TOWARDS SOIL DECONTAMINATION

IN THE REPUBLIC OF SERBIA

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CONTENTS

LIST OF ABBREVIATIONS

COP	Conference Of the Parties
CS	Contaminated Sites
EDC	Ethylene dichloride
EEA	European Environmental Agency
EIONET	European Environment Information and Observation Network
ENEA	National Agency for New Technologies, Energy and Sustainable Economic Development
EPS	Elektroprivreda Srbije
EU	European Union
GEF	Global Environmental Facility
INAIL	Institute for Insurance Against Accidents at Work
ISPRA	Institute for Environmental Protection and Research
ISS	Italian National Health Institute
JRC	Joint Research Centre
LTD	Limited company
MEAs	Multilateral Environmental Agreements
MoEP	Serbian Ministry of Environmental Protection
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated biphenyls
PCS	Potentially Contaminated Sites
PPE	Personal Protective Equipment
QSP	Quick Start Program Trust Fund
RSD	Serbian Dinar
SDG	Sustainable Development Goals
SEPA	Serbian Environmental Protection Agency
TMF	Faculty of Technology and Metallurgy
UN ENVIRONMENT	United Nations Environment Programme
UNEA	United Nations Environment Assembly
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization

I REVEALING THE PROBLEM

A very Faustian choice is upon us: whether to accept our corrosive and risky behaviour as the unavoidable price of population and economic growth, or to take stock of ourselves and search for a new environmental ethic. E. O. Wilson

The environment and the ecosystems are endangered and that is a well-known fact. Industrialization began 150 years ago and ever since, the trend of environmental degradation which influences our everyday life has shown only a little prospect of change. Numerous conferences and campaigns on this topic are organized and publications compiled with the aim of alerting stakeholders and authorities and calling them to action. Interested actors from the scientific community have joined the constant chase for the best possible definitions and concepts that can help clarify this problem. So many different explanations and theories were created in order to raise public awareness. However, the problem is still present and it is getting worse every day. This is clearly a matter of urgency. Contamination of our environment has already caused so many problems, from the loss of biodiversity to the increased number of people suffering from malignant diseases.

So far, poor environmental management practices have left behind hundreds of thousands of contaminated sites. According to the latest investigation, there are more than 650 000 registered sites where polluting activities took/are taking place in national and regional inventories of respondents (JRC, 2018).

When we declare a certain area as contaminated, we mainly refer to soil contamination. Today, soils are endangered in many ways. According to the European thematic strategy for soil protection, the Commission identified the main threats that confront soils in the EU. These threats are soil sealing, soil erosion, desertification,

salinization, soil acidification, soil biodiversity loss, landslides and soil contamination (COM(2012)46). Soil contamination can be understood as the trigger for other degradation processes, because it affects the ecosystem and causes toxicity to organisms, reducing the biodiversity, which is associated with the loss of organic soil matter, with nutrient imbalance and consequent soil erosion (JRC, 2018). Whether due to outdated technology that pollutes the environment, improper disposal of waste or as a result of an accident, soils are the first to be contaminated. Soil can often be considered as the ultimate sink for contaminants that enter the environment (Swartjes, 2011). Since pollution extends rapidly through all environmental media, hazardous substances are further transported to underground or surface waters to ultimately affect population's health.

Contaminated sites are, unfortunately, often located in the vicinity of urban zones, river flows and sensitive natural areas and it is therefore necessary to conduct regular monitoring. Numerous hazardous substances, their heterogeneity, as well as the diversity of exposure routes add to the complexity of the problems related to contaminated sites. The extent of the overall problem is unknown due to the scarcity of available data and published studies and the lack of accurate records on local populations' exposures. The fact that adds complication to the matter is that contaminated sites are most commonly found in areas with low living standards, causing serious socioeconomic impacts.

Direct exposure of people to hazardous substances from contaminated sites has been documented in a large number of cases. If we take into account hundreds of thousands contaminated sites in the European area, it is clear that the number of such incidents is relatively high. Considering this, contaminated sites should be identified and urgently remediated (WHO, 2017). Another problem related to this matter is the lack of adequate systematic assessments of the health impact of contaminated sites and poor legal policy (Mudu, 2014).

II CONTAMINATED SITES, INTRODUCE YOURSELVES

Definitions

According to the definition by the **European Environment Agency (EEA)**, contaminated sites are those where soil contamination has been confirmed, whereas potentially contaminated sites include the locations where soil contamination is only suspected but not verified. On the latter, detailed investigations need to be carried out in order to confirm whether relevant negative impacts actually exist. If negative impact on ecosystems and human health is indeed confirmed, remediation is proposed. The remediation or clean-up techniques need to be adjusted according to the current or planned use of the site. In order to monitor and track progress in the management of contaminated sites, European Environment Agency defined an indicator titled "Progress in management of contaminated sites". The stated indicator aims at assessing the adverse effects and measures taken to satisfy environmental standards according to current legal requirements (Panagos, 2013). In addition, the indicator provides evidence that countries are working on identifying potentially contaminated sites (through preliminary study and investigation), verifying if these sites are actually contaminated (main site investigation) and implementing remediation and risk reduction measures where these are required (JRC, 2018). Finally, this indicator also shows which anthropogenic activities have led to the contamination, the costs to society of the clean-up, and the achievements managing the contaminated sites.

The **Joint Research Centre (JRC)** provided definitions for contaminated and potentially contaminated sites which are very similar to the EEA's definitions, although more precisely. The following definitions are conceived in order to minimize

the possibility of different interpretation by individual countries of certain terms used in their questionnaires for data collection process (Panagos, 2013):

"Contaminated site (CS) refers to a well-defined area where the presence of soil contamination has been confirmed and this presents a potential risk to humans, water, ecosystems, or other receptors. Risk management measures (e.g., remediation) may be needed depending on the severity of the risk of adverse impacts to receptors under the current or planned use of the site."
"Potentially contaminated site (PCS) refers to sites where unacceptable soil contamination is suspected but not verified, and detailed investigations need to be carried out to verify whether there is an unacceptable risk of adverse impacts on receptors".
"Management of contaminated sites aims to assess and, where necessary, reduce to an acceptable level the risk of adverse impacts on receptors (remediate). The progress in the management of CS is traced in 4 management steps starting with a preliminary study, continuing with the preliminary investigation, followed by site investigation, and concluding with the implementation of site remediation (reduction of risk)."

