonia established the POPs Unit under auspices of the Ministry of Environment and Physical Planning.

With the fund from the GEF and the UNIDO assistance, the POPs Unit prepared the first NIP for Macedonia.

The first part of the NIP summarizes the current status in Macedonia with regards to POPs. This is the baseline inventory. The second part of the NIP details all the actions which need to be undertaken in order to meet all the obligations of the Convention.

Based on POPs inventory, the Steering Committee – formed by representatives from all ministries which have relevance to POPs, the private sector, and researchers – identified thirteen major priority areas:

1. Detailed inventory of POPs chemicals;
2. Establishment of a National POPs Center;
3. Inventory of “hot spots”;



4. Preventing uncontrolled waste combustion;
5. PCBs/Organochloride pesticides containing waste management;
6. Preparation of new and amendment of existing legislation;
7. Monitoring of POPs;
8. Providing necessary equipment for and training on POPs monitoring;
9. Public awareness and education;
10. Evaluation of adverse effects on human health;
11. Monitoring of POPs bioaccumulation in living organisms;
12. Measures for the reduction of dioxin and furan emission:
  - a. Promotion of the use of unleaded fuels,
  - b. Adoption of principles of BATs (Best Available Techniques in the industry),
  - c. Safe handling; and
13. Control of Polycyclic Aromatic Hydrocarbons (PAHs) (in Macedonia large quantities of technical waste – technical mixture of HCH isomers – are stored which need to be solved in a proper manner. Although HCH is not listed in the Stockholm Convention, it is set as the 13<sup>th</sup> priority in order to find a prompt solution for this waste).

To transform these priorities into activities the second part of the NIP contains several action plans, which detail the most feasible management options to meet the NIP objectives.

## **3.2 EUROPEAN REGULATIONS**

### **3.2.1 European Directive 2006/142/EC on Waste Management**

The EU has a framework (the Directive 2006/12/EC on waste and further modifications) for coordinating waste management in the Member States in order to limit the generation of waste and to optimize the organization of waste treatment and disposal.

Commission Decision 2000/532/EC (replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste, as further amended by Decisions 2001/118/EEC, 2001/119/EC and 2001/573/EC) supplements the cited Directive laying down rules on hazardous waste.

Council Directive 75/442/EEC (amended by Directives 91/156/EEC, 91/692/EEC, 96/350/EC, Regulation (EC) No 1882/2003) as further amended by Commission Decision 2000/532/EC (amended by Decisions 2001/118/EC, 2001/119/EC and 2001/573/EC) outlines general waste management and waste classification procedures.

### **3.2.2 European Directive 1999/31/CE on Landfill of Waste**

European Directive 1999/31/CE of 26 April 1999 on the landfill of waste gives operational and technical requirements on the waste and landfills, in order to provide measures, procedures, and guidance to prevent or reduce as far as possible negative effects on the environment. In particular, the directive gives a guide to prevent the pollution of surface water, groundwater, soil and air, and on the global environment, including any resulting risk to human health, from landfilling of waste during the whole life-cycle of the landfill.



The Directive defines the following classes of landfill:

- landfill for hazardous waste;
- landfill for non-hazardous waste;
- landfill for inert waste.

The Technical Annexes deal with:

- Annex I: General Requirements for all Classes of Landfill (location, water control and leachate management, protection of soil and water, gas control, nuisances and hazards, stability, barriers);
- Annex II: Waste Acceptance Criteria and Procedures. Only general requirements are given. The specific requirements are reported in the Directive 2003/33/EC;
- Annex III: Control and Monitoring Procedures in Operation and After-Care Phases.

### **3.2.3 European Decision 2003/33/EC Establishing Criteria and Procedures for Acceptance of Waste at Landfills**

European Decision 2003/33/EC establishes the criteria and the procedures for acceptance of waste at landfills. In the technical Annex is provided the test and procedures to be followed in order to define which type of landfill (inert, non-hazardous, hazardous waste) could accept a waste under certain conditions.

Tests consist in chemical analysis, and leachate test that should be comply with reference limits provided by the regulation.

The Appendices of the Decision deals with:

- Appendix A: Safety Assessment for Acceptance of Waste in Underground Storage;
- Appendix B: Overview of Landfilling Options Provided by Landfill Directive.

### **3.2.4 European Directives on Water and Wastewater**

The European Union, with the Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration, is establishing a framework to prevent and control groundwater pollution. This includes procedures for assessing the chemical status of groundwater and measures to reduce levels of pollutants.

This Directive put into practice prescriptions outlined in Article 7 of the Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy amended by Decision No 2455/2001/EC, Directives 2008/32/EC, 2008/105/EC and 2009/31/EC), that establishes a Community framework for water protection and management.

### **3.2.5 European Council Directive 2004/850/EC on Persistent Organic Pollutants**

HCH isomers, including Lindane (i.e. gamma-HCH), are listed in Annexes I-B (List of substances subject to prohibitions) and Annex IV (List of substances subject to waste management provisions set out in article 7) of European Council Directive 850/2004/EC "On persistent organic pollutants and amending Directive 79/117/EEC". Regulation 850/2004/EC was lately amended by regulation 1195/2006/EC in order to include thresholds for wastes containing POPs. A threshold value of 50 mg/kg was set for the sum of alpha-, beta- and gamma-HCH.



According to the cited regulations, waste consisting of, containing or contaminated by HCH (if > 50 mg/kg) must be disposed of or recovered in such a way as to ensure that the POP content is destroyed or irreversibly transformed so that the remaining waste and releases do not exhibit the characteristics of POPs. The following disposal and recovery operations, as provided for in Annex IIA and IIB of Directive 75/442/EEC, are permitted:

- D9 Physical-chemical treatment;
- D10 Incineration on land; and
- R1 Use principally as a fuel or other means to generate energy.

Derogation from the cited prescription are allowed only for certain type of wastes (including demolition wastes and soils from contaminated sites), if it is demonstrated that destruction or irreversible transformation of the POP content, performed in accordance with best environmental practice or best available techniques, does not represent the environmentally preferable option. In such case, the waste can be permanently stored only in: safe, deep, underground, hard rock formations, salt mines or a landfill site for hazardous waste (provided that the waste is solidified or stabilized where technically feasible as required for classification of the waste in Decision 2000/532/EC).

### 3.3 INTERNATIONAL REGULATIONS FOR CONTAMINATED SITES

The site investigation results, performed at the site, have been compared with the Dutch Remediation Intervention Values.

The reference limits for soil and groundwater are included in the Dutch Ministry of Housing, Spatial Planning and the Environment Circular of 4 February 2000, which defines the following limits for soil and groundwater:

**Remediation Intervention Values:** indicate when the functional properties of the soil/groundwater for humans, plant and animal life, is seriously impacted. They are representative of the level of contamination above which there is a serious case of soil contamination and intervention for remediation is needed (Tier 1 Analysis);

**Serious Contamination Below the Level of the Intervention Values:** In specific cases there is a chance that for concentrations in the soil/groundwater below the intervention levels the functional properties of the soil for humans, plant or animal life have nevertheless been seriously impacted or are in danger of being impacted and that there is a case of serious contamination;

**Target Values:** the target values indicate the level at which there is a sustainable soil/groundwater quality.

In terms of definition of remediation goals and needs, the approach common to most of the active legislation in Europe and USA is to perform a site-specific risk analysis for the Contaminant of Concerns (COCs) exceeding the Tier 1 analysis and to determine, whether the risk is not acceptable, the needed abatement of COCs.



## **4 PAST INVESTIGATIONS**

### **4.1 SUMMARY OF PAST CHARACTERIZATION ACTIVITIES**

In 2007, company Eptisa performed a site investigation within an EU-funded project managed by the European Agency for Reconstruction. The site investigation consisted of geoelectrical (resistivity) mapping with the goal of evaluating possible anomaly zones indicating contamination of soil and groundwater by HCH and Hg and to propose strategy for site remediation. The geophysical investigations were executed in the area on the North and Northeast of the waste dumps and in the former electrolysis plant Sector, arranging the profiles in the free areas around the several infrastructural and auxiliary constructions present at the site (Eptisa, 2007).

Intrusive investigations were conducted by ENACON s.r.o. at the OHIS site in 2007-2008 reportedly with the following objectives (ENACON 2007, 2008a, 2008b, 2008c, 2008d):

- assess the contamination levels of soil, groundwater and construction materials;
- characterize the two dump sites of HCH isomers waste; and
- evaluate the potential impact on home-grown vegetables nearby the OHIS site.

For these purposes, the following investigations were performed:

- 49 soil boring and 8 direct push probes (July-September 2007);
- installation of 8 monitoring wells (March 2008);
- collection of 155 soil samples (from soil boring, direct push probes, drilling of monitoring wells and 2 samples from top soil in agriculture land in Gorno Lisiče);
- one sample of street dust (collected from paved road near the electrolysis plant);
- one sediment sample of a sewer of the site;
- 15 and 17 groundwater samples from existing, new, drinking and abstraction wells, collected in March and July 2008 campaigns, respectively;
- 11 soil gas samples; and
- 75 construction material samples.

The investigation of soil contamination at the site in unsaturated zone made in August-September 2007, included borings located throughout the site Sectors from A to E. Gas sampling was also made at a depth of about 2 m bgl in the zone of expected highest Volatile Organic Compound (VOC) contamination (area of former monochloroacetic acid production, Sector C).

Data relevant to groundwater contamination were gathered in two campaigns carried out in March and July 2008 through a systematic investigation including:

- two existing wells, HS-1 and HS-2, inside the OHIS limits, installed in 2001 for a previous investigation, near the electrolysis plant and to the HCH dump;
- the 8 wells, i.e. MW1 to MW8, installed inside the OHIS limits, by Enacon in 2008, reaching a depth of about 12 m bgl, with the exception of the MW5 well reaching 15 m bgl;
- domestic wells (DW1 to DW5), outside the site; and
- extraction wells of OHIS, outside the site, consisting in well field Lisiče 1 (No. 8 wells in total) and well Lisiče 2.



All collected soil, sediments and groundwater samples were sent to a chemical laboratory for the analysis of the COCs.

Following a standard and internationally recognized approach, in absence of national soil/groundwater screening levels, the soil data gathered during the site investigation were correctly compared with the Dutch Intervention Values (DIV).

## 4.2 SUMMARY OF CHARACTERIZATION RESULTS

The last site characterization conducted by ENACON in 2007-2008 confirmed the presence of HCH isomers and Hg at significant concentrations (exceeding the DIV) in subsurface soil beneath the OHIS site as well as the presence of VOCs (namely Tetrachloroethene [PCE], and Trichloroethylene [TCE]) in the interstitial gas in the unsaturated zone beneath the former Monochloroacetic Acid Production Plant (Sector C). Chlorinated Hydrocarbons (CHC, namely 1,2-cis-dichloroethene [1,2-cis-DCE], TCE, PCE and 1,1,2,2-Tetrachloroethane [PCA]) were also found groundwater during the 2008 monitoring campaign.

### 4.2.1 HCH Isomers in Dumpsites

As reported in Section 2.3, two separate dumpsites with different extension and waste characteristics are present at the site. The widest one ( $\alpha+\beta$ -HCH isomers dump) cover an area of about 5,000 m<sup>2</sup> (100m  $\times$  50m) while the smaller dump ( $\delta$ -HCH) cover actually an area of 1,250 m<sup>2</sup> (35m  $\times$  35m).

ENACON 2008 investigation (ENACON 2007, 2008a) confirmed that in the  $\alpha+\beta$ -HCH dump the waste was originally put into direct contact with the natural ground without using bottom lining. The  $\delta$ -HCH dump consists of five underground concrete basins covered by natural soil.

Based on the ENACON 2008 drilling campaign, comprehensive of 49 borings on the whole, layers of waste material of different thickness were physically described in particular within the following boring logs: S-B-05, S-B-06, S-B-07, S-B-08, S-B-09, S-B-10, S-B-11, S-B-12, pertaining to the  $\alpha+\beta$ -dump site, and S-B-02 and S-B-04, within the  $\delta$ -HCH dumpsite (see Drawing 2).

Samples of almost pure waste, or waste material variably mixed with filling material, were collected and analyzed from boreholes S-B-02, S-B-03a,b, S-B-04, S-B-05, S-B-06 and S-B-11. HCH isomers sum concentrations around 10% in weight were detected within the dumpsites with peaks of concentration of about 80 % in borehole S-B-02 and “pure alpha-HCH” in samples taken from boreholes S-B-05 and S-B-11, that overall indicate a strong heterogeneity in the piled material.

These three waste samples having the highest HCH concentrations in dumps were characterized for their HCH isomers content as follows:

- about 13% wt  $\alpha$ -HCH, 1% wt  $\beta$ -HCH, 35% wt  $\gamma$ -HCH (lindane) and 32% wt  $\delta$ -HCH in sample S-B-02, with a dry matter content of about 94 wt%, collected at a depth of 2.0-2.2 m bgl within the  $\delta$ -dump;
- almost pure  $\alpha$ -HCH for both 2 samples of waste collected within the  $\alpha+\beta$ -dump (sample depth of 3.2-3.5 m bgl in borehole S-B-05 and 1.8-2.0 m bgl in borehole S-B-11); these two samples have a dry matter content of about 93 wt%.

The analyses of the  $\alpha+\beta$ -dump waste, resulting in practically pure  $\alpha$ -HCH, are not in line with data from Eptisa 2007 which reports around 11-12%  $\beta$ -HCH in the HCH mixture of the



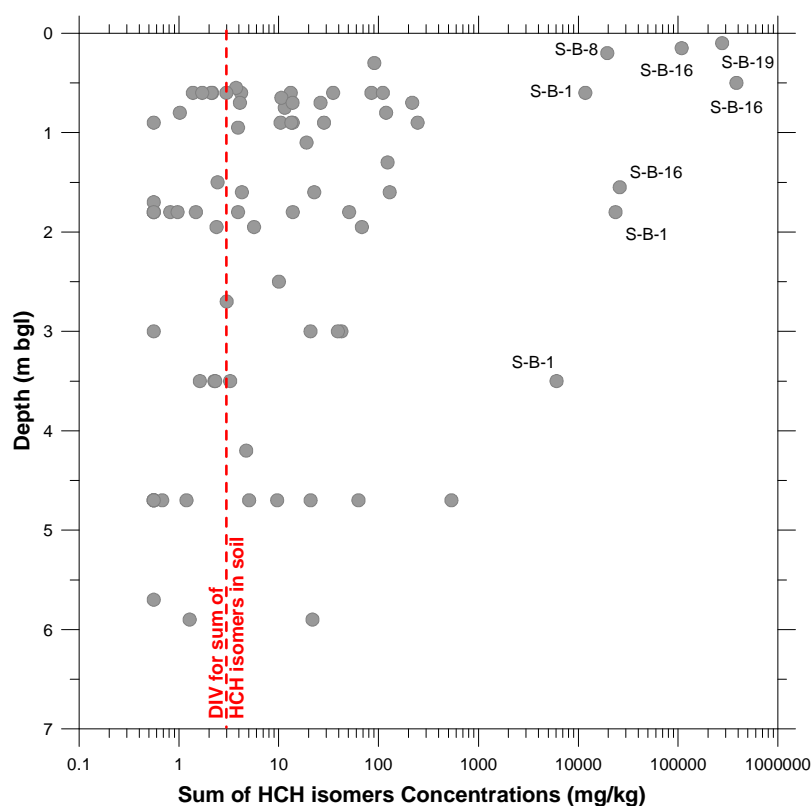
$\alpha$ + $\beta$ -dump waste. Instead, relative percentages of the HCH isomers in  $\delta$ -waste dump are fair in agreement between the two references but some heterogeneity seems to exist in the dumped material (analyses, reported to 100, of HCH-isomers: 16% of  $\alpha$ -HCH, 1% of  $\beta$ -HCH, 44% of  $\gamma$ -HCH and 39% of  $\delta$ -HCH of ENACON sample versus the 22-26% of  $\alpha$ -HCH, 5-7% of  $\beta$ -HCH, 16 – 19% of  $\gamma$ -HCH and 38-50% of  $\delta$ -HCH of EPTISA 2007 estimation).

According to the stratigraphic records from ENACON investigation, thickness of the waste in  $\alpha$ + $\beta$  dump varies from 3.2 to 4.6 m whereas the average thickness of the waste in the  $\delta$ -HCH dump is of about 1.6 m.

#### 4.2.2 HCH Isomers in Soil

The 49 soil borings performed during the 2007-2008 campaign were distributed throughout the target area Sectors (Enacon 2007, 2008a, 2008b, 2008c, 2008d). Soil samples were collected to a maximum depth of about 6 m bgl and analyzed for the four HCH isomers.

Surficial soil (until 1 m depth) was found strongly impacted by HCH isomers in most of the investigated areas. The highest concentrations were found under and close to the HCH dumps where the sum of the HCH isomers exceed DIV limit more than 100 times in some cases (see Figure 4.1; with heavily contaminated soil in those boreholes closely contouring the  $\delta$ -HCH dump, i.e., S-B-01, S-B-16, and S-B-19). With the increasing of sampling depth, the spatial distribution of the contamination decreases; however DIV limits are exceeded in several locations, and in particular under the HCH dumps, also in the deepest sampled layer, around 5-6 m bgl (Drawings 3 and 4).



**Figure 4.1: Soil Sampling Points Exceeding DIVs for sum of HCHs at the Different Depths**



Therefore, the potential HCH contamination of surficial soil (DIV exceedances) was found not only below the two HCH dump sites, but almost everywhere in the target area of the OHIS site, even not directly connected to lindane production and/or storage, while deep soil contamination was found mainly under the two HCH dumps and in the South-western part of the Sector C.

Table 4.1 summarizes the main statistical parameters of the datasets for HCH isomers in soil (excluding samples collected above ground level, within the thickness of the dumpsites, classified as waste or waste-containing material and described above). The number of samples actually collected, number of data below the Method Detection Limit (MDL), the minimum, maximum and average values of the raw data are specified in the Table, as well as the percentage (%) of data exceeding the DIVs for HCH sum in soil (note that the DIVs were not defined for single HCH isomers but only for the sum of 4 HCH isomers for which a value equal to 2 mg/kg is set).

**Table 4.1: Main Features of HCH- Isomers Dataset for In-Place Soil**

COC	No. Data [Hard Data + <MDL <sup>1</sup> ]	Min-Max (mg/kg)	Avg. (mg/kg)	DIV	Data exceeding DIV (%)
Hexachlorocyclohexane, alpha	80 [62+18]	1.00E-1 9.43E+4	2.84E+3	n.d. <sup>2</sup>	n.a. <sup>3</sup>
Hexachlorocyclohexane, beta	80 [51+29]	1.00E-1 1.21E+4	2.91E+2	n.d.	n.a.
Hexachlorocyclohexane, delta	80 [59+21]	1.00E-1 1.38E+5	2.45E+3	n.d.	n.a.
Hexachlorocyclohexane, gamma	80 [63+17]	1.00E-1 2.69E+5	5.15E+3	n.d.	n.a.
<b>HCH sum<sup>4</sup></b>	80	5.60E-1 3.84E+5	1.07E+4	2	<b>66%</b>

<sup>1</sup> Undetected concentrations (i.e., below the MDL) were included in the sample dataset by substitution of the reported value with ½ MDL

<sup>2</sup> DIV not defined

<sup>3</sup> Not applicable

<sup>4</sup> Arithmetical sum of the HCH isomers concentrations (with ½ MDL substitutions)

#### 4.2.3 Mercury in Soil

A subset of soil samples collected from boreholes in the plant Sectors A, B, C and D were also analyzed for their Hg content. Mercury contamination resulted to be limited to the former electrolysis plant, with a bigger area below the electrolysis buildings (borings S-D-02, S-D-05, S-D-08) and one isolated hot-spot (borehole S-D-07) to the East of the buildings (see Drawing 5).

The available datasets for Hg consist in total of 37 different soil sampling locations.

Table 4.2 summarizes the main statistical parameters of the datasets for Hg including number of samples actually collected, number of values below the MDL, the minimum, maximum and average values of the raw data, and the percentage of data exceeding the DIVs.



**Table 4.2: Main Features of Hg Dataset in Soil**

<b>COC</b>	<b>No. Data [Hard Data + &lt;MDL<sup>1</sup>]</b>	<b>Min-Max (mg/kg)</b>	<b>Avg. (mg/kg)</b>	<b>DIV</b>	<b>Data exceeding DIV (%)</b>
<b>Mercury</b>	37 [19+18]	1.50E-1 3.36E+2	2.88E+1	10	<b>19%</b>

<sup>1</sup> Undetected concentrations (i.e., below the Method Detection Limits) were integrated in the sample dataset by substitution of the reported value with ½ MDL.

#### **4.2.4 Chlorinated HYDROCARBONS in Soil**

Only trace amounts of TCE and PCE were found in soil samples: in the order of tens of mg/kg in some cases but below the MDL for almost all samples. However, TCE and PCE were found in high amounts in soil gases (up to 2940 mg/m<sup>3</sup>) during the soil gas monitoring at shallow depth (about 2 m bgl).

Therefore, as regards CHC contamination, discrepancies currently exist between interstitial gas analyses (which resulted above DIVs) and soil analyses (almost below DLs) and the position and volume of a “secondary contamination source” within the soil cannot be identified.

#### **4.2.5 Chlorinated Hydrocarbons and HCH in Groundwater**

During the measurements performed in March-July 2008 (ENACON, 2008c), the shallow aquifer was found at a depth of about 8-8.5 m bgl within the alluvial sediments (gravels, and loamy gravels). The uppermost layer of alluvial sediments comprises clayey silt to silty clay (thickness 1.5-5.2 m). A relatively low permeable layer of clayey/silty sediments was found investigation at about 10-12 m bgl, and this is believed the base of the shallow aquifer.

Analysis of groundwater highlighted CHC contamination (in particular, TCE, PCE and PCA) in the shallow aquifer beneath the site, with a maximum amount of CHC higher than 12 mg/l and an estimated plume width and elongation of at least 200 m and 600 m, respectively. CHC contaminated waters mainly interest the well MW6, located close to the ASTs for TCE-PCA (with sum CHC of about 12 mg/l), well MW3, also in the North sector of the site, and wells MW7 and MW8 located near the northern boundary of the site and extend down-gradient off-site (DW4) whereas trace amounts of CHC are found in OHIS wells at 2-2.3 km far from the site.

HCH isomers were also found in shallow groundwater, with maximum concentration of 30-50 µg/l (plume width and elongation approx. 150 and 800 m). Contamination of groundwater by HCH isomers was found in most of the site wells, with maximum concentrations corresponding to MW1 and MW2 close to lindane production and storage area and the HCH dump. HCH contamination, as for CHC, extends down-gradient (eastward) towards the DW-4 well.

Peaks concentrations for CHC and HCH in groundwater were found in different areas of the site, being the CHC plume mainly extended on the Northern sector of the site and the HCH in its Southern part (according to the location of the two different primary sources of contamination). Both plumes are stretched out in the W-E direction. The contamination plumes partly overlap and both extend off-site eastward, following down gradient direction of groundwater.



## **5 SITE-SPECIFIC HUMAN HEALTH RISK ASSESSMENT**

### **5.1 HHRA SCOPE AND ADOPTED APPROACH**

According to the American Society for Testing of Materials (ASTM) Standard Guide for Risk-Based Corrective Action (E2081-00) (ASTM, 2004), the risk assessment is the analysis of the potential for adverse effects on human receptors and ecological receptors caused by a COC from a contaminated site. The risk assessment activities are the basis for the development of corrective action goals and for the determination of where remedial actions are actually required.

In general, the HHRA procedure follows a tiered approach based on three subsequent levels of assessment:

- Tier 1: Risk analysis conducted at this level refers to site-generic conditions and can be used as a screening step. It takes into account direct or indirect exposure pathways, conservative exposure factors, analytical solution to transport models and on site receptors only. By applying this level of analysis, the so-called Risk Based Screening Levels (RBSLs) are obtained;
- Tier 2: This level of analysis refers to site-specific conditions and provides, therefore, a more detailed evaluation with respect to Tier 1. It involves once again the use of analytical models for estimating the concentration at the point of exposure, considering a homogenous and isotropic environmental media. By applying this level of analysis the Site Specific Target Levels (SSTLs) are calculated, and can be considered as site specific remediation targets. Both on site and off site receptors are considered; and
- Tier 3: The level 3 analysis allows a more detailed site-specific evaluation. It uses numerical models and probabilistic analysis that allow accounting for the heterogeneity of the subsoil, and for the complex geometry of the contamination source. Its application requires, however, a deeper knowledge of the physical system and, consequently, a very detailed site characterization.

The HHRA procedure can be conducted in the “Forward Mode” (FWM) or “Backward Mode” (BWM). The FWM allows estimating the health risk for the exposed receptor, either located within the site (on site) or at some distance (off site), starting from a representative concentration at the source of contamination. Starting from health risk levels considered acceptable to the exposed receptor, the BWM allows calculating the highest concentration at the source compatible with the condition of acceptability of the risk, i.e. the so-called SSTLs.

The ASTM Guide (ASTM, 2004) and the Italian “Guidelines for the human health risk analysis application for the impacted sites” (APAT, 2008) are the reference manuals which have been used for the Risk Assessment development. These guides provide the criteria for the development of a Risk-Based Corrective Action (RBCA) at chemical release sites based on protecting human health and the environment.

According to ASTM Guide, the RBCA process, by using a tiered approach that integrates site assessment and response actions with human health and ecological risk assessment, determines the need for remedial actions and allows tailoring corrective action activities to site-specific conditions and risks.



In general, the RBCA should be developed through the following operative steps:

- Step 1: development of the conceptual model of the site based on the findings of the site investigations and the knowledge of the geological, hydrogeological and hydro-chemical features of the site;
- Step 2: selection of Tier 1 to Tier 3 risk analysis and of the allowable risks;
- Step 3: development of the HHRA (typically Tier 2);
- Step 4: selection of the most appropriate SSTLs; and
- Step 5: development and implementation of the CD.

The RBCA Tool Kit for Chemical Releases software, version 2.5 (GSI Environmental, 2007), has been used for evaluating the SSTLs of the OHIS Site.

The RBCA Tool Kit is the most widely adopted risk calculation software worldwide. The RBCA Tool Kit is designed to meet the requirements of the ASTM Guide (ASTM, 2004). This tool applies the equations suggested also by the Italian Guidelines (APAT, 2008) for the definition of the input parameters and back calculation of the SSTL.

The RISC 4.0 (Risk-Integrated Software for Clean-Ups) developed by British Petroleum Oil International (BP, 2001) was also used to carry out some additional runs related to the shallow aquifer potential use for irrigation purposes.

## 5.2 DESCRIPTION OF THE ADOPTED SITE CONCEPTUAL MODEL

### 5.2.1 Physical Features of the Site

Based on the findings of the past conducted investigations at the site and related boring logs (ENACON 2007), two zones of near homogeneous lithological features were identified and a schematic multi-layer site model was consequently elaborated to support HHRA computations.

The physical model for the subsoil included:

- a first surficial layer from the ground level to 2.5 m bgl made by sandy-clay; and
- a second layer, from 2.5 m bgl to the top of shallow aquifer (average measured water depth of 8.2-8.7 m bgl in March-July 2008, respectively), mainly composed by sand.

The schematic stratigraphy of the site is reported in Figure 5.1, which also displays the identified sources of contamination for HCH isomers.

### 5.2.2 Schematization of the Sources of Contamination for HHRA

This sub-section describes the criteria followed for the schematization of the sources of contamination and the estimated areas/volumes for each of the identified “secondary sources” used for human health risk assessment simulations. These secondary sources (each of them connected to specific exposure pathways) comprise in the study case the surface soil (0-1 m bgl), the deep soil (>1 m bgl) and the groundwater. The procedure for the delimitation of the surface and volumetric extent of each contamination source, and the further definition of a “representative concentration” at the source, was based on the Thiessen polygons method and the methodological criteria suggested by the APAT guidelines for the application of the quantitative risk analysis to the contaminated sites (APAT, 2008).



#### 5.2.2.1 HCH Isomers

Data gathered from the previous investigation described in Section 4 have been plotted to graphically evaluate the area of potential contamination through the Thiessen polygons method (as suggested by APAT, 2008) and cross-sections have been developed to evaluate the vertical distribution of the contamination and the potential presence of different contamination layers.

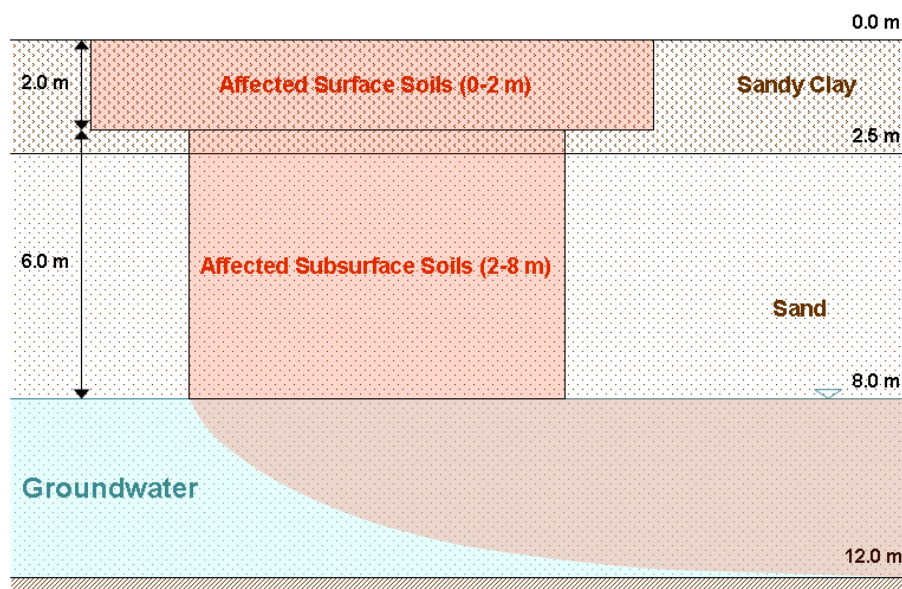
Based on the results of the graphical representation of the site contamination (reported in Drawings 3, 4 and 6), two zones of contamination were identified at different depths, and the following simplified multi-layer source model was consequently elaborated:

- a first layer from the ground level to 2 m bgl, which is extended over almost all the OHIS site (estimated surface of 46107 m<sup>2</sup>, Table 5.1), with the exclusion of only small sections of the former lindane production and storage area (Sector A), the former electrolysis plant (Sector D) and the flammable storage area (Sector E) [see Drawing 3]; and
- a deeper layer, from 2 to 8 m bgl (top of shallow aquifer), for an estimated surface of 18817 m<sup>2</sup> (Table 5.1), located under the HCH dump sites and extended to the northeast beneath the former lindane production area (Sector A) and the former electrolysis plant (Sector D) [see Drawing 4].

