

Contamination in Industrial Areas and Environmental Management in Latvia

Juris Burlakovs, Maris Klavins, Raimonds Ernsteins, and Armands Ruskulis

Abstract—Environmental contamination is a common problem in ex-industrial and industrial sites. This article gives a brief description of general applied environmental investigation methodologies and possible remediation applications in Latvia. Most of contaminated areas are situated in former and active industrial, military areas and ports. Industrial and logistic activities very often have been with great impact for more than hundred years thus the contamination level with heavy metals, hydrocarbons, pesticides, persistent organic pollutants is high and is threatening health and environment in general. 242 territories now are numbered as contaminated and fixed in the National Register of contaminated territories in Latvia. Research and remediation of contamination in densely populated areas are of important environmental policy domain. Four different investigation case studies of contaminated areas are given describing the history of use, environmental quality assessment as well as planned environmental management actions. All four case study locations are situated in Riga - the capital of the Republic of Latvia. The aim of this paper is to analyze the situation and problems with management of contaminated areas in Latvia, give description of field research methods and recommendations for remediation industry based on scientific data and innovations.

Keywords—Remediation technology, environmental quality assessment, heavy metals, hydrocarbon contamination, environmental management.

I. INTRODUCTION

SOIL and groundwater are environmental compartments that are primarily influenced by industrial development with increasing amount of industrial wastes and inadequate dumping of them. It causes a large number of contaminated sites that are disseminated in post industrialized countries [1, 2]. The 1960s can be supposed as a keystone in environmental thinking – to comprise such development that has to be based on the coexistence of the environment and industry. Throughout Europe and the USA contaminated land and hazardous sites became generally recognized in the 1970s, but a decade later most industrial nations started efforts to systemize the decision-making process for the evaluation and treatment of contaminated land. [3] In the EU estimated contaminated sites vary from 300,000 to 1.5 million that is

due to the uncertainty of the common definition for contaminated sites, different approaches to acceptable risk levels, and exposure parameters [4]. Later on there has been reported that according to the European Commission the EU counts ~ 3-5 million potentially contaminated sites and 500,000 sites known as contaminated sites. The latter needs remediation activities [5]. Methods and procedures for the ascertaining of polluted and potentially polluted sites, as well as the procedures for financing, conditions for data collection and utilization are regulated by instructions, which are derived from Directives of the European Union (EU) in the law system of the Republic of Latvia [6]. In Latvia the assessment and evaluation of contaminated and potentially contaminated sites began in the 1980s. The National Register of Contaminated Territories (NRCT) of Latvia was established in 2002 [7]. The NRCT covers the territories that are contaminated with various materials, inorganic and organic including hazardous and non- hazardous substances. In the NRCT the sites are divided in 3 categories using the following criteria. The first category includes the sites, where contamination exceeds the acceptable normative 10 times or more. The use of these areas for new building or land use purposes is possible only after territory remediation actions.

Research methods must be used to determine distribution and spatial spread of the contamination in order to apply best remediation and risk prevention strategies. [2]

Former brownfields are potential sources of environmental contamination. Site investigations are aimed at detecting and determining the extension of the polluted area and for that purpose, very often are used resistivity and/or electromagnetic geophysical methods. These studies are possible because both organic and inorganic chemicals can cause a large variation (usually a decrease) in the electrical resistivity of the earth material [8, 9]. Complex of geophysical methods can be used together with common geological and environmental research techniques. When the research is done, conclusions allow deciding what to do with the contaminated area.

The aim of remediation activities is to transform unusable property into available use and conserve land resources, to improve environmental conditions in the contaminated site and around it as well as to reduce the risk to humans and the environment. Remediation means actions taken to cleanup, mitigate, correct, abate, minimize, eliminate, control and contain or prevent a release of a contaminant into the environment in order to protect human health and the environment, including actions to investigate study or assess any actual or suspected release. Remediation may include,

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when appropriate and approved by the department, land use controls [4]. Remediation technologies can be divided into two categories: *in-situ* and *ex-situ* remediation methods [10] as well as on site and off site technologies.

The remediation technology must be chosen to decrease the mobility of pollutants and in order to choose the method the pre-investigation must be done in stages: 1) existing historical and documentary data analysis; 2) site visual assessment; 3) soil and groundwater sampling and analysis; 4) simplified hydrogeological calculations; 5) data processing and technology choose; 6) technical economic pre-evaluation of chosen technology [11, 12].

II. MATERIALS AND METHODS

A. Field Research Stage

Sampling sites in all 4 described case studies were chosen after careful analysis of historical research study materials. Sampling of soil and groundwater was done and the total area covered the area of historically known contamination with nearest neighborhood, parameters for analysis were chosen after careful documentary analysis.