According to the **World Health Organization (WHO)**, contaminated sites, following the public health perspective, are "areas hosting or having hosted human activities which have produced or might produce environmental contamination of soil, surface or groundwater, air, and food chain, resulting or being able to result in human health impacts" (WHO, 2012).

At the national level, the Law on Soil Protection[1] specifies that contaminated soils are those in which concentrations of hazardous and harmful substances are confirmed to be above the limit values, whereas in the case of potentially contaminated soils there is only a presumption of possible contamination.

In November 2010, the Government of the Republic of Serbia adopted the Regulation on the program of systematic monitoring of soil quality via indicators for assessment of soil degradation risk and methodology for creation of remediation programmes[2]. This Regulation defines the term "contaminated sites" as those locations where the presence of hazardous and harmful substances caused by human activity is confirmed, in concentrations that can cause a significant risk to human health and the environment. Article 14 specifies following types of contaminated sites:

Landfills;

- Locations contaminated by active or inactive installations or sites where hazardous substances are deposited;
- Locations of accidents, or locations polluted due to extraordinary events, including malfunctions;
- Industrial devastated locations (brownfield sites) (Figure 1).

[1]"Official Gazette of RS", No 112/2015
[2]"Official Gazette of RS", No. 88/2010 and 30/2018

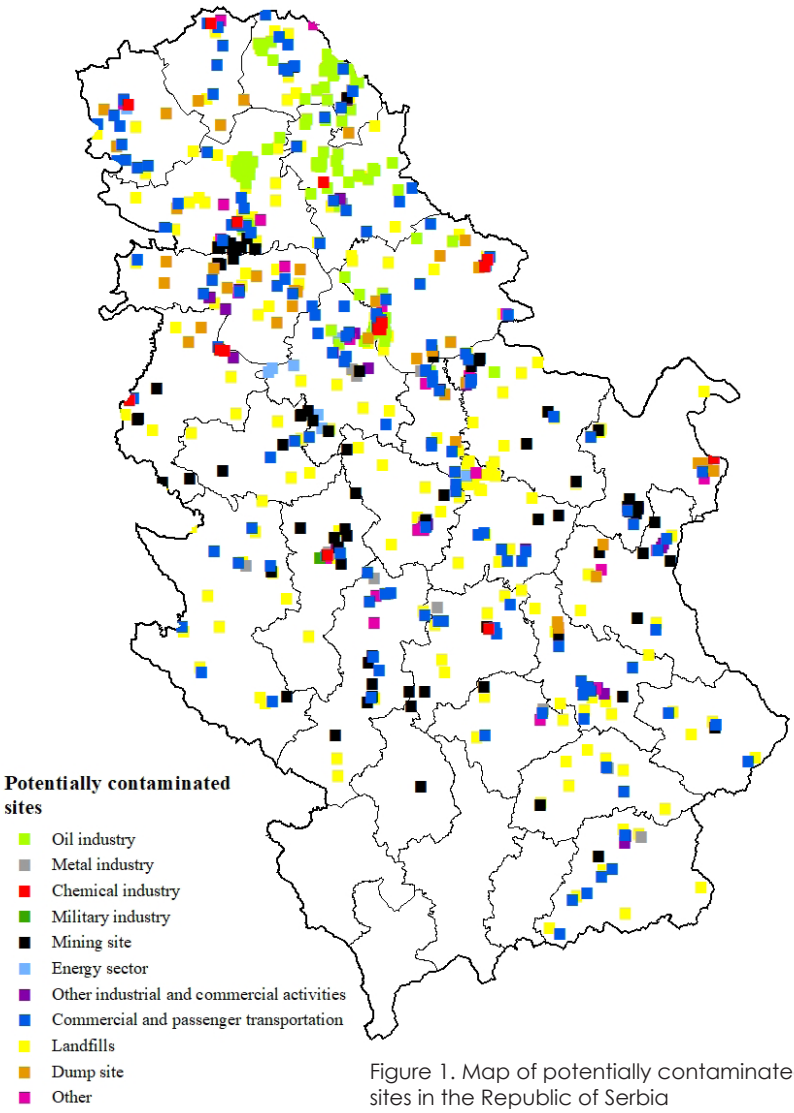

Figure 1. Map of potentially contaminated sites in the Republic of Serbia

Contaminated sites and associated risks to environment and human health

We are all witnesses to the contamination legacy. Decades of poor waste management, the use of "dirty" technologies, absence of remediation of the resulting pollution, lack of public awareness, as well as the price of sustainability, have led to incomprehensible consequences - adverse effect to both human health and the environment (Table 1).

Table 1. Land and soil – from sources to impacts on human health and ecosystems (Source: "Towards a pollution-free planet", UN Environment, 2017)

Land and soils	Human impact	Ecological effect	Ecosystem services impacted
Heavy metals from sedimentary and aerosolization processes, transport, energy production, industrial sources, contaminated sites, extractives industry	Neurological development, harmfull effects on the nervous, digestive and immune systems, lungs and kidneys	Toxicity build-up food chains	Reduction of available food due to contamination
Pesticides	Cancer, sterility and other reproductive disorders	Disappearance of bees, other insects and butterflies, reptiles, birds and mammals	Control of pests, vectors
Plastic debris and litter	Various leachates causing potential harmful effects	Congested alimentary systems, leading to starvation. Toxicity build-up in fodder and prey	Reduction in productivity and cycling of nutrients. Distorted predator prey dynamics
Pharmaceuticals from use of antibiotics in livestock	Increased antimicrobial resistance	Soil microbial populations developing new resistant forms	Provisioning services. Productivity of soil and livestock