The schematic cross section of the identified geometry for the source of contamination for HCH isomers in soil is reported in Figure 5.1.

**Table 5.1: Definition of the Source of Contamination for HCH in Soil**

Layer	Predominant Lithology	Estimated Surface / Volume (Thiessen Polygons Method)
Layer I: Surface Soil (0-2 m bgl)	Sandy Clay	46,107 m <sup>2</sup> / 92,214 m <sup>3</sup>
Layer II: Subsurface Soil (2-8 m bgl)	Sand	18,817 m <sup>2</sup> / 112,902 m <sup>3</sup>



**Figure 5.1: Cross Section of the Identified Sources of Contamination for HCH Isomers in Soil over a Schematic Stratigraphy of the Site**



For the specific aim of HHRA computation, the first layer of HCH isomer contamination in soil, defined as described above from the ground level to 2 m bgl, was further subdivided in 0-1 m and 1-2 m layers in order to account for the different exposure pathways of the two secondary sources for surficial and sub-surficial soil (i.e., dermal contact vs. leaching to groundwater etc.).

Note that the second layer has been conservatively extended from 2 to 8 m bgl (top of shallow aquifer), last investigation did not reach the bottom of contamination (the deepest collected soil samples, approx. 5-6 m of depth, resulted to be still contaminated, see Drawing 6).

Although the DIVs were not defined for single HCH isomers but only for the sum of HCH isomers (arithmetical sum of the 4 isomers), RBCA simulations were carried out on single HCH isomers because of the different toxicity and carcinogenicity of each compound.

According to the international carcinogenicity classifications, all the HCH isomers can be considered as human carcinogenic (see Table 5.2). Therefore, for risk calculations, both the toxicological and the carcinogenic properties of the single compounds have been considered.

**Table 5.2: COCs Carcinogenicity Classifications**

COC	CAS	USEPA-IRIS <sup>1</sup>	IARC <sup>2</sup>	EU <sup>3</sup>
Hexachlorocyclohexane, alpha	319-84-6	B2	2B	3
Hexachlorocyclohexane, beta	319-85-7	C		
Hexachlorocyclohexane, delta	319-86-8	D		
Hexachlorocyclohexane, gamma	58-89-9	n.a. <sup>4</sup>		
Mercury	7439-97-6	D	3	n.a.
Trichloroethylene (TCE)	79-01-6	n.a.	2A	2
Tetrachloroethane, 1,1,2,2- (PCA)	79-34-5	C	3	n.a.
Dichloroethylene, cis-1,2- (1,2-cis-DCE)	156-59-2	D	n.a.	n.a.
Tetrachloroethylene (PCE)	127-18-4	n.a.	2A	3

<sup>1</sup> International Agency for Research on Cancer (IARC) classification:

- 1: Carcinogenic to humans;
- 2A: Probably carcinogenic to humans;
- 2B: Possibly carcinogenic to humans;
- 3: Not classifiable as to its carcinogenicity to humans;
- 4: Probably not carcinogenic to humans.

<sup>2</sup> USEPA Integrated Risk Information System (IRIS) classification:

- A: Human carcinogen;
- B: Probable human carcinogen (B1: limited evidence on humans, and sufficient evidence in animals; B2: Sufficient evidence from animal studies and inadequate or no data from epidemiologic studies);
- C: Possible human carcinogen;
- D: Not classifiable as to human carcinogenicity;
- E: Evidence of non-carcinogenicity to humans.

<sup>3</sup> EU classification (Commission Directive 2009/2/EC of 15 January 2009):

- 1: Substances known to be carcinogenic to humans;
- 2: Substances which should be regarded as if they are carcinogenic to humans;
- 3: Substances which cause concern for humans, owing to possible carcinogenic effects but in respect of which the available information is not adequate for making a satisfactory assessment.

<sup>4</sup> n.a.: not assessed



Concerning the main statistical features of the HCH-isomers datasets in soil, they resulted to be, overall, not unimodal. As a matter of fact, the relevant probability plots highlighted either the presence of two superimposed populations or a certain number of outliers. These features of the datasets introduced some procedural difficulties in the definition of a reliable value for a “representative concentration” at the source for each of the four HCH isomers. Actually, datasets referring to drilling campaigns encompassing more than 10 boreholes should be handled through statistical analysis (APAT, 2008) in order to properly select a representative concentration at the source zone ( $C_s$ ); however, orders of magnitude of difference in the estimation of  $C_s$  for HCH isomers would result by considering either the UCL of the mean of one of the two partitioned populations, or the UCL of the mean of the datasets as it is, or the entire dataset excluding outliers. Considering these strong uncertainties in the HCH data processing, RBCA runs were performed in BWM for HCH and in FWM only for the confirmatory runs, i.e., to assess the compliance with respect to the cumulative risk (see Report 09-521-H2-Rev.0, D’Appolonia, 2010a).

#### 5.2.2.2 Mercury

Estimated surface of the source of contamination for Hg in soil through the Thiessen Polygons Method is reported in Table 5.3. Figure 5.2 depicts the schematic cross section of the identified geometry for the source of contamination in soil.

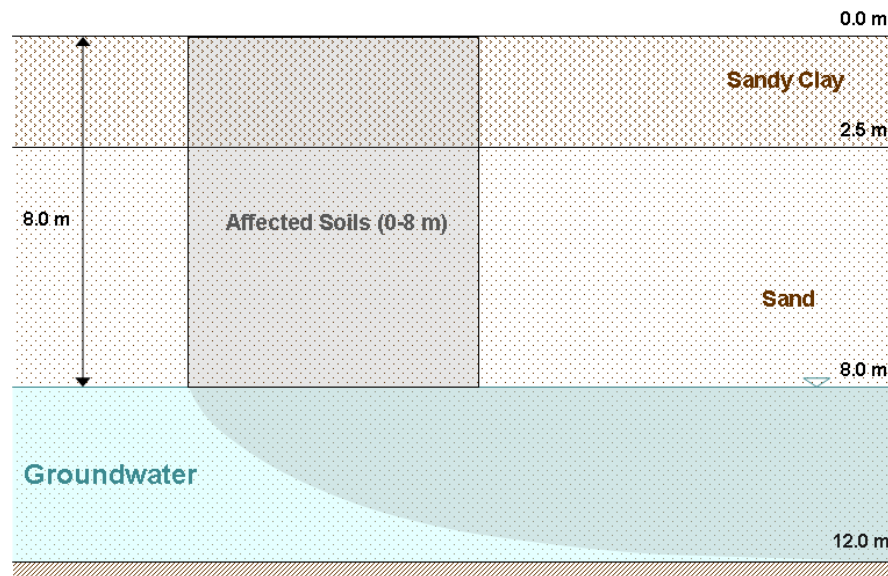
As for the HCH discussed above, the bottom of contamination was not reached at the end of the performed boreholes (around 5-6 m bgl, see Drawing 6); therefore, a unique contaminated layer extending from the soil surface to the top of the aquifer has been considered for the HHRA, further subdivided in surface (0-1 m bgl) and subsurface soil (1-8 m bgl). The Hg hot-spot, limited to the first 3-3.5 m bgl (see Drawing 6), was not considered in the HHRA, since a limited soil excavation and disposal of can allow the complete risk elimination.

Concerning the Hg in soil RBCA simulations were performed in FWM since the limited number of performed boreholes allows selecting as representative concentration of the source zone simply fixing it equal to the maximum concentration value.

**Table 5.3: Definition of the Source of Contamination for Hg in Soil**

Layer	Predominant Lithology	Estimated Surface / Volume (Thiessen Polygons Method)
Layer I: Soil (0-8m bgl)	Sandy clay (0-2.5 m)	3,777 m <sup>2</sup> / 30,216 m <sup>3</sup>
	Sand (2.5-8)	





**Figure 5.2: Cross section of the Identified Sources of Contamination for Mercury in Soil over a Schematic Stratigraphy of the Site**

#### 5.2.2.3 Chlorinated Hydrocarbons

As regards CHC contamination, the discrepancies between interstitial gas analyses (which resulted above DIVs) and soil analyses (which resulted below the detection limit for almost all samples) do not allow clearly identifying the contamination source position and volume. Furthermore, soil gas is not an easily implementable contamination source in HHRA models, which often considers only the interstitial gases generated by soil and/or groundwater contamination (secondary sources) through volatilization.

Therefore, only the presence of CHC contamination in groundwater was considered as secondary source for the HHRA.

The sum of the Sector C and Sector D surfaces (equal to 29796 m<sup>2</sup>) was assumed as representative contamination plume extension for the HHRA development.

#### 5.2.3 **Soil and Transport Parameters**

Input data for RBCA simulations concerning soil and transport parameters were chosen as described in the following:

- Organic Carbon Fraction (foc): fraction of organic carbon in soil was estimated based on relationships between grain size and TOC (g/kg) from literature data (Konen et al., 2003; Plante et al., 2006); for the “sandy-clay” lithology (referring to the approximate proportion: 50% clay – 50% sand) a foc of about 0.045 was computed and set in the relevant runs against the RBCA default foc value of 0.01; this default value of 0.01 was maintained instead for the runs involving “sand” lithology;
- foc in the saturated zone: it was set about one order of magnitude less than value characterizing the vadose zone (respecting the default relationship);
- Effective Porosity: a value of 0.28 was inputted for the “sandy clay” lithology and 0.353 for the “sand” lithology based on data from the APAT Manual (APAT, 2008);



- Groundwater Gradient: it was estimated on the basis of water level measurements carried out in the surveys of March 2008 and July 2008 in the OHIS area (ENACON, 2008c); data referring to couples of wells sufficiently spaced and aligned on a E-W direction (groundwater direction) are used in the computation, namely: MW4-MW8; MW5-MW1 and MW4-HS1; starting from the corresponding groundwater depths a mean groundwater gradient of about 0.0013 was computed for the site;
- Net Infiltration: based on the average annual precipitation of 500 mm (MEPP, 2006) a value of 4.5 mm/year was calculated by RBCA TK for “sandy clay” and a ten times higher value for sands;
- Water pH: it was set as the average value of the groundwater measurements (7.4) carried out in the March and July 2008 campaigns in the OHIS area (ENACON, 2008c);
- Hydraulic conductivity: adopted values were  $3.33 \cdot 10^{-5}$  cm/s for sandy-clay and  $4.05 \cdot 10^{-3}$  cm/s for sands (APAT, 2008).

#### 5.2.4 Contaminants of Concern

The COCs for the OHIS site are represented by the HCH isomers and mercury, both exceeding the relevant DIVs, selected as screening values for the potential contamination assessment.

Dioxins in soil, sum of Chlorobenzenes, sum Dichlorodiphenyldichloroethylene (DDE), Dichlorodiphenyldichloroethane (DDD) and Dichlorodiphenyltrichloroethane (DDT) were also found exceeding the DIV screening levels, but only in isolated locations (hot-spots) and therefore these contaminants were not included in the present soil risk assessment. In fact, the same locations are also affected by the main COCs (i.e. HCH and Hg) contamination, and it is assumed that their removal would lead to the consequent hot-spot elimination.

VOCs (namely, PCE and TCE) were also found in the interstitial gas of the former monochloroacetic acid production plant, but their concentrations in soil resulted below the relevant DIVs, hence soil can not be introduced as a secondary source of contamination for CHC.

HCH isomers, Mercury and CHC (1,2-cis-DCE, TCE, PCE and PCA) are the COCs for groundwater.

#### 5.2.5 Receptors

The following receptors were considered for the risk assessment:

- on site workers, including construction workers performing remediation activities (outdoor/indoor operations) within the OHIS site;
- on site receptors, potentially affected by the direct contact with the contaminated soil and by the indoor and outdoor contaminated vapour inhalation;
- off site receptors, potentially affected through contamination leaching from soil to groundwater, groundwater migration and ingestion or use for irrigation of potentially contaminated groundwater; and
- off site receptors, potentially affected by the indoor and outdoor contaminated air inhalation.

For the identified receptors (either on site or off site), both residential and commercial/industrial scenarios (in terms of exposure duration and frequency and other exposure-related parameters) were considered for the HHRA.



For the water wells outside the OHIS site, both residential scenario and the groundwater use for irrigation were considered.

Taking a conservative approach, the simulations were carried out considering the first residential community located down-gradient of the site along the groundwater flow direction as potential receptor for groundwater ingestion or use (i.e. first off site receptor at 150 m, calculated considering the maximum HCH contamination extension, corresponding to the contaminated topsoil).

As potential receptors for indoor/outdoor inhalation the nearest residential and commercial area were considered (conservatively neglecting the prevailing wind direction) at 80 m (off site residential receptor) and at 100 m (off site commercial receptor, with reference to the extension of the HCH contaminated topsoil).

### 5.2.6 Exposure Pathways (Transport Mechanisms)

The following Sections outlines the migration pathways that have been considered for the HHRA at the OHIS site, considering the site specific characteristics gathered from the available documentation and data.

#### 5.2.6.1 Groundwater Exposure

This exposure pathway involves the direct contact/ingestion of contaminated groundwater, which can occur in the case of a direct connection between the impacted water and the receptors, typically via drinking water well, or indirectly via groundwater use for irrigation.

Given the hydrogeological settings of the site (i.e. the presence of a shallow water bearing unit) and the known groundwater contamination level downgradient to the OHIS site, the use of the shallow aquifer for drinking purposes has been reportedly suspended several years ago in the surrounding area. However, detailed information does not exists on the lateral continuity characteristics of this shallow aquifer outside the site (i.e. connection about shallow and deeper aquifers) and the presence of single domestic drinking water wells cannot be excluded; therefore, the groundwater ingestion pathway has been conservatively included in the HHRA for all off site receptors and excluded only for on site wells.

Furthermore, the remediation targets selection need to consider the National Regulation on groundwater quality.

In particular, with reference to groundwater quality standards actually in force in the Republic of Macedonia, the Regulation for “Classification of Water” defines 5 quality classes for surface waters, water courses, natural and artificial lakes and groundwater, and gives the maximum allowed concentrations for the different classes. According to Article 4 of the Regulation for “Categorization of Watercourses, Lakes, Water Accumulations and Underground Waters”, groundwater is categorized in I-II Class, with the applicable limits for the COCs detected at the OHIS site reported in the following table.

**Table 5.4: Quality Standards for Class I-II Waters**

COC	Upper Concentration Value (µg/L)
γ-Hexachlorocyclohexane (Lindane)	0.01
Mercury	0.2
Trichloroethylene	20
1,1,2,2-tetrachloroethane	2
Dichloroethylene	1.5
Tetrachloroethylene	2



It must be noticed that such limits are very stringent, comparable with U.S. EPA standards for water which can be used for drinking purposes, and could lead to SSTLs similar or even lower than those calculated for the groundwater direct ingestion scenario through drinking water wells.

Therefore, a final evaluation of the quality standards potentially applicable to the shallow aquifer to allow its use for irrigation purposes has been carried out through a dedicated software (RISC 4.0) able to simulate the following additional exposure pathways and to back-calculate the groundwater maximum allowable levels:

- ingestion of home-grown vegetables irrigated with groundwater;
- ingestion of irrigation water;
- dermal exposure to irrigation water;
- inhalation of irrigation water spray.

#### 5.2.6.2 Outdoor Volatilization

This scenario takes into consideration that contaminants detected in surficial soil, subsoil and groundwater could potentially diffuse through the soil column and migrate to the atmosphere. As soon as the volatile constituents reach the surface, due to atmospheric dispersion, contamination could reach both on site and off site receptors.

#### 5.2.6.3 Indoor Volatilization

This scenario considers that volatile constituents in the contaminated soil could potentially diffuse through soil and migrate into enclosed space of buildings, by diffusion through the foundation slabs and/or following preferential pathways due to the presence of cracks.

Since the future presence of residential and/or commercial buildings on site can not be excluded, this exposure pathway has been considered for the HHRA.

## 5.3 SUMMARY OF THE HHRA RESULTS

### 5.3.1 Contaminated Soil Exposure

The following Sections summarize HHRA outcomes taking into account the 3 considered scenarios for land destination, i.e. on site commercial, on site residential and off site residential, and focusing on their possible implication on soil remediation.

#### 5.3.1.1 Hexachlorocyclohexane Isomers

Outcomes of the HHRA developed for HCH isomers indicate that the direct contact pathways (ingestion, dermal contact, inhalation) associated to the on site residential receptors are the limiting pathways, giving the lowest SSTLs for the soil cleanup.

Table 5.5 presents the remediation targets for soil relevant to different site uses and receptors. When simulations provided an unspecified SSTL value ( $>C_{sat}$ , not computable), SSTL values were conservatively taken equal to the corresponding  $C_{sat}$  values (reported in *italic* in Table 5.5) as they are the maximum quantifiable values for which cumulative risks is satisfied.



**Table 5.5: HCH SSTLs for Top, Shallow and Deep Soil for On Site Commercial, On Site Residential and Off Site Residential Receptors (Not Allowing Groundwater Use)**

COC	SSTL (mg/kg) On Site Commercial			SSTL (mg/kg) On Site Residential			SSTL (mg/kg) Off Site Residential		
	0-1 m bgl	1-2 m bgl	2-8 m bgl	0- 1 m bgl	1-2 m bgl	2-8 m bgl	0- 1 m bgl	1-2 m bgl	2-8 m bgl
alpha-HCH	0.39	20.93	60.86	0.001	9.55	9.88	0.34	12.46	60.86
beta-HCH	1.33	33.8	33.8	0.001	33.8	33.8	1.19	33.8	33.8
delta-HCH	0.9	558.7	992.5	0.016	118.39	127.44	3.34	332.59	992.5
gamma-HCH	1.91	284.8	284.8	0.002	284.8	284.8	129.89	284.8	284.8

Considering the commercial scenario as the most probable land use scenario for the site, the needed abatement of HCH concentrations for the topsoil layer (0-1 m bgl) is of about 3 order of magnitude for alpha-HCH and 1-1.5 orders of magnitude for the remaining three isomers.

The underlying soil layers (i.e., 1-2 m bgl and 2-8 m bgl) would require a much more limited intervention in case of a commercial use of the OHIS area; in particular, for depths greater than 1 m bgl, the area to be remediated would be only restricted to the Sector B, mostly below the HCH dumps. The relevant SSTL values are in fact higher than the most part of the data distribution, and only some outliers exceed SSTLs.

Considering the most limiting scenario (i.e. on site residential receptors) very stringent values are obtained in particular for the topsoil, where:

- an abatement in the range of 3 to 5 orders of magnitude is needed for HCH isomers; and
- the computed SSTLs are 1-2 order of magnitude lower than the minimum HCH concentration value detected in soil samples (taken equal to ½ of the MDL = 0.2 mg/kg).

SSTLs calculated for deeper layers led, as above for the commercial scenario, to a very significant reduction of the area to be remediated. Only the alpha-isomer requires a slightly wider intervention in layer 2 with respect to the corresponding case for commercial scenario.

#### 5.3.1.2 Mercury

The HHRA carried out for the Hg contamination showed that the indoor air inhalation is the limiting exposure pathway, probably due to the high Hg volatility (the Henry's Constant, which define the amount of a gas that dissolves in a liquid, is 0.47 for the mercury, about two orders of magnitude higher than those of the HCH isomers).

The target concentration proposed for the industrial/commercial use of the OHIS site resulted to be 5.18 mg/kg; while considering the same indoor air inhalation exposure pathway applied to residential receptors, the relevant SSTL resulted about three times lower (Table 5.6).

The exceeding points, in case of both commercial and residential destination, are all located in Sector D and (partly) Sector C.



**Table 5.6: Hg SSTLs for Top and Deep Soil for On Site Commercial, On Site Residential and Off Site Residential Receptors  
(Not Allowing Groundwater Use)**

	<b>SSTL (mg/kg) On Site Commercial</b>	<b>SSTL (mg/kg) On Site Residential</b>	<b>SSTL (mg/kg) Off Site Residential</b>
<b>COC</b>	<b>0-8 m bgl</b>	<b>0-8 m bgl</b>	<b>0-8 m bgl</b>
Mercury	5.18	1.50	20.55

### 5.3.2 Groundwater Exposure

In the following Sections HHRA outcomes are presented, focusing on their possible implication on soil and groundwater remediation target and goals.

Groundwater exposure pathway was evaluated in terms of both ingestion of contaminated groundwater, typically via drinking water wells, and direct contact which can occur during irrigation activities. Indirect pathways such as indoor and outdoor vapours inhalation have been also considered.

Furthermore, the remediation targets necessary to comply with national regulations about groundwater quality standards or with specifically calculated irrigation standards are also discussed.

#### 5.3.2.1 Hexachlorocyclohexane Isomers

As regard the soil leaching to groundwater and subsequent off site groundwater ingestion pathway, the carcinogenicity of HCH isomers and the proximity of residential areas led to very stringent SSTLs for the OHIS site:

**Table 5.7: SSTLs for Groundwater Protection**

<b>COC</b>	<b>Applicable SSTL for Level 1 (0-2 m bgl) (mg/kg)</b>	<b>Applicable SSTL for Level 2 (2-8 m bgl) (mg/kg)</b>
Hexachlorocyclohexane, alpha	0.004	0.003
Hexachlorocyclohexane, beta	0.014	0.012
Hexachlorocyclohexane, delta	0.084	0.074
Hexachlorocyclohexane, gamma	0.015	0.013
<b>TOTAL</b>	<b>0.117</b>	<b>0.102</b>

Using the groundwater standards of the Republic of Macedonia as input parameters for the BWM calculation, and considering as PoC the first residential area downgradient of the OHIS site, the following the SSTLs were calculated for lindane:

**Table 5.8: SSTLs Derived from Groundwater Standards (Class I-II)**

<b>COC</b>	<b>Applicable SSTL for Level 1 (0-2 m bgl) (mg/kg)</b>	<b>Applicable SSTL for Level 2 (2-8 m bgl) (mg/kg)</b>
Hexachlorocyclohexane, gamma	0.0029	0.0026



Both approaches previously presented are not realistic for the OHIS site remediation, because: i) the shallow aquifer is not used for drinking purposes, but only for irrigation, and ii) the proposed standards for Class I-II waters are not achievable in the short period without completely eliminating the HCH isomers from the whole OHIS site, which is an alternative practically not implementable.

As alternative approach, the OHIS site could be remediated to reach safe levels for on site/off site residential receptors, and groundwater standards could be calculated based on its effective use.

To this aim, a dedicated software able to simulate the exposure pathways related to groundwater use for irrigation was used to back-calculate the groundwater maximum allowable levels for HCH isomers. The following groundwater standards have been obtained:

**Table 5.9: Calculated HCH Quality Standards for Irrigation Water**

<b>COC</b>	<b>Concentration (µg/L)</b>
Hexachlorocyclohexane, alpha	0.057
Hexachlorocyclohexane, beta	0.2
Hexachlorocyclohexane, delta	0.22
Hexachlorocyclohexane, gamma	0.28

The calculated standard for lindane, in line with international standards, resulted one order of magnitude higher than the Class I-II quality standard (0.28 mg/L vs. 0.01 mg/L).

Maximum values reported in Table 5.9 were used as input parameters for the BWM HHRA calculation, considering as PoC the first residential area downgradient of the OHIS site. The following SSTLs were calculated for HCH isomers:

**Table 5.10: SSTLs Derived from Calculated Quality Standards**

<b>COC</b>	<b>Applicable SSTL for Level 1 (0-2 m bgl) (mg/kg)</b>	<b>Applicable SSTL for Level 2 (2-8 m bgl) (mg/kg)</b>
Hexachlorocyclohexane, alpha	0.02	0.017
Hexachlorocyclohexane, beta	>7.51	>7.51
Hexachlorocyclohexane, delta	0.50	0.43
Hexachlorocyclohexane, gamma	0.08	0.07

The SSTLs derived from the calculated irrigation standards would result again in the need of a complete removal of Lindane and other HCH isomers from the OHIS site for the whole soil column (except beta-HCH, which SSTLs is above the relevant soil saturation constant).

In summary, two different approaches can be considered for the OHIS site remediation:

1. Elimination of the primary contamination source (i.e. the dump sites) and soil remediation to the SSTLs for on site residential receptor protection. This approach will allow neither to reach the quality standards suggested by the National regulations for groundwater, nor the irrigation standards calculated through HHRA. In fact, confirmatory FWM runs were carried out to calculate the minimum distance at which the irrigation standards could be reached downstream of the OHIS site, which varied from about 8 to more than 17 km. Therefore, the remediation process should be completed



with a groundwater remediation system, e.g. installing a hydraulic barrier to extract and treat the contaminated water till the irrigation/discharge standards before the reinjection into the shallow aquifer.

2. Elimination of the primary contamination source and soil remediation to the SSTLs calculated from the irrigation standards. This approach will need the treatment of the whole site to very stringent remediation levels, but would avoid the groundwater treatment system.

#### 5.3.2.2 Mercury

The HHRA showed that the potential exposure pathway related to contamination leaching from soil to groundwater is not the limiting pathway for Hg, leading to SSTLs higher than the indoor air residential inhalation. Therefore, only the direct groundwater contamination is discussed in this Section.

Following the same approach already used for HCH, an initial BWM HHRA was conducted for the Hg-contaminated groundwater plume, resulting in SSTLs of 0.038 mg/L for the off site groundwater ingestion and of 0.028 mg/L for the on site indoor residential inhalation.

Further BWM analyses were conducted to calculate the SSTLs necessary to comply either with the Macedonian groundwater standards or with the irrigation water standards calculated through HHRA (which resulted 0.04 mg/L). The results are summarized in the following table:

**Table 5.11: SSTLs for Groundwater Protection**

COC	Applicable SSTL for GW Ingestion (mg/L)	Applicable SSTL for On Site Residential Inhalation (mg/L)	Applicable SSTL for Macedonian Standard (mg/L)	Applicable SSTL for Calculated Irrigation Standard (mg/L)
Mercury	0.038	0.028	0.0016	0.32

All SSTLs are higher than Hg concentrations measured at the OHIS site (according to the data available, the highest value, obtained from the monitoring well HS-1 installed in the former electrolysis plant, is 0.01 mg/L), except the SSTL calculated to comply with Macedonian quality standards, which, however, would be reached approx. 500 m downgradient of the OHIS site.

Therefore, considering the soil remediation targets, the remedial intervention for Hg could be limited to the removal of the contaminated soils with concentration above the on site residential indoor inhalation SSTL, while monitored natural attenuation can be considered enough for groundwater, which is already not dangerous either for on site and off site residential communities or for irrigation.

#### 5.3.2.3 Chlorinated Hydrocarbons

The maximum CHC concentrations detected in groundwater were used to evaluate possible risks for on site/off site receptors. The following unacceptable risks were determined:

- carcinogenic individual risk for TCE and PCA for on site/off site residential and commercial outdoor inhalation;
- carcinogenic individual risk for TCE and PCA and cumulative CHC risk for on site/off site residential and commercial indoor inhalation;



- carcinogenic individual risk for TCE and PCA and cumulative CHC risk for off site residential groundwater ingestion; and
- toxic individual risk for TCE, PCA and PCE and cumulative CHC risk for off site residential groundwater ingestion.

Backward simulations were then conducted to determine the SSTLs for the chlorinated hydrocarbons in groundwater, considering the nearest residential communities as potential receptors for groundwater ingestion and vapour inhalation both indoor and outdoor. On site receptors were also considered (residential/commercial) scenario.

The exposure pathways related to groundwater use for irrigation purposes was simulated to back-calculate the groundwater maximum allowable levels for CHC. The following groundwater standards have been obtained:

**Table 5.12: Calculated CHC Quality Standards for Irrigation Water**

<b>COC</b>	<b>Concentration (mg/L)</b>
Trichloroethylene (TCE)	0.22
Tetrachloroethane, 1,1,2,2- (PCA)	0.04
Dichloroethylene, cis-1,2- (1,2-cis-DCE)	10
Tetrachloroethylene (PCE)	0.09

The maximum allowable concentrations calculated for irrigation and the quality standards set by the National Regulations were used to complete all possible alternatives for groundwater remediation goals/target levels.

**Table 5.13: SSTLs for Groundwater**

<b>COC</b>	<b>Applicable SSTL for Groundwater Ingestion (µg/L)</b>	<b>Applicable SSTL for On Site Indoor Inhalation (µg/L)</b>	<b>Applicable SSTL for Off Site Indoor Inhalation (µg/L)</b>	<b>Applicable SSTL for Calculated Irrigation Standards (µg/L)</b>	<b>Applicable SSTL for Macedonian Standards (µg/L)</b>
TCE	29.16	1,076.2	153.1	1,049.5	95.4
1,1,2,2-PCA	1.60	453.3	76.9	190.8	9.5
1,2-cis-DCE	746.24	1,354,687.2	176,608.9	47,704.5	7.2
PCE	6.17	2,006.0	296.2	429.3	9.5

Once again, the lowest SSTLs were calculated either considering the groundwater ingestion pathway or using the national quality standards for groundwater. Instead, the use of irrigation standards calculated through HHRA or residential scenarios led to less stringent SSTLs, corresponding to lower remediation requirements.

Further HHRA forward runs were carried out to evaluate the minimum down-gradient distance from the OHIS site at which the CHC risk for residential communities would become lower than the maximum allowable levels. The “safety zones” were evaluated both for vapour inhalation of residential communities (indoor/outdoor) and for groundwater irrigation use.



CHC toxicity for vapour inhalation reaches negligible levels already at 100 m from the site boundaries, while carcinogenic effect reach safe levels after 400 m and 700 m for outdoor and indoor inhalation, respectively.

Irrigation water standards would be exceeded in a range from 100 (considering the 1,2-cis-DCE) to 1000 m (considering the 1,1,2,2-PCA).

In any case, the not-negligible risk for on site residential community makes a remedial intervention on groundwater necessary for the OHIS site with respect to CHC contamination.

Therefore, following the same approach already used for HCH, the initial remediation effort can be focused on soil remediation. During this first remediation phase a “safety zone” of approx. 1 km should be considered. Then, a second phase with a limited intervention on groundwater should be planned to ensure the potential use of the site for residential purposes.

Even if risk has been highlighted for commercial site use due to the presence of the CHC-contaminated groundwater, it will not affect on site workers during the dumps removal and the soil remediation activities.



## 6 PROPOSED APPROACH FOR SITE REMEDIATION

### 6.1 DESCRIPTION OF THE REMEDIATION APPROACH

The HHRA simulations allowed defining the remediation targets (i.e. the SSTLs) relevant to all possible future destination of the OHIS site.

In summary, as it can be seen from Section 5.3.1, a great soil remediation effort is needed for all contaminants detected at the OHIS site (i.e. HCH isomers and Hg) at least for the surficial layer (0-1 m bgl), while limited groundwater remediation is needed for organic contaminants (i.e. HCH and CHC) to ensure residential use of the site and to reduce the risk related to irrigation. Lower remediation targets are required in case commercial destination is chosen for the OHIS site. In any case, the required abatement of the current concentrations will not be lower than three orders of magnitude, requiring very efficient remediation systems.

