Technical Scoping Mission
Kalush Area, Ukraine
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A Joint United Nations – European Commission Environmental Emergency Response Mission

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Foreword

Environmental emergencies can be broadly defined as sudden-onset disasters or accidents resulting from natural, technological or human-induced factors, or a combination of these that cause, or threaten to cause, severe environmental damage and harm to human health and/or livelihoods. Regrettably, Ukraine is all too familiar with disasters. The country's most notorious disaster is the Chernobyl nuclear reactor disaster of April 1986. It had global consequences and its effects are still severe locally. The current case of Kalush does not pose the global threat of Chernobyl, but it is a major concern for local populations and symptomatic of a larger trend of past negligence of environmental considerations in Ukraine's industrialized past, having dire consequences for its population today.

This report from the joint United Nations/European Commission Technical Scoping Mission to the Kalush area highlights one such case, where a combination of threats – ongoing land subsidence and related sinkholes, salinization of ground and surface water, hazardous waste dumping and the possible collapse of several mine tailings dams – will most likely necessitate the relocation of most, if not all, local populations to safer ground.

This visit to Kalush was not the typical response mission that the UN and EC are most familiar with. However, it demonstrated the practicality of making best use of existing response mechanisms as a means of improving preparedness and identifying ways of preventing a situation from worsening. It is therefore hoped that the findings and recommendations from this joint mission will better inform relevant Ukrainian authorities and interested international partners on measures to be taken in the short, medium and long term to avoid, or at least alleviate, threats to the welfare of concerned populations.

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In 2004, the European Commission (DG-Environment and DG-ECHO) and the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) engaged in an Exchange of Letters and Standing Operating Procedures, with the aim of maximizing the use of available resources, avoiding duplication, and better supporting local governments and affected communities. The EC and OCHA both agreed to maintain dialogue at policy and operational levels, to ensure complementarity in the planning and delivery of relief assistance and to cooperate in preparedness and response, taking into account internationally agreed standards and principles. Cooperation specifically between the EC's Monitoring and Information Centre (MIC) and the Joint UNEP/OCHA Environment Unit (JEU) began in 2005 on an ad hoc basis and has since grown into a close and regular collaboration. JEU regularly shares requests for assistance with MIC. Several important joint missions have taken place in recent years, followed by joint reporting and lessons learned exercises. Such partnerships and synergy help make international response faster and more effective, with the ultimate objective of supporting the populations in need of our help.

For their contributions in making this technical scoping mission a success, we would like to extend our thanks to colleagues at the United Nations Economic Commission for Europe, the United Nations Environment Programme and the United Nations Development Programme. For providing expert staff to the mission, we are grateful to the Republic of Ireland, the Kingdom of Norway and the Norwegian Geotechnical Institute. A special thanks is owed for key technical support provided through the International Humanitarian Partnership, including an important contribution of sampling and analysis equipment from the Dutch Environmental Assessment Module. This enabled a wide variety of soil samples to be taken at affected areas and transported to the Netherlands for testing. Finally, we wish to thank the Government of Ukraine, authorities of the city of Kalush and national research institutes who did so much to facilitate this mission and provide it with a wealth of essential information.

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List of Acronyms

CTC	Carbon tetrachloride
EAM	Environmental Assessment Module
EC	European Commission
EC-MIC	Monitoring and Information Centre of the European Commission
ECHO	Humanitarian Aid Department of the European Commission
ENVSEC	Environment and Security Initiative
HCB	Hexachlorobenzene
JEU	Joint UNEP/OCHA Environment Unit
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PCE	Perchloroethene
UAH	Ukrainian Hryvnia
UN	United Nations
UNDAC	United Nations Disaster Assessment and Coordination
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNECE	United Nations Economic Commission for Europe

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Executive summary

When the mining area of Kalush, Ukraine, was declared an "emergency ecological situation zone", an official request for international assistance was received by the United Nations Environment Programme (UNEP) and the United Nations Economic Commission for Europe (UNECE). In response, a joint United Nations/European Commission team, with key support from the Environment Assessment Module (EAM) from the Netherlands, undertook a technical scoping mission from 1 to 9 March 2010. In addition to undertake a technical scoping of the risks posed by the mining facilities, the possible spread of hazardous waste, in particular Hexachlorobenzene (HCB), was investigated. The mission was conducted jointly through the United Nations Disaster Assessment and Coordination (UNDAC) system and the European Commission's Monitoring and Information Centre (EC-MIC).

The mission's specific objectives were to undertake a rapid assessment of the stability and integrity of the tailings dams, with a particular focus on the expected snowmelt and possible flooding in the spring, as well as risks stemming from subsidence. The mission also focused on scientific sampling in the vicinity of the tailings dam and hazardous waste site to screen for any immediate and/or potential threats to communities and the environment; and assisting the emergency management organizations in identifying appropriate preparedness and risk reduction measures to minimize impacts to the population. Upon completion of the mission, draft mission findings were presented to government authorities and international partners in Ukraine. This report contains the mission's final conclusions and recommendations, including the sampling and analysis undertaken by the EAM.

Despite the complexity and interdependency of the various issues that make it difficult to make any qualitative statement on the situation, the UN/EC Technical Scoping Mission considers the overall situation in the Kalush area as serious, and at certain points, critical.

However, a window of opportunity exists currently to prevent the existing situation from deteriorating into a disaster of serious to catastrophic dimensions. This window of opportunity should not be lost.

The mission further considers it unlikely that spring flooding will cause a major threat to the current situation. However, the mission notes with concern that consecutive weather events may worsen the situation rapidly.

The UN/EC Technical Scoping Mission considers the following issues of a critical nature, requiring urgent attention by the Ukrainian authorities:

- The salinization of ground and surface water, and the threat this poses to the drinking-water supply.
- The design safety levels in the tailings dams should be respected as they form the single-most important risk reduction measure.
- A breakthrough of the Dombrovski Open-Cast Mine into the Sivka River is considered to be a very likely event, with serious consequences if no corrective/preventive measures are taken.
- The spreading of HCB from the HCB storage site into the Sagopiv stream and further downstream

Independent and scientific sampling has shown the spreading of HCB into the environment at the HCB storage site. The concentrations in water at the storage facility are a factor 100 (and in some places far more than that) higher than the Ukraine standard. HCB is extremely toxic for water environments and is a persistent organic pollutant. The long-term risks of spreading are therefore high.

The UN/EC Technical Scoping Mission considers the possible dumping of HCB at dumpsite No. 1 and/or No. 4 as likely. There are indications of spreading of HCB from these sites in the vicinity of communal gardens where people cultivate vegetables for consumption.

The UN/EC Technical Scoping Mission made several technical recommendations to assist the Ukrainian authorities in abating the current situation in the Kalush area. These recommendations are at the end of this report.

The **Joint UNEP/OCHA Environment Unit,** integrated into the Emergency Services Branch of the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), is the United Nations mechanism to mobilize and coordinate the international response to environmental emergencies. It is a joint initiative with UNEP.

The **Monitoring and Information Centre** of the European Commission facilitates the mobilization and coordination of EU civil protection assistance in response to major disasters. It is the operational centre of the Community Civil Protection Mechanism, through which resources from EU Member States may be mobilized to provide immediate assistance in responding to major emergencies. It is situated in the Humanitarian Aid Department (DG ECHO) of the European Commission.

1. Introduction

This section provides the mission's context, including a brief introduction to Ukraine, the associated problems in the Kalush region as known at the start of the mission and the scope of the mission itself.

1.1 Ukraine

Ukraine is 603,700 km^2, with a population of 46.6 million inhabitants. It is situated on the Black Sea, bordered by Belarus to the north; Poland, Slovakia and Hungary to the west; Romania and Moldova to the south-west; and Russia to the east. The highest elevations are in the Carpathian Mountains in the west, and the Crimean Mountains at the southern end of the Crimean Peninsula.

Ukraine became independent after the dissolution of the Soviet Union in 1991. This began a period of transition to a market economy, which was marked by several consecutive years of recession. The mining industry is still an important sector of the Ukrainian economy, including the production of iron ore, manganese, coal, titanium, graphite and kaolin[1].

Ukraine has a mostly temperate continental climate, although a more Mediterranean climate is found on the southern Crimean coast. The average annual precipitation is 500mm, although there are considerable regional variations. The precipitation is highest in the Carpathian Mountains and lowest on the Black Sea coast. In general, the rainfall tends to be heaviest in the summer months throughout the country.

1.2 Kalush city and district

Kalush city and district are located in the north-western part of the Ivano-Frankivsk Oblast (region) in western Ukraine, at the foot of the Carpathian Mountains. The Kalush district occupies an area of 64.7000 hectares, while Kalush City comprises 6.5000 hectares. Kalush city has an estimated 68,000 inhabitants and is home to a large chemical industrial centre, parts of which have ceased to operate. Several rivers flow through Ivano-Frankivsk Oblast, the most prominent being the 1,380 km-long transboundary Dniester River, which starts in the Ukrainian Carpathians, flows through Moldova (marking the border with Ukraine) and reaches Ukraine again before emptying into the Black Sea. The area of interest to the mission is situated on the right bank of the Nadnistryansk River.

Kalush has a moderate continental climate[2]. Average annual temperature is $+7.1^0$ Celsius. Average annual rainfall is 788 mm, including a warm period with an average rainfall of 613mm and a cold season with an average of 175 mm. The district is characterized by hilly terrain, comprised of Kalush Plain and Voynyliv Highland. Absolute altitude measured from sea level varies between 278 and 350 metres.

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[1] http://www.unece.org

[2] Hydrometeorological phenomena are at the core of the natural disaster hazard profile of Ukraine due to the territory's meteorological vulnerability. Public infrastructure of transportation and housing are the most damaged sectors in peak flood times. Abnormal rainfall patterns have increased in frequency over a relatively short time, from 100 such events in 1975 to 400 events in 2006.

The Kalush district is rich in gypsum, sand, loam, clay, peat, potassium ore and gas. A large deposit of potassium salt represents a valuable commercial resource. Other primary resources are gypsum (Voynylivske, Perevosetske, Serednyanske deposits) and brick-tiling raw materials used by local brick manufacturers. Moreover, there are some sources of mineral water consisting of chloride-carbonate sodium and magnesium-calcium deposits, which have been discovered in Serednye village. This mineral water is used for manufacturing non-alcoholic beverages.

The major industrial complex of Kalush consists of eight industrial plants for processing mineral resources, a number of industries for vinyl and floor covering, and one mixed facility for electrical power, heating and hot water.

Figure 1: Map of Kalush, Western Ukraine

The mining of potash based on the Kalush-Holynskyi saline deposits provided a basis for the chemical industry in Kalush. The deposits occur in a series of sub-basins and are deformed, making mining problematic. There are a number of (open cast) mine sites around Kalush. One such site is adjacent to the Oriana Potash Fertilizer Plant, established in 1967. Potassium-magnesium production continued until the plant was shut down in October 2001. It has remained inactive since.

Industrial accidents and environmental contamination are not new issues in Ukraine. In particular, the problems of obsolete pesticides and past pollution from abandoned industrial facilities have been well documented and pose a continued health risk to the population. For example, the Environment and Security Initiative[3] lists the Ivano-Frankivsk area as highly polluted (land, air, soil) by various activities including mining, military and oil refineries.

A current urgent concern for the authorities is the impact of possible spring flooding in the Kalush area. Current levels of snowfall in the 2009/2010 winter in the Carpathians are high. Local authorities fear for the integrity of the tailings dams when snowmelt commences in spring 2010. The area was already affected by severe flooding that impacted large parts of western Ukraine in the second half of 2008.

Groundwater levels are generally high and close to the surface throughout the country. All of Ukraine is to varying degrees at risk from floods and spring runoff. The country's hilly regions are also vulnerable to landslides. In late July 2008, a major storm in Western Ukraine caused severe rainfall, generating floods, flash floods, mudflows and landslides, and causing extensive damage in the oblasts of Lviv, Zakarpattya, Chernivtsi, Ivano-Frankivsk and Ternopil. Reportedly, a storage site of 800 kg of pesticides was also destroyed during these floods.

> In 2009, UNDP investigated obsolete pesticide stockpiles in Debeslavtsi village and Spas village in the Ivano-Frankivsk Oblast, as part of the post-flood recovery activities. In certain cases, pesticides are leaking from corroded steel drums and other containers into the soil. There are two known sites in the oblast containing 1 and 1.37 tons of pesticides.

Often, expensive structural works (e.g., river protection and embankments) will be lost in the event of recurrent floods. Embankments on only one side of a river can result in the water flow being stronger on the opposite side of the river. If embankments are not built in the dynamic and movable parts of the river stream, this can provoke river stream aggression on the opposite side of the river, potentially leading to the eventual destruction of embankments. Communities in flood plain areas of Ivano-Frankivsk Oblast are undertaking structural mitigation measures on their own, based on traditional knowledge and practice, often using ineffective methods for dangerous sections of rivers[4].

Another reported issue concerns the storage of hazardous waste in the Kalush area. Chemical industries and processing plants in the area (including the former production of organo-chlorine chemicals and oil refineries) have generated waste that has been stored in the vicinity. In particular, the draft National Implementation Plan prepared under the Stockholm Convention on Persistent Organic Pollutants has identified a storage site of an estimated 11,000 tons of Hexachlorobenzene (HCB) near Kalush[5]. This waste was generated with the production of carbon tetrachloride and perchloroethylene at the former Kalush Chemical and Metallurgical Industrial Complex. Its production had an estimated capacity of 30,000 metric tons per year, generating solid wastes containing over 90 percent of HCB at a rate of 540 tons per year.

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[3] The Environment and Security Initiative (ENVSEC) is an innovative partnership of six international and regional organizations (i.e., UNEP, UNDP, UNECE, OSCE, REC and NATO as an associated partner) whose purpose is, by using a multi-disciplinary approach, to contribute to reduction of interlinked environment and security risks through strengthened cooperation among and within countries in four regions: Eastern Europe, South Eastern Europe, Southern Caucasus and Central Asia.

[4] Mocellin, J. UNDP Ukraine (2009). Recovery and Disaster Risk Reduction Assessment: Ukraine Floods. March. Kiev.

