Site Assessment and Feasibility Study of the Nubarashen Burial Site of Obsolete and Banned Pesticides in Nubarashen, Armenia

Contract № ARM/01/2013

Phase 1 and 2 investigation report

Final Draft, 17 September 2013

Responsibility

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Executive Summary

The landfill site at Nubarashen, comprising of a landfill body and surrounding land, is situated to the South-East of Yerevan on a steep mountain slope. The landfill site with the landfill body is fenced and the landfill body, a hillock, is enclosed on three sides by concrete runoff drains. Two deep trenches, collecting run-off water with sediments are situated 10 m down slope from the landfill body. The landfill body, has a surface area of approximately 0,2 hectares with a height of around 1 - 1,5 m above the surroundings, it is covered with a 40-70 cm top cover of clay lying on top of a 2 mm ruberoid liner. The in-situ volume of this top cover is 890 m^3. The quality of this top cover is relatively clean with DDT concentrations below or just above the Dutch I-value. Traces of pesticides, remains of packaging materials and erosion features are observed in the top cover. Below the ruberoid liner is a layer of 5-10 cm coarse sand on contaminated clay layers with or without pure pesticides.

From archives it is known that 512 ton of POP and obsolete pesticides supposedly was dumped in the Nubarashen landfill. From the survey it has become clear that the pesticides are dumped in five separate cells. Three cells are completely covered by the hillock, one cell is partly covered by the hillock and one cell is found outside the hillock. The most eastern cell contains wet pesticides and is a small squared structure made of stones/concrete. The central two cells have been severely affected by the illegal waste mining. But pure pesticides are still present in these cells and there has been significant mixing with the surrounding soil. The two western cells do not seem to have been affected by the waste mining. These cells contain also pure pesticides but very little mixing with the surrounding soil has taken place. Except the most eastern cell, all other cells seem to have been made by excavation and no materials were used for the cell structure. The most western cell and part of one of the central cells is present outside of the hillock. Here pure pesticides are present less than 50 cm below the surface.

In total 605 m^3 pure pesticide is still present in these five cells, the clay bottom the pit is contaminated, the expected volume is 29 m^3. In additional, approximately 1,127 m^3 of heavily contaminated soil with traces of pure pesticides is present in the hillock. Surrounding the landfill, within the fence, is a barren area of around 0.6 hectares. The topsoil of this area is heavily contaminated with pesticides till a depth of 0.5 m. The in-situ volume of the surrounding contaminated top soil is estimated at around 3,000 m^3.

The table below gives a summary of the quantities of the contaminated soil and the pure pesticides present at the landfill site.

Total quantities landfill site and landfill body	**In situ**	**Weight**
Contaminated top soil with traces of pure pesticides fenced area landfill site	3,000 m^3	5,100 ton
Slightly contaminated top cover landfill body	890 m^3	1,513 ton
Heavily contaminated top soil with traces of pure pesticides in landfill body	1,127 m^3	1,916 ton
Pesticides	605 m^3	605 ton
Contaminated clay at bottom of four excavated pits	29 m^3	49 ton

The groundwater and the surface water downstream the landfill site is not impacted by the contaminants present at the landfill site.

A pond and a leaking water main parallel to a dirt road are located uphill from the landfill site. The water main and a culver filled with soil crossing the road are blocking the natural drainage pathway of the uphill catchment area which results in standing water in the pond. The water in the pond and the water from the leaking water main infiltrate in the soil and percolates laterally in the catchment area of the landfill. This is causing extra water to accumulate in the active landslide body above the landfill site. Slope movement upstream of the landfill site is the mechanism behind the observed mass movement at the landfill site and its surrounding area. The stability of the upstream area of the landfill site is influenced by the perched ground water levels. The run-off drains surrounding the landfill site are partly dislocated, damaged and tunnelled by rain water run off causing increased accelerated erosion of the landfill area and extra infiltration of water into the contaminated soil.

A Tier 2 risk assessment concluded that only the people entering/ working at the landfill site and a buffer zone of 100 m around the landfill site have direct contact risk with the contaminated soil. Direct contact can be avoided when proper personal protective equipment is used when entering the buffer zone and site. The landfill site fence has to be maintained to prevent animals and unauthorized people to enter the site. Warning signs, warning trespasses for the risk when entering the buffer zone and/or the site have to be installed. The other possible receptor pass way are the air born contaminated fine soil particles, however direct severe impact is currently not expected. The receptor pathways of runoff water and percolating rainwater are not established.

If nothing is done accelerated site erosion will continue and off site migration of contaminants will increase, enlarging the environmental and human risks.

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1 Introduction

1.1 General

The Nubarashen landfill was used mid-1970's as a disposal site for Persistent Organic Pollutants (referred to as POPs), Obsolete Pesticides (referred to as OPs), and other chemicals and is located in a valley subject to severe erosion processes (gully, sheet and landslides). A small village comprising summer cottages is located around one kilometre down slope from the burial site, and two other villages (Verin Jrashen and Mushavan) are also located in the area at around four km distance.

Although a runoff drainage system and fencing were implemented around the site in 2004, these safeguarding measures were not maintained. Illegal excavation activities in March 2010 left the upper cover of the burial site completely damaged.

The Government of Armenia (GoA) has set up the Emergency Working Group led by the Ministry of Emergency Situations (MoES) in July 2010. Around USD 100,000 has been allocated from a special fund for an ad hoc closure. However, potential environmental and human risks still exist and the GoA through the MoES therefore decided with the funds of the Organization for Security and Co-operation in Europe (OSCE) to perform investigations and a feasibility study supporting the selection of a long term sustainable solution for the elimination of risks for the OPs and POPs waste at the landfill. In addition, a review of the health situation will be made, in order to assess which steps have to be taken on the health issues.

The Request for proposal for this investigations and a feasibility study was published in June 2012. The contract for this assignment (**Contract no ARM/01/2013**) was signed between the OSCE and Tauw on January 2013.

An overall Health & Safety (H&S) Plan was written shortly after the OSCE order to Tauw.

This **H&S Plan Site Assessment and Feasibility Study of the Persistent Organic Pollutants (POP) and Obsolete Pesticides (OP) Burial Site in Nubarashen, Armenia**, with the Tauw Reference **R001-1210169BFF-beb-V03-NL**, was issued on 25 February 2013. This H&S Plan is one of the first deliverables of this project.

The inception mission took place between 18 and 28 of February 2013. The **Final Inception Report** with the Tauw Reference **R002-1210169BKT-beb-V04-NL** was issued on 15 April 2013. This Inception report is also one of the first deliverables of this OSCE project. This document concerns the Phase 1 and Phase 2 report and is the next deliverable of this OSCE project.

1.2 Objectives

1.2.1 Introduction

The overall objective of the assessment and feasibility study is to provide a structured framework for a comprehensive site rehabilitation plan mitigating the environmental site risks. The results of the investigation will be an overview of the layout of the landfill site and body, the environmental soil and groundwater quality and the identification of migration pathways and potential receptors. To reach these objectives the assessment and feasibility study are split in three project phases. Phase 1 is the initial site assessment; Phase 2 is the detailed environmental site assessment. This report elaborates on the results of Phase 1 and 2. After Phase 1 and 2 are completed two best out of five options for the site rehabilitation, Phase 3 will be selected. Phase 3 will be reported in a separate report.

1.2.2 Phase 1 initial site assessment

Phase 1 contains the following three main tasks:

- Health and safety planning
- Start up stakeholder involvement
- Verification of the layout of the landfill

The H&S planning, which is a project cross cutting issue, is addressed in the earlier mentioned H&S Plan and reference is made to this project report for H&S issues. Stakeholder involvement is also a project cross cutting issue and is addressed in section 3 of this report. The Phase 1 verification of the layout of the landfill was carried out with a desktop study of available literature, interviews of staff that was involved in the construction of the landfill in the old days and fieldwork such as a Ground Penetrating Radar (GPR) campaign, a surface three dimensional (3D) laser scanning of topography of the landfill and its surroundings and Dynamic Cone Penetration Tests (DCPTs) to establish the soil structure and last but not least a landfill mapping campaign by installation of around 60 boreholes. This information is used to make a Digital Terrain Model (DTM) of the landfill body and its direct surrounding. With the DTM the volume of the different elements of the landfill body can be assessed. The waste characterization will be carried out by evaluation of data already presented in the OSCE project Terms of Reference (TOR), available data from the interviews, archive studies and the gathered fieldwork data during the different fieldwork campaigns.

1.2.3 Phase 2 Detailed site assessment

Phase 2 is the soil and ground investigations and risk assessment of the catchment area of the landfill. This phase comprises:

- An environmental baseline assessment of the catchment area of the landfill
- A geophysical assessment of the catchment area of the landfill
- A risk assessment of the catchment area of the landfill

1.2.4 Phase 3 Selection and pre-design the two best rehabilitation options

Phase 3 is a stepwise process and starts with the description of five viable remediation options. Doing nothing is **not** considered as an option because it is clear that if nothing is done, the erosion of the top cover of the waste body will continue, the surface drains will fill up an be displaced more (see figure 2.7). Consequently the landfill body will erode within a number of years. Pure product and contaminated soil will migrate off site and direct risks for human health and the environment will be increase severely. Therefore the proposed five viable remediation options are:

- The first option describes the proposed mitigation measures to contain environmental and human risks when there are no funds available to eliminate all environmental and human risks by removing, repacking and safely storing the repacked the POPs and OP pesticides from Nubarashen awaiting the final destruction within the coming 20 years
- The second option describes the mitigation measures when the funds for removal, repackaging and destruction are available within 10 years
- The third and fourth option describe the mitigation measures when the funds for removal, repackaging and destruction are available within 5 years
- The fifth and last option describe the mitigation measures when the funds for removal, repackaging and destruction are available within 2 years

The second step of the selection of the two best rehabilitation options comprises of a Multi-Criteria Decision Analysis (MCDA) of the five options. Based on the results the two best options will be selected and these two options are than pre-designed. The third step of phase 3 is the recommendation of the best option including an assessment of the remaining risks.

1.3 Contents of this report

This report describes in details the activities and results of Phase 1 and 2 of the site assessment and feasibility study of the Nubarashen burial site of obsolete and banned pesticides in Nubarashen, Armenia. This report presents a Conceptual Site Model (CSM) of the Nubarashen burial site. To obtain a comprehensive idea of the results of the Phase 1 and Phase 2 of this feasibility study without reading this complete report an executive summary is given as first section of this report. Following the Executive Summary and this introductory Chapter, Chapter 2 describes the Phase 1 of this feasibility study. The Quick Scan Stakeholder involvement is elaborated in Chapter 3. Chapter 4 describes the Phase 2 detailed environmental site assessment. The geophysical assessment is presented in Chapter 5. The Tier 2 risk assessment is detailed in Chapter 6. This report concludes with a listing of conclusions of the Phase 1 and Phase 2 of this feasibility study in Chapter 7. Throughout this document reference is made to the 10 appendices attached to this report.

2 Phase 1 Initial site assessment

2.1 Methodology

The project started with an inception mission, this mission was held between 18 and 28 February 2013. The inception is reported in the already mentioned Inception Report. The initial site assessment was kick-started during the Phase 1 mission. Phase 1 comprises of:

1. Health and safety planning; reported in the earlier mentioned H&S Plan
2. A verification of the burial site design
3. An assessment of the current top cover
4. A characterization of the buried pesticides waste
5. A preliminary (Tier 1) risk assessment of the catchment area of the burial site, reported in Chapter 6 the ‘Tier 2 risk assessment’

This chapter reports the carried out Phase 1 fieldwork campaigns in section 2.2, the fieldwork results are presented in section 2.3 and these data are evaluated in section 2.4. The evaluation is split in the landfill site layout (section 2.4.1), the layout of the landfill body (section 2.4.2) and the dumped waste (section 2.4.3).

2.2 Fieldwork activities

The Phase 1 fieldwork was carried during the inception mission (February 2013) and a landfill mapping campaign (August 2013). Tauw gathered field data to update the initial CSM before the first field visit. The two fieldwork campaigns were organized to complete this updated CSM. The following activities took place during these two campaigns:

- A 3D laser scanning of the landfill site, the landfill body and parts of the Nubarashen valley to produce the basis of a Digital Terrain Model (DTM)
- A Ground Penetrating Radar (GPR) campaign to reveal the layout of the landfill body
- Dynamic Cone Penetration Tests (DCPTs) to establish the soil structure of the soil outside the landfill body but inside the landfill site (fenced area)
- A landfill mapping campaign to reveal the construction of the landfill body

The complete CSM is needed to establish the environmental and human health risks. The results of the risk assessment will direct the design of the five possible remedial options and finally the selection of the two best remediation options. These options will contain each a complete set of rehabilitation measures to eliminate and/or contain the human health and environmental risks related to the landfill.

2.2.1 3D Laser Scanning

The current topography of the landfill and relevant surrounding area are measured in a very high detail using 3D terrestrial laser scanning (see figure 2.1). The 3D laser scanning will be used to:

- Make a topographical baseline map (appendix 2)
- Update the CSM, the CSM is the basis for the risk assessment
- Produce a DTM, the DTM gives the information to establish the landfill body layout and to calculate the current quantities of the different components of the landfill body
- Hydrological and geo-morphological modelling

A FARO Laser Scanner Focus 3D was used to scan the fenced landfill area and the direct surrounding downstream and the upstream the landfill. The complete scan is made with several individual scans. Each scan was geo-referenced with nine fixed points and each scan is overlapping three points of the adjacent scan. In total around ten hectares are scanned. The actual scanning took place in three days.

2.2.2 Ground Penetrating Radar

For verification of the structure of the landfill it was planned to apply GPR in a grid over the landfill body and the fenced area with a GSSI 400 MHz GPR antenna, with gridlines of 1 x 1 m (see figure 2.1). Because the soil conditions were far from optimal, the measurements started with the most important area, the landfill body itself and the area between the concrete surface runoff drains. The total area covered with the GPR is around 0.5 hectare.
Since the area is not that large and the expected top layer is about 50 cm thick, measurements were taken at 2 different settings; one for detailed recording of the top layer (about 1.5 m max, depending on soil type and moisture content) and one for deeper (but less detailed) penetration (up to about 4 m, depending on soil type and moisture content). Because it was not known whether a good enough quality of Global Position System (GPS) is available, the choice was made to position the measurements using a survey wheel; the device driven by one wheel of the survey cart measures the exact distance from a known starting point, thereby generating a local grid. Points along this grid are acquired using a hand-held GPS. The GPS recordings and the local grid are converted to a geo-referenced grid afterwards.

Due to the weather conditions (in the early morning the surface was frozen and during the day the frozen surface melted) fieldwork turned out to be very difficult. The moisture content of the clay soil varied and formed a large obstacle in conducting proper GPR measurements (see figure 2.1). It also was seen from the online reflection of the radar signal that the penetrating depth was shallow. It also was observed in the field that the difference in height of the landfill body and its surrounding is more than 1 m.
It was concluded that the combination of the weather condition, the clay and the moisture content and the top cover thickness of more than 1 m did not produce GPR results as expected.

It was decided not to survey the remaining area (the Northern part between the concrete drain and the fence) but to concentrate on the area between the concrete drains by performing different runs on the longitudinal axel of the landfill body to get the best possible results under the given conditions. The survey report of the subcontractor Medusa is presented in appendix 1.

Figure 2.1 Left: 3D Lasser scanning. Right the GPR survey cart

2.2.3 Dynamic Cone Penetration Tests

17 DCPTs were carried out in one longitudinal and three cross sections to establish the surrounding soil structure of the landfill body. Figure 2.2 gives a field setup of a DCPT and the locations of the DCPTs are given in figure 2.3. The DCPTs are performed using a standard 60 degree apex cone connected to' A size' drill rods with the same standard fall height and weight as the Standard Penetration Test.

Figure 2.2 A Left: the DCPT Geotool. Right: DCPT measurement

The DCPT value is the number of blows of the hammer required to drive the cone one foot (305 mm) into the soil. The DCPT is used as a probe to assess soil profile (layering) and the depth of the slip surface for landslide. The DCPT is a relatively simple and portable ground investigation technique that can be easily used on the slopes of the valley. The amount of force needed to push the cone into the ground is a measure of the soil type. All observation points are geo-referenced and added to the 3D model.