In many cases, contaminants are released from active industrial processes or are present in accumulated hazardous waste from past industrial activities. Often, multiple agents exist simultaneously, posing a mix of certain or suspected risks. Acute and chronic adverse effects on health in occupationally exposed groups and in the general population, as a result of industrial accidents, have been repeatedly documented. Local residents are directly exposed to hazardous substances through various types of exposure paths such as ingestion, inhalation, skin contact and dermal absorption. Most common exposure paths to the contaminants in soils are as follows (U.S. EPA, 1996):

- Direct ingestion
- Inhalation of volatiles and fugitive dusts
- Ingestion of contaminated ground water caused by migration of chemicals through soil to an underlying potable aquifer
- Dermal absorption
- Ingestion of home-grown product that has been contaminated via plant uptake
- Migration of volatiles into basements

The public has become increasingly aware of these risks, and policy debates now include how to secure industrial development that does not adversely influence health or the quality of life (Mudu, 2014). The monitoring and proper management practices in the cases of contaminated sites are recognized as one of the most effective actions in the prevention of negative impacts of contaminants on human health and the environment. The importance of assessing risks from human activities and environmental pollutants thereof has been brought to the attention of the public by the experts at various occasions.

According to the latest estimation, 85,000 chemicals are in use, and thousands of new ones are being registered every year

which makes it increasingly difficult to carry out environmental and human risk assessments of chemicals from all sources in all media (EEA, 2018). A risk assessment in this context is primary applied in order to estimate the nature and probability of adverse health effects in humans who may be exposed to hazardous substances in contaminated environmental media. The risk assessment of contaminated sites has not yet been widely used since there are still not enough ecotoxicological, hydrogeological and geomorphological studies that are an integral part of the site research, which is also an initial step in risk assessment (Ferguson, 1998). The assessment of the possible health impacts of contaminated sites is challenging because each site has its own characteristics, and it is difficult to describe typical or exemplary cases of exposure scenarios, especially for industrially contaminated sites with ongoing multiple industrial activities (WHO, 2013).

Contaminated sites and global processes and targets

In addition to numerous legal documents, there are guidelines that facilitate systematic monitoring of soil contamination and the identification of accompanying consequences. Impacts and possible risks of soil contamination on human health and environment are also described and taken into consideration in many multilateral environmental agreements on the European and global scale.

One of these documents is the so-called **Ostrava Declaration** signed by 53 countries, including the Republic of Serbia, during the Sixth Ministerial Conference on Environment and Health that took place in 2017 in Ostrava, Czech Republic. The declaration sets 7 priority action areas on environmental risks which affect human health such as:

- improving indoor and outdoor air quality for all;
- ensuring universal, equitable and sustainable access to safe drinking water, sanitation and hygiene for all and in all settings;
- minimizing the adverse effects of chemicals on human health and the environment;
- preventing and eliminating the adverse environmental and health effects, costs and inequalities related to waste management and contaminated sites;
- strengthening adaptive capacity and resilience to climate change-related health risks and supporting measures to mitigate climate change and achieve health co-benefits in line with the Paris Agreement;
- supporting the efforts of European cities and regions to become healthier, more inclusive, safer, resilient and sustainable;
- building the environmental sustainability of health systems and reducing their environmental impact.

In addition, several important documents related to the problem of contaminated sites, soil pollution and adverse impacts on human health were adopted at the third session of the United Nations Environment Assembly (UNEA) of the UN Environment Programme in Nairobi, which took place in December 2017.

The **UNEA-3** ***Resolution on Managing soil pollution to achieve sustainable development*** calls on member countries to address soil pollution in the framework of the global environment, food security and agriculture, development and health agendas in an integrated manner, especially through preventive and risk management approaches (UN Environment, 2017b). The Resolution also calls for the development of information systems on polluted sites and programmes, while stressing the need for the availability and accessibility of adequate, predictable and stable resources

for the effective prevention, reduction and management of soil pollution. Furthermore, the Resolution recalls the revised World Soil Charter and reaffirms that "*Governments should establish and implement regulations to limit the accumulation of contaminants beyond established levels to safeguard human health and well-being and facilitate the remediation of contaminated soils that exceed those levels where they pose a threat to humans, plants and animals*".

UNEA-3 ***Resolution on Environment and Health*** emphasizes the role of the Basel, Rotterdam, Stockholm and Minamata Conventions and the Strategic Approach to International Chemicals Management to support pollution prevention and protect the environment and health. It also stresses the health benefits of addressing global environmental challenges and their interrelations and calls the member states to develop an integrated environment and health policies and measures and to develop methods, tools and guidelines to promote integrated environmental and health risk assessments, building from existing work in that regard (UN Environment, 2017a).

The 2030 Agenda for Sustainable Development officially came into force on January 1, 2016 and imposed on the countries the responsibility to follow-up on defined goals and review the progress made in their implementation on the national level in the next 15 years. Even though SDGs are not legally binding, governments are expected to establish the national frameworks so as to achieve and fulfill the set Goals. The basis for improving health and reducing inequalities in Europe is adopted in the Health policy 2020 (WHO, 2013). The environmental determinants of health are directly or indirectly relevant to all SDGs (WHO, 2018) (Figure 2).

Figure 2. Interconnection between Goal 3 and other SDGs
(source: WHO, 2018)

SDGs addressing soil pollution and associated targets

Goal 1 – NO POVERTY

EQUAL RIGHTS TO OWNERSHIP, BASIC SERVICES, TECHNOLOGY AND ECONOMIC RESOURCES

By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance.

Goal 2 – ZERO HUNGER

DOUBLE THE PRODUCTIVITY AND INCOMES OF SMALL-SCALE FOOD PRODUCERS

By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.

SUSTAINABLE FOOD PRODUCTION AND RESILIENT AGRICULTURAL PRACTICES

By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

Goal 3 – GOOD HEALTH AND WELL-BEING

REDUCE ILLNESSES AND DEATH FROM HAZARDOUS CHEMICALS AND POLLUTION

By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.

Goal 11 – SUSTAINABLE CITIES AND COMMUNITIES

INCLUSIVE AND SUSTAINABLE URBANIZATION

By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries.