[5] National Plan for Implementation of the Stockholm Convention on Persistent Organic Pollutants in Ukraine (*Draft*), not dated.

Subsidence is a third reported problem associated in the Kalush area. Subsidence is the settling, compaction or caving in of land that could be caused by groundwater extraction, subsurface mining or pumping of oil and gas[6]. Subsidence has already affected residential and industrial areas. Some residences have reportedly already been demolished following the structural damage suffered due to subsidence.

On 2 February 2010, the then President of Ukraine[7] visited the former Oriana Potassium Plant. He toured the mine and production waste sites and was informed of the environmental hazards posed by these objects, including subsidence of the earth surface.

Through a presidential decree (No. 145/2010) of 10 February 2010 and subsequent Law (No. 1885-VI of 12 February), the Kalush area[8] was officially declared an "emergency ecological situation zone". The Ministries of Foreign Affairs and of Economy of Ukraine consented "to apply to the international organizations and foreign states with a request for provision of humanitarian and technical assistance for the purposes of ecological situation normalization".

A decree from the Cabinet of Ministers (No. 381-P) subsequently allocated financial resources totaling 398 million UAH (US$49 million) to the affected area on 2 March.

1.3 Technical scoping mission

On 4 February 2010, the Executive Secretary of UNECE received an official request for assistance from the Head, Secretariat of the President of Ukraine, for financial and expert assistance. A similar request was sent to the Executive Director of UNEP through the Director of the Regional Office for Europe.

Following an emergency meeting between UNECE and UNEP, this request was forwarded to the United Nations Resident Coordinator in Ukraine and the Joint UNEP/OCHA Environment Unit (Joint Environment Unit) for immediate follow-up. The Joint Environment Unit is the United Nations mechanism that mobilizes and coordinates international assistance to countries affected by environmental emergencies and natural disasters with significant environmental impact.

In response to the request, the Joint Environment Unit proposed to deploy a technical scoping mission jointly with EC-MIC, one of its key partners. A small UNDAC team was combined with experts and a Liaison Officer/Deputy Team Leader from EC-MIC, including a Senior Tailings Dam expert and a Senior Expert on Hydrology and Mining Waste. Three experts of the Dutch Environmental Assessment Module provided technical sampling and analysis support through the International Humanitarian Partnership. The team was further strengthened by a Senior Advisor on Early Recovery and Disaster Management and a Senior Programme Manager, Environment and Energy from UNDP in Ukraine. The mission took place from 1 to 9 March 2010. A detailed mission agenda and team composition is included in Annexes I and II.

[6] http://www.usgs.gov
[7] http://www.president.gov.ua/en/news/16517.html
[8] Notably "the territories of town Kalush and villages Kropyvnyk and Sivka-Kaluska of Kalush District of Ivano-Frankivsk Oblast"

The specific objectives of the mission were:

- To undertake a rapid assessment of the stability and integrity of the tailings dams, in particular with a focus on the expected snowmelt and possible flooding in the spring, as well as risks stemming from subsidence.

- To undertake scientific sampling in the vicinity of the tailings dam and hazardous waste site to screen for any immediate and/or potential threats to communities and the environment.

- To assist the emergency management organizations in identifying appropriate preparedness and risk reduction measures to minimize the impacts to the population.

The draft mission findings were presented to government authorities and interested donors in Ukraine. This report contains the mission's final conclusions and recommendations.

1.4 Methodology

The technological scoping mission made use of a combination of the following methodologies:

1. Review of existing literature such as Government reports, geological maps and satellite imagery.
2. Selected interviews with Government officials and other stakeholders.
3. Independent sampling and analysis of water and soil.
4. Visual site assessments and basic parameters measurements (such as conductivity).

The short time period available to the team to undertake the assessments limited the ability to collect data and fully understand the complexity of the many processes underlying the issues as described in this report. In addition, much of the information, which was frequently provided orally and through interpretation, could not be independently verified. As such, any errors in the information provided might be reflected in the conclusions and recommendations. Lastly, the recommendations provided by the UN/EC Technical Scoping Mission at the end of this report do not allocate specific responsibilities to the wide array of Government stakeholders involved, as this process should ideally be undertaken by the national authorities themselves.

Where possible, the UN/EC Technical Scoping Mission has made estimations regarding risk. These risk estimations are obviously subjective and only serve to provide a certain degree of guidance to decision makers in the Government to assist in setting priorities for immediate follow-up activities. In addition, due to the limited time and scope of the mission, no quantitative analysis has taken place of the consequences in terms of financial, human and economic costs. The risk analysis is divided into two components: the likelihood of an event occurring and the impact(s) the event might have.

- Likelihood: Extremely Unlikely, Very Unlikely, Unlikely, Likely and Very Likely.
- Impact: Minor, Limited, Serious, Very Serious, Catastrophic.

A relative risk value is defined as the product of the grade for likelihood and consequence, e.g. the risk value for an unlikely event (grade 3) with serious consequence (grade 4) equals a risk value of 12. These values may then be used to prioritize high-risk events. In certain cases the value of “Very Likely” has been given for the sake of the methodology. However, this value should be read as “happening” or “ongoing”.

2. Observations of the UN/EC Technical Scoping Mission

2.1 Mining facilities

The UN/EC Technical Scoping Mission conducted site visits to investigate the condition and safety of the tailings dams; the Dombrovski Open-Cast Mine; the mining waste dumps; the occurrence of mine subsidence and sinkholes; and the spreading of salts in groundwater.

Mining of the Kalush-Holynskyi salt deposits provided a basis for the chemical industry in Kalush. The salt deposits occur in a series of sub-basins at shallow depth. The salts are covered by two distinct soil layers and a gypsum cap rock on top. The top soil consists of loess (fine sand and coarse silt) typically two to five metres thick, and loam (fine sand to coarse silt). The second soil layer is a sandy gravel of 15 to 25-metre alluvial deposit, forming a regional aquifer.

The bedrock consists of evaporates of various composition. On top is the cap rock of mainly gypsum. The following three distinct deposits can be found below the cap rock:

- *Sylvinite:* a mixture of Potassium Chloride (KCl) and Sodium Chloride (NaCl)
- *Kainite:* a mixture of Potassium Chloride (KCl) and Magnesium Sulfate ($MgSO_4$)
- *Langbeinite*: a potassium magnesium sulfate mineral ($K_2Mg_2(SO_4)_3$

The salts have been mined from depths of 40m in the Dombrovski Open-Cast Mine and 60m in the Central Kainite Mine underground mine. Originally, the salts were mined for halite (the mineral form of table salt NaCl), but the major industrial mining was aimed at the potassium and magnesium ores.

2.1.1 Tailings Dams

There are five retaining structures for storage of liquid mining waste in the Kalush area: three tailings dams and two saline-solution ponds. Their exact location can be seen in Figure 2.

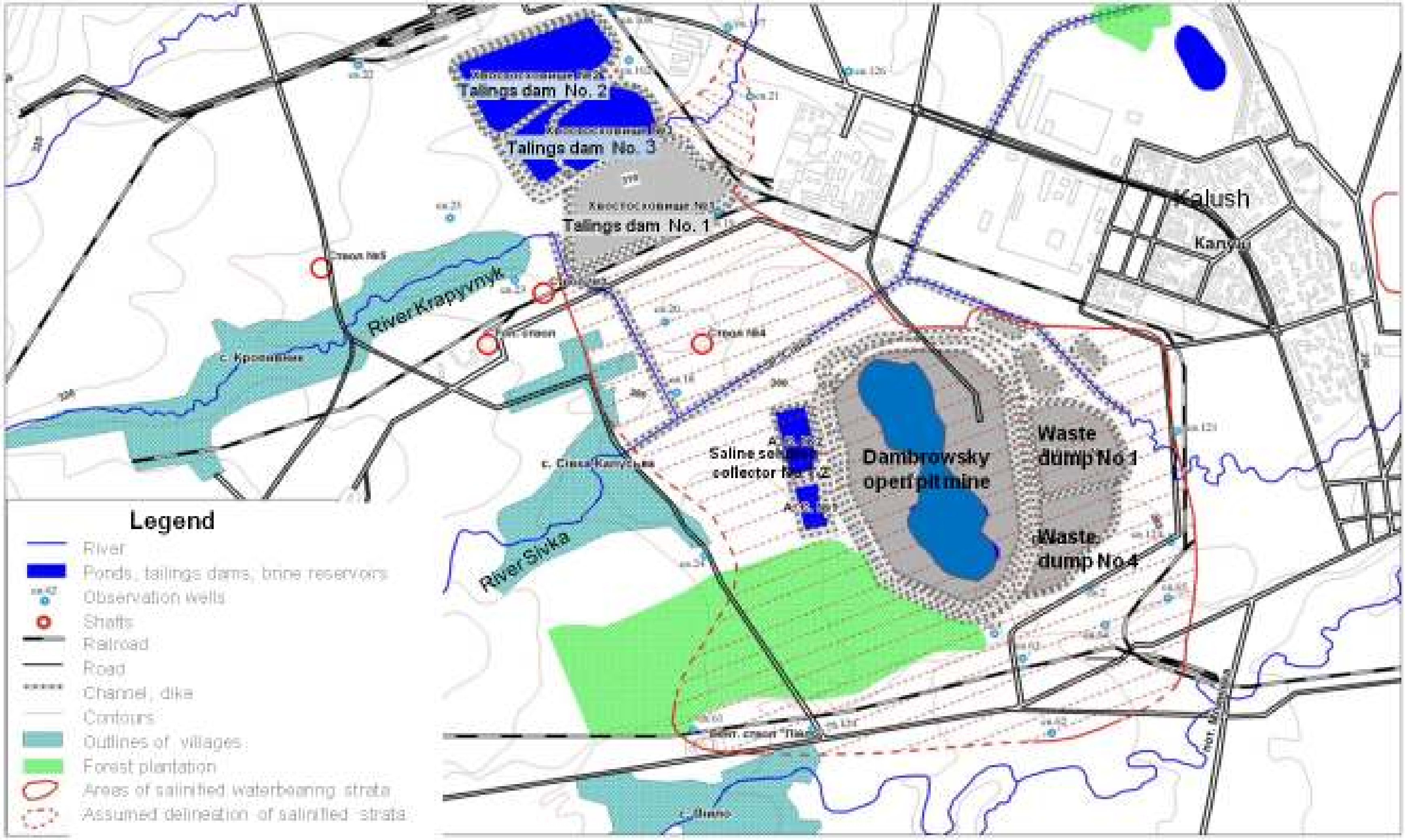

Figure 2: Location of the mining facilities

A summary of basic data of the retaining structures is provided in Table 1.

Table 1: Retaining structures

Retaining structure	Basic data
Tailings Dam No. 1	Year of construction: unknown Surface area: 54 ha Volume: 12-14×10^6m^3 Contents: halite rocks Leachate: contains 10.6 to 54.3 g/l salt Closure (suspended) would require 660,000m^3 of fill material
Tailings Dam No. 2	Year of construction: 1984 Surface area: 48 ha Volume: 10.7×10^6m^3 Filled with: solid phase 9 x10^6m^3; liquid phase 1.7×10^6m^3 Leakage in 2006 caused spill and erosion Repair works only partly successful
Tailings Dam No. 3 / sludge storage	Year of construction: 1974 Surface area: 25 ha Tailings dam No. 3 surrounds the sludge collector, but is not completed Volume: 1.3×10^6m^3, but planned/design: 0,914×10^6m^3 0.25×10^6m^3 of saline water from Mine Waste Dump No. 1 stored in the dam
Saline solution collector No. 1	Contents: saline water pumping stations on the perimeter ditch Surface area: 10 ha
Saline solution collector No. 2	Contents: brine from the Dombrovski Open-Cast Mine Surface area: 10 ha

The UN/EC Technical Scoping Mission did not obtain cross-section drawings of the dams. However, judging from the starter dam of Tailings Dam No. 3, it is assumed that the tailings dams have been constructed through the upstream method. This method is widely used, whereby new parts of the embankment are built on top of the slurries impounded during the previous stage, thus the dam crest moves "upstream". The starter and the extension dams are constructed from good sandy gravel material with adequate strength for containing the sludge and liquid in the dams.

However, the UN/EC Technical Scoping Mission considered the outer slopes of the dams as too steep for the sandy gravel material to be stable against erosion from surface water.

With respect to sealing the tailings dams, the situation appears to be as follows:

- On Tailings Dam No. 1, no special sealing has been used and therefore the bottom sealing is formed by the top soil layer of loess. However, when levelling the ground prior to construction of the dam, loess was removed at some places, exposing the sandy gravel aquifer. This means that some of the disposed wastes are in direct contact with the aquifer.
- On Tailings Dam No. 2, a polyethylene sealing membrane was placed on the bottom of the pond and on the starter dam. However, no membrane was placed on the subsequent raising of the dam. This means that the disposed wastes in this dam are at least somewhat separated from the underlying aquifer.

- On Tailings Dam No. 3, a sealing of silt and clay material was added to the starter dam, but no polyethylene sealing membrane was placed on the bottom of the pond. The sludge and brine in this dam is believed to be separated from the underlying aquifer by the loess topsoil.

None of the three tailings dams have a proper drainage system for surface water. The top of the embankments are nearly horizontal and precipitation is currently collecting in pools on their surface. This water subsequently runs down the steep, outer slope via randomly formed channels, without any proper erosion control. As a result, there are numerous erosion scars in the slopes of the tailings dams.

Tailings Dam No. 1

Tailings Dam No. 1 was no longer in use when the mining facilities were closed. However, no final and proper decommissioning has taken place. A limited soil cover is in place and a good grass cover established, as seen in Figure 3. According to the decommissioning plan, 600,000 m^3 of fill is required to establish a fully functioning cover for the dam.