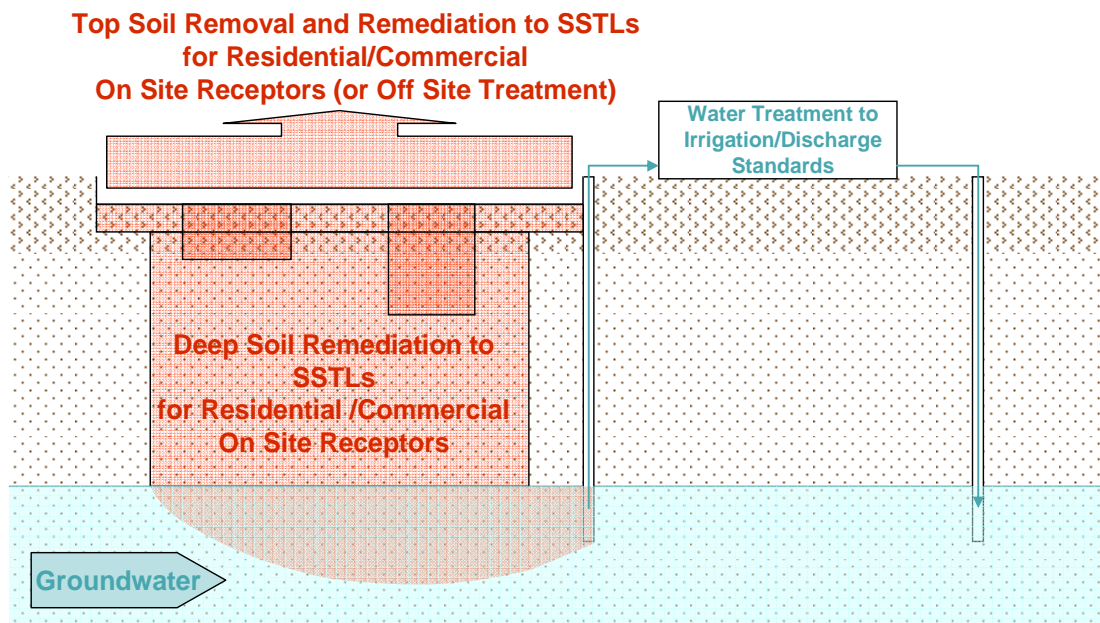
Therefore, due to the considerable amounts of waste/contaminated soils estimated and the stringent remediation targets, and in order to allow for future splitting of Project costs, a phased CD has been developed, considering different/subsequent steps to complete the site remediation. Furthermore, the use of a risk-based phased approach allows detailing, for each remediation step, possible applicable technologies, site use constraints based on residual risk for human receptors and remediation costs. In such way a clear picture of any possible solution and its possible consequences is made available for present site owners, potential site buyers and/or public Authorities and Planners.

The following phased remediation strategy is envisaged for the OHIS site:

- Phase 1: Removal of primary contamination sources (i.e. HCH dumps and contaminated buildings) and on site/off site treatment;
- Phase 2: Buildings demolition and on site treatment of hazardous materials;
- Phase 3: Removal of the surficial soil layer (from ground level to 1 m depth) from almost the whole OHIS site and soil remediation to reach safe residual levels for residential or commercial on site receptors;
- Phase 4: Excavation and on site or *in situ* treatment of the deep soil sections exceeding the SSTLs calculated for residential or commercial scenario. In this case the intervention can be limited to the hot-spots only, and the lower abatement needs allow the use of *in situ* techniques or mobile systems; and
- Phase 5: Installation of a hydraulic barrier and extraction and subsequent on site treatment of contaminated groundwater (Pump and Treat system).

The proposed approach for the OHIS site remediation is displayed in Figure 6.1, while a visual representation of different phases' progression is reported in Drawing 7.





**Figure 6.1: Proposed OHIS Site Remediation Strategy**

## 6.2 ESTIMATION OF THE REMEDIATION AREAS/VOLUMES

Based on target levels defined through the HHRA, the volume of contaminated soil to be remediated was estimated for the different contaminated layers and possible future scenarios. The absence of a defined plan for future site destination led to the use of general scenarios (e.g. commercial and/or residential), which shall be reviewed and updated once the final site destination will be set or urban plans for the area developed.

The total surface of HCH contamination was estimated through Thiessen method considering the maximum extension resulting from the four isomers exceedances.

Considering a commercial scenario, the calculated surficial soil areas for HCH-contaminated soil, Hg-contaminated soil and soil with contemporary exceedances of both COCs are reported in Drawing 8, while the deep soil areas requiring remediation (HCH- and Hg-contamination) are reported in Drawing 9. Drawing 10 and Drawing 11 respectively show the surficial and deep contamination extension for residential scenario.

The step by step actions to be undertaken following the proposed phased approach are reported in Table 6.1 and Table 6.2 for the on site commercial and residential scenarios, respectively.

These tables summarize the remediation targets (and relevant receptors) arising from the elaboration of HHRA and the estimate of the volumes potentially involved in the remediation phases. Since the remediation effort that could be implemented at the site is not known at present, for each phase also the residual risk (i.e. the potentially affected receptors by residual contamination) and the relevant site use constraints or mitigation actions (either temporary or long-term actions) are reported in tables.

In particular, each step foreseen in the phased approach is described in Table 6.1 and Table 6.2 with reference to:

- contaminated media involved (i.e., dumps and overlying soil, topsoil, shallow soil, deep soil and groundwater);



- estimated surfaces and volumes of soil to be remediated based on classed post maps displaying the points exceeding SSTLs;
- selected remediation targets (i.e. final SSTLs for relevant compounds);
- selected receptors which have been considered and for whom the risk will brought back to acceptable limits;
- receptors that would be further affected by the residual contamination at the end of a given remediation step (i.e. the risk left in place by limiting the intervention to the considered phase); and
- constraints/actions that should be adopted for the site and surroundings to control the residual risk left in place at the end of each phase.



**Table 6.1: Remediation Strategy for On Site Commercial Scenario**

Phase	Contaminated media	Estimated Surface / Volume	Remediation Targets	Selected Receptors (for Whom Risk will be Reduced Below Acceptable Level)	Potentially Affected Receptors by Residual Contamination <sup>(1)</sup>	Constraints or Mitigation Actions (Temporary or Long-term)
1	HCH Dumps (waste only)	6,380 m <sup>2</sup> / 15,620 m <sup>3</sup> <sup>(2)</sup>	100% removal	On site residential/commercial receptors	On site residential or commercial receptors and off site residential receptors	Forbid site use and prevent site access with the exclusion of remediation workers
	Overlying Soil	6,380 m <sup>2</sup> / 7,210 m <sup>3</sup> <sup>(2)</sup>	Same as surficial soil (see below)	Off site residential receptors		
2	Industrial Buildings / Structures	16,043.5 m <sup>3</sup> <sup>(2)</sup>	100% demolition	On site residential/commercial receptors Off site residential receptors	On site residential or commercial receptors and off site residential receptors	Forbid site use and prevent site access with the exclusion of remediation workers
3	Surficial Soil (0-1 m)	HCH only: 41,804.9 m <sup>2</sup> / 41,804.9 m <sup>3</sup> HCH+Hg: 8,661.8 m <sup>2</sup> / 8,661 m <sup>3</sup> Hg only: 1,241.8 m <sup>2</sup> / 1,241.8 m <sup>3</sup>	α-HCH = 0.39 mg/kg β-HCH = 1.33 mg/kg δ-HCH = 0.90 mg/kg γ-HCH = 1.91 mg/kg  Hg = 5.18 mg/kg	On site commercial (all direct and indirect contact pathways excluding groundwater use) Off site residential (all pathways excluding groundwater) <sup>(3)</sup>	On site commercial receptors (due to the residual contamination at 1-8 m bgl). Off site residential receptors using groundwater for irrigation and/or for drinking purposes	Vapour protection measures should be put in place. The site should be likely covered with a composite impervious layer and paved to stop the possible contaminant diffusion to air. Building foundations should be adequately protected to prevent indoor vapour diffusion and no indoor space should be constructed below ground level. Groundwater use for irrigation purposes should be limited downstream the OHIS site for several kilometers.
4	Sub-surface Soil (1-2 m)	HCH: 7,250.4 m <sup>2</sup> / 7,250.4 m <sup>3</sup> Hg: 9,903 m <sup>2</sup> / 9,903 m <sup>3</sup>	α-HCH = 20.93 mg/kg β-HCH > 33.8 mg/kg δ-HCH = 558.7 mg/kg γ-HCH > 284.8 mg/kg  Hg = 5.18 mg/kg	On site commercial (all pathways excluding groundwater use) Off site Residential (all pathways excluding groundwater use) <sup>(3)</sup>	On site commercial receptors (due to the residual contamination at 2-8 m bgl). Off site residential receptors using groundwater for irrigation and/or for drinking purposes	Same measures as above
	Sub-surface Soil (2-8 m)	HCH: 7,250.4 m <sup>2</sup> / 43,502.4 m <sup>3</sup> Hg: 9,903 m <sup>2</sup> / 59,418 m <sup>3</sup>	α-HCH = 60.86 mg/kg β-HCH > 33.8 mg/kg δ-HCH > 992.5 mg/kg γ-HCH > 284.8 mg/kg  Hg = 5.18 mg/kg	On site commercial (all indirect pathways excluding groundwater contact) Off site Residential (all pathways excluding groundwater use) <sup>(3)</sup>	On site commercial receptors (due to the presence of CHC in groundwater). Off site residential receptors using groundwater for irrigation and/or for drinking purposes	Same measures indicated above in terms of protection from vapour migration.  Groundwater use for irrigation purposes should be limited downstream the OHIS site (a safety zone of at least 1 km should be considered). Monitoring should be carried out to evaluate natural attenuation (with consequent safety zone reduction)



Phase	Contaminated media	Estimated Surface / Volume	Remediation Targets	Selected Receptors (for Whom Risk will be Reduced Below Acceptable Level)	Potentially Affected Receptors by Residual Contamination <sup>(1)</sup>	Constraints or Mitigation Actions (Temporary or Long-term)
5	Groundwater	-	$\alpha$ -HCH = 0.27 µg/L $\beta$ -HCH = 0.95 µg/L $\delta$ -HCH = 1.05 µg/L $\gamma$ -HCH = 1.33 µg/L  Hg = No Rem  TCE = 1049.5 µg/L PCA = 190.8 µg/L DCE = No Rem PCE = 429.3 µg/L	Off site residential receptors using groundwater for irrigation purpose	Off site residential receptors using groundwater for drinking purposes	Monitoring should be carried out to evaluate natural attenuation

<sup>(1)</sup> Assuming that a phased implementation of the remedial interventions will be adopted, this column indicates the residual risk left in place by limiting the intervention to this phase.

<sup>(2)</sup> ENACON estimation

<sup>(3)</sup> SSTLs calculated for on site receptor and off site residential receptors have the same order of magnitude. Considering the conservative approach used for off site BWM calculations (e.g. the prevailing wind direction was not considered), the proposed SSTLs are deemed protective also for off site residents



**Table 6.2: Remediation Strategy for On Site Residential Scenario**

Phase	Contaminated media	Estimated Surface / Volume	Remediation Targets	Selected Receptors	Potentially Affected Receptors by Residual Contamination <sup>(1)</sup>	Constraints or Mitigation Actions (Temporary or Long-term)
1	HCH Dumps (waste only)	6,380 m <sup>2</sup> / 15,620 m <sup>3</sup> <sup>(2)</sup>	100% removal	On site residential/commercial receptors	On site residential or commercial receptors and off site residential receptors	Forbid site use and prevent site access with the exclusion of remediation workers
	Overlying Soil	6,380 m <sup>2</sup> / 7210 m <sup>3</sup> <sup>(2)</sup>	Same as surficial soil (see below)	Off site residential receptors		
2	Industrial Buildings / Structures	16,043.5 m <sup>3</sup> <sup>(2)</sup>	100% demolition	On site residential/commercial receptors Off site residential receptors	On site residential or commercial receptors and off site residential receptors	Forbid site use and prevent site access with the exclusion of remediation workers
3	Surficial Soil (0-1 m)	HCH only: 43,051.5 m <sup>2</sup> / 43,051.5 m <sup>3</sup> HCH+Hg: 13,403.2 m <sup>2</sup> / 13,403.2 m <sup>3</sup>	α-HCH = 0.001 mg/kg β-HCH = 0.002 mg/kg δ-HCH = 0.016 mg/kg γ-HCH = 0.002 mg/kg  Hg = 1.50 mg/kg	On site residential (all direct and indirect contact pathways excluding groundwater use) Off site residential (all pathways excluding groundwater)	On site residential receptors (due to the residual contamination at 1-8 m bgl) Off site residential receptors using groundwater for irrigation and/or for drinking purposes	Vapour protection measures should be put in place (see Phase 2 in Table 6.1). Residential site use should be prohibited. Groundwater use for irrigation purposes should be limited downstream the OHIS site for several kilometers.
4	Sub-surface Soil (1-8 m)	HCH: 9,670.9 m <sup>2</sup> / 67,696.3 m <sup>3</sup> Hg: 13,403.2 m <sup>2</sup> / 93,822.4 m <sup>3</sup>	α-HCH = 9.55-9.88 mg/kg β-HCH > 33.8 mg/kg δ-HCH = 118.39 mg/kg γ-HCH > 284.8 mg/kg  Hg = 1.50 mg/kg	On site residential (all pathways excluding groundwater use) Off site Residential (all pathways excluding groundwater use)	On site residential receptors (due to the presence of CHC in groundwater) Off site residential receptors using groundwater for irrigation and/or for drinking purposes	Same as above for vapour protection.  Groundwater use for irrigation purposes should be limited downstream the OHIS site (a safety zone of at least 1 km should be considered). Monitoring should be carried out to evaluate natural attenuation (with consequent safety zone reduction)
5	Groundwater	-	α-HCH = 0.27 µg/L β-HCH = 0.95 µg/L δ-HCH = 1.05 µg/L γ-HCH = 1.33 µg/L  Hg = No Rem  TCE = 1049.5 µg/L PCA = 190.8 µg/L DCE = No Rem PCE = 429.3 µg/L	Off site residential receptors using groundwater for irrigation purpose	Off site residential receptors using groundwater for drinking purposes	Monitoring should be carried out to evaluate natural attenuation
<sup>(1)</sup> Assuming that a phased implementation of the remedial interventions will be adopted, this column indicates the residual risk left in place by limiting the intervention to this phase. <sup>(2)</sup> ENACON estimation <sup>(3)</sup> This is the sum of Area A to Area D surfaces. Only Area E was excluded due to the lack of knowledge about its state of contamination.						



## 7 REMEDIAL OPTIONS SELECTION

### 7.1 REMEDIAL ALTERNATIVES SELECTION CRITERIA

The selection of the most suitable remedial technologies was developed on the following bases:

- information gathered from technical literature and studies developed for lindane remediation, with particular reference to documents and reports developed by International organizations involved in POPs and pesticides remediation and destruction (e.g. USEPA, Federal Remediation Technologies Roundtable, International HCH and Pesticides Association, UNIDO, etc.);
- review of the preliminary technology selection developed in previous Feasibility Studies (Enacon, 2008a; 2008b; 2008c; 2008d) already carried out by D'Appolonia within the present Project framework (D'Appolonia, 2010b);
- results of a detailed market investigation conducted by D'Appolonia based on the OHIS site general settings and contamination characteristics to evaluate both the availability of suitable technologies on the current European market and the relevant technical and legal requirements/limitations and the existence of full scale technologies applicable to contaminants found at the OHIS site;
- results of further market investigations, specifically addressed to evaluate innovative on site technologies for dumpsites treatment (i.e. promising non-combustion technologies, not necessarily developed and applied at full scale) able to minimize emissions (i.e. closed-loop systems), by-products, etc., potentially applicable to different contaminants present on site.

The selected remedial technologies have been used to develop a possible remediation strategy for the OHIS site, based on the phased approach developed by HHRA. Of course, treatability lab scale/pilot tests on soil/waste/groundwater samples should be performed prior to any technology adoption at full scale to confirm its effectiveness.

In any case, the off site treatment option (i.e. incineration in off site authorized hazardous treatment plant) has been considered only in case none of the selected technologies would result viable for HCH dump sites treatment and overlying soil remediation.

### 7.2 SELECTED REMEDIAL OPTIONS

Taking into account the outcomes of the Feasibility Studies evaluation (D'Appolonia, 2010b), the HHRA results (D'Appolonia, 2010a) and the market investigation outcomes, for each remediation phase two different alternatives have been proposed in this CD, as detailed in the following Table:

**Table 7.1: Remedial Options for Each Phase and Selection Criteria**

Phase	Option 1	Option 2	Selection Criteria
1 – HCH Waste	Waste removal, on site treatment with innovative technology (i.e. mechanochemical dehalogenation) coupled with thermal desorption	Waste removal, packing, off site treatment (incineration)	Pilot testing of Option 1 (possibly funded by GEF) and cost estimation. If applicable and economically feasible, full-scale application of Opt. 1; otherwise Opt. 2



Phase	Option 1	Option 2	Selection Criteria
2 – Buildings / Structures	Buildings demolition, on site treatment of hazardous waste and subsequent backfilling	Buildings demolition, packing of hazardous waste, off site treatment (incineration)	Pilot testing of Option 1 for operative parameters and unit cost evaluation. Option 2 is only included for completeness, since thermal desorption is a proven remediation technology
3 – Surficial Soil (first meter)	Soil excavation, on site treatment and subsequent backfilling	Soil excavation, packing, off site treatment (incineration)	Pilot testing of Option 1 for operative parameters and unit cost evaluation. Option 2 is only included for completeness, since thermal desorption is a proven remediation technology
4 – Deep Soil (1-8 m)	Soil excavation, on site treatment and subsequent backfilling or <i>in-situ</i> treatment	Soil excavation, packing, off site treatment (incineration)	Pilot testing of Option 1 for operative parameters and unit cost evaluation. Option 2 is only included for completeness, since thermal desorption is a proven remediation technology
5 – Groundwater treatment	Pump&Treat		Pilot testing

Even not explicitly reported as a proper remediation phase, the pilot testing of proposed technologies is a fundamental phase of the remediation implementation operations. As a matter of fact, only pilot tests will allow both the selection of the technology that will be implemented for OHIS site remediation and the characterization of the operative parameters (e.g. treatment capacity, residual concentrations, energy requirements, etc.) necessary to refine cost estimation and project schedules.

A brief description of the selected remedial options is provided in the following Sections based on reference documentation and market investigation. A more detailed description of site-specific operating conditions and capacities is reported in Section 8.1.

### 7.2.1 Ball Milling/Mechanochemical Dehalogenation

Among other technologies proposed in literature and successfully applied at different levels for POPs treatment, the combined physical/chemical Mechanochemical Dehalogenation (MCD) process, has been retained as possible explorable innovative technologies for HCH waste decontamination.

Ball milling/MCD is based on the use of mechanical energy to initiate chemical reactions in presence of suitable reagents. During ball milling enough mechanical energy is provided to exceed the chemical forces binding the Cl atoms to the C atoms of the chlorinated hydrocarbons. In these conditions, most of the chlorine will be separated from organic molecules, leaving a residual of non-chlorinated organic substances and inorganic compounds.



#### 7.2.1.1 Advantages

- **absence of gaseous emissions:** low temperature process that does not generate gaseous emissions;
- **no generation of water effluents:** vessels are cooled down by water circulation in a hermetically closed system;
- **outputs:** at the end of the treatment, excess CaO plus hydrated lime,  $\text{Ca}(\text{OH})_2$ , will be present in the vessels together with residual non-chlorinated organic compounds (adsorbed on the surfaces of the CaO particles) that can be then thermally treated;
- **end product reusability:** the end product is a fine powder with cement-like properties. The powder can be used to produce concrete, which efficiently immobilizes all remaining contaminants, such as heavy metals.

#### 7.2.1.2 Limitations

- **noise:** high noise during treatment (milling process);
- **costs:** costs of full scale treatment are not available, relatively high cost also for pilot test phase, shipping of the equipment;
- **application time:** expected very long application times for high tonnage of contaminated soil;
- **energy demand:** high energy needs for the mechanical system which can be either run on diesel fuel, or plugged into the electricity network;
- **metal contamination:** the treatment has no effect on the concentration of Hg and other metals concentrations.

#### 7.2.1.3 Development Status

Proven the destruction of DDT and other chemical by milling with CaO, but process tested at small scale (seems uneconomical at industrial scale due to the time required). Little information is available on its use in full scale projects. Only one full scale treatment is reported in literature using similar technique for the remediation of soil contaminated with DDT, PCBs and lindane in New Zealand, with high removal efficiency for the above contaminants (USEPA, 2005).

#### 7.2.1.4 Ball Mill-MCD Applicability to the OHIS Site Contamination

Ball mill-MCD technology should be applicable to the following typologies of contamination present at the OHIS site (see Table 7.2):

- HCH waste (pure);
- Soil with low contamination by HCH (only);
- Soil with high contamination by HCH (only);
- Soil with HCH and Hg contamination.

The technology is not applicable to soil contaminated by Hg (only) and to contaminated groundwater.



**Table 7.2: Applicability of the Ball Mill-MCD Technology to the Different Typology of Soil/Waste Contamination at the OHIS Site**

Type of contamination	Applicability of the ball mill/MCD	Options for re-use of the material
<b>HCH dumps (pure)</b>	Applicable: this was the original use of this technology  Max. capacity : 3.4 t/day	<ul style="list-style-type: none"> <li>Removal <math>\text{CaCl}_2</math> by washing</li> <li>Treatment of non chlorinated organic products (design after pilot test)</li> <li>Turn residual material into hard concrete</li> </ul>
<b>Soil with low contamination by HCH (only)</b>	Potentially applicable: low contamination means short treatment duration and low amount of CaO added: the end material will be a powder of mainly soil  Max. capacity : 11.2 t/day	<ul style="list-style-type: none"> <li>Treatment of non chlorinated organic products (design after pilot test)</li> <li>May be re-used as backfill</li> </ul>
<b>Soil with high contamination by HCH (only)</b>	Potentially applicable: main difference with low contaminated soil is quantity of CaO and remaining content of non organic compounds  Max. capacity : 8.1 t/day	<ul style="list-style-type: none"> <li>Removal <math>\text{CaCl}_2</math> by washing</li> <li>Treatment of non chlorinated organic products (design after pilot test)</li> <li>Turn remaining product into concrete material or send to classical landfill</li> </ul>
<b>Soil with HCH and Hg contamination</b>	See above for HCHs, but potential immobilization of Hg and other heavy metals.  Max. capacity : 8.1 t/day	<ul style="list-style-type: none"> <li>Removal <math>\text{CaCl}_2</math> by washing</li> <li>Treatment of non chlorinated organic products (design after pilot test)</li> <li>Turn remaining product into concrete material – check for immobilization of Hg</li> </ul>

Two typologies of mobile equipments with different capacity could be currently available for on site treatment (see Table 7.3). The smaller one was primarily designed for practical scale demonstration, and its capacity due to lower rotation speed, smaller vessels, less batches/day, is only one third of that of the bigger mobile equipment.

#### 7.2.1.5 Pilot Testing Program for Ball milling-MCD Application

A pilot testing phase including will include the execution of 4 pilot tests, two for each HCH dump. Pilot tests are necessary to evaluate the effectiveness of the technology for each type of material considered suitable for treatment. Objectives of the pilot tests are:

- quantification of the average total Cl content;
- optimization of CaO content (theoretical + excess);
- evaluation of the need of using other mineral additives such as  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$ ;
- determination of treatment time necessary to reach remediation targets;
- chemical quantification of treated material (powder);



- thermal treatment applicability to treated material;
- possible capacity to immobilize Hg contamination in concrete material made from the powder (includes leaching tests);
- detailed cost assessment: maintenance costs, energy needs, CaO, water, post treatment options.

The quantity of material needed, using the relatively small mobile equipment, is 60 kg for each test.

**Table 7.3: Main Features of Commercially Available Mobile Equipment for Ball Mill-MCD Applicability at Pilot Scale**

	Demonstration model	Commercial equipment
<b>Size of the reaction vessel</b>	750 L	1,500 L
<b>No. of steel balls 4" diameter</b>	100	200
<b>Engine</b>	240 KW /AC 440 V	550 KW /AC 440 V
<b>Rotation speed (vessels)</b>	70 rpm	100 rpm
<b>Revolution speed (base)</b>	70 rpm	100 rpm
<b>Max capacity/year<sup>1</sup></b>	- Approx. 270 tons of pure pesticides - Approx. 1778 tons of contaminated soil	- Approx. 1060 tons of pure pesticides - Approx. 2540 tons of contaminated soil - Max is 3500 tons for low contaminated soil (0.1% HCHs)
<b>Duration of de-chlorination treatment/batch<sup>2</sup></b>	6-8 hours	3-4 hours
<b>Reagent</b>	CaO bricks and/or blast furnace slag (CaO-SiO <sub>2</sub> )	
<b>Possible other additives</b>	SiO <sub>2</sub> , Al <sub>2</sub> O <sub>3</sub>	
<b>Emissions during treatment</b>	No exhaust	
<b>By-products</b>	<ul style="list-style-type: none"> <li>• Non chlorinated organic compounds (mostly adsorbed benzene – depend on pesticides and treatment duration) <ul style="list-style-type: none"> <li>• CaCl<sub>2</sub></li> <li>• Ca(ClOH)</li> </ul> </li> </ul>	
<b>Plant life</b>	Up to 15 years	Up to 20 years
<b>Time for construction of new equipment</b>	2-3 months	12-15 months

<sup>1</sup> capacity/year depends on the contamination level

<sup>2</sup> without loading/unloading time; highly depends on remediation target

### 7.2.2 On site Thermal Desorption

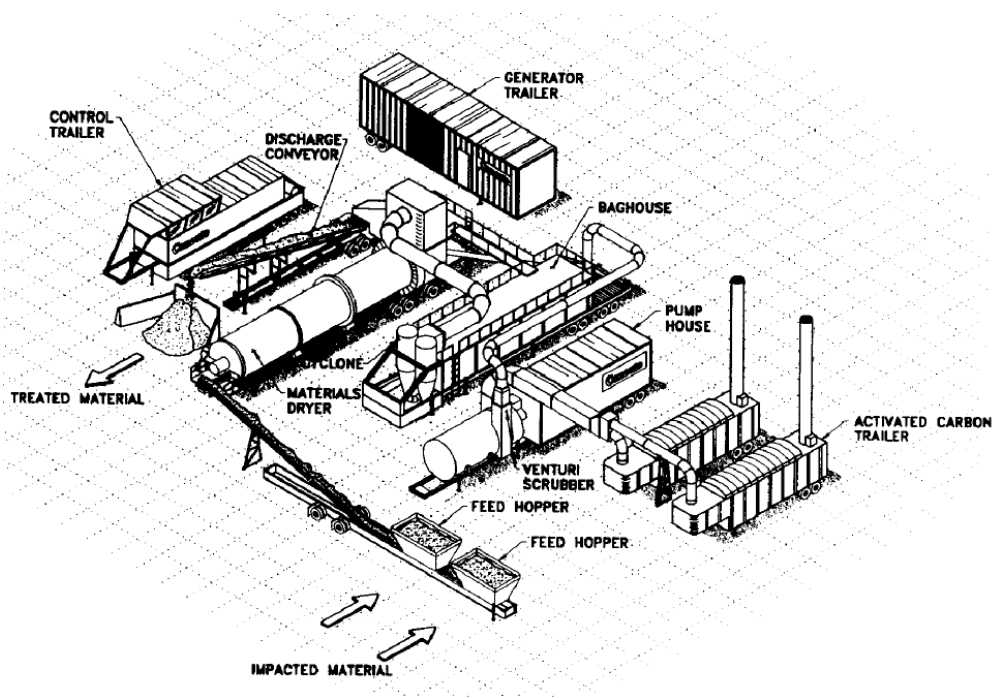
Based on the general site settings and characterization results, the literature review and the market investigation response, Thermal Desorption (TD) option can be considered as the most viable solution for surficial HCH-contaminated soils (0-1 m bgl) and the soil overlying the two HCH dumps, even if pilot tests are needed to calibrate the design parameters and the effluents post-treatment or recovery systems.



The proposed treatment technology is a well established technology for POPs treatment, and, as already mentioned, has been successfully applied also for HCH treatment. Furthermore, thermal desorption can treat different organic compounds locally found at the OHIS site and surrounding areas, i.e. dioxins, DDD, DDE, DDT and chlorobenzenes.

Thermal desorbers are designed to heat soils to temperatures sufficient to cause constituents to volatilize and desorb (physically separate) from the soil. Although they are not designed to decompose organic constituents, thermal desorbers can, depending upon the specific organics present and the temperature of the TD unit, cause some of the constituents to completely or partially decompose. The vaporized hydrocarbons are generally treated in a secondary treatment unit (e.g., afterburner, catalytic oxidation chamber, condenser, or carbon adsorption unit) prior to the release to the atmosphere. Afterburners and oxidizers destroy the organic constituents. Condensers and carbon adsorption units trap organic compounds for subsequent treatment or disposal.

Some pre- and post-processing of soil is necessary when using TD. Excavated soils are first screened to remove large (greater than 5 cm in diameter) particles. These may be sized (e.g., crushed or shredded) and then introduced back into the feed material. After leaving the desorber, soils are cooled, re-moistened to control dust, and stabilized (if necessary) to prepare them for reuse. A typical TD plant layout is reported in Figure 7.1.



**Figure 7.1: Typical TD Layout (from USEPA, 1997)**

Semi-Volatile Organic Compounds (SVOCs), pesticides, and other POPs with boiling points up to about 300°C are typically processed through direct- or indirect-fired thermal desorbers. POPs with boiling points above 300°C, such as HCH, PCBs, dioxins, and furans, may be treatable with higher-temperature systems. Essentially all soil types are amenable for treatment by TD systems. However, different soils may require varying degrees and types of



pre-treatment. For example, fine-grained soils that are excessively cohesive (e.g. silt or clay) may require shredding.

The boiling point of elemental mercury at 1 atmosphere pressure is 350°C (similar to HCH), which renders it suitable for removal by thermal processes. Thermal desorption can be considered suitable also for the Hg-contaminated soil treatment, or even for mixed HCH/Hg-contaminated soils.

The ability to successfully treat mercury impacted soil depends both on the configuration of the thermal desorption unit and on the mercury species involved (the historical source).

The off-gases generated in the process may need to pass through additional air pollution control devices such as sulphur-impregnated carbon to capture any residual mercury. Mercury reacts with sulphur in the activated carbon to form a more stable compound, mercuric sulphide.