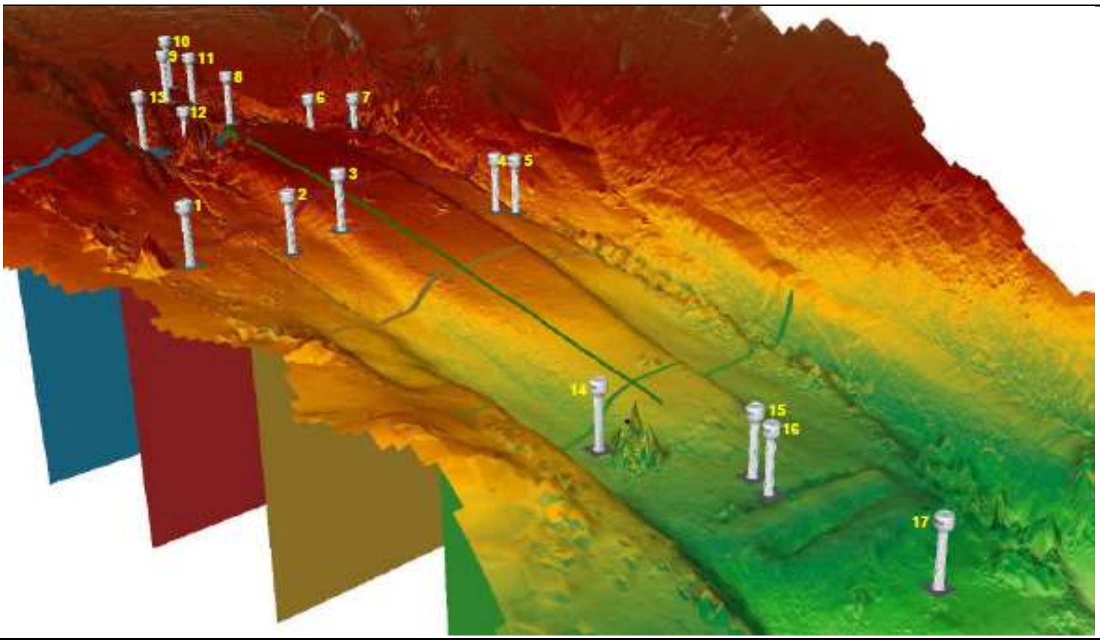

Figure 2.3 Landfill site topogarphy with 17 DCPTs locations

2.2.4 Landfill mapping campaign

Because the GPR results were not producing tangible results a landfill mapping campaign to verify the landfill body layout was carried out in he first week of August 2013. For the mapping 63 boreholes were constructed with a small diameter gouge auger (see figure 2.4). With this tool, a grid of 63 boreholes was made. For each drilling a pit was manually dug till the ruberoid liner. The gouge auger was pushed through the ruberoid liner (see figure 2.4) into the landfill body up to max. 5 m depth for verification of the presence of clay structure, pesticide waste and the bottom of the fill. The borehole grid is based on the high resolution GIS map, as to clearly log the drilling positions. All the small diameter holes were backfilled with a mixture of clay cement to avoid migration of contaminants in the subsoil. Finally, the mini pits were backfilled with clay. The extracted soil and waste is buried at the landfill. Appendix 4 gives the borehole description in bore logs, the classification of the soil layers and a photo report of the constructed boreholes.

Figure 2.4 Left: Small diameter gouge auger kit comprising of a hamer, gouge knive. Right: Gouge auger in pit with small diameter borehole through the ruberoid

2.3 Fieldwork results

2.3.1 3D Laser Scanning

The 3D Laser Scanning resulted in a computer file of a large number of points; each point has a record on the x, y, and z coordinates. This file is loaded in a Geographic Information System

(GIS). This GIS was filled with Geo data on the soil composition and the layout of the landfill body. This filled GIS is used to produce images from the site, to calculate the volume of contaminated soil at the landfill, the top cover and the volumes of the landfill body.
The results of the 3D scan can be visualized with different images. An example of such image is presented in figure 2.3.

Figure 2.5 is the same image but now with a satellite image from Google Earth. With the results of the scan longitudinal and cross sections can be produced at any position. These cross sections support the description of the CSM. Appendix 2 gives a topographical map made with the information from the laser scan, the longitudinal and cross sections of the landfill body.

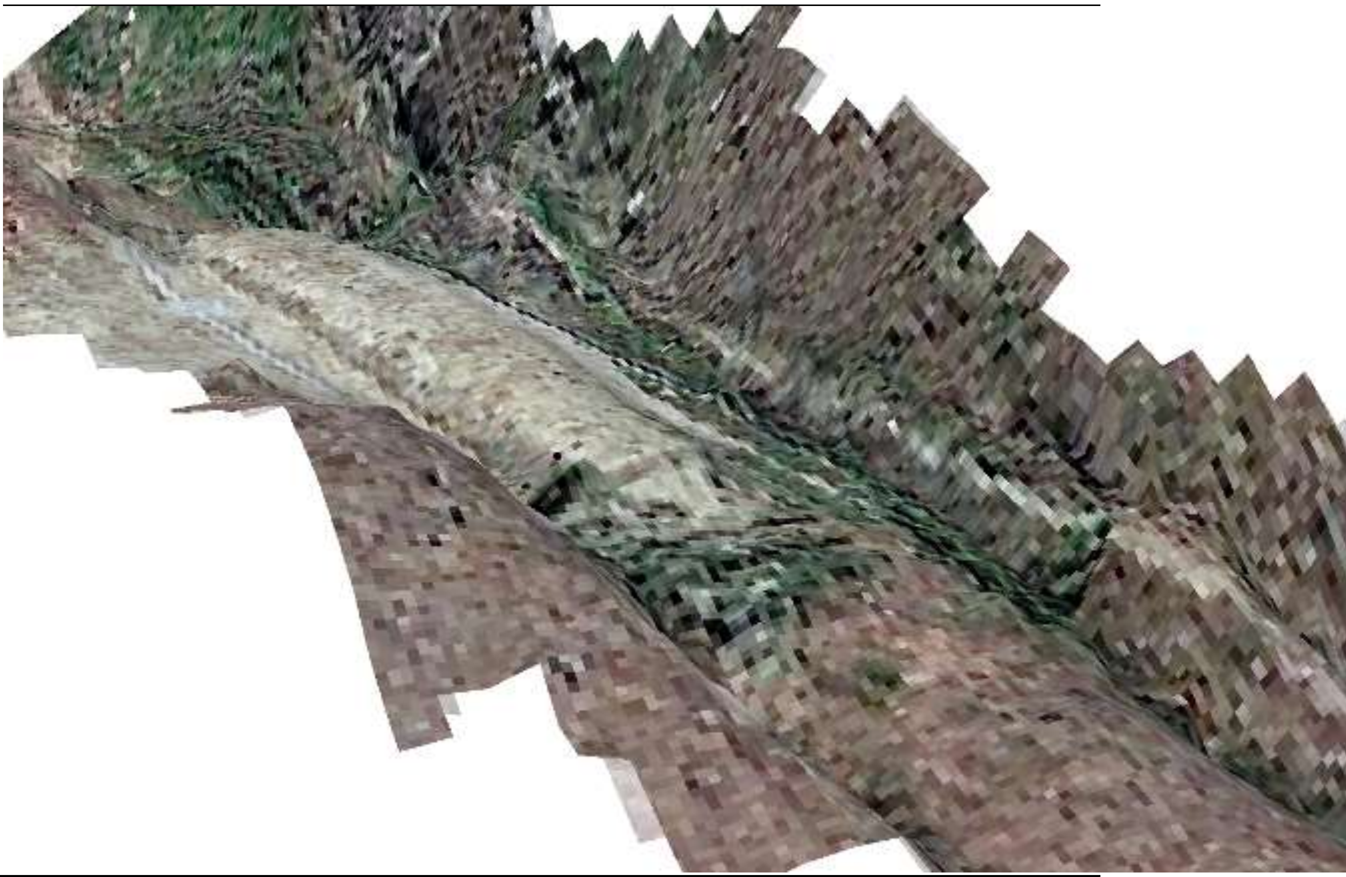

Figure 2.5 Google eath image overlaying the DTM landfill site topogarphy

2.3.2 Ground Penetrating Radar

It was anticipated that the GPR produces a spatially detailed map of variations in (soil) structure till a depth of approximately 1 to 2 m and with less detailed a spatially map of variations in (soil) structure from 2 to around 4 m. The different (soil) layering in the top 4 m of the landfill body is:

1. The top cover of clay covering the hillock
2. A ruberoid liner directly under covering clay layer
3. Drainage/ support layer of the ruberoid
4. Contaminated clay without pure pesticides
5. Contaminated clay with pure pesticides
6. Excavated pits (cells) filled with pesticide waste (bags, drums and barrels)
7. Cell build with concrete/bricks, with pesticide waste
8. Clay soil under pesticides

The different (soil) layering in the top 4 m outside the landfill body is:

1. Contaminated top clay soil consisting of colluvial material (heterogeneous soil with stones and boulders)
2. Undisturbed clay soil subsoil consisting of colluvial material

While the chosen GPR setup was suited to look into the subsurface for up to about 4 m deep, the first data analysis gave images that are blurred at this depth. In the reflection scans slight variations can be noted, but a relation to any of the concrete cell sarcophagus and or clay cells or clay structures, is speculative. In the reflection scans only slight variations in the top 0.5 m can be noted. The reasons for these variations are not clear. It appears that the top layer of the landfill consists of a relatively homogenous material. The thickness of the clay body covering the waste appears to be about 1.0 m instead of expected 0.5 m. The top layer of the surrounding area consists of more heterogeneous material with many small objects that are most likely stones and rocks. No signs of buried material have been found in the surrounding area. The weather conditions, the high clay content, the varying high soil moister content and the thicker top-layer have led to high radar-signal absorption and therefore poor GPR results in the initial data analysis.

By using a rigorous frequency filtering (and thereby removing 90 % of the signal), a layering on the landfill body that differs significant from the layering in the area outside the landfill body was observed (figure 2.6). Based on the travel time and the expected velocity in the soil material the minimum and maximum thickness of the layers is calculated (see table 2.1). The landfill body appears to be constructed by the following layers:

1. **0.00 m - till 0.70 m:** The top layer is clay and contains small objects (e.g. stones) and has a thickness a maximum 0.70 m. This maximum thickness is based on the GPR reading and an

expected velocity in the medium of 12 cm/ns, common in frozen soil. The minimum thickness of 0.40 m, used in table 2.1, is based on field observations and seen as correct and therefore used to calibrate the velocity of the GPR signal in the clay layer, resulting in a velocity of 6.7 cm/ns, which is not unlikely for wet clays

2. **0.70 m - till 1.20 m:** The different reflection in this horizon is unclear, but can be the lower boundary of the frozen layer; can be the change to other soil material; or can reflect the presence of a liner. The material does not contain visible structures and has a thickness of around 0.50 m
3. **1.20 m - 1.90 / 2.90 m:** This layer shows a very clear banding. The initial interpretation of this banding was a false response of the radar system, which led to the conclusion that the results were inconclusive. However, the fact that below this layer discordant layers are present and that the banding is absent in the transect with undisturbed soil, has led to this new interpretation. This banding is the response of the GPR to unknown, reflective material. The radar wave velocity in this layer is unknown, but will be between 5 cm/ns and 12 cm/ns, resulting in a thickness of 0.70-1.70 m
4. **1.90 / 2.90 m - 1.90 / 3.90 m (at least):** This last measured horizon is composed of layers that are discordant positioned below the horizontal banding of the layer above (horizon 3). The nature of the layering can point to the presence of natural soil. The thickness of this layer is at least 1.00 m

The area next to landfill body appears to be constructed by the following two horizons:

1. **0.00 m - 0.70 m:** The top layer is clay and contains small objects (e.g. stones) and has a thickness of around 0.70 m
2. **0.70 m - 2.70 m (at least):** Horizon 2 is composed of layers that are discordant positioned below horizon 1. The nature of the layering can point to the presence of natural soil. The thickness of this layer is at least 2.00 m

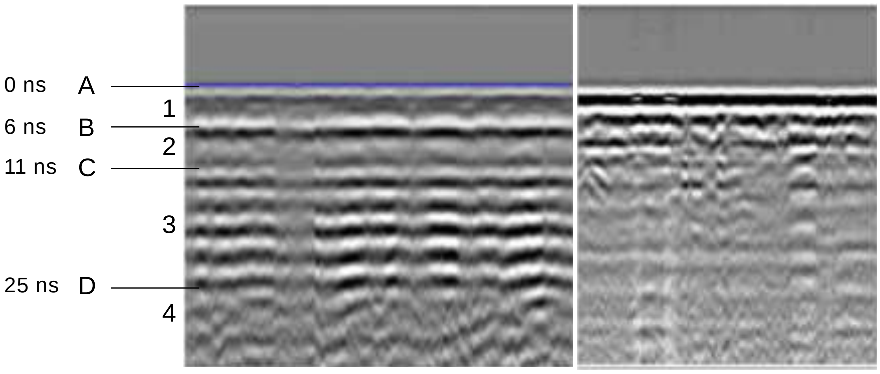

Figure 2.6 Left: GPR image landfill body. Right: GPR image outside landfill body.

Table 2.1 Max and min thickness of layers of the landfill body observed in the GPR data

Layer	Thickness (ns)	Expected velocity (cm/ns)		Accumulated depth (cm)	
		Minimum	Maximum	Minimum	Maximum
1	6	6.7	12.0	40.0	72.0
2	5	10.0	10.0	90.0	122.0
3	14	5.0	12.0	160.0	290.0
4	10	10	10	260.0	390.0

It seems the landfill body has a homogenous top cover of max 70 cm. No distinct cells and or structures are seen. The results of second data analysis are better than the first data analysis, but still there are uncertainties such as the exact extend in vertical and horizontal directions of the POPs pesticides waste. GPR does not present reliable results and mapping, using intrusive soil borings, is needed to present the landfill body layout.

2.3.3 Dynamic Cone Penetration Tests

The numbers and GPS locations of the 17 DCPTs are presented in appendix 3. Table 2.2 gives the depth of each DCPT.

Table 2.2 Depth in m minus groundlevel of the DCPTs

Number	Depth DCPT m minus ground level	Number	Depth DCPT m minus ground level	Number	Depth DCPT m minus ground level
DPT01	3.37	DPT07	4.79	DPT13	2.67
DPT02	2.69	DPT08	1.19	DPT14	4.59
DPT03	4.09	DPT09	0.38	DPT15	2.29
DPT04	3.39	DPT10	0.99	DPT16	5.57
DPT05	2.39	DPT11	1.29	DPT17	5.58
DPT06	4.48	DPT12	1.09		

The number of strokes needed to penetrate 1 inch of soil is recorded and these records are also given in appendix 3 in tabular form and in a graph for each DCPT. For the interpretation the reference values used, are presented in table 2.3.

Figure 2.7 gives the graphs of the DCPT 3 and 15 including the classification using four classes. The very soft and soft soil horizons (pink) are taken as one class. The soil horizons that have a firm to stiff consistency (green) are the second class. The horizons with the consistency very stiff are the third class (purple). The horizons with the consistency hard are the last class (brown). These classified DCPT readings are filled in the DTM.

The DCPTs results demonstrate that the topsoil outside the landfill body is very soft to soft till 0.20 - 0.50. This very soft to soft horizon is overlaying a soil horizon that is firm to stiff till a depth varying from 0.50 - max 2.00 m below ground level. Below this layer consistency of the soil horizon is varying from firm to very firm till a depth of 2.00 - 3.00 m, overlaying a hard soil horizon starting at a depth varying from 2 - 3 m below ground level. From the graphs in appendix 3 it also can be seen that in all DCPT profiles the consistency increases with the depth except for DCPT 9, 16 and 17 these are probably locations where the soil is cracked.

Table 2.3 Classification of DCPT results

Class	SPT or N value	Cohesion, C or Su	Consistency	Colour code
1	< 2	< 500 psf	Very soft	Very soft
	2 – 4	500 – 1,000 psf	Soft	Soft
2	5 – 8	1,000 – 2,000 psf	Firm	Firm
	9 – 15	2,000 – 4,000 psf	Stiff	Stiff

Class	SPT or N value	Cohesion, C or Su	Consistency	Colour code
3	16 – 30	4,000 – 8,000 psf	Very stiff	Very stiff
4	> 30	> 8,000 psf	Hard	Hard

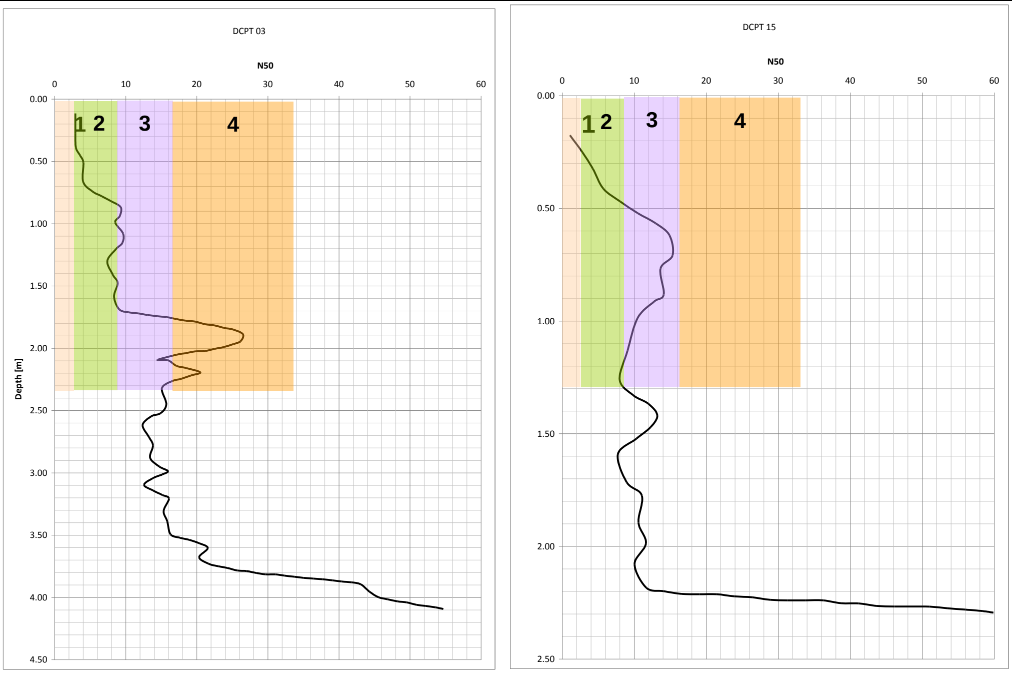

Figure 2.7 DCPT results 03 and 15

2.3.4 Landfill mapping campaign

To obtain a better picture of the layout of the landfill body 63 boreholes till a maximum depth of 4 - 5 meter minus surface are constructed during the last fieldwork campaign in August 2013. The soil profiles of the 63 boreholes are presented on bore logs and these bore logs are given in Appendix 4. Based on the borehole description the soil of the landfill body can be characterized by using the seven soil layers presented in table 2.4.