Goal 12 – RESPONSIBLE CONSUMPTION AND PRODUCTION

RESPONSIBLE MANAGEMENT OF CHEMICALS AND WASTE

By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment.

Goal 13 – CLIMATE ACTION

STRENGTHEN RESILIENCE AND ADAPTIVE CAPACITY TO CLIMATE RELATED DISASTERS

Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

Goal 14 – LIFE BELOW WATER

REDUCE MARINE POLLUTION
By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.

Goal 15 – LIFE ON LAND

CONSERVE AND RESTORE TERRESTRIAL AND FRESHWATER ECOSYSTEMS
By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements.

END DEFORESTATION AND RESTORE DEGRADED FORESTS
By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally.

Existing guidance documents related to contaminated sites

Due to the complexity of the issues related to the impact of contaminated sites on human health and the environment, creation of guidance documents is a clear need. With regard to mercury related issues, at the first meeting of the Conference of the Parties to the Minamata Convention on Mercury (COP1) that took place in Geneva in September 2017, a number of guidance documents were adopted: on trade in mercury, stocks and

sources of supply of mercury, exemptions, artisanal and small-scale gold mining, mercury releases and emissions, as well as guidance on the use of financial resources from the Global Environment Facility (GEF). Outline of the structure and content adopted at the COP1 considers methods and approaches for the following chapters, which may be used for the management of contaminated sites in general:

1. Site identification and characterization
Methodology for identification of the sites contaminated by mercury or mercury compounds should define mechanisms and techniques to characterize the contamination of a suspected contaminated site. In order to determine and assess a potentially contaminated site, one would need to conduct a desk study and organise site inspections to further understand characteristics of the site (collect information on topography, run-off potential, possibility of water sources contamination, current and previous usage of the site). Furthermore, sampling of the soil, air, and water as well as biota is a necessity for further characterization of risk to human health and the environment.

2. Engaging the public
Engaging the public through consultation process and distribution of information is considered essential. It is necessary to involve the public and stakeholders in establishing commitments as well as during the assessment and remediation processes. Activities that aim at raising public awareness are especially important in relation to reducing their exposure.

3. Human health and environmental risk assessments
For a proper assessment of the contamination's impact on human health and the environment, it is necessary to apply risk-based methodology. Although the effect of mercury is well studied, the specific site characteristics may influence the exposure pathways. In order to adequately assess the site-associated risk to human health and environment, it is necessary to determine exposure paths on each site individually.

4. Options for managing the risks posed by contaminated sites
Following the completed assessment, it is up to national authorities to conduct risk management process and take appropriate measures, choosing from a range of possible environmentally sound options.

5. Evaluation of benefits and costs
Every action related to the identification, characterisation, assessment or remediation of contaminated site needs to be evaluated from the cost-benefit perspective, while taking into account the costs of impact to local population and environment.

6. Validation of outcomes
Once an intervention has been completed, it is important to validate the outcomes and determine the effectiveness of an intervention in order to consider implementation of further activities at the site.

In line with article 12 of the Minamata Convention on Mercury, a Guidance on the management of contaminated sites is under development and foreseen to be adopted at COP2.

As a candidate country for EU membership, one of the responsibilities of the Republic of Serbia is to adjust its national legislation related to mercury with the Minamata Convention. Determining of the national requirements and needs for the ratification of the Minamata Convention, as well as the defining of the national priorities for implementation of the Convention is the main objective of the project "Development of Minamata Convention on Mercury Initial Assessment in the Republic of Serbia". The project, financed by GEF, started in 2015 and is implemented by UNDP and the Ministry of Environmental Protection of the Republic of Serbia (MoEP). The main outcome of the project is Minamata Mercury Initial Assessment Report that identifies priorities for action within the implementation plan.

One of the priorities defined within this report implies remediation measures for contaminated sites.

Diffuse and local pollution of environmental media is in most cases caused by industrial activities. Soils, air, underground and surface waters, as well as food in the vicinity of industrial zones, are affected by the contamination. The importance of good management of industrially contaminated sites inspired the creation of frameworks for the integrated assessment of the impacts of large industrial facilities. One of the latest proposed frameworks was developed based on the examples of the petrochemical industries in Sicily and it includes methods for estimating the adverse effects on the health caused by petrochemical activities. Furthermore, it contains strategies and tools for integration of health considerations into the policies and remediation plans for a specific contaminated site. This document also contains useful tips for the process of identifying the contaminated site, study design in accordance with legislation, as well as the results on the adverse effects on human health caused by industrial activities. One of the instruments for further fieldwork provided in this publication is the **questionnaire on risk assessment** which contains sets of questions related to site characteristics and living conditions, and it is used for investigation of a population's awareness in an area at risk (Mudu, 2014).

III MANAGEMENT OF CONTAMINATED SITES IN SERBIA

Legal framework for soil protection

The soil protection in the Republic of Serbia is legally established according to the:

Law on Environmental Protection ("Official Gazette of RS" No. 135/2004, 36/2009, 36/2009 -other law, 72/2009 – other law and 43/2011 – Decision of SC and 14/2016)
Law on Soil Protection ("Official Gazette of RS", No. 112/2015)
Law on Agricultural Land ("Official Gazette of RS" No. 62/2006, 65/2008 – other law and 41/2009)

A prerequisite for soil protection in the Republic of Serbia is systematic monitoring of soil quality, harmonized with the objectives defined in the national programs and strategies:

National Program of Environmental Protection ("Official Gazette of RS", No. 12/2010)
National Strategy of Sustainable Development of the Republic of Serbia ("Official Gazette of RS", No. 57/2008)
Action Plan for Implementation of the Sustainable Development Strategy ("Official Gazette of RS", No. 22/2009)

Various anthropogenic negative impacts on the soils including soil contamination, but also other types of land degradation, could be reduced through implementation of land rehabilitation programs (Vidojević et al., 2013).