The technology has been already applied at full scale to treat mercury-contaminated soils and demolition wastes at many contaminated sites, and it has been suggested by many of the Companies contacted for the preliminary market investigation. Low temperature TD system with the following components: direct-heated rotary kiln, baghouse filter, thermal oxidizer, wet quench, acid gas absorber have been used to treat Hg-contaminated waste (USEPA, 2007).

The decision as to whether or not TD is a practical remedial alternative depends upon site-specific characteristics. Treatability lab scale/pilot tests have to be performed prior to the technology adoption at full scale to confirm its applicability to HCH and Hg either separately or at the same time and to optimize the off-gas treatment and the recovery sections.

If applicable, the use of a unique treatment system would allow significant cost and treatment time reduction for the OHIS site remediation, limiting mob/demobilization operations with relevant costs, reducing pilot and calibration testing necessity, etc.

#### 7.2.2.1 Process "Calibration Tests" for Thermal Desorption

Even though preliminary analysis of soil layer features and contaminant typology may suggest a good potential for the applicability of the TD technology, pilot tests should be performed on the site soil with the scope of a quantitative evaluation of the feasibility of the treatment and relevant parameters and the setting up the optimal operative conditions.

Specific tests for thermal desorption process calibration should focus on the following issues:

- estimate the optimum operating temperature and pressure conditions for the possible implementation of a full-scale thermal desorption system;
- determine if overall efficiency in organic contaminants removal is good enough to achieve site specific soil cleanup objectives for targeted organic contaminants;
- testing other basic variables (i.e., air emissions composition, nature of by-products formed in the gas phase during the heating process, features of the final products) needed to evaluate the characteristics of the equipment for the off-gases treatment and the need of soil pre-treatments.



The first step of treatability testing phase is intended to confirm the effectiveness of thermal treatment for the specific matrix to be handled at the site of interest. Pilot tests are envisaged mainly to gather knowledge about:

- the optimum temperature-pressure conditions associated to the highest desorption rates;
- the residence time needed to achieve the treatment levels;
- the composition of the exhaust gases.

Soil samples must be collected from the most contaminated portion of the site and singularly homogenized prior to thermal desorption testing. A baseline testing of each sample (including VOCs, SVOCs, TOC, TPHs, pH, and humidity) is performed in this phase to fully characterize the input material. Separate tests should be then conducted gradually varying the temperature, at steps of about 100°C or less. Small batches of contaminated media (approx. 1000 g) are heated in a static tray of a muffle furnace over the chosen range of temperatures for different time periods, to establish the minimum treatment temperature and residence time required by the treatment standards for the COC. The reactor headspace is purged with an inert gas (i.e. nitrogen) during the thermal treatability testing to prevent auto-ignition of the organic vapours in the reactor during the testing. Vapours exiting the reactor are processed through vapour-phase activated carbon in order to prevent the release of volatilized contaminants. The furnace is adjusted to maintain constant the soil temperature throughout the established retention time. At the end, upon cooling at room T of the treated material, attainment of cleanup targets can be evaluated.

Depending on the extent of testing carried out, an understanding of the mutual relationship of treatment temperature vs. residence time may be achieved. Pilot scale burn testing of soil samples also will allow characterizing the composition of exhaust gases resulting from the thermal treatment (USACE, 1996). During thermal desorption testing additional variable linked to the soil features and affecting desorption efficiency, like moisture content of the soil, can be evaluated, possibly establishing the need of a pre-treatment on the untreated soil (feed preparation/drying) to improve the cost-effectiveness of the process.

In setting up bench and pilot scale testing for thermal desorption, problems associated to the heating of certain contaminants as PVC and mercury, must be carefully considered.

Bench-scale laboratory tests are further performed in a second phase of treatability study, when small amount of contaminated material is processed within a specific thermal desorption equipment that simulates full-scale unit operations of a specific thermal desorption technology.

Rotary Thermal Apparatus (RTA) is a bench-scale device used to do this. Few kilograms of soil are treated in an indirectly heated rotary tube. This device simulates heat and mass transfer in a rotary heating system. The RTA is a batch device and can be purged with nitrogen, oxygen, or other gases to simulate the atmosphere of various thermal treatment processes.

In the third phase of treatability testing, a pilot-scale unit should be built in direct proportion to an existing or planned full-scale system. Because this testing involves larger equipment than that used in the second phase, and the processing of increasingly amount of actual material (up to several tons), it is usually carried out on site.

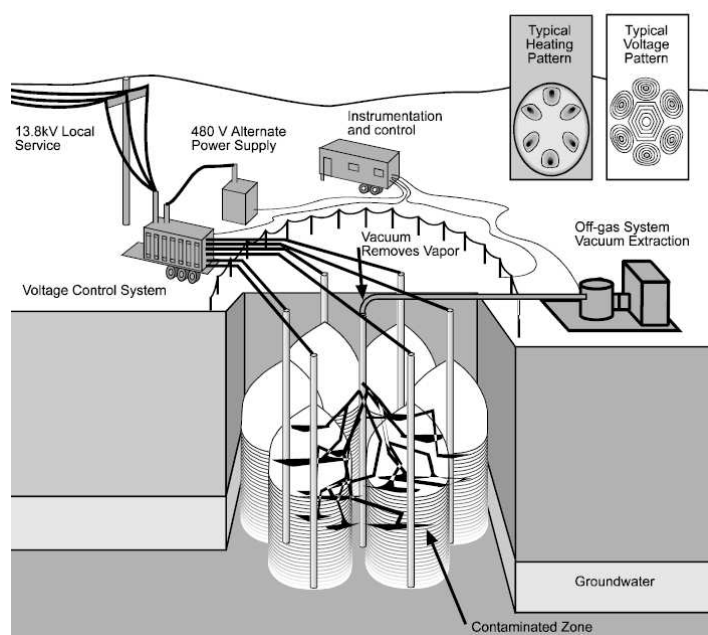
The objects of this step of testing is to predict the full performance of a projected thermal desorption system on actual site material and to reveal potential problems. Alternatively, it could act as further confirmation of the soundness of operational parameters and cost that were estimated from the two previous tiers of testing.



### 7.2.3 In Situ Thermal Desorption

In Situ Thermal Desorption (ISTD) is an in situ soil remediation process based on thermal conduction in which heat and vacuum are applied simultaneously to strip the contaminants from the subsurface soils or destroy them.

The most common setup uses a vertical array of heaters placed inside wells which are drilled into the remediation zone (see Figure 7.2). Heaters are operated at 550-750°C; and the heat is transferred into the subsurface largely via thermal conduction and radiant heat transport, which dominates near the heat sources. There is also a contribution through convective heat transfer that occurs during the formation of steam from pore water present in the soil or sediment.



**Figure 7.2: Typical ISTD Layout (from USEPA, 2004)**

By heating the soil, adsorbed and liquid phase contaminants begin to vaporize. A significant portion of organic contaminants either oxidize (if sufficient air is present) or pyrolyze once high soil temperatures are achieved. Desorbed contaminants are recovered through a network of vapor extraction wells. A vacuum is applied to these wells to induce air flow through the contaminated media creating a zone of capture. Transport of the vaporized contaminants is improved by the creation of permeability, which results from drying the soil and increasing the relative permeability. Flow paths are created even in tight silt and clay layers, allowing escape and capture of the vaporized contaminants.

Contaminant vapors captured by the extraction wells are conveyed to an off-gas treatment system for treatment prior to discharge to the atmosphere, similarly to what applied for on site thermal treatment.

Two different methods of vapor treatment can be used: one treats extracted vapor without phase separation, and the other cools heated vapor, separates the resulting phases, and manages each phase separately.



The first vapor treatment option uses a thermal oxidizer to break down organic vapors to primarily carbon dioxide and water. Due to the presence of chlorinated compounds, hydrogen chloride (HCl) gas is produced. The exhaust from the thermal oxidizer is passed through an acid gas scrubber to capture HCl gas.

The other vapor treatment option uses a heat exchanger to cool extracted vapors. The resulting liquid phase is then separated into aqueous and non aqueous phases. The non aqueous phase liquid is usually disposed of at a licensed treatment storage and disposal facility. The aqueous phase is passed through liquid-phase activated carbon adsorption units and then released into the environment. Cooled, uncondensed vapor is passed through vapor-phase activated carbon adsorption units and then vented to atmosphere.

#### 7.2.3.1 Advantages

- **no need of deep soil displacement:** in situ treatment allows avoiding excavation or soil handling and pre-treatment and is in principle a easy way to deal with a situation of “localized” contamination in the deep soil;
- **easy installation of the equipment;** i.e., multiple steel pipes are pushed into the soil by means of traditional drilling, direct push, etc.;
- **expected uniform heat distribution:** Conductive heating is a much more uniform method of heat transport regardless of soil type, stratigraphy, or degree of heterogeneity, relative to other methods of subsurface heating.

#### 7.2.3.2 Limitations

- **high treatment T needed:** high temperatures, neat the boiling point of the target substances, about 300°C, have to be maintained in the soil for a long time period for reaching the very stringent targets (only in case cleanup goals are not as stringent, the target temperature could be the boiling point of water (100 °C) which is a lot less energy demanding);
- **groundwater control and soil dewatering issues:** if high temperatures (above 300 °C) in the entire soil volume have to be reached, soil dewatering can be necessary in order to avoid heat dispersion, which can be very energy demanding;
- **corrosion issues:** due to the HCl gases have to be dealt with by treating these COCs.

#### 7.2.3.3 Development Status

Pilot- and full-scale applications have been already performed to remove PCBs. Contaminants characteristics suggest the potential applicability of this technology to POPs like HCHs; however, these contaminants have not yet been treated using in situ thermal treatment on a full- or pilot-scale basis.

Laboratory treatability studies and field project experience of contacted companies indicate that the combination of high T and long time application may lead to extremely high overall removal efficiency, even for the high boiling point contaminants.

#### 7.2.3.4 ISTD Applicability to the OHIS Site Contamination

The COCs present at the OHIS site are in the range of high boiling compounds, e.g. boiling point of lindane is 323°C. Other issues associated with the contaminants are there corrosiveness due to the production of hydrochloric acid. ISTD can be applicable at the site



treating lindane and other isomers of HCH but target treatment temperatures must be carefully evaluated through treatability studies.

To address the very stringent cleanup targets of the site, the soil have to be heated to the boiling point of the contaminants (HCH isomers and mercury). To reach temperatures above 300°C removal of all water in the soil volume could be required which can be very energy demanding.

For ISTD applicability to the OHIS site, due to the complexity of contaminants present, treatability lab scale tests are suggested before implementing in situ pilot tests.

#### 7.2.3.5 Pilot Tests for ISTD Technology

Treatability lab scale tests are carried out heating soil in steel canisters in lab. Heating the canister to different temperatures gives a thermal profile of the contaminant mass reduction from the soil. Knowing this and based on the established cleanup target the adequate target treatment temperature can be set. Depending on that temperature the order of heat losses expected for in situ tests can be derived based on local hydrogeology in order to give an estimate of the amount of energy to inject in the soil to reach the target temperature.

In situ pilot test can be performed, after the preliminary lab tests, with the aims of:

- investigating the possibility of lowering HCH-isomers concentrations down to SSTLs within the depth range of 2-8 meters bgl;
- providing data on energy consumption required for remediation and data for dimensioning the treatment facility for the eventual implementation at the full scale.

The pilot test should be executed over a 10x10 m<sup>2</sup> area located in a portion of the site considered as the most representative of the whole site. Proposed treatment depth is from subsurface soil down to the shallow water table (assumed to be 8 meters bgl). Parameters for the proposed test area are summarized in the following table.

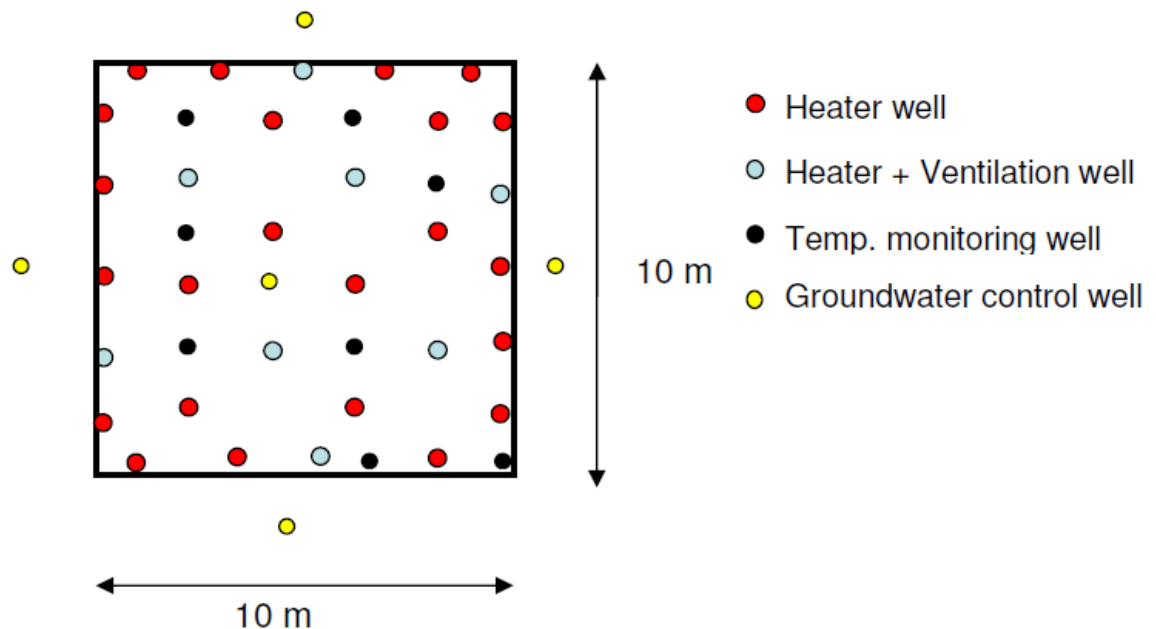
**Table 7.4: Suggested Treatment Area for ISTD Pilot Tests and Assumed Soil Features**

Parameter	Value	Unit
Treatment area	100	m <sup>2</sup>
Upper depth of treatment	2	m
Lower depth of treatment	8	m
Volume, target treatment zone (TTZ)	600	m <sup>3</sup>
Solids volume	450	m <sup>3</sup>
Porosity (assumed)	25	%
Porosity volume	150	m <sup>3</sup>
Initial saturation (assumed)	33	%
Soil weight	1,090.552	tons
Water weight	49,540	tons
Soil heat capacity	1.141	MJ/C
Water heat capacity	207	MJ/C
Total heat capacity, whole TTZ	1.349	MJ/C



The following test configuration will be adopted (see Figure 7.3 below):

- No. 23 heating wells have to be placed along the perimeters of the testing area and inside, each other at a distance of about 2.5 m;
- as a part of this grid, No. 8 combined heater + ventilation wells (2" diameter) have to be installed; the ventilation wells are screened from 2 to 8 meters bgl to ventilate the contaminated gas and steam;
- No. 5 groundwater control wells will be installed to minimize groundwater intrusion into the treatment area; and
- No. 8 temperature monitoring wells should be installed (1" wells); temperature is monitored on line in 8 points in each of these 8 monitoring wells.



**Figure 7.3: Proposed Setup for the ISTD Pilot Testing**

Target temperature for the test can be preliminary set above the boiling point of Lindane (323°C). However, the progressive mass removal starting from 100°C to 323°C will be examined to verify the possibility of working at lower temperatures.

The setup data for the pilot test including the energy balance for the test and the estimated operating time are shown in Table 7.5.



**Table 7.5: Energy Balance for ISTD Pilot Tests and Expected Operating Time**

<b>Energy Balance</b>	<b>Value</b>	<b>Unit</b>
Power input rate	239	kW
Water extraction rate during heat up (assumed)	0.2	m <sup>3</sup> /hr
Average extracted water temperature	73.6	°C
Water energy flux	20	kW
Percent of injected energy extracted as steam (estimated)	30	%
Steam extracted, average	72	kW
Energy in	239	kW
Water out	20	kW
Steam out	72	kW
Net injection	147	kW
Heating per day	9.4	°C/day
Start temperature	10	°C
Target temperature	335	°C
Estimated heat loss	50	%
<i>Power usage, total</i>	<i>580,000</i>	<i>kWh</i>
<b>Operating Time</b>	<b>Value</b>	<b>Unit</b>
Start up/running in	7	days
Dewatering	5	days
Heating to boiling point	21	days
Boiling and drying	32	days
Heating to target temperature	38	days
Sampling/analysis phase	10	days
Post treatment vapor extraction	10	days
<i>Total operating time</i>	<i>113</i>	<i>days</i>

#### **7.2.4 Off Site Waste Incineration**

In case the selected option (MCD+TD) will result not applicable for HCH dump sites remediation, the off site incineration in a specific hazardous waste treatment plant, able to deal with high chlorine content wastes, appears to be the only effective and fully developed solution for the dumps remediation. In such case, an authorized incineration plant will have to be selected, ideally within the territory of the Republic of Macedonia in order to minimize the transport of the collected wastes.

The possible use of dismissed mine disposal solution for HCH wastes was not included in this CD due to the known problem of the maximum allowable Lindane concentrations for disposal.



Hazardous waste incinerators are capable of treating wastes consisting of, containing or contaminated with any POPs, including HCH isomers. This is one of the most widely applied remediation technologies for these contaminants.

Incinerators can be designed to accept wastes in any concentration or any physical form, i.e. gases, liquids, solids, sludge and slurries.

Hazardous waste incineration uses controlled flame combustion to treat organic contaminants mainly in rotary kilns. Typically a process for treatment involves heating to a temperature greater than 850°C or, if the chlorine content is above 1%, greater than 1100°C, with a residence time greater than 2 seconds, under conditions that assure appropriate mixing. Removal efficiencies of more than 99.99% are achievable.

Depending upon the configuration, pre-treatment requirements may include blending, dewatering, screening and shredding of wastes.

Process gases require treatment to remove hydrogen chloride and particulate matter and to prevent the formation of and remove unintentionally produced POPs (e.g. dioxins). This can be achieved through a combination of types of post-treatments, including cyclones and multi-cyclones, electrostatic filters, static bed filters, scrubbers, selective catalytic reduction, rapid quenching systems and carbon adsorption. Depending upon their characteristics, bottom and fly ashes may require disposal within a specially engineered landfill.

#### **7.2.5 Pump and Treat**

Groundwater of the shallow aquifer (average water depth at 8.2-8.7 m bgl following March 2008 and July 2008 data) is mainly impacted by CHC (chlorinated hydrocarbons: 1,2-cis-DCE, TCE, PCE and PCA) up to 12 mg/l and secondarily by HCH isomers, up to 50 µg/l, and mercury.

A traditional approach based on a pump-and-treat system for hydraulic confinement of the site and water extraction could be adopted, followed by on site treatment of CHC and HCH contaminated groundwater with activated carbons.

For the design of the plant, the following basic parameters can be considered:

- empty bed contact time between the process water and the granular activated carbon: about 20 min;
- loading capacity: about 0.5-2%.

A pre-treatment for solid removal (i.e. sedimentation, sand filter with backwashing) can be considered in case of high solid contents.

As post treatment, a biological reactor can be implemented as preliminary step before activated carbons. From a general standpoint, with biological treatment an abatement ratio max 50-60% of the inlet concentration can be achieved; therefore, carbon filtration is in any case necessary to reach the calculated SSTLs values. In the biological reactor, water is circulated in a column filled with porous media where native microorganisms are attached. Nutrients and chemicals for pH control are regularly fed in the reactor, as well temperature can be controlled to enhance the biological reaction.

Once the lacking data are acquired for dimensioning the plant, pump and treat can be considered a cost effective technology for the site, allowing the removal of the contamination plume which is still quite confined to the site area.



### 7.3 SUMMARY OF SELECTED REMEDIAL ALTERNATIVES

Based on the general site settings and characterization results, the literature review and the market investigation suggest the use of TD (applied either *in situ* or on site) to treat all contaminated media (except groundwater) at the OHIS Site. Furthermore, the use of MCD coupled with TD will allow the on site treatment of the HCH waste (i.e. without off site transportation of contaminated media).

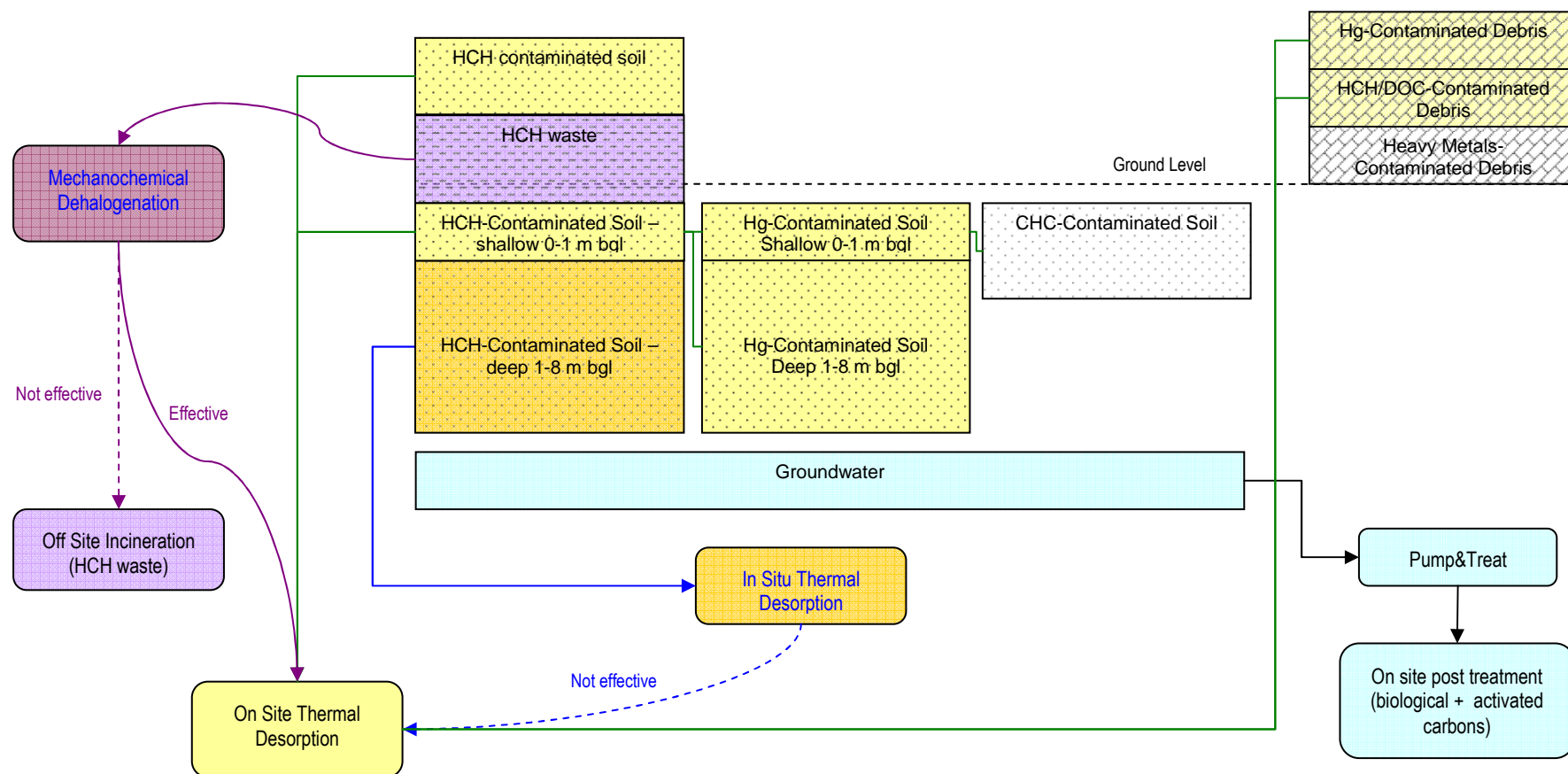
Treatability lab scale/pilot tests should be performed prior to any technology adoption at full scale to confirm its applicability to HCH and Hg either separately or at the same time and to optimize the off-gas treatment and the recovery sections.

In case the selected options will result not applicable for the OHIS site remediation, the off site incineration seems to be the preferable option for the treatment of the HCH waste and the overlying high contaminated soil. No limitation in terms of HCH content is expected for the waste acceptance. The waste should only be sent to the incineration plant packed in suitable containers or drums.

The possible technologies application to the different remediation phases and the criteria for selection are reported in Table 7.1.

Traditional and innovative remedial options potentially applicable for the remediation of the OHIS site are summarized in Figure 7.4, while preliminary operative procedures are detailed in the following Sections.





**Figure 7.4: Summary of Traditional and Innovative Remedial Options Potentially Applicable for the Remediation of the OHIS Site**



## 8 SITE REMEDIATION CONCEPTUAL DESIGN

In the following Section the preliminary operative procedures for the OHIS site remediation are reported.

Section 8.1 provides a further description of the selected technologies, with particular reference to site-specific operating conditions and capacities, and their location with respect to the planned working site layout.

The proposed working site layout and management is reported in Section 8.2, while the suggested approach for technology testing/application and for the remediation operations implementation is detailed, for each phase, in Sections 8.3 to 8.6.

Finally, environmental monitoring activities are summarized in Section 8.8.

### 8.1 DETAILED TECHNOLOGY DESCRIPTION

#### 8.1.1 On Site Mechanochemical Dehalogenation

In its actual configuration, the MCD equipment is a ball mill, able to exert extremely high mechanical energy for grinding chlorinated organics in the 3 reaction vessels. The system is cooled by external water circulation, in order to keep temperature inside the vessel below 200°C. This ensures that vaporization of heavy metals and/or organic compounds is reduced. Rotation is induced by an engine, which can be either run on diesel fuel, or plugged into the electricity network.

Main features of the full-scale reactor currently available are reported in Table 7.3.

The ball mill technology is based on the principle that when mechanical energy exceeds the chemical forces binding the Cl atoms to the C atoms, they will be separated from the pesticide molecules. The activated Cl<sup>•</sup> will then easily be captured by CaO (lime) present in the vessel to form innocuous CaCl<sub>2</sub>. The quantity of lime necessary to obtain full dechlorination of POPs depends on the amount of chlorine in the pesticide molecules or contaminated medium. Excess CaO (40-250% of the theoretical weight) is added to accelerate reaction to prevent any condensation reactions in the vessel during the treatment.

The lindane dechlorination reaction is the following (considering 40% CaO in excess):

$C_6H_6Cl_6$  (lindane) + 3CaO + 1.2CaO (40% excess) + 1.2H<sub>2</sub>O → 3CaCl<sub>2</sub> + 1.2Ca(OH)<sub>2</sub> + Non-chlorinated organic compounds (adsorbed on CaO in excess)

The unit material balance can be summarized as follows:

1 kg Lindane + 0.58 kg CaO + 0.23 kg CaO (excess) + 0.07 kg H<sub>2</sub>O → 1.1 kg CaCl<sub>2</sub> + 0.3 kg Ca(OH)<sub>2</sub> + 0.48 kg Non-chlorinated organic compounds

Based on the characterization results, HCH waste average water content (7.2%) is higher than the stoichiometric quantity needed for the reaction completion. The process diagram and material balance of the HCH dechlorination process is reported in Drawing 12.

The remaining organic products mainly consist in organic compounds with the same basic carbon-structure as the original substances, but not containing organo-chlorine parts in the molecule. In case of treatment of HCH organic residues are expected to be biphenyl and benzene, with a few hydrocarbons.

CaCl<sub>2</sub> (soluble in water) can be easily extracted from the powder by leaching with water. Ca(OH)<sub>2</sub> and residual non chlorinated organic compounds can be treated by TD and the dry CaO can then be reused as excess lime for a subsequent batch.



On the basis of the available information it was estimated by the license holder a treatment capacity of 3.4 ton/day for pure HCH. The estimated treatment capacity is based on the hypothesis that waste is composed of almost pure HCH isomers. Such assumption is very conservative, and the confirmatory sampling carried out during the waste extraction activities could reveal lower HCH concentrations (with consequent need of lower residence times in the reactors and consequent higher treatment capacity).

The plant installation on site needs a stable ground and a covered working location. If possible, one of the warehouses of the former chemical plant will be used. Alternatively, the plant will be installed in a covered area inside the temporary stockpile and treatment area described in Section 8.2.3.

#### **8.1.2 On Site Thermal Desorption**

As reported in Section 7.2.2, the traditional TD system consists of the following sections:

- soil pre-treatment unit (crushing, screening, etc.);
- feed hopper;
- rotary drier (operating temperature 450-600°C);
- hot-gas cyclone de-duster;
- cooling and moistening screw;
- afterburner (usually operating at temperatures between 800 and 900°C);
- heat exchangers;
- baghouse filter;
- gas scrubber; and
- stack.

Considering the high chlorine concentrations and significant concentration of mercury, several changes on the on site mobile treatment unit will have to be provided with respect to a conventional treatment:

- high temperature in the post-combustion (afterburner) chamber (1100°C instead of 850°C); and
- use of catalytic filters and/or activated carbon filter.

Alternatively, after the post-combustion, an abrupt cooling-down of the gases in a quencher could prevent the secondary formation of dioxins. Finally, either a baghouse filter removes fine dust from the gas stream and fixed-bed absorbers eliminate organic residues and mercury or activated carbons are spayed in the off-gas stream and finally collected with dust through a baghouse filter.

Possible process diagrams for the proposed mobile TD unit are reported in Drawing 13.

Because of these configuration changes, the TD unit capacity will decrease with respect to traditional mobile units. Considering the soil features recorded at the OHIS site, the following capacities can be expected:

- 7.9 ton/h for the surficial (0-2m) layer (clay + 17.4 % humidity); and
- 12.5 ton/h for the deep (2-8 m) layer (sand + 7.1 % humidity).

The thermal desorber will be installed in the temporary stockpile and treatment area described in Section 8.2.3. Process waters, if not directly recycled, will be sent to the waste water treatment plant (see Section 8.7.1).



### **8.1.3 In Situ Thermal Desorption**

In Situ Thermal Desorption can be applicable at the site for lindane and other HCH isomers treatment, but target treatment temperatures and achievable capacities can be evaluated only through treatability study.

As already reported, the COCs present at the OHIS site are in the range of high boiling compounds (e.g. boiling point of lindane is 323°C). Other issues associated with the contaminants are their corrosiveness due to the production of hydrochloric acid. Finally, another non negligible issue is the sub-surficial presence of groundwater, which should be controlled either using dedicated well points or through steam injection.

At this stage it is therefore not possible to estimate the full-scale capacity of the ISTD process. Only after the pilot testing phase the main process parameters will be clearly defined and the achievable residual concentrations will be evaluated. Pilot tests will also allow the set up of the off-gases treatment systems. The possible use of the TD off-gas treatment section will be also evaluated in the Detail Design.