Table 2.4 Classification of soil layers landfill site

Class	Description of classes	Colour code
1	Top cover of clay covering the hillock	
2	The ruberoid liner directly under covering clay layer	
3	Drainage/ support layer of the ruberoid	
4	Contaminated clay soil without pure pesticides	

5	Contaminated clay soil with pure pesticides	
6	Pure pesticides	
7	Clay soil under pesticides	
8	Bricks/stones/concrete	

These 8 different layers are used to classify the soil layers of the bore logs. Based on the results of the classification of the boreholes the following 5 separate cells with pure pesticides are identified. The classified bore logs are presented in Appendix 4. Appendix 4 also contains a photo report of the constructed boreholes.

Cell 1
Cell 1 is made out of bricks and or concrete and probably constructed as presented in the annex 02 of the TOR (see figure 2.89) but the lid is missing. The cell is located at the very east part of the hillock. The inner dimensions of the cell are 600 x 600 cm. The cell is covered by a purple coarse sand drainage / support layer of 10 cm, a ruberiod liner and a clay cover of 50 cm. The drainage layer is on top of a contaminated clay layer of 70 cm on a clay layer with around 50 % of pure pesticides of 75 cm followed by a 75 cm thick wet layer of 100 % pesticides (see figure 2.8). The bottom of this cell is at 280 cm below the top of the hillock. The top of the cell is at 160 cm minus the top of the hillock. The calculated volume of pure pesticides in Cell 1 is (600 x 600 x 75 cm) 27 m^3.

Cell 2
Cell 2 is a pit excavated in the original soil. This cell is located under the centre of the hillock except for northern part. This part is outside the area with the clay cover and ruberoid liner. The dimensions of this cell are 1,200 x 1,800 cm and the bottom of the cell is at 285 cm below the top of the hillock and 180 cm below the surface just north of the hillock. The layer of pure pesticides is 75 cm (from 210 cm to 285 cm under the hillock and from 110 cm to 185 cm outside the hillock). The DTM gives a calculated volume of pure pesticides in Cell 2 of 187 m^3. The first five cm of the clay soil at the bottom of the pit, 11 m^3, is contaminated by the pesticides.

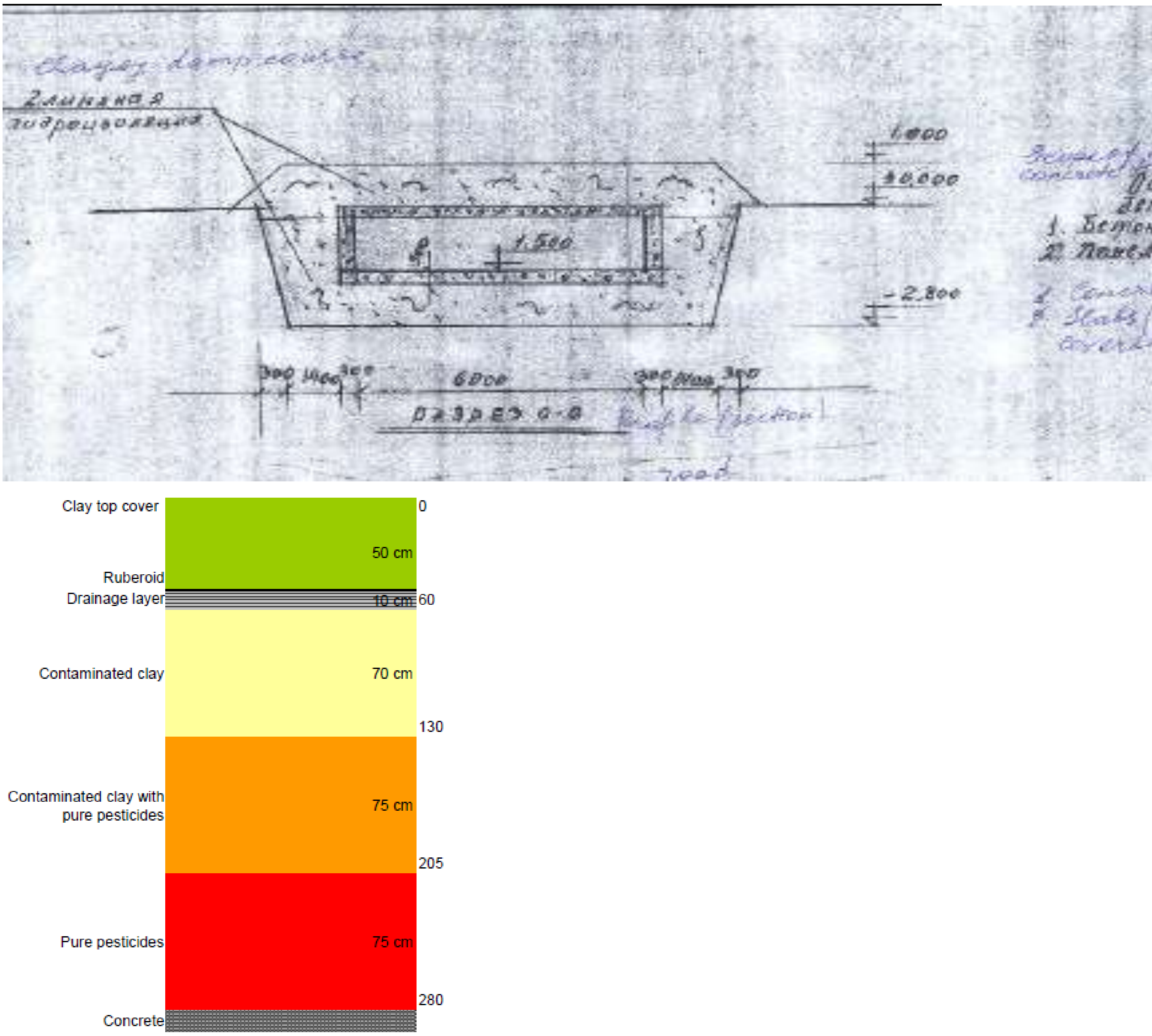

Figure 2.8 Top: Design Cell 1. Bottom: Bore profile of bore hole 337 installed in Cell 1

Cell 3

Cell 3 is located 3 meters west of Cell 2 and is also a pit excavated in the original soil. Between Cell 2 and 3, 40 m^3 of pure pesticides haven been encountered most likely this is deposited here during the waste mining. Cell 3 is completely covered by the hillock. The dimensions of this cell are 1,000 x 1,500 cm and the bottom of the cell is at 285 cm below the top of the hillock. The layer of pure pesticides is 150 cm (from 220 - 370 cm under the hillock). The DTM gives a calculated volume of pure pesticides in the Cell 3 of 178 m^3. The first five cm of the clay soil at the bottom of the pit, 8 m^3, is contaminated by the pesticides.

Cell 4
Cell 4 is located 18 meters west of Cell 3 and is also a pit excavated in the original soil. This cell is completely covered by the hillock and seems not to be disturbed by waste miners. The dimensions of this cell are 750 x 1200 cm and the bottom of the cell is around 420 - 460 cm below the top of the hillock. The layer of pure pesticides is 215 cm (from 245 - 460 cm under the hillock). The DTM gives a calculated volume of pure pesticides in Cell 4 of 109 m^3. The first five cm of the clay soil at the bottom of the pit, 6 m^3, is contaminated by the pesticides.

Cell 5
Cell 5 is located on the west side of the hillock and is also a pit excavated in the original soil. This cell is not covered by the hillock and seems intact. The dimensions of this cell are 750 x 1,200 cm and the bottom of the cell is around 285 cm below the surface. The layer of pure pesticides is 215 cm (from 100 - 285 cm minus surface). The DTM gives a calculated volume of pure pesticides in Cell 5 of 65 m^3. The first five cm of the clay soil at the bottom of the pit, 6 m^3, is contaminated by the pesticides.

The total amount of pure pesticides in the five different cells and between Cell 2 and Cell 3 is 605 m^3 which is around 605 tons. The specific weight of the pesticide depends on the moister content and type of pesticides and therefore varies. The average specific weight dumped in these cells is assessed to be around 1 ton for 1 m^3.
The amount of contaminated clay soil at bottom of the four excavated pits is around 31 m^3 which is around 53 tons. The specific weight of clay is around 1.7 ton for 1 m^3.

Appendix 2 gives the aerial view of the landfill, one transect and the 6 cross sections (Cell 1, 2, between Cell 2 and 3, Cell 3, Cell 4 and Cell 5) generated from the DTM. Table 2.5 gives all the amounts of the different landfill site and landfill body components.

2.4 Evaluations

This section describes the layout of the landfill site, the landfill body and the dumped pesticides waste in three different subsections using the:

- Information given in the tender documents
- Data gathered during the different fieldwork campaigns
- Old and recent taken pictures
- Google satellite images from the different years

- The DTM of the landfill body

2.4.1 The landfill site

The Nubarashen landfill site can be reached from Yerevan by the highway M 15. In Nubarashen is a dirt road of approximately 4 km that leads to the landfill site. One kilometre downhill the landfill is barrier. This barrier is locked and the watchman appointed by the MoES is holding the key. A portable watchman cabin stands a few yards from this barrier. A bit higher up the hill is a permanent watchman's house.

Uphill the landfill site is a dirt road passing the landfill site 300 - 400 m east. A culvert installed under this dirt road drains the runoff water from a large uphill separate catchment area.
This culvert is nearly filled up with sediments. Parallel on the north side of this road runs a water main with a diameter of half a meter (see figure 5.1). This water main is probably leaking and is blocking the natural drainage pathway of the uphill catchment area. Because the drainage way is blocked, Pond 1 is having standing water till the top of the water main. Water from Pond 1 and the pool in front of the blocked culver infiltrates in the soil and is drained into the valley of the landfill. If the water level in the pond is higher than the top of the water main, the water percolates is drained slowly through the culvert filled with sediments.

The dirt road has is connected with the landfill site by a very steep dirt road just east of Pond 1. The landfill site can be reached by both ways preferably with 4x4 car when the clayey top soil is dry. When wet it is very difficult to reach the site even with a 4x4. Trucks can only reach the site in dry periods.

The landfill site itself, is a barb wired fenced area of 165 m long and 50 m wide enclosing an area of 0.8 hectares. The steel fence poles are approximately 2.5 m high and are placed in a concrete blocks. The fence has a lockable gate were trucks can enter. This key is also with the watchman. Inside the fence area is the landfill body covert with a hillock. The landfill body is surrounded by three concrete runoff drains. One on the North of 114 m, one on the South of 120 m and one upstream the landfill of 30 m connecting both ends to the other two drains. The drain is a culvert, in front of the gate, allowing trucks to pass the drain and approach the landfill body. The drains are made out of prefab elements and the joints between elements are sealed with a concrete slab. The drains are installed to prevent runoff water to percolate the waste and to reduce the risk for site erosion. At several places the drains are tunnelled by runoff water and the drain elements are dislocated leaving open joints (see figure 2.9) between the elements. The drain to the South is connected to a gully of the natural dendritic drainage system. An embankment guides the runoff water from the Northern drain to a lower laying natural gully. The site drainage and other features of the catchment area of the landfill are discussed in section 5.

West, 10 m down slope the landfill body inside the fenced area, are two trenches of approximately 1 m deep, 18 m long and 1.5 m wide. These trenches are probably remains of a construction were in the old days liquid pesticides were burned to reduce the volume of the waste to be dumped. Currently these trenches function as runoff traps and are filling up wit runoff material.

The fenced area has a grass/herbs cover and there are a few small trees and bushes. During the fieldwork bare patches of land were observed. The vegetation of the surrounding is also grass with few trees and bushes in the gullies. Reed is growing at flat areas which are pools with standing water during wet periods. The area is used for grazing; the pools are used for watering cattle. Women and children are picking flowers looking for herbs and mushrooms in the surrounding of the landfill. The surrounding area has many features of soil erosion such as gullies, landslips and landslides. The landfill body is located on an active landslide, the landslide debris. The site erosion features are discussed in Chapter 5.

Figure 2.9 Left: Dislocated drainage element. Right: Eroded topcover landfill body

2.4.2 Landfill body

The layout of the landfill body is discussed in several documents attached to the project TOR. These documents and the information gathered in the scope of this project are used to assess the layout of the landfill body and the different quantities of the landfill body components.
Although the **1977** design prescribed the planed disposal of the pesticides in concrete containers, it is clear from other information that the landfill body is constructed differently. Geophysical investigations in **2005** did not reveal any concrete structures in the designated burial area,

however the test boreholes have only been made down to approximately 2 m of the layer of the burial site, hence the bottom construction of the burial site has not been confirmed by the conducted investigations. Further in the surroundings a number of boreholes have been made with a depth of up to 6 m. The information from theses boreholes combined with the geophysical investigations in the areas, gives a relatively clear picture of the near-surface geology but not of the landfill body itself. In **June 2010 after the new cover was installed** the MoES installed a borehole in the centre of the landfill body, up to 5.5 m below surface. The borehole reached in the 'healthy soil'. The information available on the borehole is that the top soil is 1 m thick covering a layer of waste from 1.3 - 5 m below surface.
The landfill body itself is a hillock of approximately 1.25 m high uphill, 2 m high in the middle and 1.50 m high at the down hill part with respect of the surrounding surface level of the enclosed area. The hillock is 104 m long and 16 m wide uphill, 22 m wide in the middle and 18 m wide at the down hill part. The total area of the hillock is around 0.2 ha. The topsoil of this hillock covering the dumped pesticides is a 40 – 70 cm thick clay layer and traces of pesticides and remains of packaging are observed at the surface. The top cover of the landfill body is getting eroded and at a few places the top cover has cracks (see figure 2.9). The top cover is overlaying a 2 mm ruberoid liner. The ruberoid liner is overlaying a coarse sand layer of 5 cm followed by disturbed clay layers with and without pesticides covering five different cells (one build and four excavated pits) partly filled with pure pesticides and soil mixed with pesticides (see Appendix 2). Table 2.5 summarizes the quantities of the different landfill site and landfill body components. The in-situ volumes and the volumes when excavated are presented in the table 2.5. The excavated volume of soil is around 20 % more than the in-situ volume.

Table 2.5 Quantities of the landfill side and landfill body

Component of land site	Measurements	Quantities		
		In situ *	Excavated	Weight
Landfill site				
Fenced area	0.8 ha			
Landfill body area	0.2 ha			
Fenced area except the hillock	0.6 ha			
Heavily contaminated clay with pure pesticides (see section 4.3.3)	50 cm	3,000 m^3	3,600 m^3	5,100 ton
Landfill body				
Slightly contaminate clay cover (see section 4.3.2)	40 – 70 cm	890 m^3	1,068 m^3	1,513 ton
Ruberoid liner	2 mm			
Clean white/purple coarse sandy liner support /drainage layer	5 cm	100 m^3	120 m^3	170 ton

Component of land site	Measurements	Quantities		
		In situ *	Excavated	Weight
Contaminated clay layers with traces of pure pesticides		1,127 m^3	1,352 m^3	1,916 ton
Cell 1 build (brick / concrete) with pure pesticides	600 x 600 x75 cm	27 m^3	27 m^3	27 ton
Cell 2 excavated pit with pure pesticides	1,200x1,800x75 cm	186 m^3	186 m^3	186 ton
Contaminated soil at the bottom of Cell 2		11 m^3	13 m^3	19 ton
Between Cell 2 and Cell 3		40 m^3	40 m^3	40 ton
Cell 3 excavated pit with pure pesticides	1,000x1,500x150 cm	178 m^3	178 m^3	178 ton
Contaminated soil at the bottom of Cell 3		8 m^3	10 m^3	17 ton
Cell 4 excavated pit with pure pesticides	1,200x750x215 cm	109 m^3	109 m^3	109 ton
Contaminated soil at the bottom of Cell 4		5 m^3	6 m^3	9 ton
Cell 5 excavated pit with pure pesticides	1,200x750x215 cm	65 m^3	65 m^3	65 ton
Contaminated soil at the bottom of Cell 5	1,200x750x215 cm	5 m^3	6 m^3	9 ton
Total quantities landfill site and landfill body				
Heavily Contaminated top soil with traces of pure pesticides fenced area landfill site		**3,000 m^3**	**3,600 m^3**	**5,100 ton**
Slightly contaminated top cover landfill body		**890 m^3**	**1,068 m^3**	**1,513 ton**
Clean white/purple coarse sandy liner support /drainage layer		**100 m^3**	**120 m^3**	**170 ton**
Contaminated top soil with traces of pure pesticides in landfill body		**1,127 m^3**	**1,352 m^3**	**1,916 ton**
Pesticides		**605 m^3**	**605 m^3**	**605 ton**
Contaminated clay at the bottom of four excavated pits (Cell 2, 3, 4 and 5)		**29 m^3**	**35 m^3**	**49 ton**

* Quantities are calculated by using the DTM

2.4.3 The buried waste

Reportedly a total of 512 tons of pesticides have been disposed (powders and liquids in original packaging) at the site. Base on the above described survey results, it seems to be more. All substances reported are listed in Appendix 4 and for each substance the characteristics are given. It is expected that the waste was originally packed in:

- Paper bags
- Cardboard drum of 20-30 litters
- Cardboard boxes
- Metal drum of 60-200 litters
- Plastic bags
- Glass bottles

Because the waste is for more than 40 years buried the metal drums will be rusted and too weak to be taken out without risk of breaking. The paper bags and cardboard packaging will also be decayed and will not hold the content when lifted.
The pesticide waste in the top part of the cells is mixed with clay because of the illegal waste mining and the 2010 emergency measures, the (re)capping of the waste.
The first 5 cm original clay soil of the bottom and the sides of the excavated cell are most likely heavily contaminated with pesticide and are seen as pesticides waste. The volumes of contaminated soil are given in table 2.5.