Figure 3: Grass cover on Tailings Dam No. 1

The soil cover on top is nearly horizontal, resulting in water accumulating in ponds on the top surface. Water in the ponds seeps through the soil cover and infiltrates into the saline wastes below. Some water also finds its way through the circumferential structure and emerges as saline streams in the outer slope. Some water is seeping through the entire waste and into the underlying alluvial stratum. This flow of water is causing karstification of the waste, resulting in fissures, sinkholes, underground streams and small caverns. As a result, more water is infiltrated through the waste and less is flowing off as surface water. The dam's structural stability is considered to be good under normal loading conditions. However, under high groundwater pressure and/or earthquake loading, the stability might be significantly reduced. The western part of the dam is affected by subsidence caused by the underlying Novo-Holyn mine. Future significant subsidence may cause cracking of the retaining structure and may result in a severe spill of the stored wastes through the crack.

Sampling and analysis of spreading of salts from Tailings Dam No. 1

The UN/EC Technical Scoping Mission investigated the spreading of salts leaking from Tailings Dam No. 1 into surface waters and in particular into the Sivka River. On 7 March, the team took surface water samples near Tailings Dam No. 1, and upstream and downstream from the point where a small stream from Tailings Dam No. 1 enters the Sivka River. In Figure 4, the sampling points are shown. These samples were analysed for conductivity, acidity (pH) and concentrations of several elements and salts.

Figure 4: Sampling points in surface water around Tailings Dam No. 1.

In Annex X, all results for the element and salt concentrations are presented. In Table 2, only the most relevant results are presented. In Table 3, conductivity and acidity are presented.

Table 2: Main elements found in surface water near Tailings Dam No. 1

Sampling point unit	Na mg/l	Mg mg/l	Cl mg/l	K mg/l	Ca mg/l	Mn **µg/l**	Sr **µg/l**	Cd **µg/l**	SO_4^{2-} mg/l
upstream Sivka (sampling point 4)	26	6.7	37	3.1	34	52	223	0.1	60
from pool near Tailings Dam No. 1 (sampling point 3)	27040	6060	56258	8836	251	873	2650	18	18548
in stream from Tailings Dam No. 1 to Sivka (sampling point 5)	122	36	267	44	32	134	177	0.0	130
downstream Sivka, near Dombrovski open-cast mine (sampling point 2)	82	16	138	25	34	84	234	0.1	112
downstream Sivka, at bridge near main road (sampling point 1)	72	15	24	22	34	80	227	0.1	102

Table 3: Conductivity and acidity in surface water near Tailings Dam No. 1.

Sampling point unit	Conductivity µS/cm	pH
upstream Sivka (sampling point 4)	417	8.6
from pool near Tailings Dam No. 1 (sampling point 3)	105000	8.0
in stream from Tailings Dam No. 1 to Sivka (sampling point 5)	1279	10.4
downstream Sivka, near Dombrovski open-cast mine (sampling point 2)	726	6.8
downstream Sivka, at bridge near main road (sampling point 1)	765	6.2

The results show very high concentrations of many elements, such as Na, Mg, Cl, K and Cd, and a high sulphate concentration in the pool near Tailings Dam No. 1. The conductivity in this pool was also very high. The concentrations are lower in the stream to the Sivka river, leading to a slight rise in the concentrations in the Sivka River.

The measurements give no indication of higher lead (Pb) or chromium (Cr) concentrations. During the mission, the team received data that showed high concentrations for these elements, but there was no data regarding sampling place(s) and time(s) making comparison with the mission's findings impossible. The sampling by the mission around Tailings Dam No. 1 does not confirm high lead and chromium concentrations at those locations.

The seeping of salts from Tailings Dam No.1 is not only visible but has also been demonstrated in the samples of surface waters around the dam. The salt concentrations in the pool near the dam (sampling point 3) are extremely high and this salt is spreading to the stream to the Sivka River. For comparison, the concentrations measured are above the alarm levels applied for the Rhine River. This seepage leads to a rise of concentrations by a factor 2 or 3 for some salts (Na, Mg, SO_4) and some even more (K). However, the measured salt concentrations downstream in the Sivka are low. However, this situation might deteriorate during heavy rainfall and/or floods due to a momentary greater seepage of salts. The impact on ground water has not been measured and would require further sampling and analysis.

Tailings Dam No. 2

Figure 5: North side of Tailings Dam No. 2

Tailings Dam No. 2 is filled with solids and brine, as seen in Figure 5. The liquid level is controlled by pumping brine away from the dam. The dam has a polyethylene membrane sealing at the bottom, and up to five to seven metres on the slope of the starter dam. The dam is currently filling up by precipitation. If the level is allowed to rise and no action is taken, the dam will eventually overflow. As the dam is filled with brine, equilibrium will be reached between the seepage water and the salt in the waste. It has been observed that brine is seeping through the dam in places, especially at the eastern and western sides. The dam's structural stability can be considered as good under normal loading conditions. However, under high groundwater pressure and/or earthquake loading, the stability might be significantly reduced. Precipitation collected along the slopes has caused surface erosion. The western part of the dam is furthermore affected by subsidence caused by underlying the Novo-Holin mine. Future significant subsidence may cause cracking of the retaining structure and may result in a severe spill through the crack.

Tailings Dam No. 3

Tailings Dam No. 3 (see Figure 6) is situated between Tailings Dam No. 1 and No. 2. The dam is enclosing a former sludge pond. The dam's construction is partly finished as only the starter dam has been completed. The dam contains brine but no tailings.

Figure 6: Start dam for Tailings Dam No. 3 (west side)

The dam is filling up by precipitation. If the water level is allowed to rise and no action is taken, the dam will eventually overflow. Since the dam is filled with brine, equilibrium will be reached between the seepage and the salt in the waste. No seepage has been observed through the dam. The structural stability of the dam can be considered as good. However, the dam is under high groundwater pressure and/or earthquake loading, and therefore its stability might be significantly reduced. The western part of the dam is affected by subsidence caused by the underlying Novo-Holin Mine. Future significant subsidence may cause cracking of the retaining structure and severe spill through the crack.

Risk analysis

The risks analysed for the tailings dams are related mainly to the stability of the structures and their ability to retain their contents of solid and liquid wastes. The risks are as follows:

- *Overtopping* is an event whereby the fluid level exceeds the top of the dam
- *Slope failure* is an event caused by slippage through the dam body or through the dam foundation
- *Liquefaction* is an event whereby fine grained waste inside the dam liquefies and the retaining structure yield under the pressure form the liquefied waste
- *Internal piping* is a process that reduces the dam's ability to retain fluid or waste by erosion of the liquid in the dam through defects in the dam body
- *Karstification* is a process where water seeps through the top cover and causes solution and removal of waste resulting in internal cavities
- *Subsidence* is a process whereby the ground settles and the dam loses its structural integrity due to deformation and cracking
- *Surface erosion* is a process that reduces the dam's structural integrity due to erosion of gullies in the dam's surface
- *Seepage* is the general flow of fluid through the dam due to the permeability of the dam body
- *Hazardous waste deposited* is the possibility that hazardous waste might have been deposited within the dam body

Table 4 summarizes the risk analysis for the Tailings Dams.

Table 4: Risk assessment – Tailings Dams

Issue	Likelihood	Consequence	Risk
Tailings Dam No. 1			
Slope failure/liquefaction	Unlikely	Very serious	12
Internal piping	Unlikely	Serious	9
Karstification	Likely	Serious	12
Subsidence	Likely	Serious	12
Surface erosion	Very likely	Limited	10
Seepage	Very likely	Serious	15
Hazardous waste deposited	Likely	Limited	8
Tailings Dam No. 2			
Overtopping	Unlikely	Very serious	12
Slope failure/liquefaction	Very unlikely	Catastrophic	10
Internal piping	Unlikely	Serious	9
Karstification	Unlikely	Serious	9
Subsidence	Very likely	Serious	15
Surface erosion	Very likely	Limited	10
Seepage	Very likely	Serious	15
Hazardous waste deposited	Unlikely	Serious	9
Tailings Dam No. 3			
Overtopping	Very unlikely	Serious	6
Slope failure	Very unlikely	Serious	6
Internal piping	Extremely unlikely	Limited	2
Karstification	Likely	Serious	12
Subsidence	Very likely	Serious	15
Seepage	Very likely	Serious	15
Hazardous waste deposited	Unlikely	Serious	9

2.1.2 Dombrovski Open-Cast Mine

Figure 7: Dombrovski Open-Cast Mine (north-western corner)

The salt deposits that were mined in the Dombrovski Open-Cast Mine (Figure 7) were a prime source for the Oriana Potash Fertilizer Plant. Mining continued until the plant was shut down in October 2001. At present it remains the only mine that that could physically be reopened for production. The mine was initially opened in 1967. Since then, an estimated 14.7×10^6 m^3 of potassium ore has been excavated, while an estimated deposit 32×10^6 tons of ore remains. The Dombrovski Open-Cast Mine has filled up with brine, as seen in Figure 8, having an estimated volume 12 to 15×10^6 m^3.

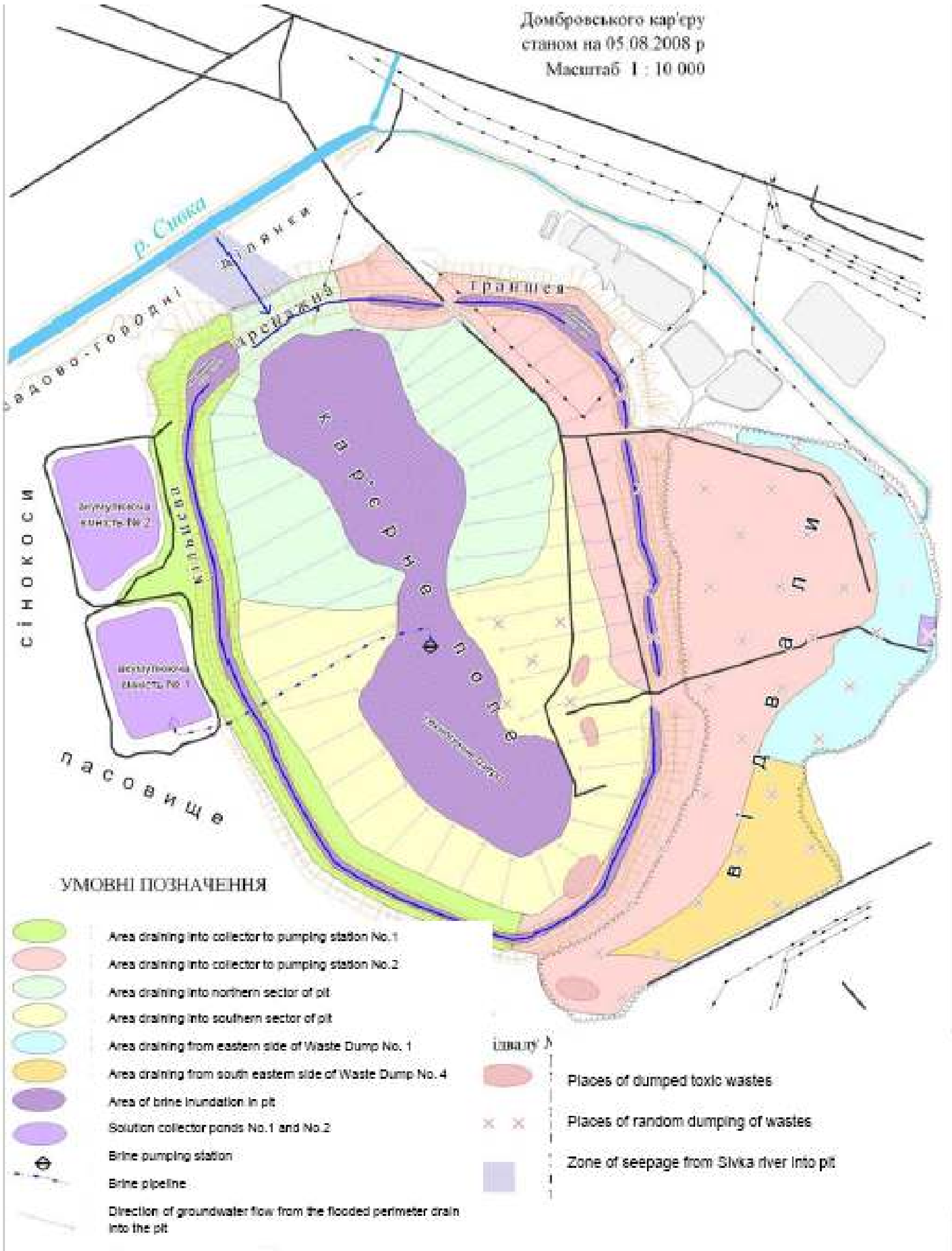

Figure 8: Plan of Dombrovski Open-Cast Mine

Drainage

Originally, the mine was surrounded by an elaborate system of drainage ditches. The system consisted of perimeter ditches that separated fresh surface water and groundwater from the saline and salt water in the pit. The freshwater could immediately be released while the saline water and brine were stored in the solution-storage pond to the west of the pit (see also Figure 8). Since the termination of mining operations, the pit has been filling up with brine. Degradation of the drainage system has destroyed the separation of freshwater and salt water. As a result, the total catchment area that drains into the pit has gradually increased.

By 2008, the catchment area had nearly doubled in surface area, with Mining Waste Dumps No. 1 and No. 4 draining into the mine. The catchment area is estimated to be between 360 and 380 ha. With an annual precipitation of 788 mm, the amount of water draining into the pit may be as high as 2.5×10^6 m^3. In addition, groundwater from the alluvium aquifer drains into the mine, mainly along the western side. Therefore, the total amount of water currently draining into the pit annually could be as high as 5×10^6 m^3. An estimated unfilled volume of 41×10^6 m^3 remains in the pit. The unfilled volume below the bottom of the alluvial aquifer stratum is 24×10^6 m^3.

Stability of the slopes in the open-cast mine

The soil at the Dombrovski Open-Cast Mine consists of 4 to 8 metres of clay closest to the surface, followed by 10 to 15 metres of sand and gravel. Under this sand and gravel layer, a cap rock of clay and gypsum of approximately 10 metres can be found, which covers the potassium-bearing salts, 30 to 35 metres under the ground surface.