## **8.2 WORKING SITE LAYOUT AND MANAGEMENT**

The remediation site operations will begin with the bounding and fencing of working areas and the set up of the logistic area where temporary facilities and welfare units will be located.

The logistic area will be created in the western side of the OHIS site, as indicated in Drawing 14 (Remediation Site Layout Plan).

A metallic galvanized fence, min. height 2 m, supported by T-shaped metal stakes will be installed. A new entrance, closed with metallic gate, will be set up adjacent to the West side of Sector B, between  $\delta$ -HCH dump and the logistic area and a new asphalted access road will be constructed to ensure the access to the logistic and to the working areas. A weighting station and a truck decontamination station will be installed close to the entrance gate, as indicated in the Remediation Site Layout Plan (Drawing 14).

As indicated in the Remediation Site layout plan, the internal road network is well developed and it will be used for the on-site transport of contaminated soil to the load out area and to deliver backfill to excavated areas once areas are cleared for backfilling.

Both the access and the internal roads will be illuminated according to diurnal and nocturnal remediation works and transportation needs. Trucks and operating vehicles circulation will be isolated from the work sites through adequate temporary fences, new-jersey and signals. Adequate velocity will be maintained and all maneuvers will be guided from outside personnel. All internal circulation ways (indicated in Drawing 14) will be maintained clear from objects and obstacles.

Based on the number of operators that could be contemporary present on site, an adequate number of welfare temporary facilities and services will be predisposed on the logistic area.

As a minimum, the following temporary facilities will be installed:

- No. 3 office trailers;
- No. 1 meeting room trailer;
- No. 1 guardroom;
- No. 1 office trailer for weighting station service;
- No. 4 locker trailers with showers and toilets;
- No. 1 sickroom trailer completely equipped;



- No. 1 canteen/dining room trailer;
- No. 1 laboratory trailer (alternatively, if possible, the laboratory present at the OHIS site will be used);
- No. 2 warehouses/stores;
- No. 1 workshop.

Office trailers will contain telephone and DSL lines and will be equipped with tables and chairs for personnel.

All trailers will be equipped with lighting, heating and air conditioning.

Portable toilets will be located next to the working areas. Along with the portable toilets, portable wash station for hand washing will be provided.

All trailers will be equipped with automatic fire alarm systems and an adequate number of suitable fire extinguishers/stations.

Electric power will be provided from the existing site power, which will be pulled from the pole into a meter and local panel. The power will then be pulled from the electrical panel to the trailers.

Water for civil use will be gathered from public aqueduct and sewages from toilets and showers will be sent to sewerage system, if available. Otherwise the logistic area will be equipped with septic tanks that will be periodically emptied by licensed subcontractors.

All spare parts, materials and equipments will be stored in suitable warehouses/stores located in logistic area. Depending on the material characteristics, open stores or covered areas with fences will be set up. Technical gas cylinders will be stored in covered and fenced secured areas away from operations and heavy equipments operations, while chemicals will be stored in covered areas equipped with spill containment systems. Adequate spill response equipments will be stored on site.

Health and safety signals and Personal Protective Equipment (PPE) requirements will be posted both at the entrance and inside the work sites. Internal road network circulation will be regulated through adequate traffic signals.

A permanent decontamination station will be set up at the exit of the site to decontaminate vehicles that are transporting contaminated soils to off site disposal facilities. The wash station will be realized through a mobile (pre-assembled) structure with automatic water jets and lateral protections (see Figure 8.1).



**Figure 8.1: Example of Mobile Tire and Wheel Wash Station**



Alternatively, a concrete pad with concrete walls equipped with drainage system will be constructed on site. Water resulting from equipment decontamination activities will be collected and sent to the wastewater treatment plant.

The access will be guarded by licensed personnel. Only authorized persons with adequate PPE could enter the working areas. A visitor log will be maintained on-site and visitors will be directed by signage to the guardroom when entering the site.

The following on site personnel will manage the activities:

- No. 1 Work Manager;
- No. 1 Technical Supervisor for demolition works;
- No. 1 Technical Supervisor for excavation and earth movements works;
- No. 3 Technical Supervisor for plants operation;
- No. 1 Administrative Manager;
- No. 1 Administrative Assistant;
- No. 1 Foreman; and
- No. 1 Health and Safety Officer.

#### **8.2.1 HCH Waste Preliminary Stockpiling/Packing and Loading Area**

Temporary HCH/HCH-contaminated soil management area will be located on the paved and partially bermed area adjacent to the North-western side of  $\alpha+\beta$ -HCH dump (see Drawing 14 and Figure 8.2) for the whole period needed to complete the HCH waste removal (approx 40 days if Option 1 is selected or more than 285 days if packing and off site transport is needed).



**Figure 8.2: Potential Location of the HCH Management Area**

To this aim, the soil stockpiles actually present within the selected area (see Figure 8.2), which, according to the information gathered, should consist of decontaminated soil, will be removed by a wheel loader and sent by trucks to the stockpiling/treatment area for analysis.



The existing paving and berms will be repaired (if needed) and the drainage system restored/set up.

The whole area (except the side in connection with  $\alpha+\beta$ -HCH dump) will be temporary fenced. Mobile hygiene facilities for personnel decontamination (see Section 8.3.11) and decontamination units for both materials and operating vehicles (see Section 8.3.12) will be placed at the area entrance. The access to the site will be possible uniquely through the decontamination units. Warning signals will be placed to restrict access to unauthorized personnel.

### **8.2.2 Demolition Waste Treatment Area**

All materials generated by the demolitions operations, if not directly stored in big-bags, containers/coffer-dams or drums before the final disposal and/or reuse, will be sent to the preliminary treatment area, which will be located in the North-western part of Sector C (see Drawing 14).

The demolition material treatment area will be subdivided into the following sectors:

- concrete crushing, magnetic separation and washing plant;
- raw concrete debris stockpiling area;
- treated concrete stockpiling area;
- steel washing/decontamination area;
- raw steel stockpiling area; and
- washed steel stockpiling area.

The stockpiling sectors will be structured to allow the storage of demolition waste in homogeneous stockpiles.

The platform will have indicative dimensions of 100 x 55 meters for a whole area of 5,500 m<sup>2</sup>. It will consist of a reinforced concrete platform (concrete with waterproofing additives reinforced through steel welded wire) of at least 20 cm thickness (the correct thickness and reinforcing wire diameter for plant and operating vehicles support will be calculated in the Detailed Design) having on three sides (excluding the South-eastern side) 20 cm thick reinforced concrete perimeter walls with height of 1 m.

The access to the platform will be guaranteed by two concrete ramps on the South-eastern side, while the remaining portion will have a concrete berm approx. 20 cm high.

The platform will have a slope of 1% towards the North-western side, where a prefabricated concrete channel will collect all leachate and run-off waters. The channel will have rectangular shape and min. dimension of 40 x 36 cm. It will be covered by a galvanized steel carriageable wire cover. The cover will be removable to allow periodic cleaning and maintenance.

The channel will be connected to an external drain well through a High Density Polyethylene (HDPE) pipe. The drain well, made of reinforced concrete, will have rectangular base of at least 2 x 2 m and minimum depth of 1.5 m, for a total volume of 6 m<sup>3</sup>. The drain well will be covered by a galvanized steel carriageable wire cover. An automatic submerged pump will allow the periodic emptying of the drain well and the leachate will be sent to the wastewater treatment plant.

The structural elements details, the reinforcing bars dimensions and the logistic of the platform will be included in the Detailed Design.



### **8.2.3 Temporary Waste/Soil Stockpiling and Treatment Area**

The temporary stockpiling and treatment area will be realized in the North-western section of the OHIS site, in a grassy area located to the North of the Sector E and West of the Sector C (see Drawing 14 and Figure 8.3).



**Figure 8.3: Potential Location of the Temporary Stockpiling/Treatment Area**

The stockpiling/treatment area will be dedicated to the following activities:

- temporary stockpiling of reusable demolition material, treated soils and demolition waste to be used for backfilling in the following remediation phases; and
- temporary stockpiling of contaminated soils and demolition waste to be treated in the thermal desorber.

The area will also contain the treatment plants and associated facilities.

The area will have indicative dimensions of 100 x 135 meters for a whole area of 13,500 m<sup>2</sup>.

Since the remediation phases will advance, as far as possible, in parallel, clean soil/demolition waste will be used to backfill already treated areas; therefore, the available surfaces within the temporary stockpiling and treatment area should be sufficient for the entire remediation project.

However, should the necessity of additional space for the temporary stockpiling of clean soil/demolition waste emerge during the remediation operations, already remediated areas will be used for temporary stockpiling.

The base of the stockpiling/treatment area will consist of the following layers (from the bottom to the top):

- granular base;
- impervious HDPE liner (min. thickness 1.5 mm);
- drainage layer (30 cm of gravel);
- geotextile (220 g/m<sup>2</sup>); and
- protective layer (30 cm of sand/soil).



The drainage layer will contain the drainage collection system, consisting of HDPE drainage pipes (min. diam. 200 mm), double walled with corrugated external surface and smooth internal surface (slotted on site). The drainage pipes will converge in 8 HDPE drain wells connected to automatic drainage/leachate collection and pumping stations.

Each side will be closed by perimeter embankments, with a height of 1 m from the ground level, obtained by a sequence of compacted soil layers. The access to the storage area will be guaranteed by a ramp with a maximum slope of 8%. The embankment inner slopes will be covered by a HDPE liner welded to the internal impervious layer.

The underlying ground will be properly prepared prior to lay the base and embankment materials. Clearing and grubbing will be completed prior to beginning of laying activities. Debris/vegetation will be removed and surface depressions or holes will be filled with suitable materials to create a uniform surface. Soil will then be compacted before the granular base laying.

Embankments will be constructed with clayey soil disposed in layers of 30 cm. Each layer will be compacted using standard compaction methods.

To avoid mixing of different materials and of different leachate, the stockpiling platform will be subdivided in different sections separated by internal berms/embankments with a maximum height of 0.5 m. The berms will be realized by compacted soil layers and will be covered by a HDPE liner welded to the internal impervious layer.

The design details, the construction sequence and the logistic of the storage/treatment area will be included in the Detailed Design.

Excavated soil will be stockpiled in piles measuring approximately 1000 m<sup>3</sup>. The stockpiles will be located on the above described area to reduce contamination of underlying soil.

Stockpiles will be sequenced as presented in Soil Management Plan that will be included in the Detail Design.

Stockpiles will be covered with Low Density Polyethylene (LDPE) liners to control dust and reduce infiltration of any rainwater. If needed, dust containment systems, such as spraying systems throughout water sprinklers, fog cannons, etc. will be used to control dust emission during loading/unloading activities.

After its construction, each stockpile will be sampled and analyzed to profile soil for on site treatment and/or off-site transportation and treatment/disposal. The schedule and procedures presented in the Stockpile Sampling Plan (included in the Detail Design) will be followed. The Stockpile Sampling Plan will provide guidance as to how to sampling results will be interpreted to make a profile decision for stockpiled soil.

A tracking and record keeping system will be implemented to manage each stockpile generated from the excavation. The information that will be recorded and tracked includes:

- Identification number that links the stockpile with the excavation source;
- Location of the stockpile within the site;
- Date(s) stockpile was generated and approximate volume;
- Sampling information, including number of samples collected, sample identifiers, date of sampling, and requested analyses; and
- Analytical data that characterizes the stockpile.

The recordkeeping system will track the stockpiled soil from the time of excavation until it is placed in a truck for off site transport or backfilling.



## 8.3 PHASE 1 – DUMPS REMOVAL ACTIVITIES

The purpose of this Section is to present the preliminary design and implementation plan of excavation activities necessary to clean up the HCH waste dumps present within the OHIS site. Handling/packing and transportation procedures will be also described in the following Sections.

The preliminary flow diagram showing the operating steps, the possible alternatives and the estimated capacities and operating times are reported in Drawing 15.

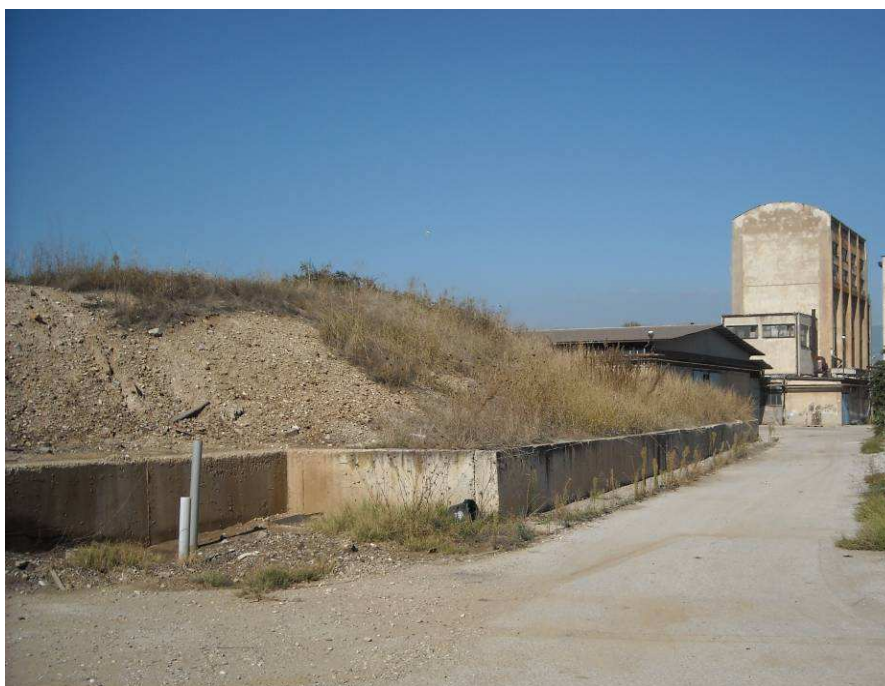
The detailed Removal plan, indicating the number of operating vehicles and resources to be used related to the site conditions and effective capacities, the operating cycles, the temporary storage, packing and loading procedures will be included in the Detailed Design.

### 8.3.1 Main Dumps Features and Estimated Waste Volumes

As reported in Section 4.2.1, two separate dumpsites with different extension and waste characteristics are present in Sector B of the OHIS site (see Drawing 14).

The bigger dump ( $\alpha+\beta$ -HCH isomers dump) covers an area of about 5,000 m<sup>2</sup> (100 x 50 m) while the smaller dump ( $\delta$ -HCH isomer dump) covers an area of 1,250 m<sup>2</sup> (35 x 35 m).

According to literature and past investigations data (EPTISA, 2007; Enacon, 2008a), the  $\alpha+\beta$ -HCH waste was originally laid on the natural ground without any precaution. All sides of the dumps are surrounded by a concrete perimeter wall with height ranging from 1.2 to approx. 3 m (see Figure 8.4). The dumps height varies from 3.2 to 4.6 m and the waste is covered by 0.60-1.50 m of natural soil.



**Figure 8.4:  $\alpha+\beta$ -HCH Isomers Dump**

The  $\delta$ -HCH dump consists of five underground concrete basins with base dimensions of 30 x 4 m and depth of 2.2 m. The basins are covered by waste and overlying soil for a total area of 35 x 35 m and an average height above ground of 1.6 m (see Figure 8.5).





**Figure 8.5:  $\delta$ -HCH Isomer Dump**

The following Table summarizes the waste quantities and average composition of the two dumps (ENACON 2008a).

Parameter	$\alpha+\beta$ -HCH Isomers Dump	$\delta$ -HCH Isomer Dump
Surface (m <sup>2</sup> )	5,000	1,225
Overlying Soil Volume (m <sup>3</sup> )	5,200	2,010
Overlying Soil Mass (ton)	9,360	3,628
HCH Waste Volume (m <sup>3</sup> )	15,000	620
HCH Waste Mass (ton)	28,500	589
HCH Waste Composition	88% $\alpha$ -HCH; 11-12% $\beta$ -HCH; 1-2% $\gamma$ -HCH (EPTISA, 2007) – 100% $\alpha$ -HCH (ENACON, 2008a)	22-26% $\alpha$ -HCH, 5-7% $\beta$ -HCH, 16-19% $\gamma$ -HCH, 38-50% $\delta$ -HCH (EPTISA, 2007) – 16% $\alpha$ -HCH, 1% $\beta$ -HCH, 44% $\gamma$ -HCH, 39% $\delta$ -HCH (ENACON, 2008a)
Estimated Concrete Volume (m <sup>3</sup> )	380	674

### 8.3.2 Concrete Demolition and Vegetation Removal

Prior to beginning soil and waste excavation of the  $\alpha+\beta$ -HCH dump, a preliminary demolition of the perimeter wall (or at least of its North-western section) and the subsequent creation of a soil ramp for the operating vehicles and trucks access will be carried out.



The concrete wall demolition will be carried out using a hydraulic excavator equipped with hydraulic hammer. The demolition material will be temporary stockpiled on site and covered by LDPE impervious sheets and subsequently loaded on a truck and transported to the demolition waste treatment area (see Section 8.2.2).

The dumps surface will then be cleared of obstructing objects (if any) and vegetation. To this aim, one dozer with ripper will be used to remove the first 10-20 cm of soil and to eradicate grass cover and roots.

Removed vegetation and roots will be collected and sent to disposal of. Soil will be loaded on trucks by one wheel loader (bucket capacity 3 m<sup>3</sup>) and sent to the stockpiling/treatment area (see Section 8.2.1).

### **8.3.3 Overlying Soil Excavation**

After the completion of demolition activities (for  $\alpha+\beta$ -HCH dump) and the vegetation removal (for both dumps), the first 0.60 to 1.50 m dumps material (overlying soil) will be excavated through machine open excavation. It is estimated that one hydraulic excavator with a bucket of 1.35 m<sup>3</sup> could complete the soil removal in approx. 12 working days (working on a single shift).

Depending on the results of the preliminary pilot testing phase (see Section 7.2.2.1), soil will be either loaded on trucks by one wheel loader (bucket capacity 3 m<sup>3</sup>) and sent to the stockpiling/treatment area (Option 1) or packed on-site (Option 2) and loaded on trucks for the off site transport to licensed treatment/disposal facility (e.g. incinerator).

### **8.3.4 Waste Removal**

$\alpha+\beta$ -HCH dump waste will be excavated through machine open excavation. It is estimated that one hydraulic excavator with a bucket of 1.35 m<sup>3</sup> could complete the waste removal in approx. 30 working days (working on a single shift).

Depending on the results of the preliminary pilot testing phase (see Section 7.2.1.5), HCH waste will be either loaded on trucks by a wheel loader (bucket capacity 3 m<sup>3</sup>) and sent to the stockpiling/treatment area for on site treatment (Option 1) or packed on-site (Option 2) and loaded on trucks for the off site transport to licensed treatment/disposal facility (e.g. incinerator).

$\delta$ -HCH dump waste will be removed from the containment basins using one hydraulic excavator equipped with suitable bucket (it is estimated that the removal could be completed in few days). Once the HCH waste will be completely extracted, the basing will be demolished (using the same excavator equipped with hydraulic hammer) and debris loaded on trucks and sent to the treatment area (see Section 8.2.2).

As for the  $\alpha+\beta$ -HCH dump,  $\delta$ -HCH dump waste will be either loaded on trucks by a wheel loader and sent to the stockpiling/treatment area (Option 1) or packed on-site (Option 2) and loaded on trucks for the off site transport to licensed treatment/disposal facility (e.g. incinerator).

### **8.3.5 Confirmatory Sampling**

Overlying soil excavation will proceed till the HCH waste layer is reached (according to the information available, it could be visually recognizable, being a white pasty to stiff inside the  $\alpha+\beta$ -HCH dump and a yellow-brown mud inside the  $\delta$ -HCH dump).

Following the same approach, the removal of HCH waste will be carried out till the underlying soil is reached.



No confirmatory sampling is needed at this stage, since the underlying soil (at least the first meter) will undergo the same excavation and treatment procedure.

#### **8.3.6 Dust Control Measures**

Soils will be managed for dust control as necessary based on air monitoring measurements and physical conditions. Common dust containment systems, such as spraying systems throughout water sprinklers, fog cannons, etc. will be used to control dust emission during excavation and packing activities. If wetting will be insufficient for dust control, soil may be covered by LDPE sheets.

#### **8.3.7 HCH Soil/Waste Treatment (Option 1)**

Soil treatability will be tested through dedicated off site thermal desorption pilot tests. The results of the preliminary pilot testing phase will affect the final destination of the surficial soil removed from the two HCH dumps.

Should HCH-contaminated soil be successfully decontaminated by thermal desorption, and an efficient off gas treatment system for chlorine abatement set up, a mobile/semi-mobile thermal desorber of suitable size (see Section 8.1.2) will be mobilized to OHIS site and dumps overlying soil will be removed and sent by trucks to the temporary stockpiling/treatment area for decontamination.

Considering a capacity of the thermal desorber operating 24 hours/day of approx. 105 ton/d a total treatment time of 68 days is foreseen for the whole soil decontamination.

Contemporarily to the soil treatability pilot test, HCH waste will be sent to off site pilot testing of mechanochemical dehalogenation. If the preliminary pilot testing of process (described in detail in Section 7.2.1.5) will result in the actual technology applicability to HCH isomers, a mechanochemical dehalogenation plant will be transported/built on site.

On the basis of the available information it was estimated by the license holder a treatment capacity of 3.4 ton/day for pure HCH.

Considering the availability of two on site plants operating in parallel 24 hours/day, a total treatment capacity of 20.4 ton/day can be obtained, corresponding to a dehalogenation time of more than 1300 days. Despite such long operating period, the dehalogenation process can still be considered applicable provided that all other activities will be conducted in parallel. On this condition, due to the considerable amount of soil to be treated by TD, the end of the dehalogenation process will precede the end of thermal treatment of all other contaminated matrices, and the dehalogenated waste will be stored for few months before the final TD (see the preliminary schedule of the activities reported in Section 9).

In any case, it has to be underlined that the estimated treatment capacity and duration are based on the hypothesis that dumps are composed of almost pure HCH isomers. Such assumption is very conservative, and the confirmatory sampling carried out during the waste extraction activities could show lower HCH concentrations (with consequent lower treatment times).

#### **8.3.8 HCH Soil/Waste Packing and Off-site Disposal (Option 2)**

In case the final destination of contaminated soil and HCH waste will be the off site treatment (dehalogenation/thermal desorption pilot testing failure), the waste will be packed in polyethylene (PE) drums compliant with international regulation for carriage of dangerous goods/waste by road (i.e. ADR 2009, Basel Convention, etc.) and sent to off site treatment



(i.e. licensed hazardous waste management facilities able to dispose of the HCH waste) either by trucks or through intermodal transport.

A specific Section dedicated to the shipment of hazardous waste indicating labeling, tracking and record keeping systems will be included in the Transportation Plan that will be developed in the Detail Design.

Drums choice strictly depends on the final destination, but a quantity of 80-120 kg/drum of product could be considered as the maximum allowable (depending on waste chlorine content). Therefore, considering the product packed in 60-l PE drums (weight max. 80 kg) and subsequently on Euro pallets, an average of 312 drums per truck (corresponding to 26 Euro pallets) can be considered, for a total waste weight of approx. 25 tons.

HCH will be manually packed by operators, drums sealed and washed, and pallets loaded on trucks by a forklift truck. It is estimated that an adequate number (>12) of operators working 24 h/day on three shifts could reach a packing capacity of 100 t/d, corresponding to approx. 130 days to complete the overlying soil removal and packing, and approx. 290 days to complete the HCH removal and packing (including excavation, labeling, weighting, decontaminating the drums, etc.).

Packed drums will be temporarily stored in a dedicate section of the stockpiling area. Drums storage will be covered and bermed, in order to provide adequate containment for any accidental leakage. Alternatively, the existing A9-A11 warehouses (see Drawing 14 and Figure 8.6) could be used for temporary drums storage. All buildings will be carefully checked to ensure their structural integrity and, if possible, samples will be taken and analyzed to avoid any health risk for workers and operators.



**Figure 8.6: Building A9 (Inside)**



### **8.3.9 Waste Transport**

Loaded trucks will move to the truck decontamination station where soil will be removed from fenders and tires and the bed will be covered.

Each truck will then move to the temporary stockpiling/treatment area (Option 1) or to the weighting station (Option 2).

It has been calculated that, in case of off-site transport, ten 25 ton-trucks will move all packed HCH waste to an hypothetical treatment plant located 2000 km from the OHIS site in more than 600 days (considering 9 hours as maximum daily journey), while intermodal transport (trucks/train) would allow the complete off site movement in approx. 194 days (considering an average capacity of 3,000 tons/month).

Each loaded truck will leave the site with a completed manifest or bill of lading for transport of soil or other material to the off site treatment location. Soil loading and off site routes will be have to be detailed in the Transportation Plan which will be included in the Detail Design.

### **8.3.10 Personal Protective Equipments**

Operators shall wear all PPE related to the protection from HCH vapours throughout the working shift.

In particular, the following PPE represent the minimum equipment of each operator:

- helmets;
- safety boots;
- protective gloves;
- Respiratory Protective Equipments (RPEs); and
- disposable protective overalls.

Suitable types of RPE will be selected through dedicated Risk assessment which results will be included in the Detailed Design. The most suitable equipments are face-mask of the highest protection class. However, depending on the Risk assessment results, also non-powered or "Negative pressure" respirators, such as disposable or re-usable half masks, could be used. Negative pressure respirators and filters must comply with the following standards:

- disposable respirator to standards EN 149;
- half mask respirator to standard EN 140;
- semi-disposable respirator to EN 405;
- particle filters and combined filters respectively to standards EN 143 and EN 14387.

Only the most efficient filtration systems should be used, i.e. FFP3 for disposable respirators and P3 for filters on re-usable respirators.

Disposable overalls of Type 5 (EN ISO 13982) will be used for HCH removal and packing operations.

Both used RPEs and overalls will be disposed as hazardous waste.

### **8.3.11 Personal Decontamination Procedures and Hygiene Facility**

Before the lunch break and at the end of each shift, personnel exiting the work area will decontaminate and remove PPE at the personnel decontamination station (mobile hygiene facility) established adjacent to the work area.



Mobile hygiene facility is a temporary facility which includes the following Sections:

- clean room;
- airlock;
- showers room; and
- dirty end.

The dirty end will be used by operators to remove all visible contamination. It will have drums for storing used PPE, tubs for washing and rinsing boots, boot racks for storage of boots. Protective overalls, disposable underclothes and gloves will be removed inside the dirty end and placed in suitable containers for disposal. Protective boots will be washed, removed and stored. All these operation will be carried out wearing RPEs.

Operators will then proceed to the shower room, where they thoroughly clean hair, body and facemask. Once completed the cleaning procedure, RPEs will be removed, switched off and thoroughly cleaned. Operators will then proceed, through the airlock, to the clean room, where they will dry off, put on clean clothes and visually inspect RPEs.

The entrance in the working area will be carried out following the same procedure in reverse order. Underclothes and protective overalls will be put on inside the clean unit. RPEs will be put on, switched on and tested before entering the dirty end.

#### **8.3.12 Decontamination Units**

The material decontamination unit is subdivided in three sections connected only by the waste bags transit basin the first two and by a flap door with PE strips the other two.

Proceeding from the working site (contaminated) to the non-contaminated area, the three sections are described in the following:

- Washing room. The contaminated operator will thoroughly wash the contaminated bags or the used tools;
- Repacking room. The cleaned bags will proceed to the repacking room through the connection basin and they will be repacked in new labeled PE bags by a non-contaminated operator;
- Storing room. The packed material will be temporarily stored in the storing room of the decontamination unit before the final packing in big-bags.

Waste waters from the decontamination unit and hygiene facility will be collected and sent to the wastewater treatment plant.

Tire and wheel wash station will be set up at the exit of the area to decontaminate vehicles that are transporting contaminated soils and waste to on site stockpiling and treatment or to off site treatment facilities. The wash station will be realized through a mobile (pre-assembled) structure with automatic water jets and lateral protection (see Figure 8.1). Water will be collected and sent to the wastewater treatment plant (see Section 8.7.1).

#### **8.3.13 Training of Personnel**

Excavation, removal and packing will be performed by licensed hazardous Contractors. Personnel on site will observe OSHA (Occupational Safety and Health Administration) Safety Standards and follow the Health and Safety Plan (which shall be included in the Detail Design).



The Contractors shall use trained operators on risks related to soil cleanup works, BAT for handling HCH waste and HCH-contaminated soil, cleaning and decontamination procedures, use of RPEs, etc.

As a minimum, the training course shall focus on the following arguments:

- handling and health hazards of HCH waste;
- site set up, maintenance and dismantling;
- personal protective equipments;
- transit procedures and decontamination;
- HCH handling and packing procedures, plant and equipment use;
- waste management and handling; and
- emergency procedures.

## **8.4 PHASE 2 – DEMOLITION ACTIVITIES**

At present, no information about possible reuse of OHIS buildings is available, therefore it is assumed that all buildings will be demolished, and demolition waste disposed or reused either on site or off site.

The purpose of this Section is to present the preliminary design and implementation plan of demolition activities. Demolition waste handling and transportation procedures will be also described in the following Sections.

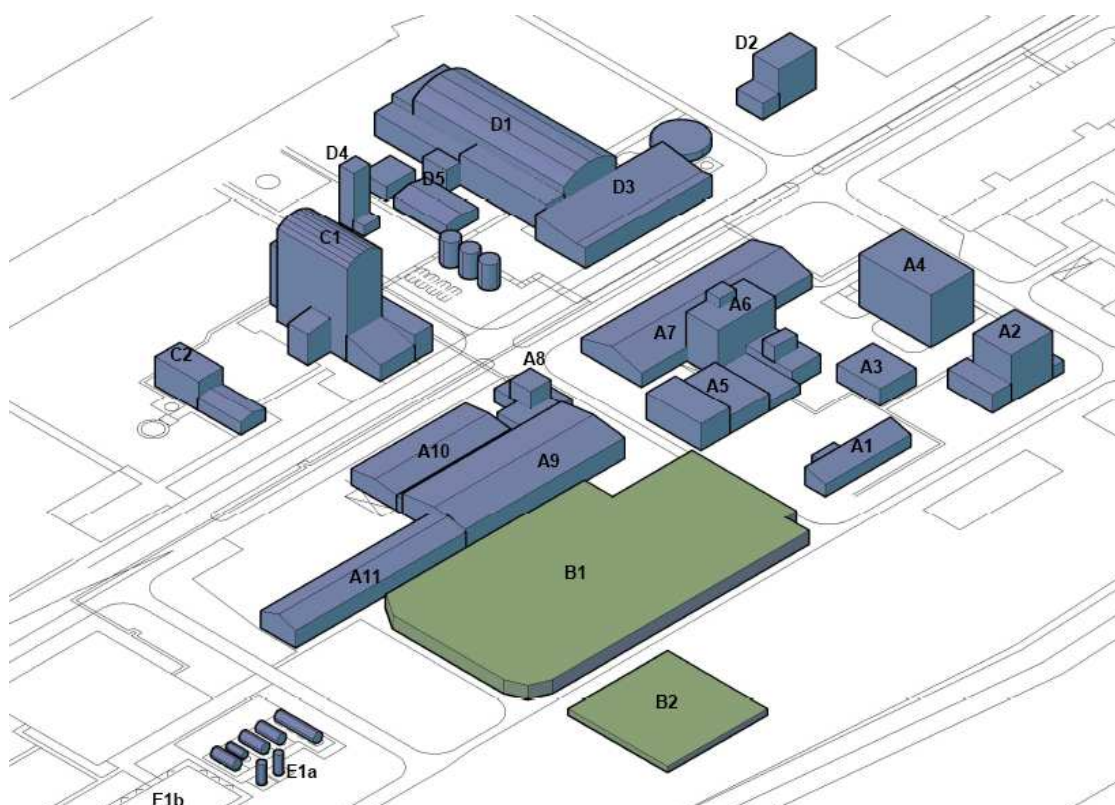
The preliminary flow diagram showing the operating steps, the possible alternatives and the estimated capacities and operating times are reported in Drawing 16.