3 Stakeholder involvement

Besides the technical data gathering the stakeholder involvement is one of the important cross cutting issues of this project. The stakeholder involvement was initiated with a Quick Scan Stakeholder Analysis made during the inception mission. This Quick Scan was used during the stakeholder workshop on 22 March 2013 to gather information for the stakeholder involvement plan to be made in Phase 3 of this project.

3.1 Quick Scan Stakeholder Analysis

In the frame of different international POPs and hazardous waste projects the Tauw consortium developed the Quick Scan Stakeholder Analysis - a tool to indicate how problems in society are handled by stakeholders. For solving the problems around the landfill Nubarashen, Ministries, local and regional departments, business, institutes for higher education and NGOs need to cooperate on a high level. A Quick Scan analysis of project stakeholders helps to establish a better understanding of:

- The level of information among stakeholders
- The different roles that the different stakeholders play to solve the social, environmental and public health problems around the landfill and eliminate existing risks
- The position of the different groups that face direct risks

Directly at the start of the project the AWHHE, the local representative of Tauw, sent out an official request to Nubarashen Stakeholders to fill in the Quick Scan Stakeholder Analysis for their own organization. As stakeholders the following 26 organizations where identified:

a. State bodies: Ministry of Nature Protection, Ministry of Agriculture, Ministry of Health, Ministry of Emergency Situations, Ministry of Economy, Ministry of Foreign Affairs, Ministry of Territorial Administration, Ministry of Defense, State Police Department, National Security Service, State Revenue Committee, Yerevan Municipality, local authorities (Nubarashen community of Yerevan)
b. International organizations: OSCE, UNDP, UNIDO
c. National research centers: Center for Ecological-Noosphere Studies of the National Academy of Sciences, 'Waste research center' SNCO, Ministry of Nature Protection, Scientific Research Institute on General Hygiene and Occupational Diseases
d. National companies: Engineer-Geologist Ltd.
e. National NGOs: AWHHE, Ecolur, Khazer, Ecoglobe, Association for Human Sustainable Development

As a special stakeholder group the following Groups at Risk where identified:

a. Workers maintaining the site
b. Inspecting officer (from governmental and from NGO background)
c. Police officers
d. Population living downstream the site
e. Herdsmen
f. Children playing in the neighborhood
g. Women collecting herbs in the neighborhood
h. Women using surface water for irrigation
i. Tourists that stay in the summerhouse direct down slope the landfill

Fourteen organizations responded by filling in the Quick Scan; of those twelve organizations took part in the project workshop on 22 March 2013 at the office of the OSCE in Yerevan where the outcomes of the Quick Scan were discussed and formulated.

3.2 The stakeholder workshop

After an update on the technical process of the project by project manager Boudewijn Fokke, Wouter Pronk from Milieukontakt International gave a presentation on the backgrounds of stakeholder involvement and the expected gains in sustainability of project results through involvement of NGOs, farmers' organizations and social initiative groups. This presentation is annexed to the report as Appendix 6.1. Then Gohar Kojayan from AWHHE followed with a presentation on the outcomes of the Quick Scan based on the reactions received thus far.
This presentation is annexed to the report as Appendix 6.2. The first outcomes of the Quick Scan caused some confusion and disagreement, but after the participants sat down and fine tuned their statements for the Quick Scan a general agreement could be reached.
On the next day AWHHE and Milieukontakt formulated the outcomes in a document. This document 'Results of the Nubarashen Quick Scan stakeholder Analysis' is annexed to the report as Appendix 6.3. A summary of this document is presented below.
AWWHE sent out official letters with a summary Quick Scan analysis to all the participants of the 22 March stakeholder meeting. The organization addressed official letters to the newly appointed officials in the aftermath of the recent presidential elections. The reactions are positively agreeing with the analysis.

3.3 Summary Preliminary Quick Scan Stakeholder Analysis

This section summarizes conclusions of the Preliminary Quick Scan Stakeholder Analysis for the Nubarashen Burial Site for Obsolete and Banned Pesticides in Armenia.

3.3.1 Key Stakeholders

- Overall, it is very positive that there is quite a diverse group of key stakeholders that have the formal objective to solve the problems around the Nubarashen Burial Site for Obsolete and Banned Pesticides
- The key stakeholders are active to solve the issue around the Nubarashen Burial Site for Obsolete and Banned Pesticides
- There is a lack of technical capability to solve the problem and there is a strong need to build technical capacity in Armenia
- There is a lack of financial capacity to solve the problems around the Nubarashen Burial Site for Obsolete and Banned Pesticides. Funding projects to solve the problems around the Nubarashen Burial Site for Obsolete and Banned Pesticides is a serious problem in Armenia. International funding is strongly required to solve the problem
- There is coordination to solve the problems around the Nubarashen Burial Site for Obsolete and Banned Pesticides. It is recognized that only in case of further improvement in coordination it is possible to solve such a complicated issue
- There is a need to raise the awareness at all levels about the need to solve the problems around the Nubarashen Burial Site for Obsolete and Banned Pesticides

Armenia has an adequate policy to tackle the problem. There is a need for the key stakeholders to clarify if the Armenian policy is in line with the international best practice of policies for POPs management.

Armenia has appropriate legislation and decision-making around the issue. There is a need for the key stakeholders to clarify if the Armenian legislation is in line with the international best practice of POPs legislation.

- Armenia needs to improve law enforcement in this area
- There is a strong need for international funding to solve the problem
- There is equally a strong need for national co-funding. International funding alone cannot solve the problem. The national government needs to show commitment here, but might not always be aware of the urgency of the issue.
- To solve the issue, there is a strong commitment from implementing agency to build on

3.3.2 General Conclusion

There are some positive prerequisites such as strong key Ministries, appropriate legislation, and high awareness of the issue among many of the key stakeholders, which attests to the fact that the issue of the Nubarashen Burial Site for Obsolete and Banned Pesticides is gaining higher priority on the political agenda in Armenia.

3.3.3 Themes for Stakeholder Involvement

1. Raise awareness among politicians in order to prioritize the issue of the Nubarashen Burial Site for Obsolete and Banned Pesticides in the national political agenda
2. Develop technical capacities among key stakeholders to solve the issue
3. Organize advocacy among donors to prioritize the issue on their funding agenda
4. The Steering Group meetings of the OSCE and UNDP projects can be used as an active inter-agency coordination and working group to channel the efforts to find sustainable solutions for the problem
5. Identify the needs among state bodies and target groups to improve the awareness about the issue
6. Identify the gaps in law enforcement and based on best practices propose improvements
7. Identify the gaps in funding implementation and based on best practices propose improvements

3.3.4 Groups at Risk

- There is a lack in information about the threats of POPs pesticides for all the groups listed in this analysis. Stakeholders have to be very well informed
- There is a lack of safety measures in order to protect the different groups listed in this analysis against negative health impacts of the Nubarashen Burial Site for Obsolete and Banned Pesticides
- There is a good basis to build awareness raising campaigns around the issue and there is an urgent need to protect the different groups against negative impacts of the Nubarashen Burial Site for Obsolete and Banned Pesticides

3.3.5 The Themes for Stakeholder Involvement

Activities around the Nubarashen Burial Site for Obsolete and Banned Pesticides

1. Develop awareness raising campaigns for the different groups at risk
2. Ensure proper protection for each group at risk to avoid negative impacts of the Nubarashen Burial Site for Obsolete and Banned Pesticides

3.4 The stakeholder involvement plan

Based on the final results of the Quick Scan Stakeholder Analysis Milieukontakt and AWHHE will draw up a stakeholder involvement plan and present this in Phase 3 of this project.

4 Phase 2 Detailed Environmental Site Assessment

4.1 Methodology

The investigation of the catchment area comprised:

1. An assessment of the current soil quality of the landfill site; reported in section 4.3 (soil quality)
2. An environmental baseline assessment of the catchment area of the landfill site (reported in section 4.3) verifying the potential spreading (receptors pathways) of the contaminants from the landfill to the soil and groundwater and determines potential migration risks, risks to humans and the environment. The environmental baseline assessment assesses:
   - The soil quality up and down gradient from the landfill
   - The shallow groundwater quality up gradient from the landfill
   - The shallow and deep groundwater quality down gradient from the landfill
3. A Geo physical assessment; reported in chapter 5 (erodability, soil texture and geo-stability)
4. A risk assessment of the burial site (reported in section 6.2) including:
   - An environmental Tier 2 risk assessment
   - An erosion study of the catchment area

4.2 Fieldwork activities

The Phase 2 fieldwork was conducted from 6 to 18 May, 2013. The shallow boreholes and the boreholes at the difficultly accessible reed ponds were performed by manual augering. The deep boreholes were performed by a mechanical rotary core Zil drilling rig, from the Armenian company 'Engineer-geologist' Ltd (see figure 4.1). A total of nine monitoring wells have been installed. The monitoring wells consist of HDPE filter pipes with filter screen (equipped with water traps and filter gauze) and PVC risers. Each monitoring well is labeled and finished with a plastic cap or metal well head and a weatherproof label providing technical details (see figure 4.2).
For an overview of the drilling locations and samples, please refer to section 4.3. The soil profile of each borehole has been described (for descriptions see Appendix 7) and relevant soil horizons were sampled. The soil at the site mostly consists of heavy clay. Further details on the soil composition can be found in Chapter 5.

After the fieldwork, the soil, standing- and groundwater samples were analyzed in the NEN-EN-ISO/IEC 17025 accredited laboratory of AL-West in Deventer, the Netherlands.

Analyzed substances in soil were Heavy metals (As, Cd, Cr, Cu, Hg, Pb, Ni and Zn), and Organ chlorine pesticides. Some of the soil samples have also been analyzed for geo-physical parameters: a) the soil texture (grain size distribution) to assess the vertical and horizontal infiltration rate, b) the field capacity and c) an indication of the erodability. This is reported in a separate chapter, Chapter 5.

Figure 4.1 Left: The Zil mechanical drill rig in action. Right: Well tubing, clean water, filter gravel and bentonite were transported to the site from Yerevan

Figure 4.2 Left: Monitoring well 8, protected by rocks. Right: Monitoring well 9, protected with steel well head. All monitoring wells are equipped with weather proof labels providing details on the monitoring wells

Analyzed substances in ground- and pond water were Heavy metals (As, Cd, Cr, Cu, Hg, Pb, Ni and Zn), Organ chlorine pesticides, Total Petroleum Hydrocarbons C10-C40 (TPH) and BTEX (Benzene, Toluene, Ethyl Benzene and Xylenes).

4.3 Results - chemical analyses

4.3.1 Testing framework

By absence of a local testing frame, the analytical results were evaluated against the different limit values defined in the Dutch Circular on Soil Remediation 2009 (*Circulaire bodemsanering 2009*), and the Decree on Soil Quality (*Besluit bodemkwaliteit*) of 1 July 2008. This so called STI evaluation frame is widely used internationally to get a first impression on contaminant levels and imminent risks.

The STI evaluation frame distinguishes between background values (***A****chtergrond****w****aarden, AW*) for soil, reference values (**S**treefwaarden) for groundwater, and intervention values (***I****nterventiewaarden*) for both soil and groundwater. The testing values (***T****ussenwaarden*) are defined as **T** = ½ (**AW** + **I**) for soil and **T** = ½ (**S** + **I**) for groundwater.

The used indications for the soil and groundwater assessment in the following sections are given in table 4.1.

Table 4.1 Indications for the assessment of the soil and groundwater sample concentrations

Concentration level	Indication	Meaning
≤ AW / S value (or < detection limit)	-	Not contaminated
> AW / S value ≤ T value	+	Slightly contaminated
> T value ≤ I value	++	Moderately contaminated
> I value	+++	Strongly contaminated

The limit values for soil are depending on soil texture, specifically clay content *(% **L**utum*) and organic matter content (*% **H**umus*). For the interpretation and assessment of the soil analytical data, clay and organic matter content have been analyzed for eight representative samples.
The calculated limit values applicable are presented, the analytical results presented in tables, the reports of the soil and water samples are included in Appendix 8.

4.3.2 Analytical results and interpretation top cover

Below table 4.2 lists the samples taken from the top cover of the landfill body (see figures 4.3 and 4.4). The motivation for taking these samples is to assess the soil quality, as well as the erodability and soil texture (reported in section 5). Appendix 2 presents maps with the sample locations. The analytical results are given in the tables A8.1 of Appendix 8.

Table 4.2 Samples from the topcover of the landfill body

Sample	Composition	Location (on top-cover landfill body)
201	CSS[1] of 6 drilling points	Most easterly quarter section of the landfill body
202	CSS of 6 drilling points	Quarter east of the middle of the landfill body
203	CSS of 6 drilling points	Quarter west of the middle of the landfill body
204	CSS of 6 drilling points	Most westerly quarter of the landfill body

Figure 4.3 Composite soil samples topsoil landfill body are presented in red (from right - east- to left - west - 201 to 204. The areas in the orange coloured section are discussed in section 4.3.3

Figure 4.4 Left: the landfill body seen in a westerly direction. Right: drilling point on topcover

[1] Composite Soil Sample: the analyzed sample was composed from a number of individual samples/ sample locations

The clay cover of the landfill body is relatively clean, with DDT present in concentrations below or just above the Dutch I-value. This is likely caused during the installation of the top cover as some contamination may have mixed into the clay cover. Visual inspection of the top cover indicated presence of some remnants of product containers, supporting this hypothesis.
The measured concentrations are much lower as compared to these measured in the top soil of the direct vicinity of the landfill body (see section 4.3.3), indicating that it is not likely that impacts from the landfill body top cover to the surrounding soil currently take place. The total volume of the slightly contaminated top cover is 890 m^3 which is 1,089 m^3 excavate (factor 1.2) and is 1,513 ton (specific weight 1.7 ton), see also table 2.6 Chapter 2.
A layer of 'ruberoid' was encountered at approximately 0.4 – 0.7 m bgl, at which depth the drilling was stopped as not to penetrate the cover.

4.3.3 Analytical results and interpretation of soil direct vicinity of the landfill body

Below table 4.4 lists the top soil samples taken in the direct vicinity of the landfill body, within the fence. The motivation for taking these samples is to assess if the top soil is impacted. These impacts could be the result of run-off of rainwater from the landfill body or from historic impacts during the filling of the landfill or during the period that the landfill was not covered and the pesticides may have spread in an uncontrolled way.
Some of the analysed samples from the top soil were collected from areas with plant cover (CSS 102, 104, 106), and some from areas with bare soil (CSS 103, 105 and 107). This is illustrated in figure 4.5. Appendix 2 presents maps with the sample locations. The analytical results are given in the tables A8.2 and A8.3 of Appendix 8.

Figure 4.5 Surface areas with - and without - plant cover, within the fence, next to the landfill body

Table 4.3 Samples in the direct vicinity of the landfill body, within the fence

Sample	Composition	Location
101	CSS of 5 drilling points	Up gradient from the landfill body
102	CSS of 3 drilling points	North from the landfill body, with plant cover
103	CSS of 4 drilling points	North from the landfill body, bare soil
104	CSS of 5 drilling points	Directly north from the landfill body, with plant cover
105	CSS of 4 drilling points	Directly north from the landfill body, bare soil
106	CSS of 5 drilling points	South from the landfill body, with plant cover
107	CSS of 5 drilling points	South from the landfill body, bare soil
108	CSS of 5 drilling points	Down gradient from the landfill body
109	CSS of 4 drilling points	Down gradient from the landfill body, in the trenches

At some locations, the shallow top soil in the direct vicinity of the landfill body (within the fence) contains high levels of DDT, DDD and DDE, as well as HCH isomers. The contamination is present in a very heterogenic way. Aside from a certain 'background level' for this area, most of the measured contaminant levels are likely associated with a 'hit or miss' of pesticide particle(s) in the soil matrix. This was also observed during the fieldwork campaign, as in some drillings outside of the landfill body, pure product was observed (white and lumpy: probably DDT or HCH; purple-pink: probably Granosan, a coloured preparation containing 2 % Ethylmercuric Chloride (see figure 4.6); yellow: Sulphur - colour and texture match exactly - not the orange-yellow colour of DNOC). Samples from boreholes in which pure product was observed were not collected for analysis based on the rationale that contamination in high levels has already been identified, and not to damage sensitive laboratory equipment. Only samples from -apparent- visually unaffected soil were submitted for analysis.