Soil monitoring in the Republic of Serbia is legally defined in the **Regulation on the Program of Systematic Monitoring of Soil Quality via Indicators for Assessment of Soil Degradation Risk and Methodology for Creation of Remediation Programs**[3] which has been harmonized with the recommendations provided in the Proposal for a Soil Framework Directive - COM(2006)232. Another legally binding document is the **Regulation on Limit Values for Polluting, Harmful and Hazardous Substances in the Soil**[4].

The Regulation on Establishing the Criteria for Determining the Status of Endangered Environment and Priorities for Rehabilitation and Remediation[5] applies to identification of the rehabilitation and remediation priorities, which are also regulated by the **Rulebook on the methodology for the development of rehabilitation and remediation projects**[6].

The systematic monitoring of the soil quality is based on the use of indicators to determine the risks of soil degradation. These indicators are defined in the National List of Indicators and they are used for reporting on the state of soil in the Republic of Serbia.

The Rulebook on the National List of Indicators of Environmental Protection[7] is established in accordance with the **Regulation on Contents and Methods of Management of the Environmental Protection Information System, Methodology, Structure, Common Bases, Categories and Levels of Data Collection, and on the Content of Publicly Released Information**[8]. The Serbian Environmental Protection Agency (SEPA) is the key national institution responsible for managing the integrated system for environmental monitoring and reporting. The process of reporting on the state of soil includes a collection of relevant information and data, followed by providing an update on the soil indicators to be used to inform decision-makers.

[3]"Official Gazette of RS", No. 88/2010 and 30/2018
[4]"Official Gazette of RS", No. 30/2018
[5]"Official Gazette of RS", No. 22/2010
[6]"Official Gazette of RS", No. 74/2015
[7]"Official Gazette of RS", No. 37/2011
[8]"Official Gazette of RS", No. 112/2009

Management of Contaminated Sites in the Republic of Serbia

The indicators are used to show progress in management of the sites where the presence of point source contamination has been confirmed, as well as to indicate implementation of rehabilitation and remediation measures. Localized contamination is associated with the areas of increased industrial activity, inadequately managed landfills, mineral extraction sites, military warehouses and areas in which accidents and soil contamination have occurred.

The indicator shows:

1. Total number of potentially contaminated sites;
2. Number of sites where the preliminary survey was carried out (in %);
3. Number of sites where detailed investigation was carried out (in %);
4. Number of sites where remediation measures are in the process of implementation
5. Number of sites where remediation was concluded (in %);
6. Incurred costs and estimated remediation costs (RSD);
7. The share of the main types of localized sources of soil contamination in the total number of identified sites (in %);
8. The share of individual branches of industry in localized soil pollution (%);
9. Main pollutants present in the contaminated soil and surface waters.

Cadastre of contaminated sites

The Serbian Environmental Protection Agency is responsible for the establishment and management of a national Cadaster of contaminated sites which is an integral part of the information system for environmental protection in the Republic of Serbia. Already upon its establishment in 2006, SEPA began with data collection and systematization of information on potentially contaminated and contaminated sites for the Cadaster. According to the Law on Soil Protection, the Cadaster of contaminated sites ***is a set of relevant data on vulnerable, contaminated and degraded soils***.

Over the years, SEPA has been continuously working to improve the methodology for data collection, data quality, and systematization. The collected data include sites where processes of degradation and devastation are manifested. The main purpose of the Cadastre is to provide systematic data on the sources of pollution such as type, quantities, method and location of discharges of pollutants into the soil, in order to implement prevention and remediation measures.

The latest update of the Cadastre database shows that **709** potentially contaminated sites and contaminated sites were identified and recorded on the territory of the Republic of Serbia, **557** of which are registered and **152** are estimated. Out of 709 sites, **478** are in need of investigation/still to be investigated and **103** are currently under investigation. A total of **41** sites are in the process of rehabilitation, whereas rehabilitation and remediation (recultivation) are completed on **52** sites where aftercare measures are currently being applied (Figure 3). The sites of former military locations, petrol and filling stations, dry cleaning, wastewater treatment installations and pipelines for the transportation of hazardous substances are not included in the Cadaster.

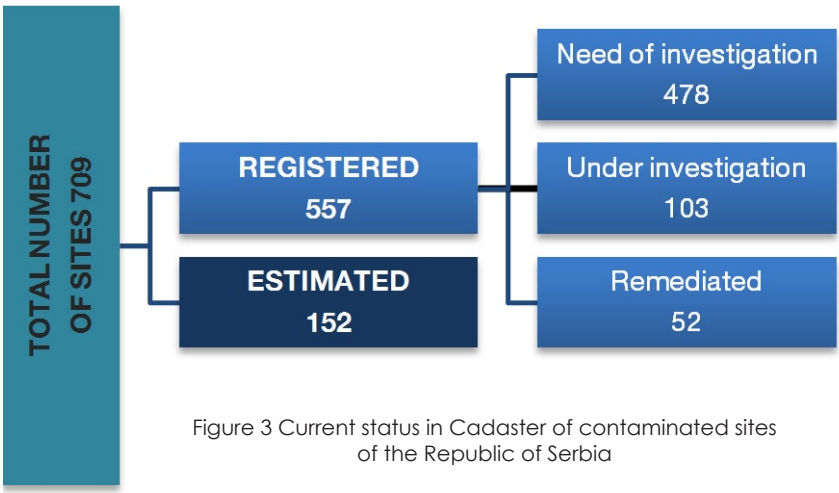

Figure 3 Current status in Cadaster of contaminated sites of the Republic of Serbia

Responsibility for contaminated sites

The legal responsibility for contaminated and potentially contaminated sites is based on the three principles of international environmental law.

One of the basic principles of environmental protection defined in the Law on Environmental Protection[9] is the **polluter pays principle**. According to this principle, polluter shall pay the compensation for environmental pollution when its activities cause or are likely to cause an environmental burden, or if it produces, uses or puts into circulation a raw material, semi-product or product containing substances harmful to the environment. The polluter shall, in accordance with regulations, bear the total cost of measures to prevent and reduce pollution, which includes environmental risk and environmental damage costs.