### **8.4.1 Summary of the Buildings and Structures to be Demolished**

A brief summary of the main building characteristics and a preliminary estimation of the demolition material volumes (excluding steel structures) is provided in the following Sections. The summary is based on the information gathered from the Feasibility Studies developed by Enacon S.r.o. (Enacon, 2008b and 2008d) and the preliminary site surveys conducted by D'Appolonia in 2009-2010.

The buildings codes used in this CD and building position are reported in Figure 8.7.





#### LEGEND

A1 – Former Storage of HCH and TCB Production  
A2 – Former Lindane Production Building  
A3 – Former Raw Material and Packaging Building  
A4 – Former Lindane Production Building  
A5 – Lockers Room, Workshops  
A6 – Organophosphates Production Building  
A7 – Granular Phosphates Production Building  
A8 – Production of Granulated Pesticides  
A9 – Storage of Final Pesticides  
A10 – Storage of Packaging  
A11 – Storage of Packaging

B1 –  $\alpha+\beta$ -HCH dump  
B2 –  $\delta$ -HCH dump  
C1 – Former Monochloroacetic Acid Production Building  
C2 – Former Acetylene Production Building  
D1 – Former Electrolysis Plant  
D2 – Transformer Station  
D3 – Former Salt Storage  
D4 – Hydrochloric Acid Production  
D5 – Former Storage of Acetylene  
E1a – Above Ground Storage Tanks  
E1b – Outdoor Storage of Flammables

**Figure 8.7: Building Inventory**

A dedicated survey shall be carried out before the Detailed Design development, in order to define the demolition strategy based on the specific construction characteristic and position of each building.

#### 8.4.1.1 Building A1 – Former Storage of HCH and TCB Production

One-storey building of rectangular plan having dimension of  $30.6 \times 7.5 \text{ m}^2$ , with shed roof of height from 3.5 to 5.2 m. The building is founded on reinforced concrete foundations. The roof is covered with corrugated asbestos-cement sheets. The main building includes two adjacent sections: a brick building with 30 cm-thick brick walls and a roofed open area with steel structure. An outbuilding of  $3.7 \times 8.2 \text{ m}^2$ , height 3.5 m is connected to the brick building.



The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.1: Building A1 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	155.2
Masonry	149.8
Asbestos-cement	1.4



**Figure 8.8: Building A1 – Former Storage of HCH and TCB Production**

8.4.1.2 Building A2 – Former Lindane Production Building

Four-storey building of rectangular plan, size of 14.25 x 12.25 m<sup>2</sup>, height of 14.2 m (flat roof). Two outbuildings concur from both sides on the main building. The main building is made of reinforced concrete with concrete walls of 25 cm. The roof is made of reinforced concrete slabs covered by tar sheets.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.2: Building A2 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	514.25





**Figure 8.9: Building A2 – Former Lindane Production Building**

8.4.1.3 Building A3 – Former Raw Material and Packaging Building

One-storey building, open from one side, of rectangular plan having approx. size of 12.5 x 15.5 m<sup>2</sup>. The height of the shed roof is 4-5 m. The building is founded on reinforced concrete foundations and the ground floor is made of concrete. Roof covering is made of corrugated sheets.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.3: Building A3 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	83.6



**Figure 8.10: Building A3 – Former Raw Material and Packaging Building**



#### 8.4.1.4 Building A4 - Former Lindane Production Building

Four-storey building, with rectangular plan of 25.3 x 15.3 m<sup>2</sup>. A two-storey outbuilding with rectangular plan (size 25.3 x 5.0 m<sup>2</sup>), height of 7.3 m and a one-storey outbuilding (rectangular plan of 20.3 x 5.5 m<sup>2</sup>, height of 3.5 m) are connected with the main building on the South-eastern side. All buildings have a reinforced concrete structure closed with brick walls of 30 cm thickness.

Internal floors are made by reinforced concrete slabs with thickness of 30 cm. The roof, made of reinforced concrete slabs, is flat (height 15.6 m). Roof is covered by tar sheets.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.4: Building A4 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	1,020
Masonry	477
Tar sheets	3.7



**Figure 8.11: Building A4 – Former Lindane Production Building**



**Figure 8.12: Building A4 (North-western side)**



#### 8.4.1.5 Building A5 – Locker Rooms, Workshop

The building, having a rectangular plan with an approx. area of 846 m<sup>2</sup>, is divided into eight sections, each having different height (from 2.7 to 7.9 m). The North-western section is a two-storey building with a height of 7.9 m, while the other sections are one-storey buildings of the height from 2.7 m to 5.1 m. The building A6 concurs on the building in its North-eastern side. All buildings have a reinforced concrete structure closed with brick walls of 30-40 cm thickness. Foundations and ground floor are made of concrete. The roofs are flat, made by reinforced concrete slabs covered with tar sheets.

A roofed open area with concrete structure is built up above the South-eastern section of the building. The shed roof (height 4-4.5 m) is made by corrugated asbestos-cement sheets.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.5: Building A5 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	728.4
Masonry	505.8
Tar sheets	5.07



**Figure 8.13: Buildings A5 and A6 (Behind)**

#### 8.4.1.6 Building A6 – Organophosphates Production Building

Three-storey building with rectangular plan of 20.4 x 10.6 m<sup>2</sup>, height 14.5 m. The building is connected through its South-western side to the building A5 and through its North-eastern side to the building A7. The machine-room of the elevator (5.5 x 4.4 m<sup>2</sup>) is located on the roof of the building. The total height is approx. 17.2 m.

The construction is made by the reinforced concrete columns with the brick walls of thickness of 30 cm. The ceilings are made of reinforced concrete of the thickness of 30 cm.



Foundations and ground floor are made of concrete. The roof is flat, made by reinforced concrete slabs covered with tar sheets.

There is an elevator leading till the fourth floor. Machines and steel tanks are present inside the building.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.6: Building A6 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	360.9
Masonry	346.3
Tar sheets	1.3



**Figure 8.14: Buildings A6 – Organophosphates Production Building**

8.4.1.7 Building A7 – Granular Phosphates Production Building

One-storey building of rectangular plan, size of 60.2 x 21.2 m<sup>2</sup>, height 6.9 m. The building is connected to the building A6. A brick outbuilding (plan size 6.4 x 3.1 m) is located in the South-eastern side. The structure of the building is made of reinforced concrete and the warehouse is closed by brick walls with thickness of 30cm. The building is founded on reinforced concrete foundation strips (external walls) and on the single foundation pads (internal columns) 1.0 m deep. The gable roof is covered by asbestos-cement sheets. Brick



walls offices and other spaces are built inside the warehouse. An external canopy made of reinforced concrete girders and asbestos-cement covering is located on the North-western side of the building.

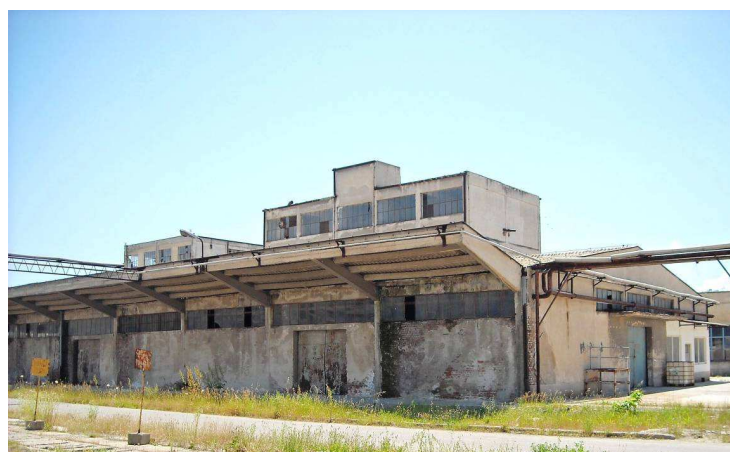
The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.7: Building A7 – Volume of Construction Materials**

<b>Material</b>	<b>Volume (m<sup>3</sup>)</b>
Concrete / Reinforced Concrete	547.6
Masonry	284.2
Asbestos-cement	9



**Figure 8.15: Building A7 – Granular Phosphates Production Building**



**Figure 8.16: Building A7 (North-western side)**



#### 8.4.1.8 Building A8 – Production of Granulated Pesticides

Two-storey brick building with L-shaped plan having a total area of 247 m<sup>2</sup>. The total height is 9.3 m. Two rectangular one-storey outbuildings (6.7 x 5.2 m<sup>2</sup> and 3.8 x 3.3 m<sup>2</sup>, height of 2.4-3.0 m and 3.1-3.9 m) are connected to the main building on its South-eastern side. The main is connected with the building A10 by a covered passage way.

Brick columns support reinforced concrete slabs and girders (thickness of 30 cm). External brick walls have a thickness of 30 cm. Reinforced concrete foundation strips (external walls, outbuildings) and pads (columns) support the structure. Depth of the foundation is 1.0 m. Roof is flat and it is covered by tar sheets. Outbuildings' roof is covered by asbestos-cement sheets.

Equipments, steel tanks and dosing machines from the granulated pesticides production are present inside the building.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.8: Building A8 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	163.4
Masonry	124.9
Tar sheets	1.1
Asbestos-cement	0.3



**Figure 8.17: Building A8 – Production of Granulated Pesticides**

#### 8.4.1.9 Building A9 – Storage of Final Pesticides

One-storey warehouse with rectangular plan, size 55.6 x 23.7 m<sup>2</sup>, height 7.5 m. The building is connected to the building A10 (North-eastern side) and to the building A11 (North-western side). The warehouse is made of reinforced concrete and steel columns, with



external brick walls of the thickness of 30 cm. The building is founded on reinforced concrete foundation strips (external walls) and on the single foundation pads (internal columns) 1.0 m deep. The ground floor is formed by the reinforced concrete pads. The gable roof is made of steel girders corrugated panels.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.9: Building A9 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	384.2
Masonry	184.7



**Figure 8.18: Building A9 (South-eastern entrance)**

#### 8.4.1.10 Building A10 – Storage of Packaging

One-storey building with rectangular plan; size 40.5 x 16.6 m<sup>2</sup>, height 5.5 m. The structure of the building is made of reinforced concrete and the warehouse is closed by brick walls with thickness of 30cm. The building is founded on reinforced concrete foundation strips (external walls) and on the single foundation pads (internal columns) 1.0 m deep. The ground floor is formed by the reinforced concrete pads. The gable roof is made of steel girders covered by corrugated panels.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.10: Building A10 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	240.1
Masonry	130.2



#### 8.4.1.11 Building A11 - Storage of Packaging

One-storey building with rectangular plan; size 60.5 x 12.4 m<sup>2</sup>, height 7.0 m. The warehouse has a steel structure and it is closed by brick walls with thickness of 30cm. The building is founded on reinforced concrete foundation strips (depth 1.0 m). The ground floor is formed by the reinforced concrete pads. The gable roof is covered by corrugated panels.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.11: Building A11 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	265.7
Masonry	199.7



**Figure 8.19: Buildings (from left) A9, A10 (North-Western Entrances) and A11 (North-Eastern Side)**



**Figure 8.20: Building A11 (North-Western and South-Western Sides)**



#### 8.4.1.12 Building C1 – Former Monochloroacetic Acid Production Building

Seven-storey building with rectangular plan; size approx. 18.6 x 36.6 m<sup>2</sup>, height 30.3. An open four-storey reinforced concrete construction with steel stairs is built on the North-eastern side.

The main building is supported by ten reinforced concrete outside pillars (0.65 x 1.3 m) and three 0.6 x 0.6 m concrete pillars. External brick walls with thickness of 30 cm close the structure. A store building, supported by reinforced concrete columns, is located in the South-western side. Internal ceilings and structure are made of reinforced concrete.

The main building has a reinforced concrete gambrel roof covered with corrugated plates.

Some equipments and tanks from the past production are present inside the building.

Three above ground vertical steel tanks (structure C3) for the chlorinated hydrocarbons storage (diameter 3.1 m, height 7.6 m) are located on the North-eastern side of the building. The tanks are built on a concrete platform of 5.65 x 14.2 m<sup>2</sup> with bricks berms 30 cm height. Some small open concrete basins and channels are built near the tanks.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.12: Building C1 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	1,903.8
Masonry	650.4
Tar sheets	0.6
Asbestos-cement	0.5



**Figure 8.21: Building C1 (Northern Side) and Chlorinated Hydrocarbons Storage Tanks**





**Figure 8.22: Building C1 (Inside)**

**8.4.1.13 Building C2 – Former Acetylene Production Building**

The building (rectangular plan 30.3 x 8.3 m<sup>2</sup>) is divided in two parts: a two-storey building (15.3 x 8.3 m<sup>2</sup>, total height of 8.7 m) with reinforced concrete structure and brick walls (thickness 30 cm) and a concrete flat roof covered with tar sheets; and a one-storey brick building (15.0 x 8.3 m<sup>2</sup>, height 4.5 m) with gable roof covered with the asbestos-cement panels.

A roofed two-storey open shed with steel structure is built on the South-eastern part of the two-storey building.

The following construction material volumes have been estimated (Enacon, 2008d):

**Table 8.13: Building C2 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	228.6
Masonry	163.2
Tar sheets	0.76
Asbestos-cement	0.77





**Figure 8.23: Building C2 – Former Acetylene Production Building**



**Figure 8.24: Buildings C1 and C2**

#### 8.4.1.14 Building D1 – Former Electrolysis Plant

It consists of a four-storey main building of rectangular plan of the approx. size of 60.4 x 24.1 m<sup>2</sup>, height of 14.5 m, and several other outbuildings of the height ranging from 3.3 m to 10.2 m, briefly described in the following:

- on the North-eastern side a transformer stations of 13 x 7.5 m<sup>2</sup> and height 6.7 m connected with a two-storey building of the size 11.1 x 7.5 m<sup>2</sup> and height of 6.7 m. A small covered steel structure (approx. size of 4.6 x 4 m, height 3.3 m) is built above the two-storey building;



- on the South-eastern side two small brick buildings (probably used for the instrumental and electric panels). The smaller one is approx. 3.5 m high, size 3.8 x 3.8 m<sup>2</sup>, while the second building is 6.5 m high and 7.5 x 3.7 m<sup>2</sup> plan; and
- on the North-western side there a three-storey outbuilding of rectangular plan of approx. 8 x 5.2 m<sup>2</sup> and height of 10.2 m.

The main building is supported by concrete pillars of 0.7 x 0.4 m<sup>2</sup> section, among which 25 cm-thick brick walls are built. Internal structure of the building is made of reinforced concrete. The reinforced concrete gambrel roof is covered with tar sheets.

Several reinforced concrete basins are built inside and near the building.

The following construction material volumes have been estimated (Enacon, 2008b):

**Table 8.14: Building D1 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	1,629.7
Masonry	1,287.4

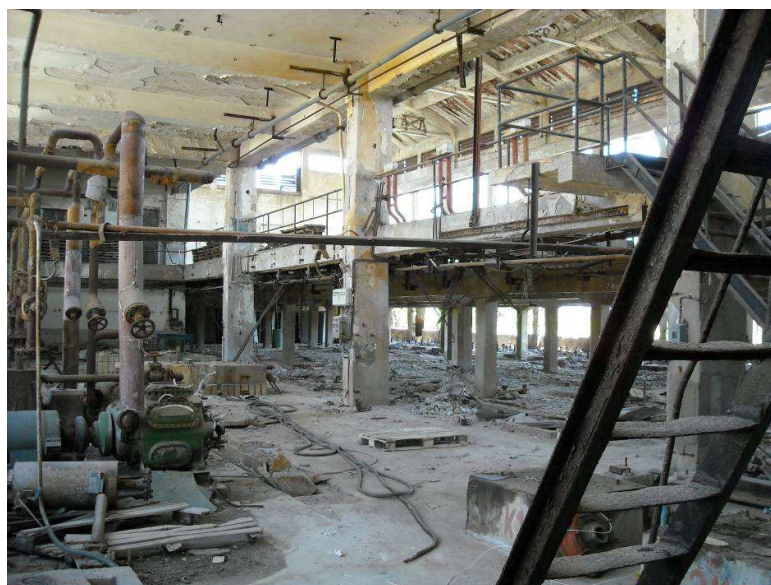


**Figure 8.25: Building D1 (South-Eastern Side)**





**Figure 8.26: Building D1 (North-Western Side)**



**Figure 8.27: Building D1 (Inside)**

#### 8.4.1.15 Building D2 - Transformer Station

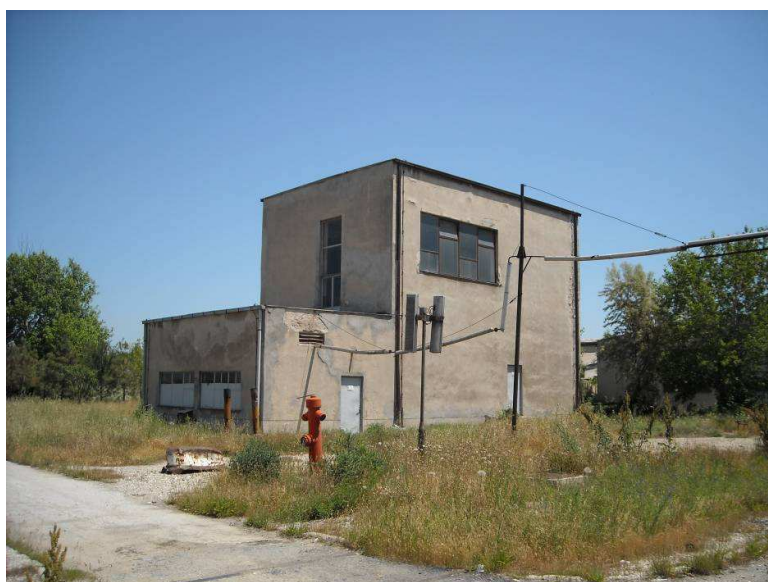
The transformer station consists of two brick buildings: a smaller one-storey building with offices having size of 5.8 x 9 m<sup>2</sup> and height of approx. 4.6 m, and the transformer station with size of 12.2 x 9 m and approx. above ground height of 12.1 m. The transformer station has a basement of approx. 2.5 m below the ground level. The shed roofs are covered with tar sheets.



The following construction material volumes have been estimated (Enacon, 2008b):

**Table 8.15: Building D2 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	213.4
Masonry	165.2



**Figure 8.28: Building D2 – Transformer Station**

#### 8.4.1.16 Building D3 – Former Salt Storage

Open warehouse with concrete basins for salt storage, having a rectangular plan of the size of 44.4 x 17.4 m<sup>2</sup> and height of 7.5 m. The structure is built adjacent to the South-eastern side of the building D1.

The structure is made of reinforced concrete and concrete tanks are built across the whole length of the structure.

The following construction material volumes have been estimated (Enacon, 2008b):

**Table 8.16: Building D3 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	608.5
Masonry	110





**Figure 8.29: Building D3 – Former Salt Storage**



**Figure 8.30: Building D3 – Storage Basin**

#### 8.4.1.17 Building D4 – Hydrochloric Acid Production

It is composed by a steel structure with rectangular plan of approx.  $5.5 \times 4.8 \text{ m}^2$  and height of approx. 17.4 m, and a small brick building (office building) of rectangular plan of approx.  $5.3 \times 3.5 \text{ m}^2$  and height of approx. 2.9 m.

The office building is one-storey brick building with 0.25 m thick walls. Foundations of the building are concrete strips with 0.45 m thickness 0.6 m depth. The roof is flat and covered with tar sheets.



The steel structure has four floors, with steel grids and railings. It is founded on concrete pads of  $0.9 \times 0.9 \text{ m}^2$ .

The following construction material volumes have been estimated (Enacon, 2008b):

**Table 8.17: Building D4 – Volume of Construction Materials**

Material	Volume ( $\text{m}^3$ )
Concrete / Reinforced Concrete	603
Masonry	36.9



**Figure 8.31: Building D4 – Hydrochloric Acid Production**

#### 8.4.1.18 Building D5 – Former Storage of Acetylene

Six steel tanks for acetylene are located in this two-story rectangular plan ( $18.3 \times 11.1 \text{ m}^2$ , height 4.2 m) warehouse with brick walls. A section of the building is built below the ground level.

The bottom floor is made of concrete while the floor above the tanks is made of steel pads. The supporting structure consists of twelve concrete columns (section  $0.3 \times 0.3 \text{ m}^2$ ). Building foundations consist of reinforced concrete pads ( $0.7 \times 0.7 \text{ m}^2$  section) reinforced concrete strips. The roof is covered by corrugated plates. A reinforced concrete structure-building adjacent to Building D5 (North-eastern side) is used for gas cylinders storage. The roof is covered by ACMs corrugated sheets.



The following construction material volumes have been estimated (Enacon, 2008b):

**Table 8.18: Building D5 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	50.2
Masonry	110.7
Asbestos-cement	1.3



**Figure 8.32: Building D5 – Former Storage of Acetylene**



**Figure 8.33: Building D5 (Rear Building)**



#### 8.4.1.19 Structure E1 – Outdoor Storage of Flammables

##### E1a – Above Ground Storage Tanks

It includes five horizontal aboveground storage tanks and two vertical above ground storage tanks.

Each of the five horizontal tanks is located in a concrete platform with berms having rectangular plan and dimensions depending on the tank size (from 8.3 x 4.3 m<sup>2</sup> to 18.2 x 6.2 m<sup>2</sup>). The basins consist of concrete slabs of 0.30 m total thickness with concrete berms having height ranging from 1.0 - 1.3 m. Three types of steel reservoirs are present:

- 13.5 m length x 3.0 m diameter (one tank);
- 7.5 m length x 3.0 m diameter (three tanks); and
- 5.4 m length x 2.0 m diameter (one tank).

A steel structure allows the access to the tanks.

The two vertical tanks (6 m height x 2.2 m diameter) are placed in a basing of rectangular plan with size of 9.6 x 4.9 m<sup>2</sup>. The basin consists of a concrete slab of 0.30 m total thickness with concrete berms 1.3 m high. The basin is subdivided in two sections by a concrete berm. The steel tanks have diameter of 2.2 m and height of 6.0 m. A steel structure allows the access to the tanks.



**Figure 8.34: Structure E1a – Above Ground Storage Tanks**





**Figure 8.35: Structure E1a – Above Ground Storage Tanks**

**E1b – Outdoor Storage of Flammables/Chemicals**

It consists of an uncovered concrete basin of rectangular plan of 27 x 20 m<sup>2</sup>. The basin bottom is made by concrete slabs 30 cm thick. The basin is 20 cm below ground level. The structure is fenced and a flowline with sprinklers runs above the basin at a height of approx. 2.5 m.



**Figure 8.36: Structure E1b – Outdoor Storage of Flammables**



The following construction material volumes have been estimated for E1 structures (Enacon, 2008d):

**Table 8.19: Structure E1 – Volume of Construction Materials**

Material	Volume (m <sup>3</sup> )
Concrete / Reinforced Concrete	570.9

#### 8.4.1.20 Summary of Construction Wastes

The total volumes of construction waste generated by the demolition of the structures and buildings (including paved areas, concrete basins, etc.) of the OHIS site are summarized in Table 8.20.

**Table 8.20: Demolition Waste Volume**

Material	Volume (m <sup>3</sup> )				
	Sector A	Sector C	Sector D	Sector E	TOTAL
Concrete / Reinforced Concrete	4,463.2	2,132.4	3,880.9	570.9	<b>11,047.6</b>
Masonry	2,402.6	813.6	1,710.2	-	<b>4,926.4</b>
Tar roofing	11.2	1.4	-	-	<b>12.6</b>
Asbestos-cement	10.7	1.3	1.3	-	<b>13.3</b>
Ceramic coatings	-	-	43.7	-	<b>43.7</b>
Asphalt	-	-	151	-	<b>151</b>

During the monitoring campaign conducted in 2008 by Enacon, 34 samples of construction materials were collected and analyzed to assess the contamination of the former lindane and organophosphates production and storage buildings (Sector A), the monochloroacetic acid and acetylene production buildings (Sector C) and the outdoor cooled storage of flammables (Sector E).

Selected samples of construction materials (19 samples) were subjected to leaching tests (Enacon, 2008d). Results were compared with the EU limits for inert waste, non-hazardous waste and hazardous waste landfills (Directive 1999/31/EC and Commission Decision 2003/33/EC). None of the nineteen construction material samples tested for leachability complied with limits for inert waste landfill (mainly due to high sulphate and DOC content). Several samples (collected in Sectors A and C) resulted so heavily contaminated by DOC (4 samples), sulphates (1 sample) and heavy metals (1 sample) to exceed the limits for hazardous waste.

A total of 10400 m<sup>3</sup> of demolition waste were calculated for Sectors A, C, E (Enacon, 2008d), of which 38% requiring treatment to meet the acceptance criteria of hazardous-waste landfills.

In addition, 28 samples of construction materials were collected from the former electrolysis plant (Enacon, 2008b).

Laboratory analyses found high contents of mercury in masonry and in concrete samples. Hg concentration exceeded 10 mg/kg in most samples. Selected samples (6) were subjected to leaching test. Results were compared with the EU limits. Five samples did not comply with limits for hazardous waste due to high concentration of mercury in water leachate.



In total, approx. 5600 m<sup>3</sup> of demolition waste was estimated for Sector D dismantling, most of which (63%) would require a preliminary treatment to achieve acceptance criteria for hazardous waste landfills (Enacon, 2008b).

Finally, 13.3 m<sup>3</sup> of asbestos-cement were estimated, corresponding to approx. 2040 m<sup>2</sup> of asbestos-cement slabs to be removed (considering an average thickness of 6.5 mm).

On the basis of the sampling campaign conducted in 2008 (ENACON 2008b and 2008d), the following preliminary categorization can be considered for the OHIS site buildings to be demolished. However, it must be noted that this is only a preliminary evaluation, and that the volumes of different waste categories can only be calculated through the waste stockpiles composite sampling and analysis.



**Figure 8.37: Preliminary Building Categorization**

#### 8.4.2 Demolition Plan

In the following Sections a preliminary summary of the techniques and methodologies which will be used for OHIS structures demolition is reported.

The Pre-demolition investigation and risk assessment and the Demolition design reports will be included in the Detail Design, indicating, for each building which undergoes demolition (described in previous Sections):

- the principal characteristics of the area (e.g. presence of pits or cavities, presence of sewages and/or slurry, presence of underground utilities, etc.);
- the static characteristics of the structures to be demolished;
- the areas for debris temporary storage and for the construction of ramps and embankments;



- the site plans and layout;
- the characteristics of the demolition machine to be used;
- the debris and dust control systems to be used; and
- the time sequence of events.

Demolition and dismantling operations will be conducted following technical criteria and rules set in the Macedonian Regulations and Technical Guidelines and international BAT Reference Documents. The demolition phase will also include the preliminary treatment (i.e. crushing, washing, magnetic separation, etc.), the temporary stockpiling and the final recycling/disposal of the demolition materials.

As regards the asbestos-cement, which was found on the site in not negligible amount, it will be removed before the beginning of the demolition phase, according to the procedure and methodologies described in Section 8.4.2.5.

Before the beginning of the operations all waste and materials originated from past productions will be removed from buildings and structures. Waste originated from the preliminary site clearance will be stored in proper areas (see Section 8.2.3) either in containers or in big bags or PE drums, depending on their nature and hazardousness.

#### 8.4.2.1 Preliminary Dust Protection Measures

After the clearance, preliminarily to its demolition, each structure will be cleaned from dust through washing, using, where possible, proper mechanical equipments and/or machines. The water will be collected and sent to the waste water treatment plant.

This preventive measure will allow the reduction of the aerial dispersion of dust during demolition and the subsequent fallout in nearby areas.

#### 8.4.2.2 Process Fluids

Before starting the demolition operations all equipments will be emptied and process fluids (which could represent an explosion or fire risk) properly collected.

Depending on the product characteristics, the emptying of the equipments will be carried out through pumping either with portable pumps or tank trucks equipped with pumping systems, or flushing water and/or steam into the equipments and collecting the fluids in proper drums or tanks.

The hydraulic oil present in mechanical reducers and gears will be pumped in PVC drums or collected by tank trucks with automatic pumping systems. The same procedure will be used for fuels.

In case semi-solidified fuel oil will be found in unused tanks, it could only be removed after tank dismantling. Therefore, safe dismantling procedures like cold cut, shear cutting, etc. will be followed, and the solid fuel will be collected and stored in proper containers and finally sent to licensed recovery facilities.

If acid storage tanks will be found within the site, before their demolition they will be emptied, repeatedly washed and neutralized and finally flushed with dry air in order to avoid the hydrogen production inside the tanks. All acid and caustic products will be stored in drums with airtight. All drums will be labeled according to national and/or international safety rules and guidelines.



A specific Emergency Response Plan in case of accidental leakages or spills of contaminated material from industrial structures/equipments will be developed and included in the Detail Design.

#### 8.4.2.3 General Buildings Demolition Methodology

Before starting structures demolition, where necessary, all sections which could potentially collapse during operations will be reinforced through cribs, metallic structures or strengthening the whole structure.

The demolition will be carried out using the following equipments:

- high reach: hydraulic excavators equipped with special booms and arms with high operating heights; and
- hydraulic excavators, with high demolition capacities.

Excavators will be equipped with hydraulic jaws, crushers, breakers and shears suitable for concrete, reinforced concrete and steel.