Without a functional drainage system, the steep slopes have become highly unstable. The upper slope has been subjected to numerous small- and medium-scale slides, especially on the western and northern sides. The southern and eastern sides have been excavated with more gentle slopes. The slides occur mainly in the overburden, which consists of loess at the top and sand/gravel alluvium below. The result is a continuous lateral expansion of the mine pit caused by the loose character of the two top layers and the steep excavated cuts. Without a proper functioning drainage system, the slopes may become as flat as 1:3 (vertical:horizontal). This implies that the pit at places may expand laterally as much as 20 to 50 metres before the slopes are stable. In addition to the loose top soil layers, the cap rock and salt below the overburden are subjected to karstification, further contributing to the instability of the slopes.

The ongoing erosion and instability of the slopes are most severe in the northern sector. At certain locations, slides have already severely affected the perimeter drain and the edge of the pit is now close to some adjacent *dachas*. Moreover, with more slides the edge of the mine pit will approach the Sivka River that runs along the northern section of the Dombrovski Open-Cast Mine. At the same time, water from the Sivka River is already seeping through the alluvial aquifer into the pit. This seepage may cause further suffusion and eventually a ravine may cut retrogressively back into the Sivka River. Such a breakthrough would lead to a rapid filling of the pit, allowing the brine to reach the aquifer. As a result, the salt plume to the south of the pit will expand rapidly. Without corrective action, a breakthrough of the Sivka River cannot be avoided.

The risks analysed are related to stability of the open-cast mine and the risks of brine spill from the pit. Specific issues that are relevant include:

- **Infiltration to aquifer** is the general flow of fluid in the pit due to the permeability of the surrounding aquifer.
- **Surface water into ring channel/mine pit** is the risk of surface water (fresh) being mixed with the brine in the perimeter channel/mine pit.

- **Hazardous waste deposited** is the risk of the possible existence of hazardous waste that might have been deposited within the pit's slopes.

Table 5: Risk assessment – Dombrovski Open-Cast Mine

Issue	Likelihood	Consequence	Risk
Slope failure	Very likely	Serious	15
Karstification	Very likely	Serious	15
Subsidence	Very likely	Serious	15
Surface erosion	Very likely	Limited	10
Surface water into ring channel/mine pit	Very likely	Serious	15
Hazardous waste deposited	Likely	Limited	8

2.1.3 Mine Waste Dumps

Mine Waste Dumps No. 1 and No. 4 are situated east and south-east, respectively, of the Dombrovski Open-Cast Mine. The two dumps cover an area of approximately 90 ha and contain an estimated 26 million m^3 of mainly overburden from the pit area, including salt-containing clays. On the east side of Waste Dump No. 1, residues from salt processing, containing up to 70 percent of salt, have been deposited. Table 6 provides an overview of basic data for the two mine waste dump sites.

Table 6: Mine waste sites

Dam structure	Miscellaneous information
Waste Dump No. 1	Surface area: 48 ha Volume: 12-15 x 10^6 m^3 Contents: overburden, including saliniferous clays. On the east side, residues from processing containing 70 % salt are deposited. Closure requires approximately 1.2 million m^3 of cover material, of which a quarter would be material for a low permeability liner.
Waste Dump No. 4	Year of construction: 1984 Surface area: 45 ha Volume: 10 to 12 x 10^6 m^3 Contents: overburden, including salt containing clays. Hazardous waste is reportedly dumped on the west side of the dump (see also section on hazardous waste further in this report). Closure requires approximately 0.8 million m^3 of cover material, of which a quarter would be material for a low permeability liner.

The Mine Waste Dump No. 1 (see Figure 9) has a round to square shape and the approximate dimensions of 0.75×0.75 km^2. With its top at 340 to 345 m in elevation, the dump rises 40 to 50 m above the surrounding landscape. The dump has not been rehabilitated, but some natural revegetation has occurred, as seen in the photo. Overall, the dump's slopes are steep. This, together with the lack of cover and vegetation, has led to severe erosion. On the dump's north, west and east sides, erosion has led to extensive spreading of sediments, which has filled the surrounding drains. The accumulation of sediments has led to surges of sediments out on the flats on the east side of the dump. On the west side it has led to gullies and erosion, breaking through the embankment between the outer and inner perimeter drain.

Figure 9: Mine Waste Dump No. 1

The Mine Waste Dump No. 4 (see Figure 10) has an elongated shape, stretching 1.2 km, and is 0.2 to 0.5 km wide. The top of the dump, which is 320 to 325 m in elevation, is relatively flat and to a large extent has been rehabilitated with cover material and vegetation. The dump rises 20 to 25 m over the surrounding landscape. On the east slope of the dump, erosion processes are active, which has led to the spreading of brines and fine material (silt and clay) into the surrounding drain. As seen in the photo, the drainage on the east side is covered by sediments.

Figure 10: Mine Waste Dump No. 4

The general lack of rehabilitation, sediment control structures and maintenance, together with the unstable slopes of Mine Waste Dump No. 1, have led to erosion, filling up of drains and uncontrolled run-off (containing brines) into surrounding waterways and into the Dombrovski Open-Cast Mine. The waste dumps are also a major, if not the major source of brine polluting the groundwater aquifer in the direction of the River Limnitsya.

The risks analysed for the waste dumps are related to the structure's stability and the effluent of water and particles from the dump.

Table 7: Risk assessment Mine Waste Dumps

Issue	Likelihood	Consequence	Risk
Mine Waste Dump No. 1			
Slope failure	Very unlikely	Serious	6
Karstification	Likely	Serious	12
Subsidence	Likely	Serious	12
Surface erosion	Very likely	Limited	10
Seepage	Very likely	Serious	15
Surface water into ring channel/mine pit	Very likely	Serious	15
Hazardous waste deposited	Likely	Serious	12
Mine Waste Dump No.4			
Slope failure	Very unlikely	Serious	6
Karstification	Likely	Serious	12
Subsidence	Likely	Serious	12
Surface erosion	Very likely	Limited	10
Seepage	Very likely	Serious	15
Surface water into perimeter channel/mine pit	Very likely	Serious	15
Hazardous waste deposited	Likely	Serious	12

2.1.4 Mine subsidence and sinkholes

There are seven underground mines in the Kalush area: four along the western rim of the city of Kalush and three in the Holyn area. Basic data on the mines is provided in Table 8.

Table 8: Mining fields – basic data

Name of mining field	Mining period	Depth to roof/floor m	Volume mined 1000 m^3	Backfilling	Unfilled volume 1000 m^3
1. Hotyn Silvinite	1961-1975	140 / 270	948	“dry method”	823
2. Central Kainite	1867-1979	60 / 250	2,116	Hydraulic filling	0
3. Northern Kainite	1940-1943 1956-1975	100 / 260	1,326	Brine	0
4. Northern Sylvinite	1943-1962	160 / 400	1,890	Level 1-3:dry fill Level 4 and below: ore waste	30
5. Novo-Holyn Eastern	1968-1995	70 / 260	6,863	Level 1-3: Silt & salt Level 4 and below: Brine, silt & salt	?
6. Novo-Holyn Sivka	1968-1995	70 / 260	5,295	Brine	?
7. Holyn	1930-1972	70 / 260	1,700	No backfilling	1,700

Subsidence

The subsidence of the surface on top of the underground mine fields (see Figure 11) has been monitored since 1947. This monitoring is based on ground surveys of benchmarks along profiles. The benchmarks are closely spaced along the profiles. However, they are widely spaced between the profiles. The benchmarks are levelled twice annually. This present monitoring system implies that the accuracy in the interpreted contours is excellent along the profile line. These lines follow mainly the streets and open fields. The accuracy is significantly poorer in between the lines where the houses are situated. Basic data on the subsidence is provided in Table 9 below.

Table 9: Mining fields – subsidence

Name	Mining period	Start of monitoring	Max subsidence (m)	Max. rate of subsidence (mm/a)	Current rate of subsidence (mm/a)
1. Hotin Sylvinte	1961-1975		2.7	211	75
2. Central Kainite	1867-1979		0.5	12	8
3. Northern Kainite	1940-1943 1956-1975		1.36	20-25 (1984)	Not observed
4. Northern Sylvinite	1943-1962	1957	4.8	450 (1961)	Not observed
5. Novo-Holyn Eastern	1968-1995	1979	0.84	13	9-13
6. Novo-Holyn Sivka	1968-1995	1979	0.188	11	6-11
7. Holyn	1930-1972	1960	1.0	≈ 20	Not observed

The maximum recorded level of subsidence, nearly three metres, has been observed in the Hotyn field. The interpreted profiles imply a flexural deformation of the ground surface. No sharp changes in subsidence were shown, indicating insignificant movement cracks or fault features. The information collected on the features affected by subsidence is highly detailed, providing the number of buildings, the number of residents and the location of critical facilities such as schools and hospitals in relationship to surface subsidence. All this information was provided (in Ukrainian) to the mission team.

To a very limited extent, the underground mines have been backfilled with solid materials that would support the mined openings. The openings have been mostly filled with brine, but in some cases also with freshwater. Filling the mines with brine does not necessarily guarantee the stability of the inter-chamber pillars. As a result of the degradation of these pillars, the ground above the mine is subsiding. This is typically a slow, gradual process that causes the flexural deformation of the ground above the pillars.

In an event in 1986, sudden ruptures due to seismic activity were observed at the Northern Kainite field. This event is related to slips along cracks or faults in the ground. In the subsiding areas, salinization of the ground takes place as brine (used to backfill the mines) is squeezed out of the mine openings and into the overburden.

During the mission, the head of the village of Kropyvnyk expressed a clear wish to investigate to what extent a resettlement option within the village boundaries - and not, as currently is foreseen, to the city of Kalush - might be feasible.

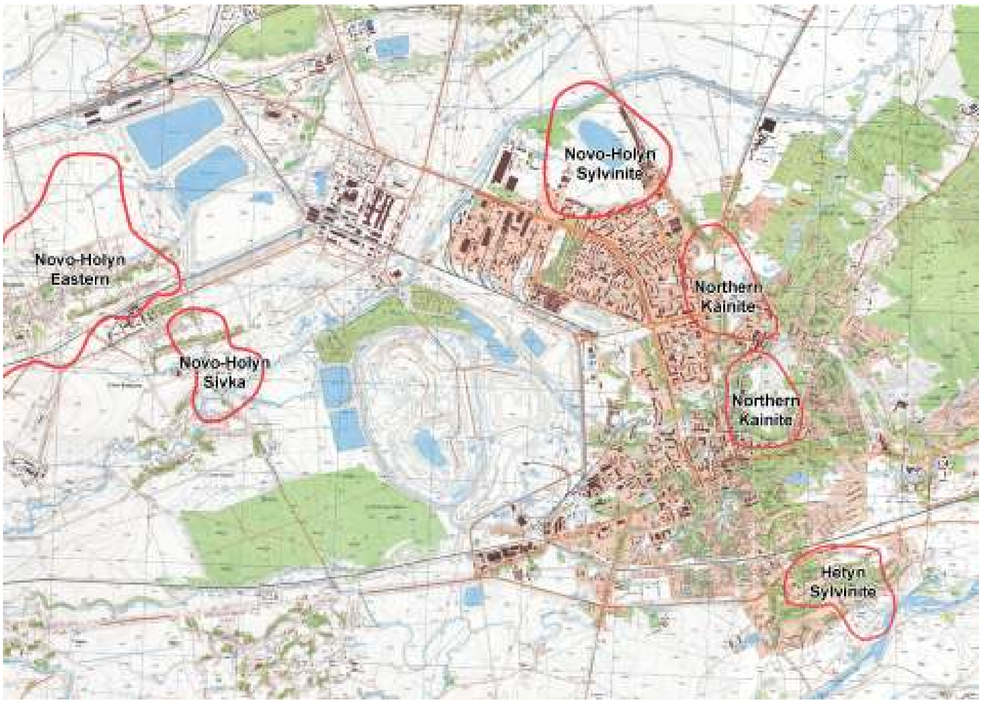

Figure 11: Areas of subsidence at the mine fields

Sinkholes

A number of sinkholes have occurred within subsiding areas. The generation of sinkholes is related to subsidence. The sinkholes vary in size from several metres to over 100 metres in diameter. The sinkholes' impact is much localized, but would have a direct impact in causing casualties if houses or apartment blocks were affected.

As the pillars between the mine openings are weakened and compressed, the rock in the roof may develop shear failure: the rock above the opening gives way and falls into the opening. In a gradual process, the cavity will expand vertically while broken rock is accumulated in the opening. When the cavity reaches the surface, it appears as a sinkhole. To a large extent, the cavity might be filled with the broken rock and overburden soil. The broken rock and soil might also soften and flow into the nearby openings in the mine. Table 10 summarizes basic data associated with the sinkholes.

Table 10: Sinkholes

Name	Mining period	Number of sinkholes	Water on surface	Structures on surface
Hotin Sylvinte	1961-1975		Lake of 2 ha	202 houses of which 26 evacuated
Central Kainite	1867-1979	6	No	118 dwelling houses of which 60 evacuated Roads and utilities
Northern Kainite	1940-1943 1956-1975	Numerous >15	Lake and in sinkholes	110 houses (420 people) already resettled
Northern Sylvinite	1943-1962		Lake of 37 ha	Garages and communal gardens
Novo-Holyn Eastern	1968-1995	7	No	About 600 houses
Novo-Holyn Sivka	1968-1995	Not observed	No	
Holyn	1930-1972	Not observed	Lake of 10 ha	

Kropyvnyk village consists of 2,151 inhabitants and 713 houses. Subsidence affects an estimated 558 of these houses. Other information provided indicates 285 houses affected with 860 inhabitants. There is no drinking water supply here and people use individual wells. The village is connected to the gas supply network. The village also houses a community centre, the village council, an out-patient clinic, a church and a school for 211 students.

In Syvka-Kaluska village, subsidence affects an estimated 304 houses (1,247 inhabitants) out of 460 houses. The village has 1,619 inhabitants. There is a community centre and also one school for 170 students.

The sinkholes pose a significant threat to residents in the mined areas as houses and utilities are destroyed, resulting in injuries and casualties. The development of the sinkholes is a relatively slow process. This allows for sinkholes to be detected by suitable geophysical methods, such as micro seismic activity, long before they appear at the surface.

The city of Kalush has already identified an area for resettlement, which could house over 6,000 people, a school and two kindergartens. According to data and calculations of the authorities, 4,328 people are at risk in the subsidence zones and in need of resettlement.