The second is the **principle of the liability of the polluter and his legal successor** defines that, if a legal entity or an individual

[9]"Official Gazette of RS" No. 135/2004, 36/2009, 36/2009 -other law, 72/2009 – other law and 43/2011 – Decision of SC and 14/2016

through legal or illegal activities pollutes the environment, they are held responsible for undertaking certain measures. The polluter or its legal successor is obliged to eliminate the cause of pollution and the consequences of direct or indirect pollution of the environment. Furthermore, the polluter is responsible for environmental pollution in case of liquidation or bankruptcy of companies or other legal entities, in accordance with the law. The changes in the ownership of companies and other legal entities necessarily involve the assessment of the zero state of the environment and the determination of environmental liability, as well as the settlement of the debts (burdens) of the previous owner for pollution and/or damage to the environment. The Liability Directive[10] has not yet been transposed into national legislation, therefore this principle still cannot be legally enforced.

The third principle, the **subsidiary liability principle**, is applied when the polluter is unknown as well as in cases when pollution originates from sources outside the country. This means that state authorities should, within their financial capabilities, eliminate the consequences of environmental pollution and reduce damage. According to the Law on Soil Protection, the funds required for the realization of the remediation and rehabilitation project should be allocated by the responsible person. In case the responsible person is unknown, inaccessible or does not act according to the inspector's order, the project is carried out by the local self-government unit and/or the autonomous province, or the Republic, in accordance with the budget, through an authorized legal entity that fulfils the conditions for performing remediation and reclamation work.

[10] Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage. http://ec.europa.eu/environment/legal/liability/index.htm

UN Environment's support to Serbia in addressing the issue of Contaminated Sites

Post-Conflict Environmental Assessment and Clean-up in Serbia

Only weeks after the 1999 conflict, United Nations Environment Programme started the assessment of the possible threats to human health and the environment arising from the air strikes. After completing fieldwork and desk studies, in October 1999, the UN Environment presented its first findings of consequences to the environment and human settlements. During field missions which were conducted mainly on industrial sites, soil, groundwater, and air were sampled and four heavily contaminated environmental "hot spots" (in the Cities of Pancevo, Kragujevac, Novi Sad, and Bor) were identified. In order to define which scientific and financial requirements are needed for urgent actions at these four hot spots, in 2000, UN Environment initiated a Feasibility study to prepare detailed technical proposals for Clean-up projects.

The following necessary measures were identified:

Pancevo:

- remediation of ethylene dichloride (EDC) pollution;
- remediation of soil and groundwater contamination at the petrochemical plant;
- rehabilitation of wastewater treatment facilities to stop the continuous discharge of untreated industrial wastewater into the wastewater canal and the Danube River;
- Remediation of the wastewater canal.

Novi Sad:

- protecting the drinking-water wells in the area between Novi Sad oil refinery and the Danube River;
- comprehensive monitoring of the area's groundwater resources;
- initiating efforts to address the contamination source zone within the oil refinery.

Kragujevac:

- remediation of a PCB-contaminated concrete floor in the paint hall
- cleaning of the wastewater pits and decontamination of wastewater in the paint hall;
- remediation of a PCB-contaminated site in the transformer station;
- transportation and treatment abroad of hazardous waste generated by Kragujevac remediation projects.

Bor:

- assessment and reduction of remaining PCB-related risks in the transformer station and the dump site;
- strengthening the overall environmental management capacities of local stakeholders.

These Clean-up activities were finished in 2003 resulting in protected and secured sources of fresh drinking water, remediated contaminated soil and groundwater, disposed hazardous waste in large amounts, fixed wastewater treatment capacities at industrial sites, and installed water and air quality monitoring stations. This was the first post-conflict assessment of its kind developed by the UN, which was later implemented in other war-affected countries such as Afghanistan, Iraq, the Occupied Palestinian Territories, and Liberia (UN Environment, 2004).

Enhanced Cross-sectoral Land Management through Land Use Pressure Reduction and Planning

The UN Environment/GEF project "Enhanced Cross-sectoral Land Management through Land Use Pressure Reduction and Planning" funded by the Global Environment Facility (GEF), started in October 2015 and is implemented by the UN Environment Europe Office – Vienna Programme Office. The main objective of this project is to develop instruments and mechanisms for integrated land use management, remediation, and capacities to reduce pressures on land as a natural resource from competing land uses in the wider landscape, while supporting reversal of land degradation. To date, the project has supported the development of a legal framework for soil protection, a Contaminated Sites module and application for data submission for the Cadaster, in addition to preliminary investigation applied at 32 industrial sites across the country (results of which are provided in Annex 1).

Suspicions that the investigated sites might have an impact on the environment and human health generated the idea to apply of PRA.MS methodology - Preliminary Risk Assessment Model for the identification and assessment of problem areas for Soil contamination in Europe.

The PRA.MS model was developed by the European Environmental Agency as a support tool for the work of the European Environment Information and Observation Network (EIONET). This methodology is based on the scoring criteria using the Source-Pathway-Receptor paradigm in the design of the conceptual model, where contaminated soil or waste disposed on/into soil represents a source (Falconi, 2005). Since PRA.MS is also applicable for site comparison and the establishment of a priority list, an initial list of hot-spot priorities was developed based on the results of 264 soil sample analyses within the conducted research.

The Italian Ministry of Environment, Land and Sea granted a contribution to the UN Environment/GEF project through a co-financing initiative entitled "Assistance to the Republic of Serbia in the Implementation of MEAs and EU Obligations through the Improvement of Pollution Monitoring of Soil Quality at Industrial Sites". Through this project, support was provided to Serbia to set-up a national soil pollution monitoring system which follows the EU environmental standards and other relevant multilateral environmental agreements (MEAs). This was accomplished through technical support to the Serbian Ministry of Environmental Protection (MoEP) and SEPA by involvement of several expert Italian institutions such as Institute for Environmental Protection and Research (ISPRA), the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), the Italian National Health Institute (ISS) and the Institute for Insurance Against Accidents at Work (INAIL).

Considering that one of the goals of the project was to strengthen the Serbian national capacities for monitoring soil quality and identifying pollution at industrial sites, training courses and field visits were organized throughout 2016.