##### 8.4.2.3.1 Demolition of Non-Structural Steel Structures

This phase will be carried out without the use of hydraulic excavators and it will include the dismantling of flowlines, equipments and steel structures without bearing functions. The access to the working areas will be guaranteed by hydraulic lifting platforms.

The preferred technique for flowlines and metallic structures dismantling, if applicable, will be the thermal cutting. Beside conventional PPE, operators shall wear protective full-face respirators with combined filter for dust and vapours, or half-face respirators with same filter and safety spectacles. The dust abatement system shall operate during the whole duration of cutting operations. Any deposit or fouling material will be collected or isolated using proper foaming products.

In case of insulated flowlines dismantling, once the insulating material will be identified, the following protective measures will be adopted:

- use of wetting agents through airless spray pumps;
- static confinement of the working area (see Section 8.4.2.5);
- use of High Efficiency Particulate Arrestor (HEPA) vacuum pumps of suitable capacity to obtain negative pressure in the enclosures;
- remove and isolate waste into labeled PE bags.

##### 8.4.2.3.2 Demolition of Masonry and Internal Structures

The internal masonry demolition shall proceed in parallel with metallic structures dismantling (see Section 8.4.2.3.1). In general the demolition will be carried out from the top to the bottom of the buildings using scaffoldings should internal floors not be enough to reach all structures.

For floors demolition, I beams will be taken off the walls and cut with oxyacetylene torch, while reinforced concrete girders will be demolished with hammer drill and rebars and embedded steel cut with oxyacetylene torch. Girders demolition will need precautionary shoring. Girder will then be cut in pieces and removed by cranes.

Reinforced concrete pillars will be secured at the top and then removed in pieces using hammer drill (presumably mounted on a small excavator) and oxyacetylene torch.



#### 8.4.2.3.3 External Structures Demolition

The reinforced concrete and metal bearing structures will be dismantled using the following procedure:

- demolition/dismantling using high reach and/or hydraulic excavators equipped with hydraulic jaws/crushers for concrete and shears for metal cutting (see Figure 8.38);
- primary crushing (from blocks of 1-1.5 m to debris with size of 30-40 cm) carried out through hydraulic excavators equipped with concrete pulverisers and loading of demolition material into truck for transport to treatment area (see Section 8.2.2);
- transport of demolition material to treatment area for secondary crushing, magnetic separation and washing;
- temporary stockpiling of demolition material for analysis and subsequent off site transport to disposal or reuse;
- reinforcing rods temporary stockpiling, load and transport to licensed recovery facilities; and
- dismantling of metal structures, volumetric reduction to suitable size, washing (if needed), load and transport to licensed recovery facilities.



**Figure 8.38: Demolition through Hydraulic Excavator Equipped with Hydraulic Jaws**

The controlled demolition of reinforced concrete structures will be carried out from the top to the bottom, proceeding in modules and crushing and/or pulverizing the concrete in place, in order to avoid the risk of untimely collapse of the remaining part of the structures.

The materials resulting from the demolition of the concrete structures, after the preliminary (primary) volumetric reduction through hydraulic excavators equipped with hydraulic crushers/pulverizers, will be sent to the treatment area to undergo the following operations:

- typology selection, to separate lithologic fraction from metal;
- secondary crushing; and
- washing.



#### 8.4.2.3.4 Metallic Structures Demolition

Steel structures will be dismantled in reverse order with respect to their construction. The parts of the structure will be removed using oxyacetylene torches and/or flexible grinding/cutting wheels. The removed parts will be lowered using cranes.

#### 8.4.2.4 Dust Control Measures

Using high reach machines, due to the high altitude of the demolition operations, dust development needs to be avoided through the suitable dust containment systems, such as:

- spraying systems throughout water jets;
- pressure lances operating from elevated platforms;
- fog cannons; and
- spray systems applied on demolition arms.

The washing of structures and debris will be carried out using the minimum quantities of water, in order to avoid run-off phenomena.

In case extraordinary atmospheric events with intensities higher than the maximum thresholds, the demolition operations will be precautionarily interrupted.

#### 8.4.2.5 Asbestos Containing Materials

The identification and removal of Asbestos Containing Materials (ACMs) will be carried out prior to demolition commencement on site. The ACMs dismantling shall be carried out by licensed contractors.

The area surrounding the ACMs removal worksites will be temporary fenced and appropriate warning signals will be placed to restrict access to unauthorized personnel.

If necessary, to remove insulating ACMs from pipes, confined areas shall be realized insulating the scaffoldings with PE sheets and connecting the enclosures to extraction fan equipped with HEPA filtering systems (99.99% abatement).

The access to the confined area will be realized through suitable decontamination areas for both workers and equipments.

#### *Preliminary Encapsulation of Asbestos Cement Sheets*

Before their removal, asbestos sheet covers will be treated with suitable wetting/encapsulating agents through low-pressure airless spray pumps. The operation will be usually conducted on the exposed (external) side of the asbestos sheet cover before removal. The lower (internal) side will be treated before piling in elevation or at ground level.

#### *Asbestos Sheets Dismantling Procedure*

The dismantling of the asbestos sheet covers will be carried out preferably from the outer side. If needed, the dismantling could also be carried out from the inner side using hydraulic platforms. Fasteners, clamps and bolts will be removed through manual utensils, avoiding the use of any cutting or demolishing tool. If needed, only tools equipped with extraction systems with HEPA filtration could be used. Once fasteners will be removed, the sheets will be removed and temporary piled on site.



### *Stockpiling Procedure*

The asbestos cement sheets will be piled either at the removal site or at ground level. The sheets will be piled with the encapsulated side turned downwards in order to allow the impregnation of the untreated side. Each side of the piled sheets will be treated before the final packing.

The lowering of the asbestos cement sheets or sheet piles will be carried out through hydraulic cranes or platforms.

### *Packing Methodology*

The piled sheets will be placed into suitable packing made of PE sheets at least 0.15 mm thick, sealed with adhesive tape and labeled. The crushed ACMs will be collected and placed into PE bags of suitable thickness.

Packed asbestos sheets piles will be temporarily placed within containers and sent to licensed disposal facilities.

### *Daily Cleanup of the Working Area*

During removal operations, all ACM fragments will be immediately removed or sucked and placed in PE bags. At the end of each shift the working site will be cleaned from fragments and dust through vacuum cleaner equipped with HEPA filters.

### *Personal Protective Equipments*

Dismantling operators shall wear all PPE for work at height and for accidental objects impacts. All PPE related to the protection from ACM dust shall be wear throughout the working shift.

In particular, the following PPE represent the minimum equipment of each operator:

- helmets;
- safety boots without laces;
- protective gloves;
- RPEs;
- disposable protective overalls; and
- safety belts with energy dissipation systems.

Suitable types of RPE will be selected through dedicated Risk assessment which results will be included in the Detailed Design. The most suitable equipment for most ACMs dismantling operations are the power assisted respirators with full face-mask of the highest protection class (EN 12942 Class TM3). However, depending on the Risk assessment results, also non-powered or "Negative pressure" respirators, such as disposable or re-usable half masks, could be used in supporting operations. Negative pressure respirators and filters must comply with the following standards:

- disposable respirator to standards EN 149;
- half mask respirator to standard EN 140;
- semi-disposable respirator to EN 405;
- particle filters and combined filters respectively to standards EN 143 and EN 14387.



Only the most efficient filtration systems should be used, i.e. FFP3 for disposable respirators and P3 for filters on re-usable respirators.

Disposable overalls of Type 5 (EN ISO 13982) or Type 6 (EN 13034) will be used for ACMs removal operations.

Both used RPEs and overalls will be disposed as asbestos-containing waste.

*Personal decontamination procedures and hygiene facility*

Before the lunch break and at the end of each shift, before leaving the working area, operators will carry out the following decontamination procedures.

Mobile hygiene facility is a temporary facility which includes the following three sections:

- clean room;
- airlock;
- showers room; and
- dirty end.

The dirty end will be used by operators to remove all visible contamination. Before leaving the working area (or the enclosures) and entering the dirty end, operators will vacuum off with Class H vacuum cleaner fitted with brush attachments RPEs and protective clothes. Protective overalls, disposable underclothes and gloves will be removed inside the dirty end and placed in suitable containers for disposal. Protective boots will be removed and stored. All these operation will be carried out wearing RPEs.

Operators will then proceed to the shower room, where they thoroughly clean hair, body and facemask. Once completed the cleaning procedure, RPEs will be removed, switched off and thoroughly cleaned. Operators will then proceed, through the airlock, to the clean room, where they will dry off, put on clean clothes and visually inspect RPEs.

The entrance in the working area will be carried out following the same procedure in reverse order. Underclothes and protective overalls will be put on inside the clean unit. RPEs will be put on, switched on and tested before entering the dirty end.

*ACMs Decontamination Unit*

The ACMs decontamination unit is subdivided in three sections connected only by the waste bags transit basin the first two and by a flap door with PE sheets the other two.

Proceeding from the working site (contaminated) to the non-contaminated area, the three sections are described in the following:

- Washing room. The contaminated operator will thoroughly wash the contaminated bags containing the ACMs or the used tools;
- Repacking room. The cleaned bags will proceed to the repacking room through the connection basin and they will be repacked in new labeled PE bags by a non-contaminated operator;
- Storing room. The packed ACMs will be temporarily stored in the storing room of the decontamination unit before the final packing in big-bags.

Waste waters from the decontamination unit and hygiene facility will be collected and sent to the wastewater treatment plant.



#### *Monitoring of Airborne Asbestos Fibers*

During ACMs dismantling operations air monitoring will be carried out to assess the concentration of airborne asbestos fiber levels that have been generated by the removal / remediation process both inside and outside the working area. Final monitoring will then be carried out to check that the area is suitable for re-occupation on completion of asbestos work.

To this aim, a measured volume of air will be drawn through a 25 mm-diameter filter. The breathable fibers on a measured area of the filter will be counted using phase contrast optical microscopy, and the concentration of the fibers in the air will be calculated and compared with regulation thresholds.

#### *Training of Personnel*

The ACMs removal Contractor shall use trained operators on risks related to asbestos works, best techniques for dismantling and handling ACMs, cleaning and decontamination procedures, use of RPEs, etc.

As a minimum, the training course shall focus on the following arguments:

- types, uses and risks of ACMs
- health hazards of asbestos and legislation
- site set up, maintenance and dismantling
- personal protective equipments
- transit procedures and decontamination
- ACMs dismantling procedures, plant and equipment use
- waste management and handling; and
- emergency procedures

### **8.4.3 Demolition Waste Treatments**

#### **8.4.3.1 Crushing and Washing Plant**

The debris generated by the demolition operations will be sent to the secondary crushing (the primary volume reduction will be carried out through excavators with concrete pulveriser jaws in proximity of the demolished structures) and washing plant which should be able to produce inert materials reusable for backfilling or other civil engineering uses.

The plant will have a capacity of 500 ton/day and it will consist of the following sections:

- secondary crushing to reduce size to 7-8 cm;
- magnetic separation for metal and steel parts; and
- washing with industrial water or acid water (max. 5% sulphuric acid) through rotary drums.

The 7-8 cm-sized material will be sent to temporary stockpiling for the sampling and verification of conformity.

The fine-grained material collected from the rotary drum will be collected in a settling basin/thickener or separated through cycloning. The wastewater will be sent to the wastewater treatment plant, while sludge will be sent to dehydration.



Considering a total volume of demolition materials (concrete, reinforced concrete and masonry) of 16000 m<sup>3</sup>, corresponding to approx. 24000 tons, a total treatment time (working on a single shift per day) of approx. 50 days is expected.

The flow chart of the demolition and treatment process is reported in detail in Drawing 16.

#### 8.4.3.2 Steel Washing/Decontamination

A specific area for the washing and decontamination of dismantled steel and metallic structures and piping will be realized inside the demolition material treatment platform. It will consist of a bermed area with separate collecting system. Two basins will be realized inside the area: a first basin for the steel structures immersion and a second basin for the rinsing through pressure lances. The metallic structures moving will be realized through a wheel loader. All along the perimeter of the washing area impermeable barrier will be erected to avoid contamination spreading. The washing personnel will be equipped with impermeable coveralls (Type 6), full-face protections, protective gloves and boots.

#### 8.4.3.3 Demolition Waste Decontamination (Optional)

As reported in Section 8.4.1.20, demolition activities will generate a total of 15974 m<sup>3</sup> of debris (concrete/reinforced concrete and masonry), 46.8% of which possibly requiring further treatment due to exceedance of the Commission Decision 2003/33/EC limits for hazardous waste landfill. In fact, elevated HCH and Hg values were found respectively in Sector A and Sector D buildings, while exceedances of 2003/33/EC limits were found in leachate samples for DOC, sulphates, heavy metals and mercury throughout the site.

The majority of contaminants should mainly adhere to fine materials and dust, therefore the preliminary treatment (crushing and washing) should be able to decontaminate most of demolition debris (especially from heavy metals and inorganic contaminants).

However, conservatively adopting past investigation estimations, 7468 m<sup>3</sup> of demolition material will possibly undergo thermal desorption, which could completely eliminate HCH and other organic contaminants.

Considering a capacity of the thermal desorber operating 24 hours/day of approx. 300 ton/d a total treatment time of 38 days is foreseen for the whole soil decontamination.

## 8.5 PHASE 3 – SURFICIAL SOIL EXCAVATION AND TREATMENT

The purpose of this Section is to present the preliminary design and implementation plan of excavation activities necessary to meet the cleanup goals for the surficial soil identified in Section 5.3.1.

Drawing 8 and Table 6.1 identify the initial excavation limits and surface individuated using the cleanup goals summarized in Section 5.3.1.

After removal of soil from the initial excavation limits, the status of the excavation will be evaluated using confirmatory samples. If the confirmatory sampling results are higher than the cleanup goal(s), further excavation will occur until subsequent confirmation samples indicate that the cleanup goals have been achieved.

The preliminary flow diagram showing the operating steps, the possible alternatives and the estimated capacities and operating times are reported in Drawing 17.

The detailed Excavation plan, indicating the number of operating vehicles and resources to be used related to the site conditions and effective capacities, the operating cycles, the temporary storage, packing and loading procedures will be included in the Detailed Design.



### 8.5.1 Equipments and Procedures

Suitable earth moving equipments and operating vehicles will be selected to conduct soil excavation, transport and backfilling operations, following the criteria indicated in the table below:

**Table 8.21: Earth Moving Equipments Use**

	Track-type Tractor/Dozer with Ripper	Hydraulic Excavator	Wheel loader	Dozer	Scraper	Truck/Dumper	Motor Grader	Compactor
Clearing and ripping	■							
Excavation		■		■	■			
Loading		■	■		■			
Earth Movement			■	■				
Transport					■	■		
Unloading					■	■		
Backfilling				■	■		■	
Final Grading				■			■	
Compaction								■

Common excavation practices based on groundwater protection and side slope stability criteria will be followed. Among others, the following criteria will be observed:

- minimum distance from the first aquifer shall be guaranteed: the excavation operations should involve only the unsaturated soils, i.e. the bottom of the excavation should lie above the maximum excursion level of the local unconfined aquifer;
- in case of need, dewatering systems or well points will be installed;
- natural impermeable barriers, if present, will be as far as possible preserved and not excavated; and
- maximum side slope shall guarantee sufficient stability (a side slope of 45% can be retained as the limiting value).

### 8.5.2 Site Clearing and Vegetation Removal

Prior to any excavation, utilities that could be affected by the work will be marked and verified through joint surveys with OHIS representatives and/or through geophysical surveys (e.g. pipe locator, ground penetrating radar, etc.), if needed. If necessary, a specific emergency response and restoration plan will be prepared in the event that an active utility is damaged.



The areas of concern will then be cleared of obstructing objects and debris (if any) and of vegetation. To this aim, a dozer with ripper will be used to remove the first 10-20 cm of soil and to eradicate grass cover and roots.

Removed vegetation and roots will be collected and sent to disposal of. Soil will be loaded on trucks by a wheel loader (bucket capacity 3 m<sup>3</sup>) and sent to the stockpiling/treatment area (see Section 8.2.3).

### **8.5.3 Excavation Procedures and Progression**

After the completion of site clearing and vegetation removal, the first meter of soil will be excavated through machine open excavation.

The areas of concern (indicated in Drawing 8) will be excavated in homogeneous parcels. Areas with different possible contamination will be removed and stockpiled separately. The detail of the excavation progression, the temporary management area/loading zones shifting with work and excavation progression, etc. will be provided in the Excavation plan.

Soil will be excavated with hydraulic excavator and moved to the temporary stockpiling/treatment area with 12-16 m<sup>3</sup>-capacity trucks.

One hydraulic excavator with a bucket of 1.35 m<sup>3</sup> could complete the HCH-contaminated soil excavation in 39 working days (working on a single shift). The removal of HCH/Hg-contaminated soil and Hg-contaminated soil will be completed in further 10 days.

Excavated areas will be widened or deepened if soil confirmation sampling data indicate that the excavation objective has not been achieved. Excavation will continue until the target levels set in Table 6.1 will be reached.

Depending on the results of the preliminary pilot testing phase, soil will be either loaded on trucks by one wheel loader (bucket capacity 3 m<sup>3</sup>) and sent to the stockpiling/treatment area (Option 1) or packed on-site (Option 2) and loaded on trucks for the off site transport to licensed treatment/disposal facilities (e.g. incinerators).

### **8.5.4 Confirmatory Sampling**

Soil confirmation samples will be collected to demonstrate that soil exceeding cleanup goals has been entirely removed.

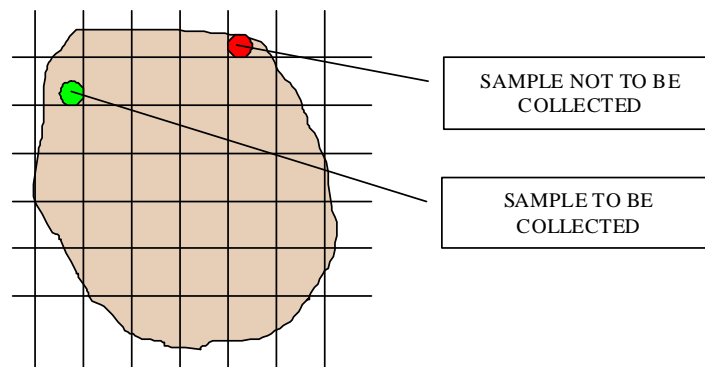
Upon reaching the excavation limits, confirmation samples will be collected from soil parcels which, according to the HHRA results should not be further excavated (see Figure 8.39), and analyzed by licensed laboratory. The results of the confirmation sampling will direct termination or continuation of the excavation. If additional excavation is conducted, it will be followed by additional round(s) of confirmation sampling.

As a preliminary concept, it is proposed to collect a composite soil sample every 625 m<sup>2</sup> or at least one every excavated pit (if smaller than 625 m<sup>2</sup>). The samples will be collected by:

- defining 25 x 25 m regular grid on the bottom; and
- mixing four individual samples (aliquots) randomly distributed over the grid.

Each sample will be collected from the bottom of the excavated pit to a depth of 10-15 cm below the bottom surface. Should the 25 x 25 m grid exceed the base area of the excavated pit, the sample will be collected if at least half the mesh is within the bottom area (see following Figure).





**Figure 8.39: Criterion for Perimeter Meshes Sampling**

For side walls, it is proposed to collect a composite soil sample every 500 m<sup>2</sup> of side wall or at least one every 100 m of perimeter of the excavated pit. In any case at least one sample every excavated pit shall be collected if smaller. The sample will be collected by composing four individual samples (aliquots) randomly distributed both longitudinally and vertically for each 500 m<sup>2</sup> subarea of the sidewalls.

Each composite sample will be tested for the contaminants of concern (HCH/Hg) belonging to the different remediation areas for which remediation goals set by the HHRA are exceeded.

The Confirmatory Sampling Plan (to be included in the Detail Design) will provide detailed guidance as to how confirmation sampling will be conducted and to how results will be interpreted to support a decision whether the excavation has met the performance standard or whether additional excavation is needed.

#### **8.5.5 Dust Control Measures**

Soils will be managed for dust control as necessary based on air monitoring measurements and physical conditions. Common dust containment systems, such as spraying systems throughout water sprinklers, fog cannons, etc. will be used to control dust emission during excavation and packing activities. If wetting will be insufficient for dust control, soil may be covered by LDPE sheets.

#### **8.5.6 HCH/Hg-Contaminated Soil Treatment (Option 1)**

Similarly to Phase 1, soil treatability will be tested through dedicated off site thermal desorption pilot tests (especially for Hg and HCH/Hg-contaminated soils).

Should HCH-contaminated and/or Hg-contaminated soils be successfully decontaminated by thermal desorption, a mobile/semi-mobile thermal desorber of suitable size (see Section 8.1.2) will be mobilized to OHIS site, and excavated soil will be sent by trucks to the temporary stockpiling/treatment area for thermal treatment.

Considering a capacity of the thermal desorber operating 24 hours/day of approx. 105 ton/d, a total treatment time of 397 days is foreseen for the HCH-contaminated surficial soil treatment.

HCH/Hg and Hg-contaminated soil (considering the same treatment capacity) will require a further 82+35 days for the complete decontamination.



#### **8.5.7 Soil Packing (Option 2)**

In case the final destination of contaminated soil will be the off site treatment (i.e. pilot testing failure), the waste will be packed in PE drums compliant with international regulation for carriage of dangerous goods/waste by road (i.e. ADR 2009, Basel Convention, etc.) and sent to off site treatment either by trucks or through intermodal transport.

As for previous phases, considering the product packed in 60-l PE drums (weight max. 80 kg) and subsequently on Euro pallets, an average capacity of 100 t/d is expected, corresponding to approx. 753 days to complete the HCH-contaminated surficial soil removal and packing, and to approx. 156+23 days for HCH/Hg and Hg-contaminated soil.

Packed drums will be temporarily stored in a dedicate section of the stockpiling area. Drums storage shall be covered and bermed, in order to provide adequate containment for any accidental leakage. Alternatively, the existing A9-A11 warehouses (see Drawing 14 and Figure 8.6) could be used for temporary drums storage. All buildings shall be carefully checked to ensure their structural integrity and possibly samples shall be taken and analyzed to avoid any health risk for workers and operators.

#### **8.5.8 Soil Transport**

Loaded trucks will move to the temporary stockpiling/treatment area (Option 1) or to the decontamination station (where soil will be removed from fenders and tires and the bed will be covered) and the weighting station (Option 2).

In case of Option 2 selection, ten 25 ton-trucks could transport all packed HCH-contaminated soils to an hypothetical treatment plant located 2000 km from the OHIS site in more than 1,645 days (considering 9 hours as maximum daily journey), while intermodal transport (trucks/train) could allow the complete off site movement in approx. 502 days (considering an average capacity of 3,000 tons/month). HCH/Hg and Hg-contaminated soils transport to off site treatment will require further 390 days considering road transport or 119 days considering intermodal transport.

Each loaded truck will leave the site with a completed manifest or bill of lading for transport of soil or other material to the off site treatment location. Soil loading and off site routes will be detailed in the Transportation Plan which will be included in the Detail Design.

#### **8.5.9 Safety and Training of Personnel**

Excavation and removal will be performed by a licensed hazardous substances removal contractor. Personnel on site will observe OSHA safety standards and follow the approved Health and Safety Plan (included in the Detail Design), which addresses the safety of personnel performing or entering excavations for the purposes of surveying and operating equipment.

### **8.6 PHASE 4 – DEEP SOIL EXCAVATION AND TREATMENT**

The purpose of this Section is to present the preliminary design and implementation plan of excavation activities necessary to meet the cleanup goals for the deep soil identified in Section 5.3.1.

Drawing 9 and Table 6.1 identify the initial excavation limits and surface individuated using the cleanup goals summarized in Section 5.3.1.

After removal of soil from the initial excavation limits, the status of the excavation will be evaluated using confirmatory samples. If the confirmatory sampling results are higher than



the cleanup goal(s), further excavation will occur until subsequent confirmation samples indicate that the cleanup goals have been achieved.

The preliminary flow diagram showing the operating steps, the possible alternatives and the estimated capacities and operating times are reported in Drawing 18.

The detailed Excavation plan, indicating the number of operating vehicles and resources to be used related to the site conditions and effective capacities, the operating cycles, the temporary storage, packing and loading procedures will be included in the Detailed Design.

#### **8.6.1 HCH-Contaminated Soil *In Situ* Thermal Desorption (Option 1)**

If successful ISTD pilot tests will be performed at the OHIS site, a full scale installation will be set up by the HCH-contaminated deep soil.

At this stage it is not possible to estimate the full-scale capacity of the ISTD process. The main process parameters will be discussed in the Detail Design, which will also define the off-gases treatment systems, including the possible use of the TD off-gas treatment section.

#### **8.6.2 Contaminated Soil Excavation and Treatment (Option 2)**

The unique alternative to ISTD, in case of pilot tests failure, will be the excavation of the deep soil and the subsequent treatment, either on site or off site at licensed facilities.

##### **8.6.2.1 Equipments**

Suitable earth moving equipments and operating vehicles will be selected to conduct soil excavation, transport and backfilling operations, following the criteria indicated in Table 8.21.

The access to the excavated areas for trucks and operating vehicles will be guaranteed by a ramp with a maximum slope of 8%.

##### **8.6.2.2 Excavation Procedures and Progression**

The areas of concern (indicated in Drawing 9) will be excavated through machine open excavation. The detail of the excavation progression, the temporary management area/loading zones shifting with work and excavation progression, etc. will be detailed in the Excavation plan.

Soil will be excavated with hydraulic excavator and moved to the temporary stockpiling/treatment area with 12-16 m<sup>3</sup>-capacity trucks.

It is estimated that one hydraulic excavator with a bucket of 1.35 m<sup>3</sup> could complete the HCH-contaminated deep soil excavation in 78 working days (working on a single shift). The removal of Hg-contaminated soil and Hg-contaminated soil will be completed in 106 days.

Excavated areas will be widened or deepened if soil confirmation sampling data indicate that the excavation objective has not been achieved. Excavation will continue until the target levels set in Table 6.1 will be reached.

Depending on the results of the preliminary pilot testing phase, soil will be either loaded on trucks by one wheel loader (bucket capacity 3 m<sup>3</sup>) and sent to the stockpiling/treatment area (Option 1) or packed on-site (Option 2) and loaded on trucks for the off site transport to licensed treatment/disposal facilities (e.g. incinerators).



#### 8.6.2.3 Confirmatory Sampling

Soil confirmation samples will be collected to demonstrate that soil exceeding cleanup goals has been entirely removed.

Upon reaching the excavation limits, confirmation samples will be collected and analyzed by licensed laboratory. The results of the confirmation sampling will direct termination or continuation of the excavation. If additional excavation is conducted, it will be followed by additional round(s) of confirmation sampling.

Similarly to previous Phase, a composite soil sample will be collected every 625 m<sup>2</sup> or at least one every excavated pit (if smaller than 625 m<sup>2</sup>).

For side walls, it is proposed to collect a composite soil sample every 500 m<sup>2</sup> of side wall or at least one every 100 m of perimeter of the excavated pit. In any case at least one sample every excavated pit shall be collected if smaller.

Each composite sample will be tested for the contaminants of concern (HCH/Hg) belonging to the different remediation areas for which remediation goals set by the HHRA are exceeded.

The Confirmatory Sampling Plan (to be included in the Detail Design) will provide detailed guidance as to how confirmation sampling will be conducted and to how results will be interpreted to support a decision whether the excavation has met the performance standard or whether additional excavation is needed.

#### 8.6.2.4 Dust Control Measures

Soils will be managed for dust control as necessary based on air monitoring measurements and physical conditions. Common dust containment systems, such as spraying systems throughout water sprinklers, fog cannons, etc. will be used to control dust emission during excavation and packing activities. If wetting will be insufficient for dust control, soil may be covered by LDPE sheets.

#### 8.6.2.5 HCH/Hg-Contaminated Soil Treatment (Option 2A)

Should HCH-contaminated and/or Hg-contaminated soils be successfully decontaminated by thermal desorption, excavated soil will be sent by trucks to the temporary stockpiling/treatment area for decontamination.

Due to the different physical features of deep soil (i.e. different grain size and fine particles content) a capacity of 166 m<sup>3</sup>/d can be assumed for the HCH-contaminated soil with the thermal desorber operating 24 hours/day. A total treatment time of 305 days can then be foreseen for the HCH-contaminated deep soil treatment.

For Hg-contaminated soil (due to the different off-gas treatment set up), a capacity of 105 m<sup>3</sup>/d can be conservatively assumed. Therefore, further 659 days should be considered for the complete deep soil decontamination.

#### 8.6.2.6 Soil Packing (Option 2B)

In case the final destination of contaminated soil will be the off site treatment (thermal desorption pilot testing failure), the waste will be packed in PE drums compliant with international regulation for carriage of dangerous goods/waste by road (i.e. ADR 2009, Basel Convention, etc.) and sent to off site treatment either by trucks or through intermodal transport.



As for previous phases, considering the product packed in 60-l PE drums (weight max. 80 kg), an average capacity of 100 t/d is expected, corresponding to approx. 914 days to complete the HCH-contaminated deep soil removal and packing, and to approx. 1248 days for HCH/Hg and Hg-contaminated soil.

Packed drums will be temporarily stored in a dedicate section of the stockpiling area. Drums storage shall be covered and bermed, in order to provide adequate containment for any accidental leakage. Alternatively, the existing A9-A11 warehouses (see Drawing 14 and Figure 8.6) could be used for temporary drums storage. All buildings shall be carefully checked to ensure their structural integrity and possibly samples shall be taken and analyzed to avoid any health risk for workers and operators.

#### **8.6.2.7      Soil Transport**

Loaded trucks will move to the temporary stockpiling/treatment area (Option 2A) or to the decontamination station (where soil will be removed from fenders and tires and the bed will be covered) and the weighting station (Option 2B).

In case of Option 2B selection, it is estimated that packed HCH-contaminated soils could be transported to off site treatment in 1997 days if road transport is the selected option, or in 610 days through intermodal transport. Hg-contaminated soils transport to off site treatment will require further 2727 days considering road transport or 879 days with intermodal transport.

Each loaded truck will leave the site with a completed manifest or bill of lading for transport of soil or other material to the off site treatment location. Soil loading and off site routes will be detailed in the Transportation Plan which will be included in the Detail Design.

#### **8.6.3      Safety and Training of Personnel**

Excavation and removal will be performed by a licensed hazardous substances removal contractor. Personnel on site will observe OSHA safety standards and follow the approved Health and Safety Plan (included in the Detail Design), which addresses the safety of personnel performing or entering excavations for the purposes of surveying and operating equipment.

#### **8.6.4      Shoring and Setbacks**

The deep soil excavation will be shored where the depth of excavation could endanger nearby structures or site personnel during construction.

Shoring or other measures will be implemented to ensure that the excavation meets OSHA safety standards for construction personnel. Shoring and setback requirements will be described in the Health and Safety Plan.