The presence of pure product outside of the landfill body is explained by the photos taken in April 2010 (Appendix 4 of the TOR) before the top cover was (re)-installed, that clearly show pure product was laying scattered around the current landfill body perimeter (see figure 4.6).
Another observation is the presence -or absence- of plant cover. Some of the analysed samples from the topsoil were collected from areas with plant cover (CSS 102, 104, 106), and some from areas with bare soil (CSS 103, 105 and 107). The analytical results indicate much higher contaminant levels in the 'bare soil' composite soil samples as compared to the 'plant cover' composite soil samples.
Although the absence of plant cover may not necessarily be related to only POPs pesticides, it does relate to the presence of some of the substances buried in the landfill such as herbicides.
The total volume of the contaminated topsoil (0.5 m bgl) around the landfill body is 3,000 m^3 which is 3,600 m^3 excavate (factor 1.2) and is 5,100 ton (specific weight 1.7 ton), see also table 2.6 Chapter 2.

Figure 4.6 Left: pure product particle on auger head (likely Granosan). Right: The situation (April 2010) before closing of the landfill, with pesticide waste scattered around the current landfill body.

4.3.4 Analytical results and interpretation sediments in the reed ponds

Below table 4.7 lists the samples taken from the sediments in the reed ponds down-gradient from the landfill body in a gully that was anticipated to carry run-off water from the landfill down to the valley. The first reed pond, Pond 1 is located up-gradient from the landfill and serves as a baseline situation for the other, (down-gradient) ponds. Appendix 7 presents maps with the sample locations. Figure 4.3 presents a birds' eye view that is very useful in understanding the situation of the ponds and gullies. The analytical results are given in table A8.4 of Appendix 8.

Table 4.4 Samples of the sediments in the reed ponds in site surroundings

Sample	Composition	Location
Pond 1	CSS of 3 drilling points	Up gradient from the landfill body
Pond 5	CSS of 3 drilling points	In a gully, 100m down-gradient from the landfill
Pond 6	CSS of 3 drilling points	In a gully, 300m down-gradient from the landfill
Pond 7	CSS of 3 drilling points	In a gully, 630m down-gradient from the landfill
Pond 8/9[2]	CSS of 3 drilling points	In a gully, 720m down-gradient from the landfill

DDD and DDE were measured in detectable levels (below the 'slightly contaminated' limit value) in the sediments of Pond 1 (up-gradient from the landfill).

[2] Pond '8/9' is actually the same Pond. The name was chosen for reason of consistency as it corresponds with drilling numbers 8 and 9, both located at the side of Pond 8/9. The other drilling numbers do not have corresponding ponds

The sediments of the Ponds 5 and 6 contain slightly elevated levels of DDD, as well as slightly elevated levels of HCH and Endosulfan in Pond 5 which is located closest (100m) to the landfill. The levels in the sediment of Pond 5 are relatively low, as one would expect that part of the run-off water from the landfill would end up in Pond 5.
Based on visual inspection in the field, Ponds 6 and 7 (and possibly 8/9) appear not to be directly connected to the potential surface run-off from the landfill area (see figure 4.4). Concentrations of DDT, range from detectable (below the 'slightly contaminated' limit value) in Pond 7, to slightly contaminated in Pond 6. The sediments in Pond 8/9 were measured to contain the highest levels of DDT of the five ponds. The second gully meets the first gully (with Ponds 6 and 7) at Pond 8/9. The second gully (the left one in figure 4.3) also does not appear to be directly connected to the potential surface run-off from the landfill area, based on visual inspection of the terrain topography (see figure 4.3). It does however drain the upper part of the valley close to the landfill. Although the gullies appear to not be directly connected to the runoff water from the landfill, it cannot be excluded that one or both gullies are (also) fed with water that has infiltrated into the landslide area.

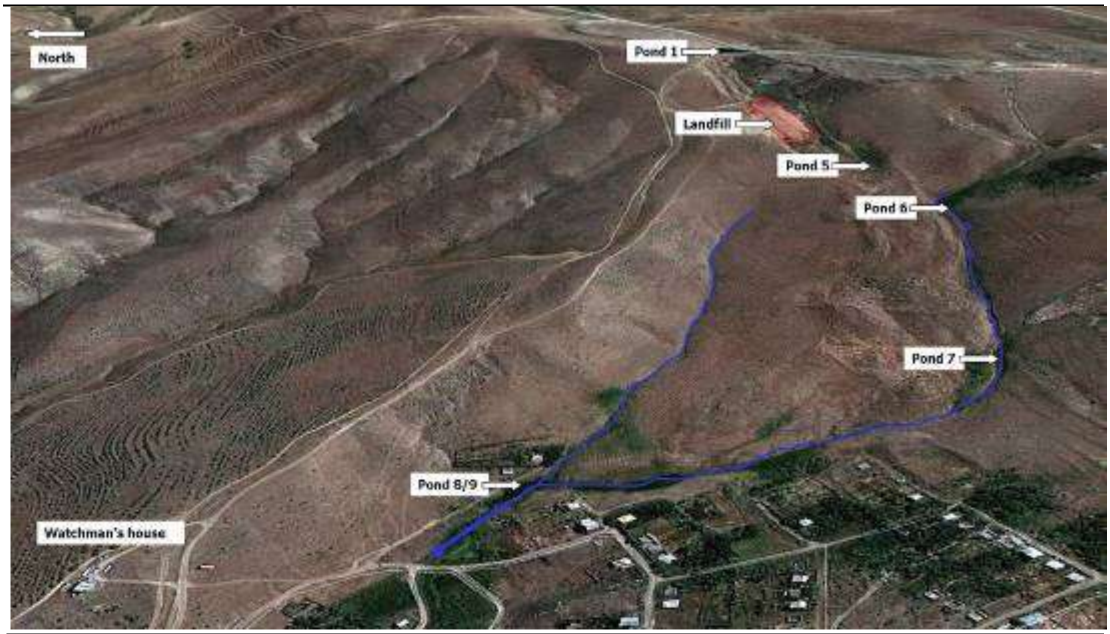

Figure 4.3 Bird eye's view image of the area. Both gullies merge at Pond 8/9

Figure 4.4 Left: Reed Pond 8/9 with the drilling rig installing monitoring well 9. Right: Reed Pond 6. This photo indicates that the gully is likely not connected to the landfill run-off. The landfill is located up-gradient, to the left, from the Tauw colleague walking in the top left of the picture, whereas the water feeding the gully appears to come from the top right of the picture

4.3.5 Analytical results and interpretation soil from the landfill surroundings

Below table 4.9 lists the samples taken from the soil arisings from the drillings in the surroundings of the landfill. Appendix 2 presents maps with the sample locations. The analytical results are given in the Tables A8.5 and A8.6 of Appendix 8.

Table 4.5 Samples from drilling points in the site surroundings

Sample	Composition	Location
2	2 (0-0.5m bgl)	5 m up gradient from the landfill body perimeter
3	3 (0-0.5m bgl)	5 m down gradient from the landfill body perimeter
4	4 (4-5m bgl)	5 m down gradient from the landfill body perimeter, in a trench intercepting run-off
5	5 (1-1.5m bgl)	At Pond 5, in a gully, 100m down-gradient from the landfill
5	5 (4-4.5m bgl)	At Pond 5, in a gully, 100m down-gradient from the landfill
9	9 (4-5 m bgl)	In a gully, near Pond 8/9, 720m down-gradient from the landfill

The samples taken from the soil arisings from the drillings in the site surroundings generally contain slightly, to strongly elevated levels of DDT. The strongly elevated levels were measured in the topsoil of drillings 2 and 3. There is no significant difference between the concentrations in drilling 2 (5 m up-gradient from the landfill body) and 3 (5 m down-gradient from the landfill body), which is explained by the fact that all soil in the direct vicinity of the landfill is impacted, as concluded in section 4.3.3.

The sample from drilling 4 (4-5 m bgl) contains only detectable levels of DDT/DDD/DDE, whereas a shallower sample from nearby drilling 41 (0.8-1.0) likely contains very high concentrations of pesticides (visual observation and strong smell), but for this reason was not submitted for chemical analysis.

The samples from drillings 5 and 9 exhibit slightly elevated concentrations of pesticides, mainly DDT. It cannot be ruled out that the samples from the greater depths (4-5 m) are false positives that have been caused by accidental cross-contamination during the drilling. This is supported by the low permeability of the soil.

4.3.6 Analytical results and interpretation groundwater and standing water

Table A8.7 of Appendix 8 gives analytical results of the samples taken from the groundwater from the monitoring wells that yielded water, and from the reed ponds containing water. Appendix 2 gives the sample locations.

The groundwater from monitoring wells 1 (filter 4-5 m bgl), 7 (filter 3-4 m bgl) and 9 (filter 18.2-22.2 m bgl) does not contain detectable levels of the analysed range of pesticides. Nor does the standing water from Ponds 1 and 7 contain detectable levels of the analysed range of pesticides.
The other installed monitoring wells (2, 3, 4, 5 and 8) did not contain groundwater. Ponds 5, 6 and 8/9 also did not contain standing water and hence could not be analysed.
The slightly elevated levels of mineral oil (TPH) and Aromatic Hydrocarbons in monitoring well 9 (filter 18.2-22.2 m bgl) are likely caused by the mechanical drilling operation.

It is concluded that significant (i.e. long distance) migration of pesticides via the groundwater appears unlikely, although it is difficult to support this conclusion given the limited number of monitoring wells containing groundwater (especially close to the landfill body).
The fact that the (semi-permanent) groundwater table is present at relatively great depth makes the ‘spreading by groundwater migration’ pathway very unlikely or at least insignificant. With few exceptions, all substances stored at the landfill are very poorly water soluble, and would need to travel through a thick clay layer (i.e. low permeability) before reaching the (semi-permanent) groundwater in the first place. Nevertheless the presence of a volume of contaminated water (held in the pores) directly down-gradient from the landfill (where the concrete drains discharge) is not unlikely.

5 Limited geophysical site assessment

This Chapter elaborates on the geo-physical characteristic of the landfill site, its surrounding and the catchment area of this landfill in three sections. The first section gives a description of the catchment area of the landfill. The second section elaborates on the soil permeability. The last section deals with the geo-stability of the landslide body with landfill.

5.1 Drainage system and catchment area

The catchment area of the landfill is formed by the valley enclosed by the surrounding ridges. The drainage pattern of the catchment area is (unstable) dendritc. Due to very active erosion process (see figure 5.1) such as landslides and gully erosion, natural drainage gullies are blocked and new gullies are formed. Erosion is initiated by cracks (swell and shrink cracks) and cavities in the (Montmorillonitic) clay surface after the dry summer.

Upstream just across the watershed is pool, earlier called Pond 1 (see figure 4.3). This pool has for a large part of the year standing water because a water main is forming a barrier to drain completely. If the water level in the pool is higher than the top of the water main (see figure 5.2), the water flows towards the culvert under the Geghadir - Jrashen grassland dirt road passing 300 - 400 meter upstream the landfill. This culvert is half blocked with sediments and prevents rapid drainage of the standing runoff water. The standing water in the Pond 1 and the standing water between the water main and the blocked culvert infiltrate in the soil and percolate lateral in the landslide body in the catchment area of the landfill site, contributing to the instability of this landslide body. Saturation of the landslide body, in addition to atmospheric precipitation, takes place.

The runoff in the catchment area is deviated to the concrete drains of the landfill site enclosing the landfill body. The runoff water from the Southern concrete drain ends in Pond 5 and the water in Pond 5 drains lateral in the landslide debris. The runoff water from the Northern concrete drain deviated to the gully draining the water to Pond 5. This runoff water also infiltrates and flows lateral in the in the top four meter of the landslide debris towards Pond 8/9.

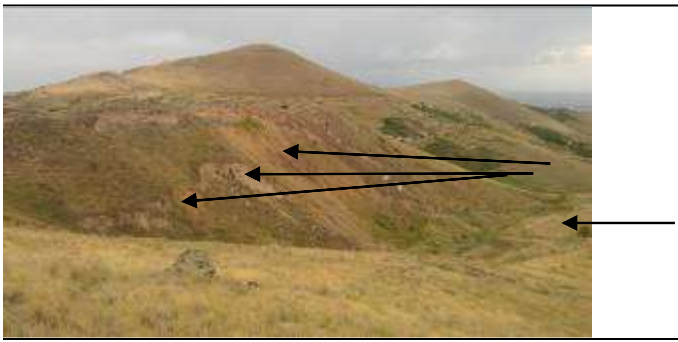

Figure 5.1 Active erosion of the landfill site valley

Figure 5.2 Left: The water main preventing the water to flow to the colvert Middle: The blocked culvert Right: Pond 1, the water main, the blocked culvert and the dirt road

5.2 Permeability and soil characteristics

The local geo-hydrology and soil characteristics on the site are determined by means of the following data:

- The nine borehole logs of the installed boreholes
- The 17 DPT-probings
- The four soil permeability tests
- The four soil samplings and grading curves

The Nubarashen landfill site is situated on the landslide debris of an active landslide. The debris comprise of silty, Montmorillonitic clays with volcanic toof stone stones, boulders and blocks at various depths. From DPT-probing it can be seen that the stiffness of the top layer and landfill body is soft to firm. Generally from 2 to 4 m bgl and deeper the soil stiffness becomes very stiff to hard.

Soil samples from the four boreholes where the permeability tests are carried out are analyzed for the grain size distribution. The results and the classification of the texture according to the USDA classification are presented in Appendix 8. The soil texture in the top soil (0.0 - 0.5 m bgl) varies from clay loam to loam, the soil texture of the deeper soil horizons vary from clay to sandy clay loam.

The four soil permeability tests were conducted to determine the hydraulic conductivity of the soil at various depths. The soil permeability test used was the inverse auger borehole method.
The principle of this test is to fill a well or borehole with an amount of water and measure the rate of fall of the water level in the well or bore hole. For the test, four wells were used to determine the hydraulic conductivity of the soil at the screened interval. The results of the tests are presented in table 5.1.
The values as presented in table 5.1 are quite high for the clay soils. This is especially true at well 3 where a hydraulic conductivity value is measured of 1.96 m/day which is far too high for a clay soil. Generally for soils consisting of clays and silt values for the primary permeability between 0.05 and 0.001 m/day are more common. The detected permeability values that are much higher are seen as the secondary permeability values.

Table 5.1 Results inversed auger hole tests

Well	Screened interval (m bgl)	Soil type at screened interval	Hydraulic conductivity (m/day)
1	4 - 5	Clay	0,15
2	3 - 4	Sand, stones and clay	8,55
3	3 - 4	Clay	1,96
7	4 - 5	Clay	0,14

This high hydraulic conductivity is explained by the cracks, cavities and/or other heterogeneities of the landslide debris in the soil have influenced the measurements. It can also be seen that the hydraulic conductivity at the sandy and stony parts at well 2 is much higher than the other measurements. If a horizontal layer of this sandy or stony layer and meso and macro pores are present over a larger area, a significant amount of lateral transport can take place in this layer of

landslide debris. This phenomenon is supporting the described lateral drainage of the runoff water from Pond 5 and the Northern concrete drain of the landfill.
Given the soil stiffness and the low permeability of the silty clays underlying the landfill body, it can be concluded that at around 2 tot 4 m bgl there will be a significant increase in resistance to vertical infiltration of water into the underlying soil. As a result of this a perched water table can be formed in the top layer of the valley and landfill body during wet seasons. This causes horizontal transport of water through the topsoil layer of the landfill site and can also cause overland flow during periods of heavy rainfall causing gully erosion when flowing through cracks and cavities. The formation of a perched water table in the top layer also influences the activity of the landslide. This is schematically represented in figure 5.3.

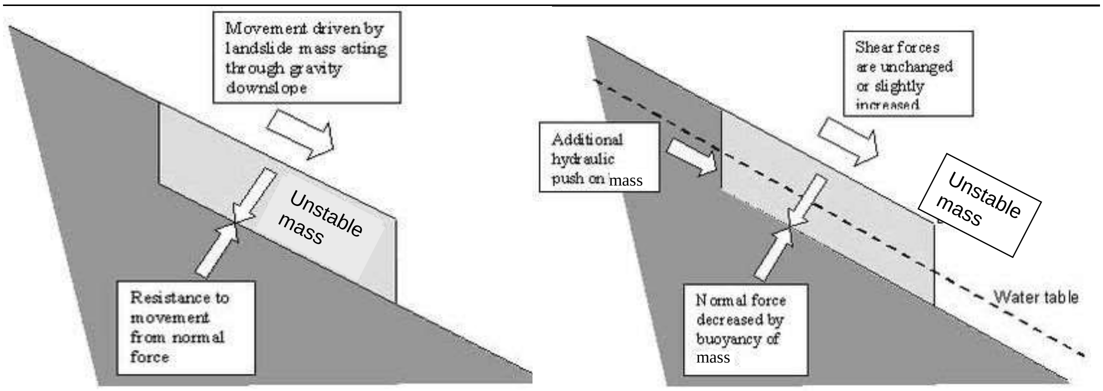

Figure 5.3 Diagram illustrating the resistance to, and causes of, movement in a slope system consisting of an unstable mass

5.3 Geo stability of the landslide

5.3.1 Introduction

Observations in the field and the site assessment results as described above indicate that the Nubarashen landfill is located at the top part of the active landslide body. The landfill site itself (fenced area) is relatively flat but is surrounded by steeper terrain. Especially upstream of the landfill site, the terrain is steep and shows signs of previous landslides in the form of terraces (see Figure 5.3). It is assumed that the driving force of the lateral mass movement in the flatter terrain is the slope instabilities upstream. The slope stabilities upstream appear to be activated by the inflow of water from the small (man-made) Pond 1 (see figures 4.3 and 5.1) at the top of the slope.
In order to confirm that the upstream mass movement is the mechanism behind the mass movement in the landfill site (as described in section 5.2), a numerical stability analysis is carried out. The stability analysis is performed based upon ‘Bishops’ method.