One of the activities in the frame of the project was to support the accreditation of SEPA as the national laboratory for soil sampling and analysis. This included procurement of an Atomic Absorption Spectrometer, Server for data storage and Personal Protective Equipment (PPE) for the investigation of the contaminated sites.

Supporting the Western Balkan Region in the Implementation of Multilateral Environmental Agreements through Strengthening of Institutional Framework and Capacity Building

In the frame of the regional project "Supporting the Western Balkan Region in the Implementation of Multilateral Environmental Agreements through Strengthening of Institutional Framework and Capacity Building", a training was organized in March 2018 on selected topics such as the development of characterization plans, soil and groundwater sampling, selection of remediation technologies and comparative risk assessment, among others. The characterization plans were developed with the support of the experts from ISPRA Institute for two pilot sites: former industrial sites of Zorka non-ferrous metallurgy complex in Šabac and Viskoza chemical industry in Loznica. The characterization plans were developed according to the preliminary data collected during the joint field visits aimed at understanding the current state of the sites, conducting soil sampling as well as the interviewing of local authorities and followed by a desk study of the existing documentation for these sites. The proposed detailed investigation in the facility in Šabac is shown on Figure 4.

Figure 4. Proposed investigation in Zorka non-ferrous metallurgy, Šabac

This cooperation has contributed to the exchange of knowledge and experience, which will enable SEPA to independently develop characterization plans for the remaining 30 sites in the frame of the UN Environment/GEF Project.

Strengthening Serbian national capacities and inter-sectorial synergies for safe management of contaminated sites and related hazardous substances to prevent negative impact on human health and the environment

The UN Environment/WHO QSP Project is being implemented in 2018 by the WHO Regional Office for Europe in coordination with the Ministry of Environmental Protection and the Ministry of Health with the local expert support of the Institute of Public Health "Dr Milan Jovanovic Batut". The financial support for the project implementation was provided by the UN Environment's Strategic Approach to International Chemicals Management, Quick Start Program Trust Fund. The project aims at supporting the development of a methodology for assessment of health risk to population in zones close to contaminated sites in Serbia, and enhancing cross-sectoral cooperation and strengthening technical capacities, among others. The project also includes a case study in the City of Bor, where an operating mining and smelting complex is located.

Other related support

Environmentally sound management and final disposal of PCBs

Another project funded by the GEF which inter alia targets sites contaminated with polychlorinated biphenyls (PCBs)

is implemented by United Nations Industrial Development Organization (UNIDO).

The project is co-financed by the state-owned electric utility power company Elektroprivreda Srbije (EPS) and the Ministry of Environmental Protection of the Republic of Serbia and is implemented by the Faculty of Technology and Metallurgy of the University of Belgrade (TMF).

The main objective of the project is to protect human health and the environment by reducing and eliminating the releases of and exposure to PCBs. This will be achieved through the establishment of a management system and the final disposal of 200 tons of equipment contaminated with PCBs.

According to the results obtained within UN Environment/GEF project, three industrial sites were selected for further investigation. A more detailed investigation and the assessment of risk to human health and the environment will be conducted on only one of these three sites, followed by pilot remediation.

IV WHAT NEXT?

Given the strong impact of the environment on human health, a healthy environment must be a priority. Every initiative aimed at reducing environmental pressures should be welcome. Promoting the importance of monitoring the state of the environment is a prerequisite for timely response to potential environmental damage. On the other hand, knowing the nature and the extent of pollution already present in our surroundings is crucial for preventing further threats to human health.

Having in mind that pollution is "oblivious" to state borders, the management of contaminated sites is an activity of international significance. Both national and international funds must be committed to support the management of contaminated sites that typically includes pollution monitoring, detailed investigation of sites, development and implementation of remediation and rehabilitation plans, etc. Also, the application of "urgent measures", such as removal of hazardous waste as an active source of pollution at site, is one of the most important steps preceding remediation and rehabilitation.

As stated above, several projects related to contaminated sites management in the Republic of Serbia have been successfully implemented so far. However, project results should not be taken for granted, but rather used to further address the issue and ameliorate the environment, while reducing health impacts. Therefore, each of these projects brings us only to an introduction to the next step that needs to be realized.

One of the UN Environment/GEF project outcomes is the priority list of contaminated sites for remediation. Out of 32 investigated sites, 14 sites require remediation. For most of the remaining sites, **detailed investigation** of the extent of contamination is still needed. It is therefore suggested that the next step forward should be the

development of characterization plans and remediation projects for priority sites.

In addition, it is important to develop the **National Strategy for Management of Contaminated Sites** and an **Action Plan** for the coming period. Establishment of a legal framework for contaminated sites will be crucial for ensuring a faster and more efficient response to the problems related to the contaminated sites. It is also necessary to strengthen the institutional capacities to enable adequate management.

Having in mind that the Guidance on the management of contaminated sites is expected to be adopted on the next Conference of the Parties to the Minamata Convention on Mercury (COP2), **establishment of the National Mercury Partnership** to assist its future implementation should be considered, as set out in the Mercury Initial Assessment Report.

Last but not least is the **application of the methodology for risk assessment to human health at contaminated sites**. In the light of the investigation of the City of Bor within the UN Environment/WHO QSP project, it is expected that detailed investigation and risk assessment to human health and the environment will continue in other locations that are known to be contaminated as well.

As a conclusion, all future actions with regard to contaminated sites and related impacts on human health need to be implemented as soon as possible. It is owing to the projects listed above that we have had the opportunity to scratch the surface of this burning problem, but further action must and can be taken. Our healthy environment, our well-being, and our sustainable future are common tasks that we can achieve only through joint efforts. We should not allow for the next step we make to be delayed for too long. So, let's get down to work.