### **8.7      PHASE 5 – GROUNDWATER TREATMENT**

As reported in Section 7.2.5, a traditional approach based on a pump-and-treat system for hydraulic confinement of the site and water extraction, followed by on site treatment of CHC and HCH contaminated groundwater with activated carbons is considered adequate for the treatment of shallow aquifer below OHIS site.

A pre-treatment for solid removal (i.e. sedimentation, sand filter with backwashing or flocculation/sedimentation system) can be set up to remove suspended solids, while biological reactor can be possibly implemented as preliminary step before activated carbons (if needed).



To this aim, the on site waste water treatment plant foreseen to treat all effluents from operating sites and equipments can be adequately upgraded to treat extracted groundwater treatment. The proposed plant configuration is reported in the following Section.

Once the lacking data will be acquired and pilot test performed to evaluate operative parameters for the full scale application, pump and treat can be considered a cost effective technology for the site, allowing the removal of the contamination plume with consequent risk elimination for nearby communities.

#### **8.7.1 Waste Water Treatment Plant**

A Wastewater Treatment Plant (WWTP) will be set up before the beginning of the remediation activities to decontaminate and reuse wastewaters coming from the different operating plants/remediation operations.

The following wastewaters will be received and treated by the WWTP:

- preliminary building washing and dust prevention operations;
- runoff water from stockpiling/treatment platforms;
- washing of demolition material;
- soil washing (if coarse material washing section will be activated);
- scrubbing; and
- decontamination operations.

Once the hydraulic barrier will be built on site and started, the WWTP will be also used to treat groundwater extracted from the shallow aquifer beneath OHIS site.

The WWTP will be located on the grassy area North-west to the Section E (see Drawing 14). All drainage wells will be connected with the WWTP through dedicated flowlines running as far as possible along the site perimeter, in order to avoid any interference with the remediation activities.

The area will be paved and an adequate secondary containment system will be provided to contain tanks' volume in case of leakage or rupture.

Wastewaters from operative sections will be directed to an above ground equalization tank/basin, designed to equalize concentration and flow fluctuations of the incoming wastewater before entering the downstream treatment equipment. The tank will be continuously stirred, and liquid level and temperature monitored.

Wastewaters will flow from the equalization tank to the neutralization system (if needed). The pH of the influent wastewater will be adjusted by the addition of either sodium hydroxide or sulfuric acid, as required, to effect the precipitation of dissolved solids and metals.

Suspended and dissolved solids separation will be accomplished through a flocculation system followed by a clarifier or in an integrated flotation/clarification system (which consists of a rapid mix chamber, a flocculation chamber and a lamella plate clarifier unit). In both cases, waters are pumped to a mixing chamber where coagulant chemicals/polyelectrolyte solutions are injected into the wastewater with mixing and subsequently the wastewater flows by gravity into the circular clarification system or into the inclined plate clarifier tank.

The clarified supernatant overflow will be discharged to the biological/filtering process while the sludge generated at the bottom of the clarifier will be sent to the sludge treatment system.



The sludge treatment system will consist of a thickening basin and an automatic filter press. Solids will be pumped to thickener from the bottom of the clarifier. The sludge will be subsequently transferred to the filter press and dewatered, forming a solid cake for disposal of.

If necessary, activated carbons (or multi-media) filters will remove remaining contaminants (e.g. organic constituents) from the clarifier overflow effluent before the recycling or the final discharge. Depending on the organic content, a biological reactor can be implemented as intermediate step before activated carbons filtering.

Treated wastewater will finally flow through the wastewater discharge monitoring station, where pH, temperature and flow will be measured. Automatic sampling will be also conducted at the monitoring station to check the achievement of the remedial targets and or require reuse standards.

The process diagram of the proposed WWTP is reported in Drawing 19.

## **8.8 ENVIRONMENTAL MONITORING ACTIVITIES**

Environmental monitoring activities will be carried out during the whole remediation duration to identify (and mitigate) any possible environmental impact which may result from on site operations. Monitoring will have to range from visual inspection of the facilities and equipments to more extensive ambient emissions monitoring.

A detailed Environmental Monitoring Plan (EMP) will be developed in the Detailed Design.

### **8.8.1 Air Monitoring**

During execution of building demolitions, waste and contaminated soils excavation and final backfilling activities, the air dust concentration will be monitored.

Monitoring will be carried out through suitable automatic air monitoring stations. Intake air volume will be automatically measured and fine particle filters will be periodically extracted and analyzed for quantification of total and fine dust content and metals concentration.

For each dust monitoring cycle, a detailed analytical log will be compiled. Meteorological data (air temperature, pressure, climatic conditions, wind direction, etc.) relevant to the observation period will be also recorded on each log. Monitoring data will be normalized considering the meteorological conditions and finally recorded in table format.

Four compass sampling stations (N, S, W, E) will be selected at the site borders. Monitoring station number could be increased, and location changed based on specific activities and meteorological conditions (e.g. prevailing wind direction).

Field gas measurements using portable instruments of CO<sub>2</sub>, O<sub>2</sub>, CH<sub>4</sub>, H<sub>2</sub>S and Total Volatile Hydrocarbons (TVHs) or Volatile Organic Compounds (VOCs) will be conducted monthly. More accurate ambient air quality monitoring campaigns will be conducted at least quarterly at four compass monitoring points located at the site borders.

Air monitoring will be performed in accordance with the Air Monitoring Plan included in the Detail Design.

### **8.8.2 Noise Monitoring**

Noise monitoring will be carried out to verify operational phase noise levels. Noise levels will be measured before the beginning of operations (baseline data) and at least every six months during site operations. According to World Bank/IFC General EHS Guidelines, noise monitoring programs will be designed and conducted by trained specialists. Typical



monitoring periods should be sufficient for statistical analysis and may last 48 hours with the use of noise monitors that should be capable of logging data continuously over this time period, or hourly. The type of acoustic indices recorded depends on the type of noise being monitored, as established by a noise expert. Monitors should be located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface (e.g., wall).

Four compass sampling points will be selected at the site borders.

#### **8.8.3 Groundwater Monitoring**

Groundwater monitoring campaigns will be carried out during remediation operations to identify the water contaminants in groundwater resources by accidental leakages and spills, upstream and downstream of the remediation site. To this aim, groundwater from monitoring well network installed at the OHIS site (well selection will depend on the operations progression) will be sampled and measured quarterly for parameters detailed in the EMP.



## **9 PRELIMINARY TIME SCHEDULE**

Preliminary time schedules for the OHIS site remediation, respectively considering HCH treated on site (MCD coupled with TD) or off site (incineration) are provided in Drawing 20 and Drawing 21.

Work organization in three daily shifts of 8 hours each (i.e. 24 working hours/day) and 6 working days per week have been considered for the time schedule development.

The total treatment time for the proposed remediation strategy has been estimated based on the remediation capacities reported in previous Sections. The parallel execution of different phases has been considered, in order to allow minimizing inoperative times and consequently reducing as much as possible the whole remediation time.

Off site transport duration has been calculated considering as a calculation basis, ten 25 ton-trucks transporting all packed HCH waste to an hypothetical treatment plant located 2000 km from the OHIS site and considering 9 hours as maximum daily journey. Instead, 3,000 tons/month is the capacity used for intermodal transport.

Considering the possible use of mechanochemical on site dealogenation coupled with TD, the whole remediation activities duration have been estimated in five years and seven months. Instead, the off site treatment for HCH waste, due to the considerable amount of soil to be desorbed on site and the mobile plant limitations previously described, will only lead to a reduction of the total remediation time of few months.



## **10 COST ESTIMATION**

The economical investment needed for each project phase implementation has been estimated using the following sources:

- several quotations received from potential technology Suppliers in Europe;
- Standard Price Codes in force in Italy;
- current Italian market prices;
- past remediation projects already developed by D'Appolonia; and
- estimations/economic data gathered from local Partners.

All prices (except the direct Companies' quotations and Macedonian current prices) have been weighted to take into account the different products/manpower cost between Italy and Macedonia. When not directly obtained, prices were calculated through a detailed price analysis.

In particular, for the selected technologies, the following unit prices, based on received quotations, were used:

- unit cost for MCD pilot tests (including chemical analysis of pesticide content at various stages and heavy metal content, chemical analysis of non chlorinated organic compounds, pilot test, assessment of frequency of maintenance and energy requirements and optimization of post-treatment options) was set to 13,440 Euro;
- initial investment for full scale MCD on site installation is 4,700,000 Euro (including start-up);
- MCD operational costs (without post treatment), quoted in the range of 100-500 Euro/ton, was set to 175 Euro/ton;
- the unit price for TD lab/pilot test was set to 40,000 Euro;
- TD cost, quoted in a range of 70-250 Euro/ton depending on the size of the thermal desorber, was set to 75 Euro/ton. Mobilization, installation, demobilization and return transport costs (ranging from 550,000 to 650,000 Euro) was set to 600,000 Euro;
- ISTD pilot testing phase with the configuration described in the previous Sections will cost around 675,000 Euro (not including the expenses for the treatment of extracted gases, drilling of the wells, establishment of power supply and use of power);
- incineration cost, typically in the range of 400 to 900 Euro/ton, was set to 480 Euro/ton, on the basis of the quotations obtained;
- off site transport cost was set to 85 Euro/ton (including Governmental fees); and
- on site pump and treat pilot test (2 to 4 m<sup>3</sup>/h) cost was set to 40,000 Euro.

Even not explicitly included in the total cost estimation (since a preliminary cost for a pump and treat system can be quantified only with more specific data regarding hydrogeology and dimensioning of the hydraulic barrier), as a preliminary indication, a plant pumping 50 m<sup>3</sup>/h can have a price ranging between 250,000 and 400,000 Euro, with operating costs ranging between 60,000 and 120,000 Euro per year.

Table 10.1 and Table 10.2 detail the cost estimated for each remediation phase respectively considering either the possible on site utilization of MCD coupled with TD for HCH waste treatment and TD for all other contaminated matrices (Option 1) or the off site treatment of HCH waste coupled with on site TD for other contaminated media (Option 2). As already underlined in previous Sections, it is unlikely that Option 2 will be implemented, but it can



not be excluded a priori, and only pilot testing could confirm the applicability of selected treatment options. Therefore, Option 2 costs have been included for both comparison purposes and completeness of the present study.

The price analysis carried out for each item not directly obtainable from cited sources is reported in Table 10.3.

Due to the considerable cost of the whole activities, the same phases' subdivision of the proposed remediation approach has been maintained for the cost estimation, in order to allow possible splitting of future tendering process and following remediation activities.

Prices may be reduced based on outcomes of pilot applications (when final treatment rates will be calibrated), but also based on bottom excavation sampling results (which may result in lower volume of contamination sources).



**Table 10.1: Cost Estimation for Each Remediation Phase Considering On Site MCD for HCH Waste**

BoQ1	HCH Waste Dehalogeantion and Thermal Desorption				
Item No.	Item Description	U.M.	Quantity	Unit Price	Total
	<b>PILOT TESTING PHASE</b>				
1	Dehalogenation pilot test on HCH waste (4 tests x 60 kg each)	pcs	4	13,440.00	€ 53,760.00
2	Thermal desorption pilot test on soil	pcs	3	40,000.00	€ 120,000.00
3	Thermal desorption pilot test on dehalogenated waste	pcs	3	40,000.00	€ 120,000.00
				<b>SUM</b>	<b>€ 293 760.00</b>
	<b>WORK SITE INSTALLATION</b>				
4	Temporary facilities installation, fences, work site installation	pcs	1	78,449.84	€ 78,449.84
5	Demolition waste treatment area building	m2	5,500	35.80	€ 196,909.88
6	Temporary stockpile and soil treatment area building	m2	13,500	37.26	€ 502,959.24
7	Wastewater treatment area building	m2	2,500	35.80	€ 89,504.49
8	WWTP mob and installation	lump sum	-	-	€ 700,000.00
				<b>SUM</b>	<b>€ 1 567 823.45</b>
	<b>PHASE 1 - DUMPS REMOVAL</b>				
	<b>HCH DUMPS OVERLYING SOIL REMOVAL AND TREATMENT</b>				
9	Thermal desorber mob/demob and installation	pcs	1	600,000.00	€ 600,000.00
10	Alpha+beta HCH dump overlying soil removal	m3	5,200	2.68	€ 13,929.07
11	Alpha+beta HCH dump overlying soil thermal desorption	ton	9,360	75.00	€ 702,000.00
12	Delta HCH dump overlying soil removal	m3	2,010	2.68	€ 5,384.12
13	Delta HCH dump overlying thermal desorption	ton	3,618	75.00	€ 271,350.00
				<b>SUM</b>	<b>€ 1,422,663.19</b>
	<b>(OPT 1) HCH DUMPS WASTE REMOVAL AND TREATMENT</b>				
14	Mechanochem Dehalogenator building/installation (inside A9-A11 buildings)	lump sum	-	-	€ 4,700,000.00
15	Delta HCH dump waste removal	m3	620	2.68	€ 1,660.77
16	Delta HCH dump waste dehalogenation	ton	589	175.00	€ 103,075.00
17	Delta HCH dehalogenated waste thermal desorption	ton	589	75.00	€ 44,175.00
18	Alpha+Beta HCH dump waste removal	m3	15,000	2.68	€ 40,180.00
19	Alpha+Beta HCH dump waste dehalogenation	ton	28,500	175.00	€ 4,987,500.00
20	Dehalogenated HCH waste thermal desorption	ton	28,500	75.00	€ 2,137,500.00
				<b>SUM</b>	<b>€ 12,014,090.77</b>
				<b>SUM</b>	<b>€ 13,606,753.96</b>
	<b>PHASE 2 - BUILDINGS DEMOLITION</b>				
21	Asbestos removal	m2	2,041.5	13.89	€ 28,352.35
22	Buildings and structures demolition	m3	85,000	23.66	€ 2,011,156.67
23	Crushing/Washing/Magnetic separation	ton	24,026.5	26.97	€ 647,994.71
24	Hazardous waste treatment (thermal desorption)	ton	11,201.8	75.00	€ 840,135.00
25	Wastewater treatment	m3	70,000	7.54	€ 527,602.80
				<b>SUM</b>	<b>€ 4 055 241.52</b>



BoQ1	HCH Waste Dehalogeantion and Thermal Desorption				
Item No.	Item Description	U.M.	Quantity	Unit Price	Total
	<b>PHASE 3 - SURFICIAL SOIL REMOVAL AND TREATMENT</b>				
26	HCH-contaminated surficial soil excavation	m3	41,804.9	2.68	€ 111,981.39
27	HCH-contaminated soil treatment (thermal desorption)	ton	75,248.82	75.00	€ 5,643,661.50
28	HCH-Hg-contaminated surficial soil excavation	m3	9,903.6	2.68	€ 26,528.44
29	HCH-Hg-contaminated soil treatment (thermal desorption)	ton	17,826.48	75.00	€ 1,336,986.00
				<b>SUM</b>	<b>€ 7,119,157.34</b>
	<b>IN-SITU THERMAL DESORPTION PILOT TESTING</b>				
30	Pilot plant installation	lump sum	-	-	€ 732,050.00
31	Pilot testing	lump sum	-	-	
				<b>SUM</b>	<b>€ 732,050.00</b>
	<b>PHASE 4 - DEEP SOIL REMOVAL AND TREATMENT</b>				
	<b>(OPT 2) HCH-CONTAMINATED DEEP SOIL REMOVAL AND TREATMENT</b>				
32	HCH-contaminated deep soil excavation	m3	50,752.8	2.68	€ 135,949.83
33	HCH-contaminated soil treatment (thermal desorption)	ton	91,355.04	75.00	€ 6,851,628.00
				<b>SUM</b>	<b>€ 6,987,577.83</b>
	<b>Hg-CONTAMINATED DEEP SOIL REMOVAL AND TREATMENT</b>				
34	Hg-contaminated deep soil excavation	m3	69,321	2.68	€ 185,687.85
35	Hg-contaminated soil treatment (thermal desorption)	ton	124,777.8	75.00	€ 9,358,335.00
				<b>SUM</b>	<b>€ 9,544,022.85</b>
				<b>SUM</b>	<b>€ 16,531,600.69</b>
	<b>PHASE 5 - PUMP&amp;TREAT</b>				
36	Pilot testing of P&T system (4 m3/h)	lump sum	-	-	€ 40,000.00
37	WWTP upgrading				
38	Wells drilling and piping				
39	Groundwater extraction and treatment				
				<b>SUM</b>	<b>€ 40,000.00</b>
	<b>ANALYSES</b>				
40	Demolition monitoring and waste analyses				€ 600,000.00
41	Confirmatory excavation bottom sampling and analyses				€ 300,000.00
42	Soil analyses for on site treatments				€ 1,000,000.00
43	Water analyses				
				<b>SUM</b>	<b>€ 1,900,000.00</b>
	<b>TOTAL</b>				<b>€ 45,846,386.96</b>



**Table 10.2: Cost Estimation for Each Remediation Phase Considering Off Site Incineration for HCH Waste**

BoQ2	HCH Waste Incineration				
Item No.	Item Description	U.M.	Quantity	Unit Price	Total
	<b>PILOT TESTING PHASE</b>				
1	Dehalogenation pilot test on HCH waste (4 tests x 60 kg each)	pcs	4	13,440.00	€ 53,760.00
2	Thermal desorption pilot test on soil	pcs	3	40,000.00	€ 120,000.00
3	Thermal desorption pilot test on dehalogenated waste	pcs	3	40,000.00	€ 120,000.00
				<b>SUM</b>	<b>€ 293,760.00</b>
	<b>WORK SITE INSTALLATION</b>				
4	Temporary facilities installation, fences, work site installation	pcs	1	78,449.84	€ 78,449.84
5	Demolition waste treatment area building	m2	5,500	35.80	€ 196,909.88
6	Temporary stockpile and soil treatment area building	m2	13,500	37.26	€ 502,959.24
7	Wastewater treatment area building	m2	2,500	35.80	€ 89,504.49
8	WWTP mob and installation	lump sum	-	-	€ 700,000.00
				<b>SUM</b>	<b>€ 1,567,823.45</b>
	<b>PHASE 1 - DUMPS REMOVAL</b>				
	<b>HCH DUMPS OVERLYING SOIL REMOVAL AND TREATMENT</b>				
9	Thermal desorber mob/demob and installation	pcs	1	600,000.00	€ 600,000.00
10	Alpha+beta HCH dump overlying soil removal	m3	5,200	2.68	€ 13,929.07
11	Alpha+beta HCH dump overlying soil thermal desorption	ton	9,360	75.00	€ 702,000.00
12	Delta HCH dump overlying soil removal	m3	2,010	2.68	€ 5,384.12
13	Delta HCH dump overlying thermal desorption	ton	3,618	75.00	€ 271,350.00
				<b>SUM</b>	<b>€ 1,422,663.19</b>
	<b>(OPT 2) HCH DUMPS WASTE REMOVAL AND TREATMENT</b>				
14	Delta HCH dump waste removal and packing	ton	589	86.85	€ 51,155.24
15	Delta HCH dump waste off site transport	ton	589	85.00	€ 50,065.00
16	Delta HCH dump waste off site treatment	ton	589	480.00	€ 282,720.00
17	Alpha+beta HCH dump waste removal and packing	ton	28,500	85.44	€ 2,435,073.76
18	Alpha+beta HCH dump waste off site transport	ton	28,500	85.00	€ 2,422,500.00
19	Alpha+beta HCH dump waste off site treatment	ton	28,500	480.00	€ 13,680,000.00
				<b>SUM</b>	<b>€ 18,921,514.00</b>
				<b>SUM</b>	<b>€ 20,514,177.19</b>
	<b>PHASE 2 - BUILDINGS DEMOLITION</b>				
20	Asbestos removal	m2	2,041.5	13.89	€ 28,352.35
21	Buildings and structures demolition	m3	85,000	23.66	€ 2,011,156.67
22	Crushing/Washing/Magnetic separation	ton	24,026.5	26.97	€ 647,994.71
23	Hazardous waste treatment (thermal desorption)	ton	11,201.8	75.00	€ 840,135.00
24	Wastewater treatment	m3	70,000	7.54	€ 527,602.80
				<b>SUM</b>	<b>€ 4,055,241.52</b>



BoQ2	HCH Waste Incineration				
Item No.	Item Description	U.M.	Quantity	Unit Price	Total
	<b>PHASE 3 - SURFICIAL SOIL REMOVAL AND TREATMENT</b>				
25	HCH-contaminated surficial soil excavation	m3	41,804.9	2.68	€ 111,981.39
26	HCH-contaminated soil treatment (thermal desorption)	ton	75,248.82	75.00	€ 5,643,661.50
27	HCH-Hg-contaminated surficial soil excavation	m3	9,903.6	2.68	€ 26,528.44
28	HCH-Hg-contaminated soil treatment (thermal desorption)	ton	17,826.48	75.00	€ 1,336,986.00
				<b>SUM</b>	<b>€ 7 119 157.34</b>
	<b>IN-SITU THERMAL DESORPTION PILOT TESTING</b>				
29	Pilot plant installation	lump sum	-	-	€ 732 050.00
30	Pilot testing	lump sum	-	-	
				<b>SUM</b>	<b>€ 732 050.00</b>
	<b>PHASE 4 - DEEP SOIL REMOVAL AND TREATMENT</b>				
	<b>(OPT 2) HCH-CONTAMINATED DEEP SOIL REMOVAL AND TREATMENT</b>				
31	HCH-contaminated deep soil excavation	m3	50,752.8	2.68	€ 135,949.83
32	HCH-contaminated soil treatment (thermal desorption)	ton	91,355.04	75.00	€ 6,851,628.00
				<b>SUM</b>	<b>€ 6,987,577.83</b>
	<b>Hg-CONTAMINATED DEEP SOIL REMOVAL AND TREATMENT</b>				
33	Hg-contaminated deep soil excavation	m3	69,321	2.68	€ 185,687.85
34	Hg-contaminated soil treatment (thermal desorption)	ton	124,777.8	75.00	€ 9,358,335.00
				<b>SUM</b>	<b>€ 9,544,022.85</b>
				<b>SUM</b>	<b>€ 16,531,600.69</b>
	<b>PHASE 5 - PUMP&amp;TREAT</b>				
35	Pilot testing of P&T system (4 m3/h)	lump sum	-	-	€ 40,000.00
36	WWTP upgrading				
37	Wells drilling and piping				
38	Groundwater extraction and treatment				
				<b>SUM</b>	<b>€ 40,000.00</b>
	<b>ANALYSES</b>				
39	Demolition monitoring and waste analyses				€ 600,000.00
40	Confirmatory excavation bottom sampling and analyses				€ 300,000.00
41	Soil analyses for on site treatments				€ 1,000,000.00
42	Water analyses				
				<b>SUM</b>	<b>€ 1,900,000.00</b>
	<b>TOTAL</b>				<b>€ 52,753,810.19</b>



Table 10.3: Price Analysis

Item No.		Item Description	U.M.	Unit Price	Quantity	TOT
BoQ1	BoQ2					
4	4	<b>Temporary facilities installation, fences, work site installation</b>				
		<i>Metallic galvanized steel fence, 50x50, diam. 2 mm, min. height 2 m, T-shaped metal support stakes, etc.</i>	Euro/m2	19.15	552	10,570.80
		<i>Temporary facilities for Offices, Canteen, Toilets, etc.</i>	Euro/m2/month	3.00	5,400	16,200.00
		<i>Temporary facilities for Lockers, Washrooms/showers</i>	Euro/m2/month	2.00	5,400	10,800.00
		<i>Temporary facilities for storage</i>	Euro/m2/month	1.50	10,800	16,200.00
		<i>Temporary facilities for workshops</i>	Euro/m2/month	3.00	5,400	16,200.00
		<i>Road foundation excavation. Trench machine excavation to a max. depth of 2 m in loose soils</i>	m3	4.06	81	328.54
		<i>Granular sub-base and cement bound granular base</i>	m3	10.00	81	810.00
		<i>Surficial base finishing</i>	m2	1.50	405	607.50
		<i>Bituminous emulsion</i>	m2	0.60	405	243.00
		<i>Supply, placing and compacting of bituminous binder</i>	m2	6.00	405	2,430.00
		<i>Supply and placing of New Jersey</i>	m	58.00	70	4,060.00
					<b>TOT</b>	<b>78,449.84</b>
					<b>Quantity</b>	<b>1</b>
					<b>Unit Price</b>	<b>78,449.84</b>
5	5	<b>Demolition waste treatment area building</b>				
		<i>Trench machine excavation to a max. depth of 2 m in loose soils</i>	m3	4.06	1,100	4,461.60
		<i>Granular base</i>	m2	7.46	5,500	41,052.00
		<i>Reinforcing welded wire supply and placing</i>	m2	1.11	5,500	6,116.00
		<i>Supplying and placing of concrete (class 250 with Rck <math>\geq</math> 25 N/mm4; thickness 20 cm)</i>	m2	20.96	5,500	115,280.00
		<i>Supply and placing of formwork</i>	m2	20.00	210	4,200.00
		<i>Vertical rebars supply and placing</i>	m2	0.28	210	58.38
		<i>Supplying and placing of concrete (class 300 with Rck <math>\geq</math> 30 N/mm4; thickness 20 cm)</i>	mc	110.00	52.5	5,775.00
		<i>Drain well (6 m3)</i>	pcs	829.10	1	829.10
		<i>Prefabricated concrete channels (40x36)</i>	m	17.84	100	1,784.00
		<i>Galvanized steel carriageable wire cover (27x40).</i>	m	113.85	100	11,384.80
		<i>Sumberged pump</i>	pcs	5,969.00	1	5,969.00
					<b>TOT</b>	<b>196 909.88</b>
					<b>Quantity</b>	<b>5500</b>
					<b>Unit Price</b>	<b>35.80</b>
6	6	<b>Temporary stockpile and soil treatment area building</b>				
		<i>Trench machine excavation to a max. depth of 2 m in loose soils</i>	m3	4.06	13,500	54,756.00
		<i>Granular base</i>	m2	7.46	13,500	100,764.00
		<i>Supply and placing of impervious HDPE liner thickness 1.5 mm. Including welding.</i>	m2	4.73	13,500	63,801.00
		<i>Supply and placing of gravel for drainage layer</i>	m3	23.83	4,050	96,493.28
		<i>Supply and placing of geotextile 220 g/m2</i>	m2	1.96	13,500	26,392.50
		<i>Supply and placing of sand/soil for protective layer</i>	m3	34.22	4,050	138,595.05
		<i>Embankments construction using compacted soil</i>	m3	7.90	1,910	15,082.32



Item No.		Item Description	U.M.	Unit Price	Quantity	TOT
BoQ1	BoQ2					
		HDPE drain wells	pcs	86.70	8	693.60
		HDPE drainage pipe (diam. 200 mm), double wall, corrugated external surface, smooth internal surface. Slotted on site.	m	6.77	250	1,691.50
		Automatic drainage/leachate collection and pumping station	pcs	4,690.00	1	4,690.00
					<b>TOT</b>	<b>502,959.24</b>
					<b>Quantity</b>	<b>13,500</b>
					<b>Unit Price</b>	<b>37.26</b>
<b>9</b>	<b>9</b>	<b>Thermal desorber mob/demob and installation</b>				
		Thermal desorber mob/demob and installation – quotation #1	Euro	550,000.00	1	550,000.00
		Thermal desorber mob/demob and installation – quotation #2	Euro	650,000.00	1	650,000.00
				Average		600,000.00
					<b>TOT</b>	<b>600,000.00</b>
					<b>Quantity</b>	<b>1</b>
					<b>Unit Price</b>	<b>600,000.00</b>
<b>10</b>	<b>10</b>	<b>Alpha+beta HCH dump overlying soil removal</b>				
		Open excavation including on-site transport (<1500 m) to temporary stockpile area	m3	3.54	5,200	18,387.20
		Common excavation	m3	1.50	5,200	7,800.00
		Open excavation	m3	3.00	5,200	15,600.00
				Average		13,929.07
					<b>TOT</b>	<b>13,929.07</b>
					<b>Quantity</b>	<b>5,200</b>
					<b>Unit Price</b>	<b>2.68</b>
<b>-</b>	<b>14</b>	<b>Delta HCH dump waste removal and packing</b>				
		Open excavation (in waste)	m3	2.68	620	1,660.77
		Supply of 60-L PE Drums	ton	15.60	589	9,188.40
		Supply of Euro pallets	ton	4.00	589	2,356.00
		Manpower	ton	64.43	589	37,950.07
					<b>TOT</b>	<b>51,155.24</b>
					<b>Quantity</b>	<b>589</b>
					<b>Unit Price</b>	<b>86.85</b>
<b>-</b>	<b>17</b>	<b>Alpha+beta HCH dump waste removal and packing</b>				
		Open excavation (in waste)	m3	2.68	15000	40,180.00
		Supply of 60-L PE Drums	ton	15.60	28500	444,600.00
		Supply of Euro pallets	ton	4.00	28500	114,000.00
		Manpower	ton	64.43	28,500	1,836,293.76



Item No.		Item Description	U.M.	Unit Price	Quantity	TOT
BoQ1	BoQ2					
					TOT	2,435,073.76
					Quantity	28,500
					Unit Price	85.44
22	21	<b>Buildings and structures demolition</b>				
		<i>Controlled demolition including transport</i>	m3	17.63	85,000	1,498,720.00
		<i>Demolition of structures in reinforced concrete</i>	m3	20.45	85,000	1,738,250.00
		<i>Demolition of any kind of building</i>	m3	17.90	85,000	1,521,500.00
				Average		1,586,156.67
		<i>Preliminary crushing to max. size of 30 cm</i>	m3	5	85,000	425,000.00
		<i>Preliminary structure washing</i>	m3			
					TOT	2,011,156.67
					Quantity	85,000
					Unit Price	23.66
23	22	<b>Crushing/Washing/Magnetic separation</b>				
		<i>Secondary crushing to a max. size of 80 mm. Washing and magnetic separation including water and electricity consumption</i>	ton	26.97	24,026.5	647,994.71
					TOT	647,994.71
					Quantity	24,026.5
					Unit Price	26.97
24	25	<b>Wastewater treatment</b>				
		<i>Manpower (five years plant operation)</i>	lump sum	-	70,000	453,124.80
		<i>Polielektrolite (2-4 g/m3)</i>	m3	0.01	70,000	938.00
		<i>Flocculant (50-100 g/m3)</i>	m3	0.02	70,000	1,540.00
		<i>Energy (60 kW power consumption)</i>	m3	1.03	70,000	72,000.00
		<i>(considering a capacity of 70 m3/h)</i>				
					TOT	527,602.80
					Quantity	70,000
					Unit Price	7.54

MZ/MNC/EN/GBD/PAR/MGC:mcs



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