The leading failure plane is assumed to have a circular type of shape (see figure 5.3 red dashed lines). The trials that analyse the stability analysis are based on a grid of centre points of slip circles and a set of horizontal tangent lines of the corresponding slip circles. The centre of the leading slip circle is normally situated near the top of a slope at a fictive position in the air. Prior to the stability analysis an area wherein the centre of the leading slip circle is situated has to be defined. The input of the expected zoning is presented by all the black crosses in figure 5.4. However, the leading slip circle might very well be situated outside the prior defined zone.
In such case, it is possible to perform a stability analysis whereby the leading slip circle is calculated in an iterative way. The slip circle analysis automatically migrates towards the location where the safety factor is considered minimal. Therefore, the red crosses in figure 5.4 embody the final zones wherein the centre of the leading slip circle is calculated.
The lines characterize the zoning of the base of the slip circle. The base of the leading slip circle also needs to be estimated. In other words, the location of the deepest position of the leading slip circle needs to be defined prior to the stability analysis (green lines). In consequence the deepest position of the leading slip circle actual might be situated at a different position. The final zoning is defined by the red lines.

The importance of the water level is demonstrated by varying the pore water pressures in the stability analysis. The water pressure is simulated by the water level of the perched water table. The following scenarios are analyzed:
1. Perch water level at 1.33 meter blow surface level
2. Perch water level at 1.21 meter below surface level
3. Perch water level at 1.06 meter below surface level
4. Perch water level at 0.90 meter below surface level

5.3.2 Assumptions
In the overall stability analysis the following assumptions are made:
- The landfill body is slightly elevated
- The overall slope at the landfill site is considered low
- The landfill site is a relative flat part of the terrain
- On a local level the landfill body is considered stable
- The terrace levels above the landfill site are the result of mass movement
- These terraces are the result of earlier massive slope failure (figure 5.3)

Stability requires that the sum of the driving moments is equal to a certain resisting moment. The driving moment is usually defined as the sum of soil moment (unit weight), water moment (water levels), and loads moment (weight by building, truck, et cetera).

The resisting moment (M_r) is defined as the moment caused by the shear stresses along the circular arc around the centre of the slip circle. In practice the shear (τ) is dependent on effective cohesion (c') and internal friction angle (ϕ).
Unit weight and strength parameters are estimated based upon engineering judgement and soil description and are given in table 5.2.

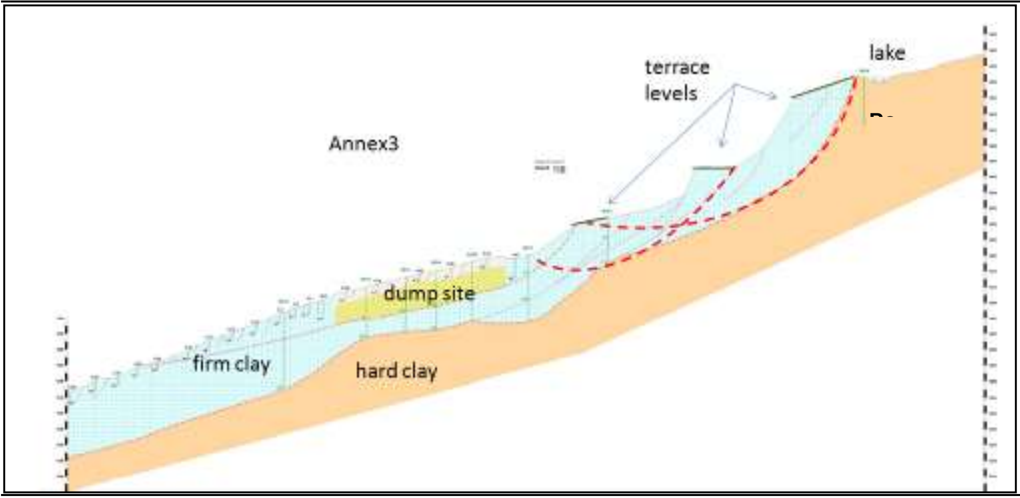

Figure 5.4 Geotechnical interpretation of section (ref. annex 3 by Dr. Yadoyan)

Table 5.2 Assumed geotechnical parameters

Soil name	Unit weight g/g_{sat} [kN/m^3]	Cohesion c'[kN/m^2]	Internal friction angle [°]
Waste dump	15/15	2.50	15.00
Firm clay	19/19	15.00	22.50
Hard clay	19/19	15.00	22.50

5.3.3 Stability analysis

An overall stability analysis is performed with the Bishop Slip Circle failure criterion (see Appendix 9 for the results). Three critical sections are analysed. The governing slip circle is determined. In practice, the leading safety factor of the soil body above the landfill site is determined. Fluctuation in dry/wet soil conditions alternated the stability factor as the vertical effective stress (σ'_v) is adjusted.

To gain insight in the stability factor two scenarios are analysed:

1. Saturated slope - Groundwater level 0.5 m below grade over the entire slope
2. Drained slope - Groundwater level 9.0 m below grade over the entire slope

In addition, a water level at the Pond 1 on top of the slope is maintained. The results of the overall stability analysis are presented in table 5.3.

Table 5.3 Overall stability waste dump area

Appendix	Stability Factor [-] Saturated conditions	Stability Factor [-] Dry conditions)
8-5	0.91	1.33
Chart 6	0.70	1.01
Chart 7	0.99	1.49

These stability results can be summarised as follows:

- If the slope is completely saturated the slope is not stable in any of the sections (Safety Factor average = 0.86). In this scenario deep seeded sliding plane would result in a slope failure above the landfill area. As a result the newly created surface above the landfill would decrease the stability of the landfill body
- If the slope is dry the overall stability is guaranteed in all three sections (Safety Factor average = 1.28). In all three sections the safety factor changes with fluctuating water levels. Clearly, the water level of the slope (more specific: the top slope area near the lake) has a major impact on the slope stability

5.4 Evaluation

The Nubarashen landslide is characterized by three slipping surfaces, three landslide head terrace-shaped formations, cracks on the lateral surface lengthwise and cracks of up to 1 m width transverse on the landslide body, as well by involvement of large-scale erosion phenomena. The length of the landslide is about 1,000 m and it is notable for elevated accumulations in the tongue part. Slope movement upstream of the landfill site is the mechanism behind the observed mass movement in the landfill site and its surrounding area. The stability of the upstream area of the landfill site is controlled by the perched ground water levels. By lowering the perched ground water table or reducing the influx of water into the slope, the stability of the landslide will improved and the risk for erosion such as mass movement will be reduced significantly. A simple measure is to drain Pond 1 by making a passage for the standing water under the water main and opening the blocked culvert under the road and repair possible leaks in the water main that runs along the between Pond 1 and the road. This and other recommendations will be taken into consideration in the design of the landfill rehabilitation in the next phase of the project, Phase 3.

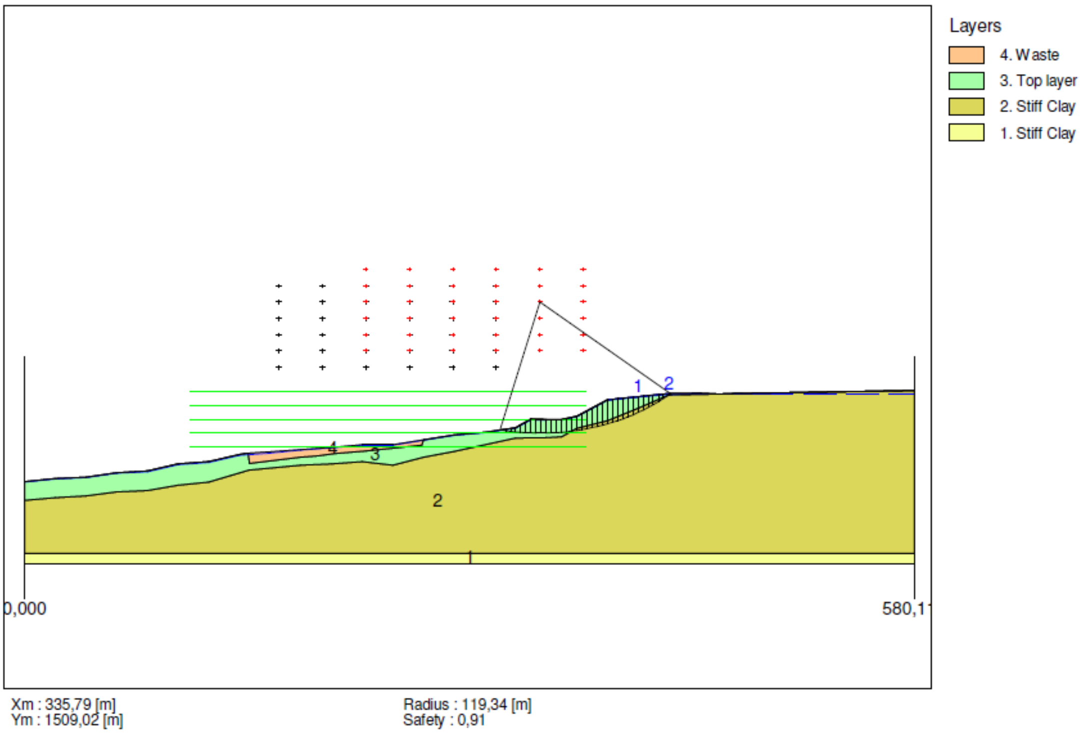

Figure 5.5 Critical Circle Bishop

6 Tier 2 risk assessment

This chapter gives in the first section the source of the contamination, the potential receptors pathways are discussed in the second section. The third section elaborates on the results of human health risk assessment. The conclusions of the Tier 2 risk assessment are presented in the last section of this Chapter.

6.1 Source of contamination

Based on the information presented in chapter 4 of this report, it can be concluded that the topsoil within the fence is contaminated with pesticides; the soil contamination seems to be very heterogeneous. There are areas with relatively uncontaminated topsoil and areas with very high levels and also small spots with pure product of pesticides present in the topsoil within the fence. So the main source of contamination is contaminated topsoil and the traces of pure product which are occasionally present in topsoil.

The other potential source of contamination is the dumped pesticides waste in the landfill body. Leaching of pesticides from the four excavated Cells and spilled pesticides between Cell 2 and 3 into ground- and surface water is not confirmed by the current data and therefore not taken into account in this human health risk assessment. It is also mentioned that the pesticides in the constructed Cell 1 are wet, which is an indication that the bottom and sites of Cell 1 are still watertight.

Elevated levels of pesticide are reported in the topsoil outside the fence in an earlier soil investigation (Dvorska at al. (2012)). Based on available data it cannot be excluded that locally in the area outside the fence strongly contaminated soil or pure pesticide is present (possibly historic origin from the time when landfill was filled or due to the illegal opening of the landfill body in 2010). Therefore it is suggested to set-up a buffer zone of around 100 m around the fenced area. It is suggested to restrict access to the buffer zone to avoid contact of residents/farmers and livestock to contamination spots. For the risk assessment the area within the buffer zone will be treated in the same way as the area within the fence.

The topsoil in the downstream ponds is not contaminated and therefore not seen as (secondary) source and therefore not taken into account in this human health risk assessment.

6.2 Relevant pathways and receptors

Table 6.1 gives an overview of the sources, pathways and receptors taken into account in the Tier 2 human health risk assessment. Potential receptors taken into account in this human health risk assessment are:

- Workers on-site (adults) with the following exposure pathways:

- Via direct contact to contaminated topsoil and spots of pure product
- Possible contact with airborne contaminated fine soil particles

- Farmers and residents (adults and children) with exposure pathways:
  - Mainly via direct contact to contaminated topsoil
  - Possible contact with airborne contaminated fine soil particles
  - Via animal products e.g. from cattle and/or poultry roaming freely over contaminated soil in the direct surroundings of the landfill site

Table 6.1 CSM for the human health risk assessment of the Nubarashen burial site

Contaminated source media	Exposure routes	Receptors	Explanation
Topsoil within fenced area and buffer zone	• Direct contact • Run off • Wind erosion • Leaching	• Workers	• Direct contact with contaminated topsoil • Airborne contaminated soil particles
Topsoil outside buffer zone	• Direct contact • Run off • Wind erosion • Leaching	• Residents • Farmers	• Direct contact with contaminated topsoil • Airborne contaminated soil particles • Animal products from animals that have contact with contaminated soil
Vegetation growing on topsoil outside buffer zone	• Direct contact • Ingestion	• Residents • Farmers	• Consumption of plant products grown on contaminated soil • Consumption of eggs, milk and cream
Groundwater	• Leaching • Groundwater transport	• Downstream users	• Water used as drinking water for animals and gardening • **Currently significant transport not confirmed by data presented here**
Surface water in ponds downstream	• Run off • Surface water transport	• Downstream users	• Water used as drinking water for animals and gardens • **Currently significant transport not confirmed by data presented here**

The chemicals of concern which are taken into account in the risk assessment are DDT, DDD and DDE as well as α-HCH and γ-HCH. The toxicity assessment of these chemicals of concern is given in Appendix 10.1. According to Dutch risk assessment guidelines for contaminated sites DDT, DDD and or DDE as well as α-HCH and γ-HCH are assessed based on threshold

effects (as non-carcinogens). In some countries (some) of these compounds are considered (probable human) carcinogens (e.g. US-EPA IRIS database).
In a study about POPs release to the environment Dvorska et al. (2012) calculated cumulative cancer risk probabilities for adults for the surroundings of the Nubarashen pesticide burial site based on concentrations of DDT and related compounds in two composite egg samples and one sample of cow's milk and cream, respectively. With the information supplied in the study (including the supplementary material) the calculations could not be reproduced. The information regarding POPs concentrations in animal products published in the study of Dvorska and co-authors is valuable, however the number of the samples is limited and the study does not give evidence for a causal relationship between the current condition of the landfill site and the concentrations of POPs in animal products in the surroundings of the landfill site. Further research is needed to find out whether to include or exclude cancer risks for residents in the risk assessment.

In this risk assessment, a quantitative Tier 2 risk assessment was performed for two scenarios: workers on site, exposed to pesticides mainly via topsoil with very high concentrations and residents in the surroundings exposed to pesticides mainly via topsoil and also via food (home grown vegetables). The human health risks were quantified using the CSOIL model (CSOIL2000, RIVM 2001). Calculations were performed evaluating DDT as threshold substance with a maximum permissible risk limit of 0.5 µg/kgd.

6.3 Results of human health risk assessment

For workers on the site (fenced area including buffer zone), CSOIL2000 calculates a human health risk limit of about 1,500 mg/kg for DDT. So the maximum pesticide concentrations reported here are in the order of magnitude of the human health risk limit. As the calculations were performed for the maximum soil concentrations and taking into account that the distribution of the soil contamination is heterogeneous it can be concluded that these pesticide concentrations do not result in exposure above acceptable levels for workers, as there are no workers on the contaminated spots on regular (day-by-day) basis. However the results also show that access to the site should be restricted to prevent the access of unauthorized persons on the contaminated area. Soil concentrations higher than 50 mg/kg might require further action based on the technical guidelines related to the Stockholm Convention.
As locally pesticides with a high acute toxicity might be present in the topsoil also in the form of pure pesticide, health risks related to acute toxicity cannot be excluded for the fenced area including the buffer zone. The site and the buffer zone should not be accessed without adequate protective equipment, farmers, residents and agricultural animals should not access the site including the buffer zone.

For the residential scenario including home-grown vegetable consumption, CSOIL2000 calculates human health risk limits between 1 mg/kg and about 10 mg/kg for DDT for lifelong exposure, depending on the type of pesticide and the type of food produced in gardens and the proportion of home produced food. Details of the calculations are given in Appendix 10.2.
For agricultural soils where animal products are produced, lower values of POPs are required, however the values are difficult to quantify. Canadian Soil Quality Criteria for Environment and Human Health state a soil concentration of 0.7 mg/kg for (total) DDT in agricultural soil and 0.01 mg/kg for Lindane in agricultural soil. Based on current Soil Quality Criteria for POPs pesticides in topsoil (mostly between 1-10 mg/kg or lower in case animal products need to be included) and the calculations made with CSOIL, it is suggested to further clarify details regarding the concentrations of pesticide in eggs and milk products in the surroundings of the site.

6.4 Evaluation risk assessment

A summary of the risk assessment for the Nubarashen burial site is given in the table 6.2 below. The risks on the site are mainly determined by:

- The stability of the landfill (risk of sliding and spreading of the pesticides)
- Further events of illegal access/waste mining
- Heterogeneous distribution pattern of contamination and potential presence of pure pesticide in top soil

As risks to human health cannot be excluded for residents/farmers on the fenced area and in the buffer zone surrounding of the fenced area, it is suggested to take measures to increase stability of the landfill and to raise awareness regarding the toxicity of POPs to help prevent further damage of the safeguarding structures and to prevent contact of residents/farmers and farm animals with strongly contaminated topsoil and pure pesticide on topsoil.