In the affected areas, there are no industrial enterprises holding hazardous materials that could cause secondary impacts. The Municipality of Kalush no longer allows new construction in the four subsidence zones in its territory. However, as construction permits were issued prior to this, some newer houses have been constructed in these zones.

2.1.5 Salt Plume Generation and Movement

The spreading of salt brines to surface and groundwater in the Kalush area is primarily caused by the existence of the tailings dams, mine waste/salt dumps, Dombrovski Open-Cast Mine, the saline solution collector dams and the underground mining cavities.

Brine is water with a salt concentration above 50 g/l, i.e. saturated or nearly saturated with salts. For comparison, saline water contains 30-50 g salt/l and brackish water 0.5-30 g salt/l. The concentration of brines and saline water entering the aquifer has not been identified, nor has the concentration of salts in the monitoring boreholes. In available documents, concentration is mentioned as gram salt per litre. Concentrations of specific parameters are not reported. Brines span from 50 g salt/l to 450 g salt/l. It is mentioned that infiltration of brines leads to concentrations of 10.6-54.3 g salt/l in adjacent aquifers, i.e. mainly saline water, which seems plausible. The outer perimeter of the salinized areas is assumed to be set at the limit value for fresh water (0.5 g/l).

Waste containment areas

From the waste containment areas, i.e. the Tailings Dams, Mine Waste Dumps and Saline Solution Collector Dams, the spreading of salt is generated by the following processes:

- Direct seepage and infiltration to the water-bearing strata
- Seepage from the waste dumps and the fronts of the dam embankments to the surface
- Surface water run-off from the Mine Waste Dumps and Tailings Dam No. 1

Figure 12: Salt fan at the embankment of the south-east side of Tailings Dam No. 1

The conditions of seepage from the surface are accelerated by extensive erosion of waste dumps and the fronts of the dam embankments. Only the vegetated parts with low inclination on Tailings Dam No. 1 and Waste Dump No. 4 are not subject to erosion. On Mine Waste Dump No. 1 and along the embankment of Tailings Dam No. 1, erosion gullies several metres in width and depth can be observed (see Figure 13, showing surface discharge or brines on the east side of Waste Dump No. 1, flowing to the open-mine pit). Lack of vegetation and steep slopes have contributed to the formation of gullies and increased the potential for internal erosion within the dump mass. The erosion increases instability of the waste dump and dam embankments by creating preferential paths for water undercutting some slopes and generally washing material away.

Figure 13: Surface discharge or brines on the east side of Waste Dump No. 1

The mission conducted field measurements of electrical conductivity (Siemens/m) and temperature around the tailings dams and the mine waste dumps. Extremely high values of electrical conductivity (5-17.6 S/m) were registered at large seepage points along the tailings dam embankments (east side of Tailings Dam No. 2; south-west side of Tailings Dam No. 2; north-west, south-west and south-east side of Tailings Dam No. 1). This indicates a very high salt content, which was also clearly seen by extensive salt fans (see Figure 12). On the south-east and south-west side of Mine Waste Dump No. 1, electrical conductivity measurements on stream discharge originating from seepage of brines also showed extremely high values ranging from 15.3 to 17.8 S/m. These measurements can be compared with the electrical conductivity of sea water, which is about 4 S/m. This corresponds to a salt content of 3.5 percent or 35 g/l. The salt content of the seepage measured corresponds roughly to a 40-150 g/l, indicating seepage of brines. Figure 14 shows Mine Waste Dump No. 1 and dumps closer to the mine pit (area of 1.5x1 km^2). The white spots are precipitated salt and the effect of extensive seepage from the waste.

The risks analysed for the saline-solution ponds are related mainly to the stability of the structures and their ability to retain the liquid wastes they contain.

Table 11: Risk assessment – Saline-solution ponds

Issue	Likelihood	Consequence	Risk
Overtopping	Unlikely	Serious	9
Slope failure	Very unlikely	Very Serious	8
Internal piping	Unlikely	Serious	9
Karstification	Unlikely	Serious	9
Subsidence	Very likely	Serious	15
Surface erosion	Very likely	Limited	10
Seepage	Very likely	Serious	15
Hazardous waste deposited	Very unlikely	Serious	6

Figure 14: Mine Waste Dump No. 1 and dumps closer to the mine pit

Dombrovski Open-Cast Mine

Since 2008, the Dombrovski Open-Cast Mine has had an accelerated accumulation of water due to slope failure and subsequent loss of the northern part of the perimeter drain. Surface water and groundwater that used to drain into the perimeter drain have since been drained into the open pit, causing the catchment area to double in size. Because of the rising water level, the two former water bodies in the pit are now joined. In the near future, the continuous rising of the water level will lead to decanting of the brines in the pit to the surrounding water-bearing strata. The uppermost brines in the pit have an estimated salt concentration of approximately 80 g/l. With a groundwater gradient towards the south-southeast, the mineralization will spread towards the River Limnitsa.

Underground mines

The underground mining cavities are another source of salt brines in the surrounding environment that have been backfilled with brines. Subsidence affecting these mines leads to the release of the brines through fractures, sinkholes and mine shafts. Depending on the grade of subsidence and groundwater pressure, the brines are spreading to the water-bearing strata or directly to the surface. Due to continuous, and at some places accelerating, subsidence the spreading of salt from the underground mines will continue and locally increase. The Novo Golin Mine, which is situated only 40 m from the Limnitsa River, is largely filled with brines. The expected subsidence of up to 20 m and collapse of cavities will eventually lead to an extensive constant spreading of brines to the Limnitsa River.

Extent of salinization

The spreading of the salt brines and saline water has led to the salinization of the aquifer (water-bearing strata) in an area of 20-25 km^2. The worst affected area, of approximately 15 km^2, stretches almost 6 km from Tailings Dam No. 2 in the north-west, to 1 km south of Mine Waste Dump No. 4. The width of the plume is approximately 2 km in the north and approximately 3 km in the south. The area has been delineated based on samples from monitoring wells together with geophysical surveys. The extent of salinization of the aquifers downstream from the underground mines is monitored at the Kalush mine, but a quantitative assessment of the salinization area is lacking. In 2006-2007, 14 additional monitoring wells were established for mapping of salinization. At the Novo Holyn Mine, monitoring wells are not present and the extent of salinization of the aquifer is unclear. A rough estimation based on the size of the areas subjected to subsidence is that 5 to 7 km^2 of aquifer could be affected by salinization. In addition, surface water spreads brines to the Kropyvnyk and Sivka Rivers in north-easterly direction. It is unclear if, and to what extent, salinization is affecting aquifers further downstream due to river bank infiltration of affected surface water. However, it can be assumed that surface water in the vicinity of brine sources would increase the affected area of the underlying aquifers with some additional square kilometres.

2.2 Hazardous Waste

A key task of the Technical Scoping Mission was to undertake scientific sampling in the vicinity of the tailings dams and the hazardous waste site to screen for any immediate and/or potential threats to communities and the environment.

2.2.1. Hexachlorobenzene

In 1973, the production of carbon tetrachloride (CTC) and ethylene tetrachloride (ETC) began in Kalush, producing 540 tons of solid waste per year that contained over 90 percent Hexachlorobenzene (HCB).

HCB is a persistent organic pollutant. This means that this substance degrades slowly and accumulates in the food chain. It is considered as a probable human carcinogen, a proven carcinogen to animals and highly toxic to aquatic organisms. It was used as a fungicide for agricultural products such as wheat. At room temperature, HCB is a white, solid substance. Its solubility in water is poor (in databases, maximum solubility is described as 'not' to <0.1 mg per litre). It binds well with soil and particles. Spreading of HCB through the air is likely to occur through the spreading of soil particles. The evaporation of HCB to air is low, at 20° C the vapour pressure is $1x10^{-6}$ kPa. This means that air concentrations around a dump site in an undisturbed situation are expected to be low. Only during clean-up operations may toxic concentrations in air (quickly) arise when not handled with proper care and precaution.

Ukraine standards for HCB are:
- In surface water: 0.001 µg/l (= 1 ng/l)
- In soil: 0.03 mg/kg dry matter (= 30 ng/g)
- In air: 0.9 $\mu g/m^3$

These standards are comparable to the standards in other countries. For example, HCB background concentrations in Dutch soils are 0.0085 mg/kg dry matter (= 8,5 ng/g).

In the Stockholm Convention on Persistent Organic Pollutants, to which Ukraine is a Party, the elimination of HCB is targeted. Article 6.1.d states that HCB waste is to be "handled, collected, transported and stored in an environmentally sound manner" and "disposed of in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed…".

2.2.2. The HCB Storage Site

For the first three years of production of CTC and ETC in Kalush, no dedicated storage site existed yet and HCB waste was reportedly stored at several places in the Kalush Area. The only evidence that could be provided of such a storage site was of Mine Waste Dump No. 1 and/or No. 4, east of the Dombrovski Open-Mine Pit (see Figure 15). This "storage" would today be classified as uncontrolled dumping. The mission viewed photographs of scattered barrels near the open-cast mine, but could not determine their location or contents. The mission did not focus on locating these barrels because the dumpsite is large and the team did not have the equipment needed to locate them. Therefore, the condition of these barrels is unknown. Barrels may have corroded, and if present, with HCB possibly having leaked into the areas of Mine Waste Dump No. 1 and/or 4.

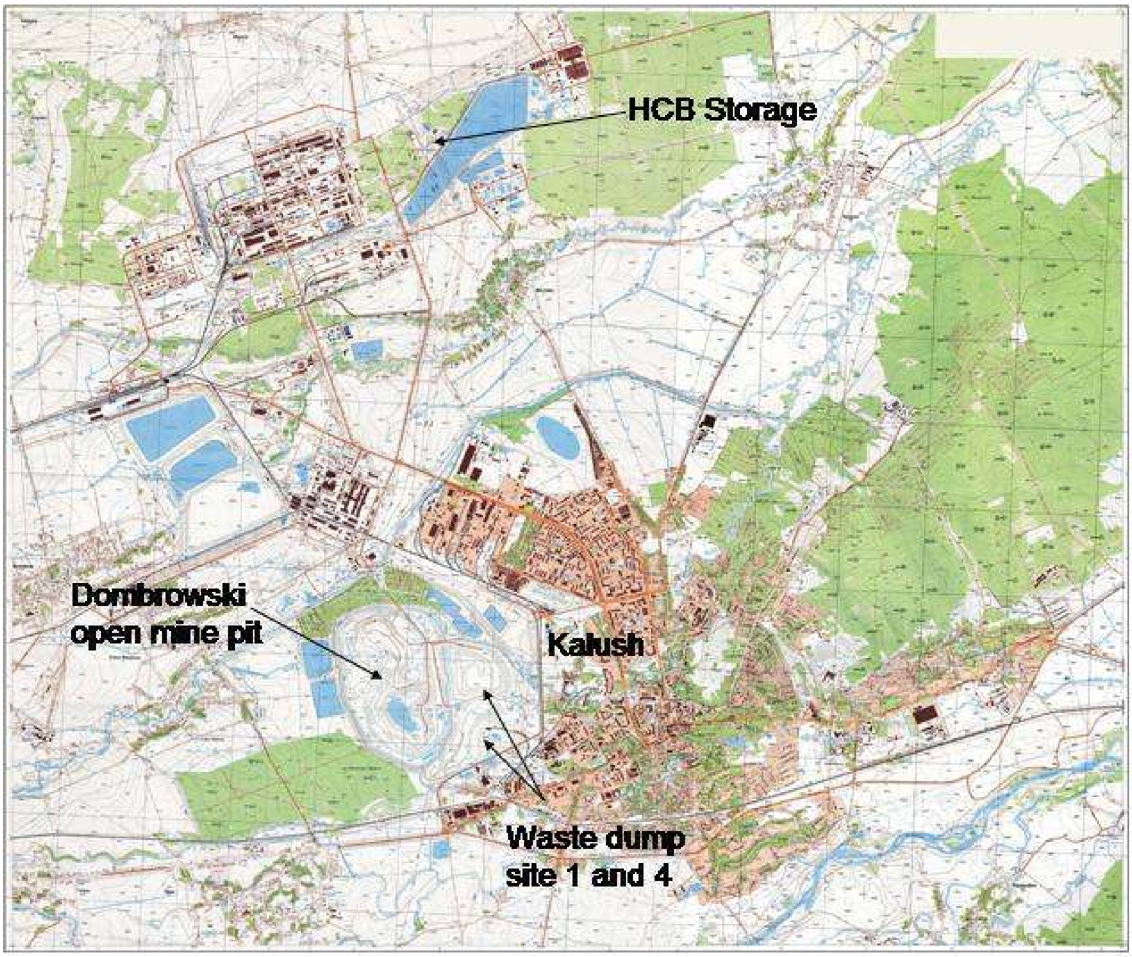

Figure 15: Location of the HCB storage and waste dump sites.

The HCB storage site (see Figure 15 for location; see Figure 16 for image) was fit for use three years after HCB production began and was used until 2000. At present, the barrels lie in water that has entered the storage site. These barrels will therefore be corroding or have corroded and it is likely that HCB is being released into the environment. Though the solubility of HCB in water is low, a certain amount of HCB in the water is expected when leakage has occurred.

Local authorities requested the UN/EC Technical Scoping Mission for data on the possible spread of HCB, as well as heavy metals around the HCB storage site.

The HCB storage site contains 12 modules (basins). Nine modules are filled, closed and covered, the ninth with a smaller layer of clay on top of it. One module (the tenth) is half-used, not completely covered and filled with water. The remaining two modules are not used.

Figure 16: Google Earth image of the HCB storage site.

The HCB storage site modules are basins consisting of a bottom layer of natural clay, followed by a polyethylene film (0.2 mm), rows of three 200-litre barrels on top of each other, filled with sand and stones, a polyethylene film again and 50 cm of clay. Information provided to the mission indicates that during the installation of the modules, water was not prevented from entering. This means that, the barrels may have been in water from the beginning.

As the level of water in the modules is less than 1 metre from the surface, all barrels are in water and likely corroding.