The first sub-category, which can be outlined in a distinct way, contains the *former dump sites* of mixed waste. In former USSR municipal, residential, housing, and building waste as well as hazardous substances and materials were often dumped in these dump sites.

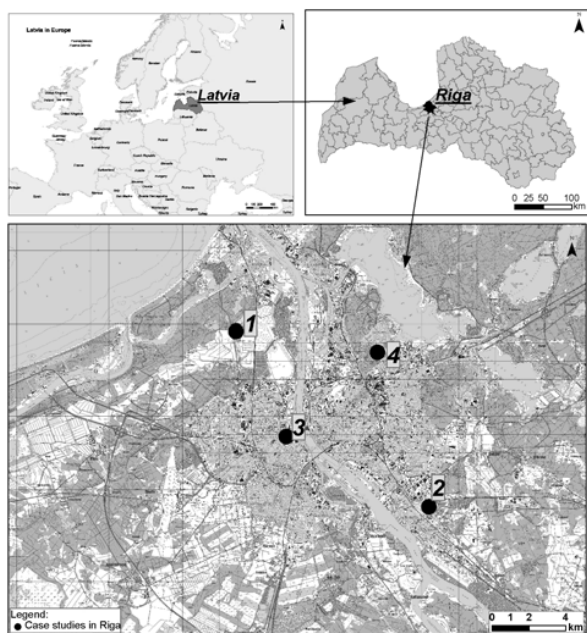


Fig. 1 Location of case studies in Riga

1) *Kleisti Dump Site*. The VLF-EM is an electromagnetic method and operates in frequency ranges between 5 and 30 kHz. This method is considered as one of geophysical methods used in contamination plume research.

Electromagnetic data was collected and interpreted in order to plan drilling and sampling sites for evaluation of contamination in soil and groundwater. Drilling works were done with *Fraste „Terra - in”* and *“Iveco”* drilling machines. The auger drilling method has been chosen, and boreholes 1-12 m of depth were drilled, including those done through the waste [13]. Temporary monitoring wells were input in sites around and on the dump hill sites. Groundwater sampling and further analysis of possible contamination parameters were done. Surface waters, sediments from ditches were sampled in closest area around these two dump sites on indicative parameters. The odor testing was done for the air sampled from the waste massif, in order to quantify the possible smell emissions while works of re-cultivation would be done. Emissions and gases were calculated based on the U.S. Environmental Protection Agency developed model LandGEM (Landfill Gas Emission Model - Version 3.02.) [14].



Fig. 2 Kleisti Dump Site (Nr. 1 in Fig. 1) Location of drilling sites, leachate and groundwater flow directions

LandGEM calculations are used for household waste decomposition rate of the first order equation which takes into account the decomposition of waste disposed in municipal solid waste landfills. This program provides a relatively simple approach gases emissions assessment. Models developed in the U.S. dumps empirical observation basis. The model adopted in the data may instead be placed in the field observations.

Areas of *industrial contamination (brownfields)* – in these territories a lot of raw materials including heavy metals,

various their compounds, inorganic and organic substances have been used. Industrial development simultaneously caused site contamination that in many cases is set as historical contamination. The former military industrial areas could also be included in this sub-category, but in the frame of the current paper we separate those for better understanding [15].

2) *Former wooden industry brownfield*. Similarly to the first study sampling of soil with was done from the upper part of the soil cover till the depth of approximately 0.3m, to estimate the soil quality at the research territory. Totally 50 soil samples were taken, mixed in 2 joint soil samples, which represent soil quality. 13 deep samples were taken and all of samples were analyzed for oil products and heavy metal concentrations (Cu, Ni, Pb, Zn, Cd, Cr, Hg and As). 8 groundwater monitoring wells were equipped and after the stabilizing of parameters 8 groundwater samples were taken for OPC (oil product concentration), COD (chemical oxygen demand), BOD (biological oxygen demand), dry matter content, N_{total} , P_{total} and chloride concentration. Also from three of eight wells there were taken additional samples for heavy metal concentration detection (Cu, Pb, Zn, Hg, Cd, As, Cr).

General group of contaminated areas in Latvia comprises ex-warehouses, former and existent fields of iron-scrap, the well-worn industrial facilities, territories with various contaminating materials and substances, e.g. agricultural chemicals. Their further use is frequently liable after adjustment activities in these territories however the environmental and risk assessment must be done in order to obtain information on environmental situation and quality of those territories. Remediation market in Baltic States including Latvia is still developing in a fast rate. Environmental consulting enterprises are doing assessments of environmental quality while the construction companies after bureaucratic procedures can proceed with remediation works [15].