Table 6.2 Summary of the results of the risk assessment for the Nubarashen burial site

Contaminated source media	Exposure routes	Receptors	Unacceptable risks?
Topsoil within fence and buffer zone	• Direct contact • Run off • Wind erosion • Leaching	• Workers	• No if PPE is used • Possible • Possible • Not confirmed by current data

Contaminated source media	Exposure routes	Receptors	Unacceptable risks?
Topsoil outside buffer zone	• Direct contact • Run off • Wind erosion • Leaching	• Residents/farmers	• No • Possible • Possible • Not confirmed by current data
Vegetation growing on topsoil outside buffer zone	• Direct contact • Ingestion of animal product	• Residents • Farmers	• Possible • Clarification needed
Groundwater	• Groundwater transport • Run off • Surface water transport	• Downstream users	• Currently significant transport not confirmed
Surface water	• Leaching • Run off • Surface water transport	• Downstream users	• Currently significant transport not confirmed

7 Conclusions

- The fenced landfill site at Nubarashen:
  - Is 0.8 hectares large
  - Comprises of a landfill body (0.2 hectare) and surrounding land (0.6 hectare)
  - The landfill body is a hillock of 1.5 m high and is enclosed at three sides by concrete runoff drains
  - The clay cover (0.4 – 0.7 m) of the 0.2 hectare landfill body is slightly contaminated with pesticides
  - The estimated in/situ volume of the contaminated landfill cover is at around 890 m^3
  - The topsoil of the surrounding 0.6 hectare is heavily contaminated till of 0.5 m
  - The estimated in/situ volume of the fenced contaminated top soil is at around 3,000 m^3
- The landfill body itself contains/has:
  - A 2 mm ruberoid liner on a 5 cm thick sandy layer under the clay cover of 0.4 – 0.7 m
  - Five isolated cells with 506 m^3 of pure pesticides and contaminated clay (29 m^3) at the bottom of the cells
  - Contaminated clay layers (1,127 m^3) with traced of pure pesticides
- The groundwater and the surface water downstream the landfill site is not impacted
- Uphill from the landfill site:
  - Are a pond with standing run off water and a dirt road with a leaking water main
  - The run off water drainage is blocked by water main and a culvert filled with sediments
  - The standing water in the pond and the water from the leaking water main infiltrate in the soil and percolates laterally in the catchment area of the landfill
- The perched groundwater table upstream is influencing the stability of the landslide
- Slope movement upstream of the landfill site is the mechanism behind the observed mass movement at the landfill site
- Lowering the perched ground water table reduces the influx of water into the slope and will improve the stability of the landslide
- The Tier 2 risk assessment concluded that only the people entering/ working at the landfill site and in a buffer zone of 100 m around the landfill site have direct contact risk with the contaminated soil
- Direct contact can be avoided when proper personal protective equipment is used when entering the buffer zone and site and be restricting entrance of the landfill site and buffer zone

Appendix

1

Geophysical mapping of a landfill Armenia Report 2013P413R2

Appendix

2

Topographical map and Digital terrain Model

- **Topographical map**
- **Overview DTM**
- **View of the dump site based on the GPR Results**

Appendix

3

DCPT results

Appendix

4

Bore logs mapping landfill body

Appendix

5

Characterization dumped hazardous waste

Appendix 6

Stakeholders involvement

Appendix

7

Bore logs

Appendix

8

Tables with analytical results, analytical certificates and STI limit values

Table A8.1 Analytical results soil (mg/kg) topcover landfill body

Sample description	201		202		203		204	
Depth (m bgl)	**(0-0.5)**		**(0-0.4)**		**(0-0.4)**		**(0-0.4)**	
Clay size fraction (%)	**30**		**30**		**30**		**30**	
Organic matter (%)	**7**		**7**		**7**		**7**	
METALS								
Arsenic (As)	5.8	-	5.4	-	5.8	-	6.8	-
Cadmium (Cd)	< 0.1	-	0.1	-	< 0.1	-	0.12	-
Chromium (Cr) ###	21	-	25	-	25	-	20	-
Copp5er (Cu)	51	+	57	+	50	+	47	+
Mercury (Hg) ##	< 0.05	-	< 0.05	-	< 0.05	-	0.05	-
Lead (Pb)	18	-	20	-	19	-	17	-
Nickel (Ni)	24	-	29	-	27	-	24	-
Zinc (Zn)	66	-	74	-	70	-	61	-
CHLORINATED HYDROCARBONS								
Hexachlorobenzene (HCB)	< 0.05	-	< 0.1	-	< 0.05	-	< 0.05	-
PESTICIDES								
Sum of 2,4 and 4,4 DDD	< 0.05	-	< 0.1	-	< 0,05	-	0.25	+
Sum of 2,4 and 4,4 DDE	< 0.05	-	< 0.1	-	< 0.05	-	0.31	+
Sum of 2,4 and 4,4 DDT	0.74	++	1.6	+++	0.57	+	4.9	+++
Aldrin	< 0.05	-	< 0.1	-	< 0.05	-	< 0.05	-
Alpha-Endosulfan	< 0.05	-	< 0.1	-	< 0.05	-	< 0.05	-
Alpha-HCH	< 0.05	-	< 0.1	-	< 0.05	-	< 0.05	-
Beta-HCH	< 0.05	-	< 0.1	-	< 0.05	-	< 0.05	-
Gamma-HCH	< 0.05	-	< 0.1	-	< 0.05	-	< 0.05	-
Heptachlor	< 0.05	-	< 0.1	-	< 0.05	-	< 0.05	-
Not in STI-list of the SPA								
Dieldrin	< 0.05		< 0.1		< 0.05		< 0.05	
Endrin	< 0.05		< 0.1		< 0.05		< 0.05	
delta-HCH	< 0.05		< 0.1		< 0.05		< 0.05	
T-Chlordane	< 0.05		< 0.1		< 0.05		< 0.05	
Endosulfan Sulphate	< 0.05		< 0.1		< 0.05		< 0.05	
Cis-Heptachloroepoxide	< 0.05		< 0.1		< 0.05		< 0.05	
Isodrin	< 0.05		< 0.1		< 0.05		< 0.05	
Telodrin	< 0.05		< 0.1		< 0.05		< 0.05	
Dry matter (Dm) (%)	74.2		74.6		75		76.9	

##: compared to the I-value for an-organic Mercury

###: compared to the I-value for Chromium (III)

Table A8.2 Analytical results soil (mg/kg) direct surroundings landfill body, within fence boundary

Sample description	101		102		103		104		105	
Depth (m bgl)	(0-0.2)		(0-0.2)		(0-0.2)		(0-0.2)		(0-0.2)	
Clay size fraction (%)	30		30		30		30		30	
Organic matter (%)	7,3		7,3		7,3		7,3		7,3	
METALS										
Arsenic (As)	7.1	-	5.2	-	8	-	7.5	-	12	-
Cadmium (Cd)	0.11	-	0.12	-	0.42	-	0.13	-	0.23	-
Chromium (Cr) ###	27	-	29	-	28	-	27	-	27	-
Copper (Cu)	55	+	49	+	110	+	53	+	160	++
Mercury (Hg) ##	< 0.05	-	0.16	+	1.8	+	< 0.05	-	22	++
Lead (Pb)	20	-	16	-	20	-	20	-	19	-
Nickel (Ni)	27	-	29	-	28	-	31	-	28	-
Zinc (Zn)	84	-	64	-	410	+	69	-	310	+
CHLORINATED HYDROCARBONS										
Hexachlorobenzene (HCB)	< 0.05	-	< 0.05	-	< 5	-	< 0.05	-	7.1	+++
PESTICIDES										
Sum of 2,4 and 4,4 DDD	0.36	+	0.37	+	52	+++	0.09	-	73	+++
Sum of 2,4 and 4,4 DDE	2.44	+++	1.52	++	<5	-	0.29	+	18.3	+++
Sum of 2,4 and 4,4 DDT	5.8	+++	6.1	+++	910	+++	1.87	+++	1400	+++
Aldrin	< 0.05	-	< 0.05	-	< 5	-	< 0.05	-	< 5	-
Alpha-Endosulfan	< 0.05	-	< 0.05	-	< 5	-	< 0.05	-	< 5	-
Alpha-HCH	< 0.05	-	< 0.05	-	20	+++	< 0.05	-	29	+++
Beta-HCH	< 0.05	-	< 0.05	-	< 5	-	< 0.05	-	< 5	-
Gamma-HCH	< 0.05	-	< 0.05	-	< 5	-	< 0.05	-	10	+++
Heptachlor	< 0.05	-	< 0.05	-	< 5	-	< 0.05	-	< 5	-
Not in STI-list of the SPA										
Dieldrin	< 0.05		< 0.05		< 5		< 0.05		< 5	
Endrin	< 0.05		< 0.05		< 5		< 0.05		< 5	
Delta-HCH	< 0.05		< 0.05		< 5		< 0.05		< 5	
T-Chlordane	< 0.05		< 0.05		< 5		< 0.05		< 5	
Endosulfan Sulphate	< 0.05		< 0.05		< 5		< 0.05		< 5	
cis-Heptachloroepoxide	< 0.05		< 0.05		< 5		< 0.05		< 5	
Isodrin	< 0.05		< 0.05		< 5		< 0.05		< 5	
Telodrin	< 0.05		< 0.05		< 5		< 0.05		< 5	
Dry matter (Dm) (%)	76.1		78.3		74.8		75.6		75.7	

##: compared to the I-value for an-organic Mercury

###: compared to the I-value for Chromium (III)

Table A8.3 Analytical results soil (mg/kg) direct surroundings landfill body, within fence boundary

Sample description	**106**		**107**		**108**		**109**	
Depth (m bgl)	**(0-0.2)**		**(0-0.2)**		**(0-0.2)**		**(0-0.2)**	
Clay size fraction (%)	**30**		**30**		**30**		**30**	
Organic matter (%)	**7.3**		**7.3**		**7.3**		**7.3**	
METALS								
Arsenic (As)	6.6	-	11	-	7.3	-	6.6	-
Cadmium (Cd)	< 0.1	-	< 0.1	-	< 0.1	-	0.12	-
Chromium (Cr) ###	35	-	28	-	37	-	31	-
Copper (Cu)	50	+	120	++	62	+	56	+
Mercury (Hg) ##	0.08	-	3.5	+	0.31	+	0.15	-
Lead (Pb)	14	-	15	-	16	-	17	-
Nickel (Ni)	38	-	29	-	40	-	32	-
Zinc (Zn)	58	-	140	-	69	-	68	-
CHLORINATED HYDROCARBONS								
Hexachlorobenzene (HCB)	< 0.05	-	< 5	-	< 10	-	< 10	-
PESTICIDES								
Sum of 2,4 and 4,4 DDD	0.48	+	< 5	-	< 10	-	< 10	-
Sum of 2,4 and 4,4 DDE	0.71	+	< 5	-	< 10	-	< 10	-
Sum of 2,4 and 4,4 DDT	7.1	+++	115	+++	31	+++	30	+++
Aldrin	< 0.05	-	< 5	-	< 10	-	< 10	-
Alpha-Endosulfan	< 0.05	-	< 5	-	< 10	-	< 10	-
Alpha-HCH	< 0.05	-	210	+++	< 10	-	< 10	-
Beta-HCH	0.087	+	17	+++	< 10	-	< 10	-
Gamma-HCH	< 0.05	-	51	+++	< 10	-	< 10	-
Heptachlor	< 0.05	-	< 5	-	< 10	-	< 10	-
Not in STI-list of the SPA								
Dieldrin	< 0.05		< 5		< 10		< 10	
Endrin	< 0.05		< 5		< 10		< 10	
delta-HCH	< 0.05		23		< 10		< 10	
T-Chlordane	< 0.05		< 5		< 10		< 10	
Endosulfan Sulphate	< 0.05		< 5		< 10		< 10	
Cis-Heptachloroepoxide	< 0.05		< 5		< 10		< 10	
Isodrin	< 0.05		< 5		< 10		< 10	
Telodrin	< 0.05		< 5		< 10		< 10	
Dry matter (Dm) (%)	81.9		78		80.8		72.9	

##: Compared to the I-value for an-organic Mercury

###: Compared to the I-value for Chromium (III)

Table A8.4 Analytical results soil (mg/kg) reed ponds in site surroundings

Sample description	Pond 1		Pond 5		Pond 6		Pond 7		Pond 8/9	
Depth (m bgl)	**(0-0.2)**		**(0-0.2)**		**(0-0.5)**		**(0-0.2)**		**(0-0.2)**	
Clay size fraction (%)	**28**		**33**		**20**		**20**		**19**	
Organic matter (%)	**9,1**		**7,5**		**6**		**6**		**5,9**	
METALS										
Arsenic (As)	19	-	6,2	-	7,7	-	6,8	-	8,6	-
Cadmium (Cd)	0.13	-	0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Chromium (Cr) ###	79	+	43	-	31	-	51	+	37	-
Copper (Cu)	99	+	62	+	65	+	52	+	56	+
Mercury (Hg) ##	< 0.05	-	< 0.05	-	< 0.05	-	< 0.05	-	< 0.05	-
Lead (Pb)	34	-	17	-	21	-	18	-	18	-
Nickel (Ni)	93	++	47	+	42	+	48	+	45	+
Zinc (Zn)	110	-	65	-	75	-	62	-	63	-
CHLORINATED HYDROCARBONS										
Hexachlorobenzene (HCB)	< 0.001	-	< 0.001	-	< 0.05	-	< 0.001	-	< 0.05	-
PESTICIDES										
Sum of 2,4 and 4,4 DDD	0.011	-	0.031	+	< 0.05	-	0.0016	-	< 0.05	-
Sum of 2,4 and 4,4 DDE	0.005	-	0,056	-	< 0.05	-	0,0019	-	< 0.05	-
Sum of 2,4 and 4,4 DDT	< 0.001	-	0.33	+	0.48	+	0.0082	-	1.44	+++
Aldrin	< 0.001	-	< 0.001	-	< 0.05	-	< 0.001	-	< 0.05	-
Alpha-Endosulfan	< 0.001	-	0.0023	+	< 0.05	-	< 0.001	-	< 0.05	-
Alpha-HCH	< 0.001	-	< 0.001	-	< 0.05	-	< 0.001	-	< 0.05	-
Beta-HCH	< 0.001	-	0.0015	+	< 0.05	-	< 0.001	-	< 0.05	-
Gamma-HCH	< 0.001	-	< 0.001	-	< 0.05	-	< 0.001	-	< 0.05	-
Heptachlor	< 0.001	-	< 0.001	-	< 0.05	-	< 0.001	-	< 0.05	-
Not in STI-list of the SPA										
Dieldrin	< 0.001		< 0.001		< 0.05		< 0.001		< 0.05	
Endrin	< 0.001		< 0.001		< 0.05		< 0.001		< 0.05	
Delta-HCH	< 0.001		< 0.001		< 0.05		< 0.001		< 0.05	
T-Chlordane	< 0.001		< 0.001		< 0.05		< 0.001		< 0.05	

Endosulfan Sulphate	< 0.001	< 0.001	< 0.05	< 0.001	< 0.05
Cis-Heptachloroepoxide	< 0.001	< 0.001	< 0.05	< 0.001	< 0.05
Isodrin	< 0.001	< 0.001	< 0.05	< 0.001	< 0.05
Telodrin	< 0.001	0.004	< 0.05	< 0.001	< 0.05
Dry matter (Dm) (%)	55.2	74.2	68.5	68.8	74.6

##: compared to the I-value for an-organic Mercury

###: compared to the I-value for Chromium (III)

Table A8.5 Analytical results soil (mg/kg) site surroundings

Sample description	2		3		4		5		5	
Depth (m bgl)	(0-0.5)		(0-0.5)		(4-5)		(1-1.5)		(4-4.5)	
Clay size fraction (%)	37		25		42		25		30	
Organic matter (%)	6,7		5,9		5,2		6,3		7	
METALS										
Arsenic (As)	6.7	-	7.6	-	4.5	-	7.3	-	7.6	-
Cadmium (Cd)	0.12	-	0.14	-	0.2	-	< 0.1	-	< 0.1	-
Chromium (Cr) ###	20	-	37	-	21	-	39	-	45	-
Copper (Cu)	55	+	54	+	51	+	56	+	61	+
Mercury (Hg) ##	0.09	-	< 0.05	-	< 0.05	-	< 0.05	-	< 0.05	-
Lead (Pb)	18	-	16	-	18	-	15	-	18	-
Nickel (Ni)	24	-	42	+	27	-	43	+	46	+
Zinc (Zn)	67	-	60	-	64	-	59	-	67	-
CHLORINATED HYDROCARBONS										
Hexachlorobenzene (HCB)	< 0.05	+	< 0.05	-	< 0.001	-	< 0.05	-	< 0.001	-
PESTICIDES										
Sum of 2,4 and 4,4 DDD	0.366	+	0.34	+	0.0047	-	< 0.05	-	0.0113	-
Sum of 2,4 and 4,4 DDE	1.32	++	2.95	+++	0.064	-	< 0.05	-	0.0053	-
Sum of 2,4 and 4,4 DDT	6.8	+++	8.6	+++	0.0739	-	0.49	+	0.187	+
Aldrin	< 0.05	-	< 0.05	-	< 0.001	-	< 0.05	-	< 0.001	-
Alpha-Endosulfan	< 0.05	-	< 0.05	-	< 0.001	-	< 0.05	-	0.0071	+
Alpha-HCH	< 0.05	-	< 0.05	-	< 0.001	-	< 0.05	-	0.0031	+
Beta-HCH	< 0.05	-	< 0.05	-	< 0.001	-	< 0.05	-	< 0.001	-
Gamma-HCH	< 0.05	-	< 0.05	-	< 0.001	-	< 0.05	-	< 0.001	-
Heptachlor	< 0.05	-	< 0.05	-	< 0.001	-	< 0.05	-	< 0.001	-
Not in STI-list of the SPA										
Dieldrin	< 0.05		< 0.05		< 0.001		< 0.05		< 0.001	
Endrin	< 0.05		< 0.05		< 0.001		< 0.05		< 0.001	
Delta-HCH	< 0.05		< 0.05		< 0.001		< 0.05		< 0.001	
T-Chlordane	< 0.05		< 0.05		< 0.001		< 0.05		< 0.001	
Endosulfan Sulphate	< 0.05		< 0.05		< 0.001		< 0.05		< 0.001	