A monitoring network for groundwater was built around the storage site in 1991. This network consists of six, 5 to 8 metres-long metal pipes in the ground. Oriana monitored groundwater until 2005. Thereafter, monitoring was performed by the epidemiological institute in Kalush. No concentrations of HCB were found, apart from one measurement at module 10 in 2008 (in 2009, this point was not sampled because it was a surface water sample and therefore not a sampling point belonging to the groundwater network). The institute analyses HCB with a rather qualitative method, yielding results stating, for example, “presence of HCB acknowledged”.

Flooding, as occurred in 2008, does not affect the HCB storage site as it is at a higher elevation.

On 5 March, the mission received water samples taken by the Kalush epidemiological institute at the normal monitoring points. Most samples were from groundwater, the other from surface water. In addition, a sample for surface water was taken in module 10 (where HCB was detected in 2008) and two samples were taken of the adjacent Sapogiv stream.

The samples were analysed at the Institute for Public Health and the Environment in the Netherlands for HCB and heavy metal concentrations. The mission noted that the monitoring pipes at the storage site were made of metal and were corroding. Thus, metal (iron) concentrations in the water samples were expected and could not be directly linked to corroding barrels in the storage.

Figure 17 and Figure 18 show the sampling points. Points 1 to 6 are on or near the storage site. The other points are further upstream (sampling points 9 and 10) or downstream (points 7 and 8) from the storage site.

Figure 17: Location of sampling points near the HCB storage site.

Figure 18: Sampling points on or near the HCB storage site.

Table 12 gives the measured concentrations of HCB. This table is an extract of Table A2.1 in Annex VIII, where results of other substances are also given. The detection limit for HCB was 0.3 ng/l, which is below the Ukraine standard for HCB concentrations in water of 1 ng/l. All samples contained HCB concentrations higher than the Ukraine water standard. This is remarkable for the samples taken upstream of the storage site (sampling points 9 and 10) and cannot be explained by spreading from the HCB storage site. It is advised to take additional reference samples at these points to verify the findings and clarify the concentrations by possible other upstream sources. Three samples taken at the storage site contain HCB concentrations higher than 100 ng/l. The highest concentration was 3,500 ng/l.

Apart from HCB, the analysis showed the presence of pentachlorobenzene. This substance is a degradation product of HCB and is formed under anaerobic conditions.

The mission considers the sampling points of the monitoring network at the HCB storage site to be adequate for detection of HCB spreading. However, the monitoring network is inadequate for monitoring the spread of heavy metals, and of iron in particular, because the metal sampling pipes in the ground are corroded. Since there are no suspected sources for heavy metals other than the stored (and likely corroded) barrels, this is not the main concern associated with this storage.

Based on the sampling results, it can be concluded that HCB is leaking and spreading into the environment from the HCB storage site. The concentrations in water at the storage facility are a factor 100 (and in some places far more than that) higher than the Ukraine standard. The spreading has reached the local stream and HCB is further spread by the Sapogiv stream.

Table 12: HCB concentrations (ng/l) at the HCB storage site

Sampling point	Type of water	Sample	HCB
1*: south of storage site (around module 8 or 9)	groundwater	water + sediment	**3476**
2: in module 10	surface water	water + sediment	**91**
3*: north-east of module 1	groundwater	water + sediment	**134**
4: south-east of storage site	surface water	water + sediment	**79**
5*: south of storage site, around module 3 (estimated)	groundwater	water + sediment	**169**
6*: north-west of module 8 (estimated)	groundwater	water + sediment	**17**
7*: downstream, near farm	groundwater	water + sediment	**4**
8: river, downstream	surface water	water + sediment	**12**
9*: river, upstream	groundwater	water + sediment	**1**
10: river, upstream	surface water	water + sediment	**9**

Sampling points marked with an * are part of the existing monitoring network

2.2.3. Possible presence of HCB in Mine Waste Dump No. 1 and No. 4

Downstream of Mine Waste Dump sites No. 1 and No. 4, samples of soil and groundwater were taken for analysis of HCB concentrations. The mission had limited time to perform a complete investigation of the spreading of HCB. As such, nine sample points of groundwater (if possible) and soil were taken from the upper layer (maximum depth: two metres), meaning that only the first groundwater layer was sampled. This sampling strategy means that only a screening of potential HCB spreading was conducted. It should therefore be noted that if HCB was not detected, one cannot conclude that no spreading has occurred and a more detailed investigation is advised.

Figure 19: Sampling at the HCB storage site

In Figure 20, the sample points are shown. Samples of soil were taken at all points. However, it was not possible to take groundwater samples at all points as rocks made the ground impenetrable.

Sampling points 1 through 5 are close to some dachas. Sampling point 1 is just outside a back garden. Sampling points 6 through 9 are at a greater distance from houses, but some of these points are located in communal gardens where people are cultivating vegetables for private consumption.

Figure 20: Sampling points near Mine Waste Dump Sites no. 1 and no. 4.

In Table 13, the concentrations in groundwater and soil are given as measured at the sampling points. Note that the concentrations in water are presented in ng/l and the concentrations in soil in ng/g. The concentrations in soil are the concentrations as sampled, not in dried soil, and are therefore not comparable to the standards for soil. This is because the sampling was intended only as a preliminary screening, focused on whether or not HCB was present.

In the water samples, HCB was only detected at sampling point 9. In soil, HCB was detected in more samples, but at low concentrations (<10 ng/g wet ground) in most of them. Only at sampling point 9 was a concentration above the standard for soils found (128 ng/g in wet ground, where the standard is 30 ng/g in dry ground) at the same point where HCB was detected in groundwater.

As Table A2.2 in Annex VIII shows, other pesticides such as Dichlorodiphenyltrichloroethane (DDT) were also found. For comparison, these concentrations are below Dutch standards for soil pollution (1.7 µg/g in dry soil).

Table 13: HCB concentrations near Mine Waste Dump Sites no. 1 and no. 4

Sampling point (see Figure 20)	Sample type	Component	HCB
1	groundwater	water	<0.3 ng/l
		water and sediment	<4 ng/l
	ground		1.2 ng/g
2			
	ground		5.1 ng/g
3	groundwater	water	<0.3 ng/l
	ground		<1 ng/g
4			
	ground		<1 ng/g
5	groundwater	water	<0.3 ng/l
		water and sediment	8 ng/l
	ground		<1 ng/g
6	groundwater	water	<0.3 ng/l
	ground		<1 ng/g
7	groundwater	water	<0.3 ng/l
	ground		<1 ng/g
8	groundwater	water	0.51 ng/l
	ground		5.1 ng/g
9	groundwater	water	3.2 ng/l
	ground (peat)		128 ng/g
	ground (clay)		<1 ng/g

Table 14: Risk assessment of HCB exposure

Issue	Likelihood	Impact
Exposure of humans at HCB storage site	Unlikely (if place is fenced off) in the short term. Likely in the long term.	Moderate Serious
Exposure of the environment at the HCB storage site	Very likely	Serious
Exposure of humans at dump site No. 1 and/or No. 4	Likely	Serious
Exposure of the environment at dump site No. 1 and/or No. 4	Likely	Serious

Figure 21: Pollution investigations near Mine Waste Dump Sites No. 1 and 4

2.3 Response preparedness

Due to the wide array of risks and ongoing hazards present in the Kalush area, a complex response strategy should be in place, linking local responses to regional, national and possibly international response mechanisms. As such, a brief overview is provided of the resources and structures available at the various levels in Ukraine. Based on this, certain gaps in the system are identified.

In Ukraine, the primary responsibility for emergency response lies with the Ministry of Emergencies and Population Protection from the consequences of the Chornobyl Catastrophe, which was established in 1996. The Ministry's coordination and response structures operate at four levels: the national, regional and local levels, and hazard or site-specific level. This structure is designed to allow for escalation of emergency response/coordination, which allows for a top-down or bottom-up activation/approach. In a national emergency, a cabinet of ministers – chaired by the prime minister – will coordinate national strategic issues. In a major emergency, the Ministry has the legislative authority to respond to such disasters. Up to 70,000 civil protection personnel are in place nationally. A generic national emergency plan exists and could be activated in the event of a national catastrophic incident.

Following the declaration of the Kalush area as an ecological disaster zone, additional funds have been allocated to the local authorities to support the voluntary relocation of parts of the population and industrial units; take measures to prevent the contamination of drinking water; and rebuild the open-cast mine. However, there are no specific provisions or roles foreseen for the Ministry of Emergencies, nor are there any budgetary allocations.

The Kalush region is one of the 14 regions of the Ivano-Frankivsk Oblast. As a result of the significant industrial activity in Kalush, it is classified as a "high risk category" for emergency management purposes. Under present legislative arrangements, the city's mayor is mandated with the inter-agency coordination function during local emergency response. Nationwide, there are six rapid reaction centres, one of which is located 20 km from Kalush. These centres are under the direct control of the national administration and can be deployed to support the local emergency services.

In Kalush, all basic emergency response and preparedness arrangements appear to be well in place, including site-specific emergency planning arrangements for the various industrial plants. The arrangements include specific emergency plans, qualified personnel, and equipment and resources in preparation for a variety of emergency scenarios (including search and rescue during flood situations, fire fighting for chemical fires and others). Larger scenarios, such as a tailings dam collapse, have not been included at the local level beyond immediate search-and-rescue activities. Some concerns on the current state of monitoring (for example of drinking water) and early warning devices (in particular linking these monitoring results to emergency services, such as the supply of drinking water) would indicate a need for modernization and investment. Plans are tested and updated at regular intervals, including following major disasters such as the floods in 2008.

Although the emergency services seem to be generally prepared, the impacts of a complex major environmental disaster, such as a collapse or breach of a tailings dam, would most likely be beyond the capacity of local responders and immediately be of national or possibly international dimension. Early warning systems, in particular with neighbouring countries, have not been reviewed as part of this mission. If they exist, they should be well tested and functioning.

3. Conclusions and Recommendations

It is important to note that the current situation in the Kalush area has developed over many years and has been extensively researched by various institutions, government agencies and academia, all of which were considered to be sound and of high professional quality. As such, the problems, including causes and possible solutions, have been well identified. Most of the information contained in this report is therefore a compilation and consolidation of this body of knowledge, with the understanding that little or no verification of the provided baseline data has taken place.

A major underlying cause of many of the problems faced today, including the risk of failure of the tailings dams and salinization of groundwater and surface water, can be traced back to a number of crucial design errors when the mine and its tailings dams were commissioned, and a lack of subsequent appropriate maintenance. The sudden end of operations, without any proper decommissioning measures, not even temporary, has contributed greatly to the current state of the dams and open-cast mine.

It appears that strategic options on the future of the potassium mine activities have a delaying impact on the decision-making process to reduce the current risks of the mining facilities. From a liability perspective, it is not expected that a new investor would assume any responsibility for the mine and tailings in its current state. It is therefore crucial that authorities decide whether to commence with a full process of decommissioning the mine and tailings dams. The current approach of keeping the mine and tailings in a dormant mode of operations does not allow for any structural improvements to be made.

3.1 Conclusions

The UN/EC Technical Scoping Mission concludes that the issues at stake in the Kalush area are of a very complex and often interdependent nature. As such, no detailed and in-depth analysis has been possible within the mission's duration. The mission and its findings should be seen as a first step in a three-phased cycle, consisting of a scoping phase, a technical feasibility phase and a financial support phase.

The UN/EC Technical Scoping Mission considers the overall situation in the Kalush area as serious, and at certain points, critical.

However, a window of opportunity exists currently to prevent the existing situation from deteriorating into a disaster of serious to catastrophic dimensions. This window of opportunity should not be lost.

The mission further considers it unlikely that spring flooding will cause a major threat to the current situation. However, the mission notes with concern that consecutive weather events may worsen the situation rapidly.

The UN/EC Technical Scoping Mission considers the following issues of a critical nature, requiring urgent attention by the Ukrainian authorities:

- The salinization of ground water and surface water and the threat this poses to the drinking water supply

- The design safety levels in the tailings dams should be respected as they form the single-most important risk reduction measure
- The breakthrough of the Dombrovski Open-Cast Mine into the Sivka River is considered to be a very likely event with serious consequences if no corrective/preventive measures are taken
- The spreading of HCB from the HCB storage site into the Sagopiv stream and further downstream

Independent and scientific sampling has shown the spreading of HCB into the environment at the HCB storage site. The concentrations in water at the storage facility are a factor 100 (and in some places far more than that) higher than the Ukraine standard.. HCB is extremely toxic for water environments and is a persistent organic pollutant. The long-term risks of spreading are therefore high.

The UN/EC Technical Scoping Mission considers the dumping of HCB at dumpsite No. 1 and/or No. 4 as likely. There are indications of HCB spreading from these sites in the vicinity of communal gardens where people cultivate vegetables for consumption.

3.2 Recommendations

The recommendations of the UN/EC Technical Scoping Mission have been divided into two parts. The first part provides recommendations at policy level, while the second part provides the technical recommendations. The recommendations are not listed in order of priority.

Recommendation 1
Ukraine, under its international commitments to the Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention), should finalize the draft National Implementation Plan, which includes a section on HCB in Kalush. Following this, it is recommended that discussions take place with the Secretariat of the Convention on the possibilities to receive further financial (co-funding) or technical assistance for capacity-building and the promotion of transfer of technology.

Recommendation 2
As affected communities in the Kalush area are in the vicinity of a planned UNDP-Ukraine risk reduction initiative, it is recommended that discussions take place between authorities and UNDP Ukraine to consider reformulating the UNDP project "Community-based integrated risk recovery from Ukrainian floods"[9] to include the Kalush area, or to initiate a new disaster mitigation project to address the affected communities in the Kalush area in an encompassing risk reduction strategy.

The inclusion of parts of the recommendations of this report in the current United Nations Development Assistance Framework should also be considered.

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[9] The UNDP project "Community-based integrated risk recovery from Ukrainian Floods" introduces innovative approaches based on integrated risk management to control accelerated river bank erosion and activations of landslides in five at-risk villages of the Carpathians. It is a pilot study that will test approaches to risk reduction using the community members as labour force, providing emergency income in times of accentuated economic crises. It will also transfer knowledge of new techniques in securing assets to community members. It will address key UNDP practice areas of natural disaster management and early recovery to recovery through livelihoods and income recovery, infrastructure, shelter-housing, governance and natural disaster response.