3) *Former agricultural machinery factory*. Sampling of soil was done in the upper part of the soil till the depth of 0.3m and 0.5-0.8m in 3 sectors (90 samples mixed in 6 joint samples). 16 groundwater monitoring wells were installed. Pumping tests were performed in order to gain the data to plan pump-and-treat use for remediation. All soil samples were analyzed for Zn, Cu, Pb, Cd, Cr, Ni, OP content. The groundwater was analyzed for same parameters and COD, BOD additionally.

Territory geomorphology is slightly undulating and technogenically changed. Earlier the area was the floodplane of the armlet of the River Daugava, but now it is covered by approximately 4 m thick technogenic filled soil layer, which is made of sand, debris, mud and other wastage. The filled soil almost at all of the territory is underlayed by 0.5 m thick flood plane mud and clayey sand. Thick Littorina Sea fine marine sand sediments are embedded under this layer by several meters. Hidrogeologically the first groundwater horizon is upper groundwater and it is found in filled soil as well as in marine fine sand sediments. Areas, where there is no mud or

clayey sand, groundwater makes the common groundwater horizon. Groundwater level in the territory depending of the season is at the depth of 0.9m till 2.1m from the surface. The wider amplitude of levels can be seen in filled soil layer (up to 0.9m). The direction of the groundwater flow is to the River Daugava. Ground and groundwater in the territory is strongly contaminated with heavy metals, separate areas also with oil products [16]. Thus geological and geomorphological conditions are improving the leaching of contaminants to the River Daugava and the Baltic Sea.

Two cycles of the research were done here in 2001 and 2008-2009 with following remediation of solvent and heavy metal contamination in 2002-2004 and 2009 respectively.

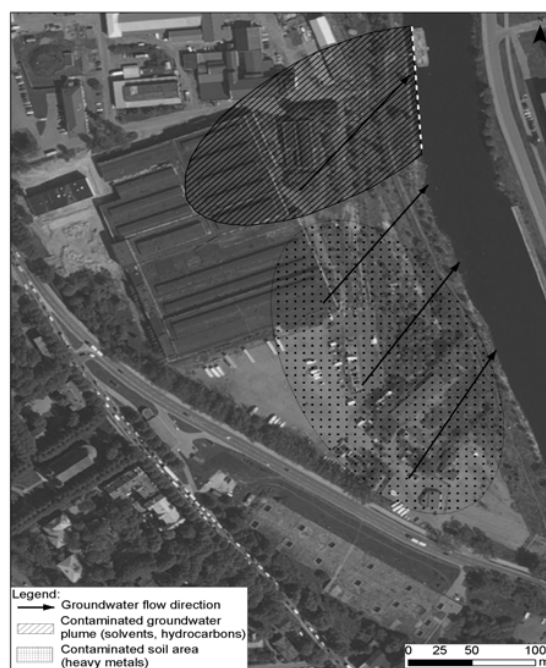


Fig. 3 Former agricultural machinery factory "Selmash" (Nr. 3 in Fig. 1). Contaminated areas with heavy metals and solvents, two cycles of remediation done in 2002-2004 and 2009

Another very important group is *former military territories*, after the collapse of the former USSR. After the World War II more than 1,000 units of Soviet Army forces were located in about 600 military objects that occupy ~ 10% of Latvia territory. The largest firing-grounds were Zvārde, Liepājas Navy port (Karaosta), Rudbārži missile base, and Lielvārde airfield. Site pre-investigations and remediation has been carried out in some of former military territories, e.g. Rumbula airfield where soil and groundwater was contaminated with oil products. Total area of 6 ha is contaminated with oil products and during 2000-2002 there were pumped out 1730 m³ contaminated groundwater (~80 m³ pure oil product) [7]. Contamination with heavy metals, toxic organic substances, and also with oil products was determined in about 11 military territories. In spite of the remained historical contamination

some of these territories are readjusted for the use of another purpose, e.g. the area of Riga Freeport.

4) *Former military warehouses area.* To estimate the soil quality at the investigation territory, sampling of soil was taken from the upper part of the soil in the depth of 0.40 m. A hand probe was used for this purpose. The sampling territory of 30ha was split into 7 sub-areas, each of 4-5 ha area on average. One joint sample was taken in deeper horizon (0.4-1.0 m) of the soil. Seven drilling points in 7 sub-areas were selected, and 7 deeper samples were mixed in a joint sample in order to have the information about the average heavy metal content in the deeper interval for the whole area. 175 shallow and 7 deep samples were taken from each of these sub-areas and accordingly mixed in 7 and 1 joint samples for heavy metal laboratory analysis [17].