Cis-Heptachloroepoxide	< 0.05	< 0.05	< 0.001	< 0.05	< 0.001
Isodrin	< 0.05	< 0.05	< 0.001	< 0.05	< 0.001
Telodrin	< 0.05	< 0.05	< 0.001	< 0.05	< 0.001

##: compared to the I-value for an-organic Mercury

###: compared to the I-value for Chromium (III)

Table A8.6 Analytical results soil (mg/kg) site surroundings

Sample description	**9**	
Depth (m bgl)	**(4-5)**	
Clay size fraction (%)	**37**	
Organic matter (%)	**6**	
METALS		
Arsenic (As)	3.9	-
Cadmium (Cd)	< 0.1	-
Chromium (Cr) ###	35	-
Copper (Cu)	50	+
Mercury (Hg) ##	< 0.05	-
Lead (Pb)	15	-
Nickel (Ni)	27	-
Zinc (Zn)	60	-
CHLORINATED HYDROCARBONS		
Hexachlorobenzene (HCB)	< 0.05	-
PESTICIDES		
Sum of 2,4 and 4,4 DDD	< 0.05	-
Sum of 2,4 and 4,4 DDE	< 0.05	-
Sum of 2,4 and 4,4 DDT	0,47	+
Aldrin	< 0.05	-
Alpha-Endosulfan	< 0.05	-
Alpha-HCH	< 0.05	-
Beta-HCH	< 0.05	-
Gamma-HCH	< 0.05	-
Heptachlor	< 0.05	-
Not in STI-list of the SPA		
Dieldrin	< 0.05	
Endrin	< 0.05	
Delta-HCH	< 0.05	
T-Chlordane	< 0.05	
Endosulfan Sulphate	< 0.05	
Cis-Heptachloroepoxide	< 0.05	
Isodrin	< 0.05	
Telodrin	< 0.05	

##: compared to the I-value for an-organic Mercury

###: compared to the I-value for Chromium (III)

Table A8.7 Analytical results groundwater and standing water in the reed ponds (µg/L)

Location	M.Well 1		Pond 1		M.Well 7		Pond 7		M. Well 9	
Filter depth (m bgl)	(4-5)				(3-4)				(18.3-22.3)	
METALS										
Arsenic (As)	20.8	+	< 5	-	< 5	-	< 5	-	< 5	-
Barium (Ba)	160	+	97	+	11	-	110	+	41	-
Cadmium (Cd)	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Cobalt (Co)	< 2	-	< 2	-	7,1	-	2.5	-	< 2	-
Copper (Cu)	9.2	-	3.9	-	3	-	4.3	-	< 2	-
Mercury (Hg) ##	0.12	+	0.04	-	< 0.03	-	< 0.03	-	0.1	+
Lead (Pb)	7.8	-	< 5	-	< 5	-	< 5	-	50	++
Molybdenum (Mo)	24	+	23	+	5.3	+	20	+	7.8	+
Nickel (Ni)	9.8	-	< 5	-	19	+	5.4	-	< 5	-
Zinc (Zn)	9.1	-	< 2	-	< 2	-	< 2	-	2.1	-
AROMATIC COMPOUNDS										
Benzene	< 0.2	-	< 0.2	-	< 0.2	-	< 0.2	-	0.5	+
Ethyl benzene	< 0.5	-	< 0.5	-	< 0.5	-	< 0.5	-	5.2	+
Toluene	< 0.5	-	< 0.5	-	< 0.5	-	< 0.5	-	6.1	-
Sum of Xylenes									25	+
Naphthalene	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	2.6	+
CHLORINATED HYDROCARBONS										
Hexachlorobenzene (HCB)	< 0.1	+	< 0.1	+	< 0.1	+	< 0.1	+	< 0.1	+
PESTICIDES										
Sum of 2,4 and 4,4 DDD	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Sum of 2,4 and 4,4 DDE	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Sum of 2,4 and 4,4 DDT	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Aldrin	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Dieldrin	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Endrin	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Alpha-Endosulfan	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Alpha-HCH	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Beta-HCH	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Gamma-HCH	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
Heptachlor	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-	< 0.1	-
OTHER COMPOUNDS										
TPH C10-C40	< 50	-	< 50	-	< 50	-	< 50	-	53	+
Not in STI-list of the SPA										
Delta-HCH	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	
T-Chlordane	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	
Endosulfan Sulphate	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	
Cis-Heptachloroepoxide	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	
Isodrin	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	
Telodrin	< 0.1		< 0.1		< 0.1		< 0.1		< 0.1	

##: compared to the I-value for an-organic Mercury

Appendix

9

Geophysical data

Appendix

10

Tier 2 Risk Assessment

A10.1 Introduction

The parameters used to calculate the risk limit values for soil (calculated with CSOIL2000, RIVM 2001) for workers on the site and for residents in the surroundings of the site are listed in this appendix. The tables A9.1 to A9.4 are used to present these data in a structured manner. This appendix also comprises additional calculations to estimate the contribution of the consumption of animal products like eggs and cream to the tolerable intake and additional information regarding soil quality criteria for agricultural use. At the end of this appendix a list of literature used is given.

A10.2 Information given in tables A9.1 to A9.4

- Table A9.1 represents the toxicity assessment and gives the toxicological limit values for long term exposure for humans for DDT, DDD, DDE as well as α-HCH and γ-HCH based on a report published by the Dutch Institute Public Health and Environment (Baars et al. (2001))
- Table A9.2 gives the calculated risk limit values for DDT, DDD, DDE as well as α-HCH and γ-HCH for workers on-site. The most important exposure routes taken into account are direct contact (ingestion of soil & dermal contact) and inhalation of soil particles. The table gives the calculated value for each individual pesticide compound. Furthermore for DDT (the pesticide determining the human health risks on the site due to the high concentrations) the table gives an overview of the contribution [%] of the individual exposure routes considered to the sum of the total calculated exposure corresponding to a soil content equal to the remediation target value
- Table A9.3a and b gives the calculated risk limit values for DDT, DDD, DDE as well as α-HCH and γ-HCH for residents/farmers in the surroundings of the site. The most important exposure routes taken into account are direct contact (ingestion of soil & dermal contact), the consumption of some plant crops grown on contaminated soil and inhalation of soil particles. The table gives the calculated value for each individual pesticide compound. Furthermore for DDT (the pesticide determining the human health risks on the site due to the high concentrations) the table gives an overview of the contribution [%] of the individual exposure routes considered to the sum of the total calculated exposure corresponding to a soil content equal to the remediation target value
- Indicative calculations are performed for the calculated contribution [%] of eggs to an intake of DDT equal to the value of the maximum permissible risk limit derived by the Dutch RIVM (see toxicity assessment)
- Table A9.4 gives Canadian Soil Quality Criteria for (total) DDT and Lindane for agricultural use
- At the end of the appendix an overview of the literature used is given

A10.3 Information regarding parameters used for calculations

Table A10.1 Toxicity assessment / Toxicological limit values long term exposure for human for different organochlorine pesticides long term toxicological limit values used in the risk assessment (MPR: maximum permissible risk limit, Baars et al. (2001), and criteria for drinking water use, WHO guideline values, GLV, WHO 2011)

Compound	Toxicological limit values for long term exposure in mg/kgd	Criteria for drinking water use µg/L
DDT, DDD and DDE	MPR (RIVM): 5*10-4	GLV (WHO): 1 (Sum total DDT)
Alpha HCH	MPR (RIVM): 1*10-3	
Gamma HCH	MPR (RIVM): 4*10-5	GLV (WHO): 2

Human exposure factors

The following basic assumptions for are used for human exposure factors in the calculation of the human health risk limit values:

- Body weight: 70 kg body weight (adult, worker and residential) and 15 kg body weight (child)
- Workers: exposed as adult
- Lifelong exposure residents: 6 years exposure as a child plus 64 years exposure as an adult
- Soil ingestion rate 20 mg/d (adult, worker; corresponding to twice the CSOIL default value); 50 mg/d (adult, residential, CSOIL default); 100 mg/d (child, residential, CSOIL default)
- Exposure time 2 h outside every day (worker), for residential exposure default values of CSOIL were used
- Residential, crop consumption: belowground crops: e.g. roots, tubers, potatoes 134 g/ adult person day
- Residential, crop consumption: aboveground vegetables: 250 g/adult person day

Table A10.2 Calculated risk limit values for DDT, DDD, DDE as well as α-HCH and γ-HCH for workers working on contaminated soil regularly 2 h per day. Contribution of exposure routes considered to total calculated exposure [% of total calculated exposure at a soil content corresponding to the risk limit value]; values for individual organochlorine pesticides are given in this table. * permeation of water pipes is not included as there are no shower facilities on site

Scenario	Exposure of workers, regularly working on contaminated soil 2 h/day outdoors											
Contaminant	Risk limit value mg/kg d.m.	Soil ingestion	Derm uptake ind	Derm uptake outd	Inhal soil	Inhal ind	Inhal outd	Plant ingestion	Perm* drinkw	Vapors shower*	Derm uptake shower*	Exposure air*
DDT	1,368	78%	0.7%	18.7%	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%
DDE	1,368	78%	0.7%	18.7%	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%
DDD	1,368	78%	0.7%	18.7%	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.4%
a-HCH	2,073	78%	0.7%	18.7%	2.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%
g-HCH	109	78%	0.7%	18.7%	2.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	2.5%

Table A10.3a Calculated risk limit values for DDT, DDD, DDE as well as α-HCH and γ-HCH for residents living on contaminated soil consuming vegetables and tubers grown on contaminated soil (fraction of home produced crops 10 %, fraction of market crops 90 %). Contribution of exposure routes considered to total calculated exposure [% of total calculated exposure at a soil content corresponding to the risk limit value]; values for individual organochlorine pesticides are given in this table. * inhalation indoors and exposure during showering is not included assuming the soil contamination is not present underneath the building

Scenario	Exposure of residents, living on contaminated soil, 10 % of vegetables produced on contaminated soil											
Contaminant	Risk limit value mg/kg d.m.	Soil ingestion	Derm uptake ind	Derm uptake outd	Inhal soil	Inhal ind*	Inhal outd	Plant ingestion	Perm* drinkw	Vapors shower*	Derm uptake shower*	Exposure air*
DDT	20.7	5.1%	0.0%	0.4%	0.0%	0.0%	0.0%	94.4%	0.0%	0.0%	0.0%	0.0%
DDE	11.50	2.8%	0.0%	0.2%	0.0%	0.0%	0.0%	96.9%	0.0%	0.0%	0.0%	0.0%
DDD	28.5	7.0%	0.0%	0.6%	0.1%	0.0%	0.0%	92.3%	0.0%	0.0%	0.0%	0.1%
a-HCH	66.5	8.2%	0.1%	0.7%	0.1%	0.0%	0.0%	91.0%	0.0%	0.0%	0.0%	0.1%
g-HCH	0.83	2.5%	0.0%	0.2%	0.0%	0.0%	0.0%	97.2%	0.0%	0.0%	0.0%	0.0%

Table A10.3b Calculated risk limit values for DDT, DDD, DDE as well as α-HCH and γ-HCH for residents living on contaminated soil consuming vegetables and tubers grown on contaminated soil (fraction of home produced crops 30 % for tubers/roots and 50 % for aboveground vegetables, fraction of market crops 70% and 50 %, respectively). Contribution of exposure routes considered to total calculated exposure [% of total calculated exposure at a soil content corresponding to the risk limit value]; values for individual organochlorine pesticides is given in this table.
*** inhalation indoors and exposure during showering is not included assuming the soil contamination is not present underneath the building**

Scenario	**Exposure of residents, living on contaminated soil, 30 % (roots) and 50 % (aboveground vegetables) of vegetables produced on contaminated soil**											
Contaminant	Risk limit value mg/kg d.m.	Soil ingestion	Derm uptake ind	Derm uptake outd	Inhal soil	Inhal ind*	Inhal outd	Plant ingestion	Perm* drinkw	Vapors shower*	Derm uptake shower*	Exposure air*
DDT	7.09	1.7%	0.0%	0.2%	0.0%	0.0%	0.0%	98.1%	0.0%	0.0%	0.0%	0.0%
DDE	3.89	1.0%	0.0%	0.1%	0.0%	0.0%	0.0%	99.0%	0.0%	0.0%	0.0%	0.0%
DDD	9.84	2.4%	0.0%	0.2%	0.0%	0.0%	0.0%	97.3%	0.0%	0.0%	0.0%	0.0%
a-HCH	23.20	2.8%	0.0%	0.2%	0.0%	0.0%	0.0%	96.9%	0.0%	0.0%	0.0%	0.0%
g-HCH	0.22	0.7%	0.0%	0.1%	0.0%	0.0%	0.0%	99.2%	0.0%	0.0%	0.0%	0.0%

Indicative estimation of the contribution (%) of consumption of eggs with a DDT concentration as reported in the supplementary material to the study by Dvorska and co-authors (2012).

In the study egg samples composed of 5 eggs from a village at 1.5 km and 2 km from the site were found to contain 16.7 µg/kg and 17.1 µg/kg DDT (o,p plus p,p isomers). For a child consuming 3 such eggs per week (corresponding to about 21 g per day) and assuming a body weight of a child of 15 kg, a daily intake of
(0.017 mg/kg*0.021 kg/d) / 15 kg = 0.00002 mg/kg can be calculated. Based on a MPR of 0.0005 mg/kgd, this daily intake of DDT corresponds to about 5 % of the MPR of DDT (using the MPR value from Baars et al (2001)).

It is noted that the number of egg samples is very low, so the concentrations measured might not be representative. Also, based on the current data given in this report and data from the study by Dvorska and co-authors there is no conclusive evidence for a causal relationship between the DDT in the egg samples and milk and cream samples taken at 1.5 km and at 2 km from the landfill site. Possible other sources (besides the landfill) of POP in the food items are household waste burning (as mentioned in the study), however it is also unclear whether DDT has been used on the sampling locations in the past or whether there is an elevated background concentration of POP pesticides in the area related to past use.

General remarks

It is difficult to estimate the contribution of food to the exposure of residents living at contaminated sites. Models often only calculate for a part of the food items (e.g. only vegetable and tuber crops as in CSOIL, see tables A9.3a and A9.3b) and often model calculations of food concentrations might be conservative resulting in an overestimation of the risks. Generally it is assumed that food, and especially animal products high in fat, are an important source of intake of POP pesticides. On contaminated sites, intake via food can be far more important than intake via direct contact to contaminated soil, especially if exposure occurs via different food items such as eggs and milk. Further data are needed for a better assessment of the importance of the contribution of different food items to total exposure. Also, the current data are not sufficient to establish a link between the landfill site in the current situation and the POP concentration reported for eggs, milk and cream.

The main focus of this risk assessment is to provide decision support for the definition of further steps to set up a site rehabilitation plan mitigating the environmental site risks posed by the Nubarashen Landfill site in the current situation. In this respect the focus of the risk assessment differs from studies such as the study by Dvorska and co-authors, as the risk assessments aims at supporting the determination of measures to be taken to improve the safety on the short term until further definition of outline and time planning of the rehabilitation plan for the site.

Soil Quality Criteria for Agricultural Use

Table A10.4 Canadian Soil Quality Guideline Values (GLV) for the Protection of Human Health and the Environment, Guideline Values for Agricultural Use

Compound	Soil Quality GLV Agricultural Use mg/kg
(Total) DDT	0.7
Lindane	0.01

Literature used

- Advice of EU Scientific Committee regarding the evaluation of DDT (retrieved on 17 June 2013) http://www.favv.be/wetenschappelijkcomite/adviezen/_documents/ADVIES_AVIS01-2013_DossierSciCom2011-04_Anenx1_Fiche1.11_DDT_000.pdf
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- Dvorska et al. (2012) Obsolete pesticide storage sites and their POP release into the environment-an Armenian case study. Environ Sci Pollut Res 19: 1944-1952 plus supplementary material
- Ritsema et al. (2006) Obsolete Pesticides in Armenia (Inception visit to Armenia) Milieukontakt International, Amsterdam / Tauw, Deventer, NL