Recommendation 3
The Ukrainian authorities should consider discussing with the Environment and Security Initiative possible collaboration on the implementation of the recommendations in this report, in particular if the risk of pollution or other impacts on the Dniester River is identified. Collaboration options could include technical support and/or catalytic co-funding of projects focusing on in-depth assessment studies and capacity-building.

Recommendation 4
Addressing the risks identified by the UN/EC Technical Scoping Mission should be fully integrated into response planning at the local, regional and national levels. As such, monitoring plans (for dam stability, subsidence, environmental contamination, etc) should be clearly linked to early warning systems (including threshold levels for intervention) and response plans.

For the potential international dimensions of any future disaster, the provisions from the UNECE Conventions on the Transboundary Effects of Industrial Accidents and on the Protection and Use of Transboundary Watercourses and International Lakes (including the Safety Guidelines for Tailings Management Facilities developed under these two Conventions), as well as the voluntary Environmental Emergency Guidelines, endorsed by the international Advisory Group on Environmental Emergencies, would provide a useful reference framework.

Ukraine is further encouraged to take advantage of available capacity-building programmes to improve policy and institutional frameworks on industrial safety, in particular the assistance programme under the UNECE Convention on the Transboundary Effects of Industrial Accidents.

Technical recommendations

The next section contains detailed technical recommendations to assist the Ukrainian authorities in abating the current situation in the Kalush area.

Recommendation 5
Given the spreading of HCB, the UN/EC Technical Scoping Mission recommends to urgently undertake a wider investigation into the extent of the spreading, including identifying immediate risks for public health. This investigation should use quantitative method with known detection limits for analysing HCB concentrations in ground, surface and drinking water (including drinking water inlet points).

Recommendation 6
The mission recommends the urgent clean-up of the HCB storage site and the safe storage and/or destruction of HCB. An evaluation of appropriate destruction techniques should inform the actual clean-up. The clean-up of the HCB storage site and waste dump site should be done with care in order to prevent the spread of soil and particles in the air. Toxic concentrations in the air could spread across a wide area if the clean-up is not properly done.

Recommendation 7

Until the clean-up of HCB at the storage site has taken place, the site should be closed to the public to prevent exposure. It would be advisable to fence the area and post signs stating clearly that it is a dangerous site.

Recommendation 8
At Mine Waste Dump Sites No. 1 and No. 4, it is recommended to undertake a thorough investigation to determine the precise location of HCB dumping and the spread of HCB, with special attention to the communal gardens and drinking water wells.

Recommendation 9
The tailings dams are relatively safe in a short-term perspective, under the strict condition that the level in the dams is kept providing a reasonable freeboard and within the designed safety levels. Dam monitoring should be improved by including the measurements of settlements and the amount and content of the seepage water.

Recommendation 10
A free-draining buttress should be added to the toe of Tailings Dam No. 2. The buttress should cover the part of the dam close to the subsidence area of Novo-Holin Mine. This will give the dam an ability to withstand leakage through any potential crack caused by subsidence of the ground underneath the dam.

Recommendation 11
The cover of Tailings Dam No. 1 should be completed in a way that separates surface water from the saline water inside the dam. The top cover should ensure that the wastes inside remain in a semi-dry state. For final decommissioning, Tailings Dams No. 2 and No. 3 should be given a cover, following the same guidelines as for No. 1.

Recommendation 12
The threat of a breakthrough of the Dombrovski Open-Cast Mine into the Sivka River should be eliminated. The solution will, however, require a feasibility study of the options. Until then, the situation must be closely monitored by several new monitoring wells with piezometres to observe the groundwater table level. This monitoring system needs to be clearly linked to the decision-making process of the feasibility study, as well as to the emergency response system.

Recommendation 13
Without further delay, the perimeter drain of the Dombrovski Open-Cast Mine must be rehabilitated to separate the inflow of freshwater from the saline water and brine in the open pit. Intermediate measures could possibly also include establishing a cut-off wall between the River Sivka and the open pit or a sealed conduit (culvert or lined canal) to stop the river infiltrating into the underlying aquifer.

Recommendation 14
The alluvial aquifer should be completely sealed off from the brine in the Dombrovski Open-Cast Mine. The solution to this should be based on a combination of draining and sealing. The drainage should mainly be driven by gravity and minimal pumping.

Recommendation 15
Rerouting of the Sivka River to the west of the pit may have a combined solution. It will eliminate the breakthrough of the river into the pit. It may also form an active barrier between the aquifer and the pit. It is recommended that a detailed feasibility study is undertaken to

determine the positive and negative impacts (including financial and environmental) of such diversion.

Recommendation 16
Mine Waste Dumps No. 1 and No. 4 should be properly decommissioned in order to stop sediment and salt reaching the surrounding waterways and aquifers. It will also stabilize the conditions affecting the Dombrovski Open-Cast Mine. Decommissioning will require flattening of the steep slopes before covering the dumps, which would require the mine waste dumps to be spread out over a larger area (> 100 Ha).

In a long-term perspective, it is recommended to decommission Waste Dump No. 1 together with the northern part of Waste Dump No. 4. Decommissioning should start with the southern part of Waste Dump No. 4 as the northern part will most likely be integrated into the closure of Waste Dump No. 1. The southern part is situated closest to the aquifer and the rivers towards the south and most likely includes toxic waste. The landscaping before covering the waste dump will be a large-scale operation and could lead to the exposure of waste surfaces and to major erosion. The same thing could happen when covering the dump. For this reason, it is important to have effective drainage systems and sediment control features and to implement the covering stepwise (annually) in restricted areas.

Recommendation 17
Until full decommissioning commences, new perimeter drains and a set of sediment control features, such as silt fences, sediment traps and sediment settling ponds, should urgently be constructed around Mine Waste Dumps No. 1 and No. 4.

Recommendation 18
It is expected that covering the waste dumps will drastically reduce the infiltration through the Mine Waste Dumps and seepage of saline water to the aquifer. However, if these measures in the long term prove to be insufficient to reduce the spreading of saline water, additional measures such as cut-off walls around the dumps should be considered.

Recommendation 19
Monitoring of the subsidence should be improved and the wide spacing between the surveying lines filled in. The ground survey should be combined with satellite observations, e.g. LIDAR[10] images. If the subsidence rate increases beyond the average 20 mm annually, evacuation of houses and closure of utilities must be considered.

Recommendation 20
Evacuation and resettlement of houses close to the existing sinkholes should be implemented without further delay. Where objects of significant value on the ground are at risk, backfilling the mine opening underneath could also be considered and, if feasible, implemented.

Recommendation 21
In the long-term perspective, a new land-use planning should be applied based on all the existing underground mines as well as the saline groundwater. Leaving the area with small shallow lakes may be an option without spreading the brine in the mine.

[10] Light Detection And Ranging (LIDAR) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses.

Recommendation 22

An extensive monitoring programme of the salinizatiuon needs to be set up, focusing on:

i) Better characterize the chemical composition (including heavy metals) and alteration of the salt plumes.

ii) Characterize how the spreading of salt corresponds with climatic and hydrologic changes.

iii) Better define how and to what extent salt is spreading to waterways and aquifers (including water balance calculations).

iv) Set up detailed monitoring close to the sources of brines to be able to evaluate the effect of technical measures (rehabilitation and decommissioning).

v) Set up monitoring at the fringes and in front of the salt plumes to be able to evaluate the effect on the significant rivers and aquifers (including effect on the municipal water supply scheme).

vi) Set up programmes for ecological monitoring of affected rivers (including River Limnitsva).

Extensive programmes for decommissioning the brine sources have to be implemented to mitigate the salinization of the aquifers and surface water. However, even if the sources of the brines are isolated or removed, it will be several hundred years before natural flushing of the aquifer occurs. Therefore, two available options should be considered: restrict the use of groundwater in the area of pollution and let nature take its course, or actively address the issue of salinization of the aquifers. For the latter, consideration should be given to the following rehabilitation methods: containment or accelerated discharge.

Annex III contains an overview of a proposed timeline for the recommendations, as well as for consolidated large-scale pilot field studies and intermediate measures.

Annexes

Annex I: Composition of UN/EC Technical Scoping Team
Annex II: Mission Itinerary
Annex III: Timeline for implementation of technical recommendations
Annex IV: Consolidated large-scale pilot field studies and intermediate measures
Annex V: Conductivity measurements
Annex VI: Potential Tailings Dam Collapse – Overview Map
Annex VII: Geological profile of the Kalush mine, Central Kainite field
Annex VIII: Analytical results for HCB and other persistent organic pollutants
Annex IX: Analytical results for salt concentrations in surface water

Annex I: Composition of UN/EC Technical Scoping Team

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Annex II: Mission Itinerary

1 March

Arrival of Ms. Brammann, Ms. Mocellin, Mr. Nijenhuis, Mr. Keeley, Mr. Schols, Mr. Holmstrom, Mr. Valstadt
Meeting with UN Resident Coordinator a.i., UNDP Country Director
Team constitution – tasks and objectives of the mission

2 March

Meeting with UN Resident Coordinator a.i., UNDP Country Director and EC Delegation
Briefing by line Ministries (e.g. Ministry of Foreign Affairs, Ministry of Environment, Ministry of Industrial Policy, Ministry of Emergencies, Ministry of Health)
Arrival of Ms. Van Putten and Mr. Masselink
Discussion of the mission plan

3 March

Working with documents
Meeting with Geology Service of Ukraine
Meeting with Ministry of Emergencies of Ukraine
Meeting with Accounting Chamber of Ukraine
Travel to Ivano-Frankivsk

4 March

Meeting with Mr. Mykola Paliychuk, Head of Ivano-Frankivsk Oblast State Administration with press participation (local and national television)
Travel to Kalush City
Briefing by Deputy Major of Kalush, Mr Vasyl Petriv
General Assessment of the sites with City representatives

5 - 7 March

Kalush sites assessment and sampling:
Tailings dams 1, 2 and 3
Dombrovski open-cast mine (closed from operation)
Hexachlorobenzene Storage Site
Subsidence areas and sink holes
Meeting with local emergency services
Briefing by National Technical University of Oil and Gas, Ivano-Frankivsk
Briefing by State Research Institute of Halurgy
Meeting with the Institute of Epidemiology

8 March

Return travel to Kiev
Meeting of UN/EU Assessment Team to discuss and draft final report
Videoconference with the MIC – Debriefing

9 March

Debriefing meeting UN/UNDP Senior Management
Meeting with Deputy Head of the Office of the President, Ms Iryna Akimova
Joint Meeting, chaired by the Minister of Foreign Affairs, H.E. Mr Poroshenko, with relevant Ministries of Ukraine and donors
Departure of the team

Annex III: Timeline for implementation of technical recommendations

Short-term perspective (0-1 year)

- Conduct the necessary maintenance to avoid failure of Tailings Dam No. 2.
- Establish better and more comprehensive monitoring system together with the necessary assessments for it to be established.
- Characterize the site conditions more comprehensively.
- Characterize available geological and waste materials for use in the constructions for decommissioning or rehabilitation.
- Conduct conceptual design for the constructions for decommissioning or rehabilitation (covers, buttresses, drainage systems, cut-off walls, etc.).
- Conduct training programmes in environmental monitoring and environmental engineering for the local and regional institutes.

Intermediate perspective (1-3 years)

- Conduct design and implement large-scale pilot field trials for all facilities to be decommissioned or rehabilitated, together with performance monitoring and evaluation. Such stepwise approach is necessary to predict the environmental risks and construction costs before deciding final solutions. The field areas to be chosen for pilot trials will be those most urgent for action at the tailings dams, mine waste dumps, toxic waste dumps, open-cast mine and underground mine shafts.

Long-term perspective (3-6 years)

- Conduct the final design and construct the technical measures necessary for decommissioning of rehabilitation of the tailings dams, saline-solution collectors, mine waste dumps, toxic waste dumps, open-cast mine and underground mine shafts.
- Conduct long-term performance monitoring of decommissioned facilities.

Annex IV: Consolidated large-scale pilot field studies and intermediate measures

The intermediate measures to be conducted as a large-scale pilot field study should correspond with the most urgent large-scale measures. As mentioned previously, these are:

1. <u>Tailings Dam No. 2 – Tailings dam safety measures</u>
   Complement the western dam embankment with buttress, toe drains and reduced slope angles with better cover against erosion.

2. <u>Dombrovski Open-Cast Mine – Proactive measures to avoid flooding of the pit</u>
   Establish a cut-off wall between the River Sivka and the pit or a sealed conduit for the River Sivka. Reduce slope angles of the overburden down to the cap rock at the northern end of the pit. Establish a new perimeter drain between the River Sivka and the northern end of the pit.

3. <u>HCB storage site – Possible decommissioning of selected storage modules/cells.</u>
   If the HCB waste is not to be destroyed, measures should be taken to isolate the waste. Most likely this would include covering/sealing of the modules in which the waste is deposited. Pilot field trials should then be set up to construct such measures for one or two modules. Because of the very toxic nature of the waste, the site's physical and environmental conditions should be carefully assessed before and after such field trials.

4. <u>Mine Waste Dump No. 4 – Decommissioning of the southern part of the dump.</u>
   Landscape the dump to establish the correct slope angles. Establish a multi-layer cover for the dump, including low permeability soil liner, drainage layer and protection cover with vegetation. Establish new drains around the dump.

5. <u>Tailings Dam No. 1 - Decommissioning of the southern part of the tailings dam.</u>
   The southern embankment of the tailings dam is the worst affected by erosion and releases most brine to the environment. Measures include landscaping the southern quarter of the tailings dam; establishing a multi-layer cover for the dump, including low permeability soil liner, drainage layer and protection cover with vegetation; reducing slope angles of the embankment with better cover against erosion; and establishing drains for surface water and seepage from the tailings dam.

6. <u>Underground mines - Grouting and backfilling of the Eastern Holyn Mine field.</u>
   The subsidence and collapse of the underground mines at the eastern part of the Novo Holyn Mine could lead to severe destruction of land and properties. It is also a major threat to the environment and water supply of Kalush due to salinization. For this reason, the mine field could be suitable for large-scale pilot field trials directed towards improved methods for backfilling and grouting of underground caverns and shafts.