B. Remediation Planning

All the data was carefully analyzed, results compiled in reports and compared to legislation. Research steps allowed to give main conclusions for the recommending the best available technologies for remediation. Following remediation technologies are or can be applied in Latvia: 1) stabilization/solidification (S/S); 2) soil flushing; 3) electrokinetic treatment; 4) phytoremediation and 5) bioremediation. The applicability of remediation technology is dependent on site-specific conditions, type of contaminants and other factors. The following contaminated site division can be proposed – former dump sites of mixed waste, former military territories, industrial brownfields, especially liquid and semi-liquid hazardous sites, and in general contaminated areas. Mostly contamination with heavy metals and oil products was observed in all case studies reported in the article. Four case studies described in the paper have similar geological and hydrogeological properties of site, but different scale of the problem. Thus remediation also was planned and done in different scale.

C. Project Risks and Difficulties

The opportunity to collaborate within the EU remediation framework of historically contaminated territories gives one a chance to carry out environmental research and follow-up with remediation projects in problematic areas. The problem is that some of contaminated areas are still not in the priority list, but anyway create problems for the environment and block the use of these areas for residential and commercial reconstruction. These projects should be viewed as pilots for further development of remediation works in Latvia. The use of technologies for the remediation and demobilisation of toxic agents should contain further research after the pre-assessment and might be done to draw a technical economic sketch for the use of remediation technologies regarding the type of contamination, the size of the problem and the specifications of the investigated areas. After careful analysis contaminated areas were divided according amount, concentration of pollutants, land use, geological and hydrogeological situation. Risks on implementation of project

strategies include not only technical difficulties, but financial and legislative aspects as well. If the area is of greater economic interest then more investors are ready to deal with the contamination problem and are ready to solve it. In such scenario cheaper and more effective remediation choice is of great importance.

D. Implementation Stage

As contaminants such as oil products are very often found in former brownfield and military areas, contaminant sources, amount and flows would be determined before the implementation of remediation starts. Excavation of contaminated soils can be applied, but only if these can be transported to hazardous waste landfill and if the amount is negligible; otherwise it is not acceptable. The network of groundwater monitoring wells in surroundings must be developed, where regular monitoring of groundwater will be performed to control the contaminant flow / groundwater quality and flow direction in future. It is recommended to carry out a risk assessment based on a planned regular (2-4 times per year) groundwater monitoring data. In addition, groundwater quality in surroundings and planned residential and commercial building areas with random selection method should be regularly monitored. The final implementation of remediation works is done by construction companies after the careful consideration of capabilities in order to avoid the mismatch of those to the size and importance of problem. The supervision and control is done by legal institutions and expert teams.

III. RESULTS AND DISCUSSION

1) *Kleisti Dump Site* was used for disposal of various type of waste in 50-ties to 70-ties of 20th century, the contamination was clearly detected in the dump mass, main concern of the contamination was regarding heavy metals and oil products. Riga Development Plan 2006-2018 [13, 18] says that old former dump sites must be remediated and re-cultivated according environmental legislation, thus two cycles of research were done. Examinations of studies indicated that the most contaminated parts are the soft dry waste layer and the water saturation (infiltrate) under the waste layer. Dry waste layer in both dump sites is seen to have very strong heavy metal pollution, but leachate - a high content of heavy metals and organic substances, including petroleum products. Also concentration of total nitrogen, nitrogen compounds, total phosphorus, chlorides, sulfates were detected, as well as indicative parameters of COD and BOD. Additionally microbiological analysis was done (*Escherichia coli*, total coliforms, microbial colonies and enterococci). The research results on COD, BOD, chlorides and nitrogen in groundwater show great environmental impact of leachate in the direction of dominating groundwater flow [18].

2) *Former wooden industry brownfield* is not listed in the list of contaminated sites, but there was detected considerable contamination of soil in several sites from 1.1-8.6 g/kg.

Groundwater contamination did not appear during the pre-assessment that can be explained on very dense geotechnical conditions of the soil and disturbed groundwater flow through and around the filled soil layers. Possibly the leaching of OPC contamination plume by precipitation in groundwater is happening here. There were no heavy metal contamination exceeding legislative limits detected in the area, but some higher values of Cu, Pb and Cr comparably to geochemical averages were found [19].

3) *Former agricultural machinery factory* area at some places is highly contaminated with OP, BTEX (benzene, toluene, xylene and ethylbenzene) and heavy metals, so that this area experienced two remediation cycles and two assessments of environmental pollution. The first remediation cycle was done in a 3 year long time period regarding the solvent (BTEX) pollution, which included regular pump-and-treat works. After the first remediation cycle still was found a great amount of pollution with OP, BTEX and heavy metals, which were found during the second assessment. Legislative organs demanded the second cycle of remediation regarding OP and heavy metals, which was completed in 2009, so that HM values were diminished under the critical level, but the solvent problem remained [16].