Annex V: Conductivity measurements

Below tailings dams

Table A1.1: Conductivity measurements – below tailings dams

Reading No.	El. Conductivity (mS/m)	Temperature (˚C)	Photo Ref. No.	Comments
1	2200	-	056	Stream N.E. side of TD2
2	2220	-	057	Just downstream large seepage point
3	17600	4	058	Just downstream large seepage point
4	16750	7,2	059	Lower part of salt fan, E side of TD2
5	16700	9,5	060	Seepage just above salt fan
6	1600	1,7	064	Seepage on N. side of TD2
7	31	2,2	065	Channel N. of road on N. of TD2
8	850	1,7	066	Seepage close to crest N.W. side of TD2
9	192	2,7	070	Seepage on W. side of TD2
10	200	0,3	071	Channel W. side of TD2
11	5700	4,7	072	Seepage on S.W. of TD2
12	52	1,1	072	Channel S.W. side of TD2
13	3900	4,3	073	Seepage channeled S.W. side of TD2
14	2330	2,1	074	Channel S.W. of TD2
15	5040	6,4	077	Seepage/stream in gully N.W. side of TD1
16	1150	2,1	077	Stream N.W. of TD1
17	1550	1,8	077	Stream N.W. of TD1
18	15400	1	078	Seepage/stream in gully W. side of TD1
19	380	0,5	079	Stream in gully, close crest, W. side of TD1
20	11350	2,1	082	Seepage channeled S.W. side of TD1
21	112	1	083	Channel S.W. of TD1
22	16800	0,7	084	Seepage channeled S.W. side of TD1
23	3890	0,7	085	Seepage channeled S. side of TD1
24	2700	1,7	086	Channel S. of TD1
25	14700	6,5	091	Stream in gully, close crest, S. side of TD1
26	9900	2	093	End of channel S.E. of TD1

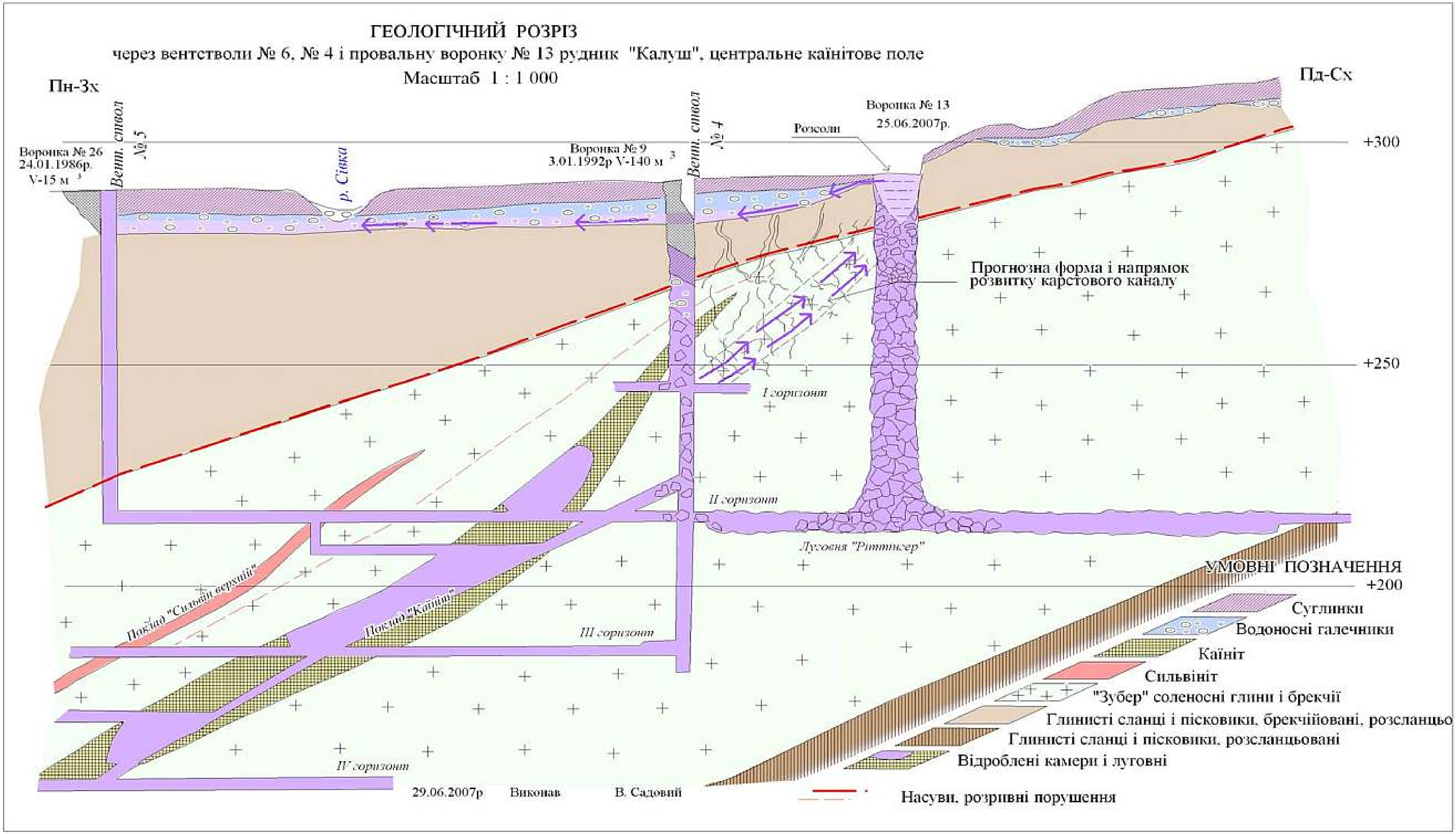
Below waste dumps

Table A1.2: Conductivity measurements – below waste dumps

Reading No.	El. Conductivity (mS/m)	Temperature (˚C)	Photo Ref. No.	Comments
1	4000	2,6	1	Dike S.W. of Waste Dump No. 4
2	1370	0,5	2	Stream in ravine into ring channel
3	15300	5,3	3	Dike S.E. of Waste Dump No. 1
4	14200	4,5	4	Channel towards the E., S.E. of WD No. 1
5	8000	2	-	Channel towards the N., E. of WD No. 1
6	17810	6,2	5	Stream on road flowing into ring channel

Annex VI: Satellite Overview Map – UNOSAT

Annex VII: Geological profile of the Kalush Mine, Central Kainite field



Geological profile through the shafts No. 6, No. 4 and sinkhole No. 13 of the Kalush Mine, Central Kainite field. The arrows show the flow of salinized groundwater from the shafts to the water-bearing strata and the River Sivka. The pathways of the groundwater flow are due to fracturing and karstification around the shafts and sinkholes.

Annex VIII: Analytical results for HCB and other persistent organic pollutants

Table A2.1: Concentrations of organic pollutants at and near the HCB storage site (concentrations in ng/l)

Sampling point	Type of water	Sample	Pentachloorbenzeen	Trifluralin	HCB	beta-HCH	o,p-DDE	p,p-DDE	o,p-DDT	p,p-DDT	Mirex	PCB-52	PCB-101	PCB-118	PCB-138	PCB-153
1: south of storage site (around module 8 or 9)	groundwater	water + sediment	**16**	<0.3	**3476**	<1.7	<0.2	<0.5	<0.4	<0.6	<0.5	<0.4	<0.4	<0.3	<0.5	<0.4
2: in module 10	surface water	water + sediment	**241**	**0.46**	**91**	<1.9	<0.2	<0.5	<0.4	<0.5	<0.5	<0.4	<0.4	<0.3	<0.6	<0.5
3: north-east of module 1	groundwater	water + sediment	**9.2**	<0.5	**134**	<2.1	<0.4	**1.6**	<0.8	<1.1	**2.5**	**0.7**	<0.5	**0.95**	<0.8	**1.2**
4: south-east of storage site	surface water	water + sediment	**7.7**	<0.7	**79**	<2.4	<0.3	<0.6	<0.6	<0.8	<0.7	<0.5	<0.5	<0.5	<0.7	<0.6
5: south of storage site, around module 3 (estimated)	groundwater	water + sediment	**98**	<0.3	**169**	<2.0	<0.3	<0.6	<0.6	<0.8	<0.6	<0.4	<0.4	<0.6	<0.6	<0.5
6: north-west of module 8 (estimated)	groundwater	water + sediment	**3.3**	<0.4	**17**	<1.9	<0.3	<0.5	<0.5	<0.6	<0.5	<0.4	<0.4	<0.3	<0.6	<0.5
7: downstream, near farm	groundwater	water + sediment	**0.5**	<0.3	**4.4**	<1.7	<0.2	<0.5	<0.5	<0.5	<0.5	<0.4	<0.4	<0.3	<0.5	<0.4
8: river, downstream	surface water	water + sediment	**1.2**	<0.6	**12**	<2.5	<0.3	<0.6	<0.6	<0.8	<0.6	<0.5	<0.5	<0.4	<0.7	<0.6
9: river, upstream	groundwater	water + sediment	<0.3	<0.5	**1.1**	<1.9	<0.2	<0.5	<0.4	<0.5	<0.5	<0.4	<0.4	<0.3	<0.5	<0.4
10: river, upstream	surface water	water + sediment	**0.8**	<0.5	**8.8**	<2.2	<0.3	<0.5	<0.5	<0.6	<0.6	<0.5	<0.4	<0.4	<0.7	<0.5

Table A2.2: Concentrations of organic pollutants around the Dombrovski open-caste mine (water concentrations in ng/l, concentrations in ground in ng/g)

Sampling point (see Figure 2020)	Sample type	Analysed fraction	Unit	Pentachloorbenzeen	Trifluralin	Hexachlorobenzene	beta-HCH	o,p-DDE	p,p-DDE	o,p-DDT	p,p-DDT	DDD op'- [TDE]	DDD pp'- [TDE]
1	groundwater	water only	ng/l	<0.4	<0.5	<0.3	**2.1**	<0.2	**0.6**	<0.7	<0.5		
		water and sediment	ng/l	<3	<	<4	**15**		**35**	**8**	**43**		
	ground		ng/g			**1.2**	**1.6**	**1.4**	**40**	**8.7**	**32**	**15**	**33**
2													
	ground		ng/g			**5.1**	<1	<1	**1.8**	**1.1**	**3.2**	<1	1.5
3	groundwater	water only	ng/l	<0.3	<0.4	<0.3	<1.6	<0.2	<0.4	<0.4	<0.4		
	ground		ng/g			<1	<1	<1	**1.2**	<1	<1	<1	<1
4													
	ground		ng/g			<1	<1	<1	<1	<1	<1	<1	<1
5	groundwater	water only	ng/l	<0.4	<0.5	<0.3	<2.0	<0.2	<0.5	<0.4	<0.5		
		water and sediment	ng/l	<3	<	**8**	<13		<6	<5	<8		
	ground		ng/g			<1	<1	<1	<1	<1	<1	<1	<1
6	groundwater	water only	ng/l	<0.3	<0.5	<0.3	<1.9	<0.2	<0.5	<0.4	<0.5		
	ground		ng/g			<1	<1	<1	<1	<1	<1	<1	<1
7	groundwater	water only	ng/l	<0.4	<0.5	<0.3	<2.1	<0.3	**2.2**	<0.4	<0.6		
	ground		ng/g			<1	<1	<1	**4.4**	<1	**3.0**	<1	2,5
8	groundwater	water only	ng/l	<0.5	<0.7	**0.5**	<2.5	<0.3	<0.6	<0.5	<0.7		
	ground		ng/g			**5.1**	<1	<1	1,1	<1	**1.4**	<1	<1
9	groundwater	water only	ng/l	<0.3	<0.5	**3.2**	<2.2	<0.3	<0.5	<0.5	<0.8		
	ground (peat)		ng/g			**128**	<1	<1	<1	<1	<1	**2.9**	**11**
	ground (clay)		ng/g			<1	<1	<1	<1	<1	<1	<1	<1

Annex IX: Analytical results for salt concentrations in surface water

Table A3.1: Elements in surface water samples near Tailings Dam No. 1.

Sampling point	Na	Mg	P	Cl	K	Ca	Cr	Mn	Fe	Cu	Zn	Sr	Cd	Pb
Detection limit (DL)	0.2	0.05	0.05	0.21	0.1	0.15	0.5	4	0.05	0.5	4	1	0.05	0.2
unit	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	**µg/l**	**µg/l**	mg/l	**µg/l**	**µg/l**	**µg/l**	**µg/l**	**µg/l**
1 (downstream Sivka, at bridge near main road)	72	15	0.02	24	22	34	0.7	80	0.40	1.9	7.3	227	0.1	0.4
2 (downstream Sivka, near Dombrovski open mine pit)	82	16	0.03	138	25	34	0.7	84	0.40	1.9	6.1	234	0.1	0.4
3 (from pool near Tailings Dam No. 1)	27040	6060	< D.L.	56258	8836	251	< D.L..	873	< D.L.	< D.L.	< D.L.	2650	18.0	< D.L..
4 (upstream Sivka)	26	6.7	0.02	37	3.1	34	0.7	52	0.30	2.3	4.5	223	0.1	0.4
5 (in stream from Tailings Dam No. 1 to Sivka)	122	36	0.04	267	44	32	0.5	134	0.40	2.2	12	177	0.0	0.4

Table A3.2: Salts in surface water samples near Tailings Dam No. 1.

Sampling point	NO3	SO4
Detection limit (DL)	0.31	0.48
unit	mg/l	mg/l
1 (downstream Sivka, at bridge near main road)	9.5	102
2 (downstream Sivka, near Dombrowski open mine pit)	8.8	112
3 (from pool near Tailings Dam No. 1)	0.0	18548
4 (upstream Sivka)	8.0	60
5 (in stream from Tailings Dam No. 1 to Sivka)	17	130

Note: PO_4^{3-} could not be analysed, but since the concentrations of P in Table A3.1 are low, this concentration must also be low.