4) *Former military warehouses area*. Former military area 'Jaunais Mežaparks' has slightly higher ordinary metal and heavy metal contents in soil due to previous logistic and warehousing activities in the past. Point sources of heavy metal contamination possibly are leaching further to the groundwater. Visual assessment and photographic evidence provided material that area is possibly polluted also with oil products. The contamination is not very high like in areas of directly industrial soil as in most contaminated parts of Riga and Liepāja harbors, but still is exceeding target values. Heavy metal content in soil can be additionally influenced by anthropogenic atmospheric loads as the diffusive pollution [20].

TABLE I
COMPARISON OF RESEARCH TECHNOLOGIES

Site	Research methods	Stages for problem solution
Kleisti Dump Site	Geophysical Geological Hydrogeological Modelling Soil, groundwater, leachate, waste analysis Microbiological waste and leachate analysis LandGEM air emission modeling Olfactometry	1) Pre-investigation decision to promote detailed research 2) Detailed research finished 3) Remediation planning one 4) Solving environmental management and legislation problems 5) Implementation of the remediation (in progress) 6) Risk assessment (in future)
Former wooden industry brownfield	Geological Hydrogeological flow analysis Soil, groundwater analysis Environmental risk analysis	1) Pre-investigation decision to promote detailed research 2) Object not in priority list – decision for risk monitoring 3) Perspective remediation planning in future (recommendatory)
Former agricultural	Geological and hydrogeological research	1) Pre-investigation 2) Environmental hazard

<i>machinery factory</i>	Remediation 1. stage by pump-and-treat and after assessment Detailed 2. stage research of soil, groundwater Contamination hydrogeological modeling	diminishment by 1 st stage remediation (pump-and-treat) 3) Detailed research and creating the remediation action plan 4) Soil and groundwater 2 nd stage remediation 5) Object status change (taken out from the list of contaminated sites) 6) Construction works 7) Risk assessment and monitoring system (in future)
<i>Former military warehouses area</i>	Geological and geophysical research Hydrogeological flow evaluation Soil and groundwater analysis	1) Pre-investigation decision to promote detailed research 2) Object not in priority list – decision for risk monitoring 3) Future land use planning 4) Preparation for construction in future 5) Monitoring plan (advisable, not recommended officially) 6) Construction works

Former industrial sites of various contamination amount and concentration can be composed of hazardous waste as well as all other types of waste. In the former USSR, various kind of municipal, residential and construction waste as well as hazardous substances and materials were often deposited as in dump sites and industrial and military areas, which now can be classified as brown fields.

These sites must be remediated and re-cultivated and the risk assessment of ecological threats must be done. Four sites mentioned in the article are describing most common types of contaminated areas and research practices in order to decide the plan for the type of remediation and risk diminishment.

All contaminated areas must be researched and the plan must be as follows: a) Site identification and historical data analysis; b) Visual assessment and designing the pre-investigation; c) Pre-investigation (geological and/or geophysical); d) data analysis and the choice of best available remediation and/or risk hazard diminishment technology; e) detailed research of the site; f) technical economic analysis and calculations of costs; g) implementation control; h) post-remediation monitoring.

IV. CONCLUSION

Legislative aspects, environmental quality assessment, costs, risk assessment and detailed remediation and post-remediation planning should be performed as well as technologies for comparison evaluated in order to start the process.

The fate of contaminants, including heavy metals, macrocomponents, oil products, various chemicals and other COD and BOD agents must be estimated before the process of remediation can be started. Historical information and data from previous research stages give the main core for the decision making. Different land use in former times lead the pre-investigation for environmental quality assessment and

afterwards special technologies of remediation can be applied such as:

a) *in-situ* and *ex-situ* technologies – excavation with separation and concentration of valuable materials, stabilization/solidification of some areas in site and out of site;

b) *in-situ* technologies – soil as the infiltrate source flushing for groundwater contamination level diminishing, electrokinetics, barriers/treatment walls around the waste dump area, chemical treatment, soil amendments, and phytoremediation;

c) *ex-situ* technologies – soil washing and bioremediation in some cases.

The main concerns are all around the costs and legislative peculiarities when those are opposite to business interests. Decision makers should be strict about the process of pre-investigation, research and remediation, but the decision must allow some flexibility in order to avoid too high costs and stagnation of remediation process followed because of this reason.

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