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ANNEX 1 - Catalogue of 32 investigated sites

The first phase of the Project included a selection of 32 industrial sites suspected to be contaminated in accordance with project criteria from the Inventory managed by SEPA (Figure 5). Data and information on previous land use, type of industry, surface area, type and quantity of hazardous substances on the location and the surrounding area, soil and groundwater quality, as well as geological, pedological, and hydrological features were collected from previous studies and through numerous consultations. Identification of the receptors of pollution and potential exposure routes was conducted within field missions in the period from September-December 2016. A soil sampling plan was designed based on the collected documentation about the locations and information collected during field visits. In 2017, soil sampling was conducted and soil analysis included the determination of the presence of heavy metals, mineral oils, PCBs, PAHs, following the analysis of the basic physical-chemical and mechanical properties of the soil.

The Institute of Public Health of Belgrade compiled a Summary Technical Report on the Surveyed Locations with recommendations for the best available techniques and best environmental practices for the recovery and remediation of the locations. These recommendations were given based on the results of the survey and conditions across 32 selected industrial locations (Table 2). Additional resources from the UN Environment Fund have allowed for the collection of water and sediment samples at 17 sites, analyzed for a specific set of parameters. The final result of the project is a compiled priority list of contaminated sites for rehabilitation and remediation, reduction of pollution effects on the environment and human health and improved control of contamination.

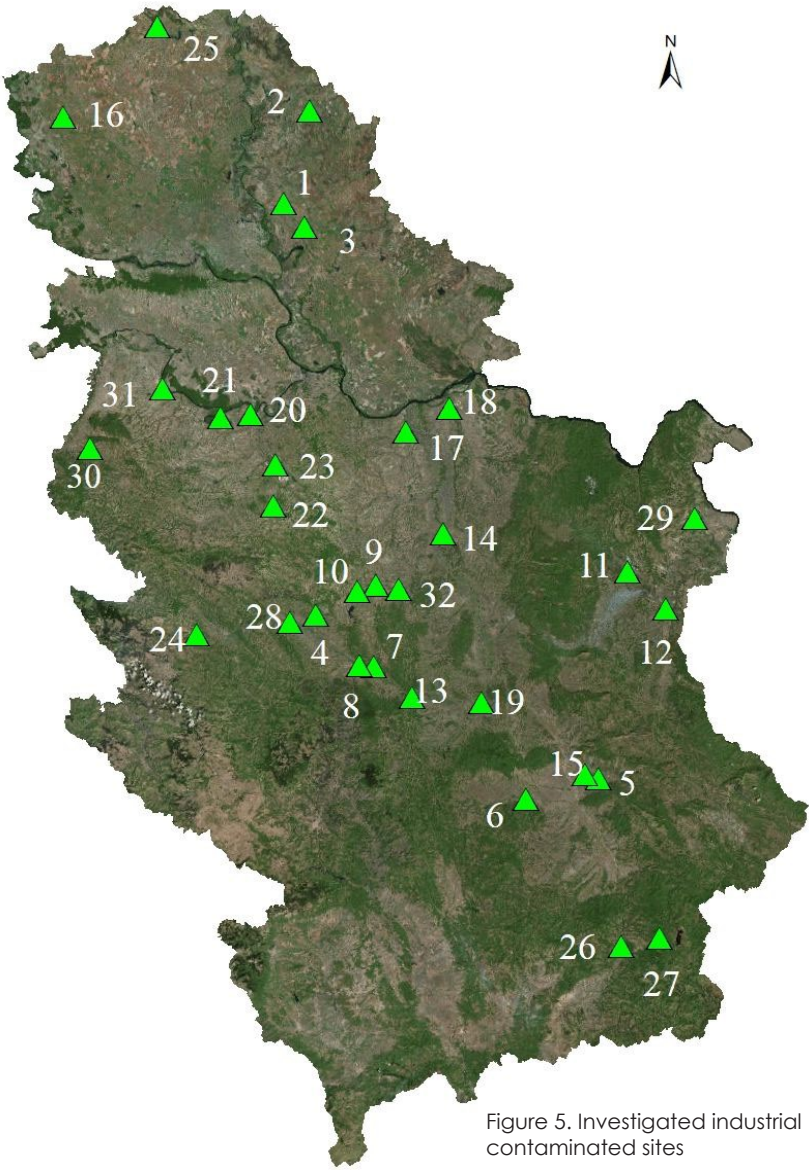
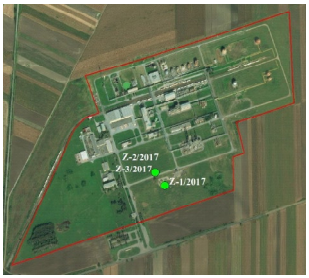


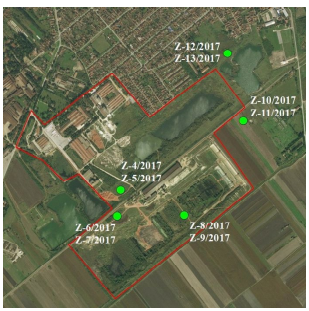
Figure 5. Investigated industrial contaminated sites

1.Synthetic Rubber Factory HIP Petrohemija, Elemir, Zrenjanin



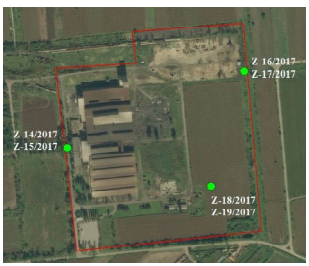
Sample number	Exceeded limit values	Exceeded remediation values
Z-1/2017	Ni	
Z-2/2017	Ni	
Z-3/2017	Ni	

2. Industrial Complex Toza Marković, Kikinda



Sample number	Exceeded limit values	Exceeded remediation values
Z-4/2017	C10-C40, Cu, Pb, Zn	
Z-5/2017	C10-C40, Cu, Pb	Zn
Z-6/2017		
Z-7/2017		
Z-8/2017	Ni	
Z-9/2017		
Z-10/2017		
Z-11/2017		
Z-12/2017		
Z-13/2017		

3. Metal Industry Radijator LTD, Zrenjanin



Sample number	Exceeded limit values	Exceeded remediation values
Z-14/2017	C10-C40	
Z-15/2017	Zn, C10-C40	
Z-16/2017	Cu, C10-C40	PCB
Z-17/2017	Cr, Cu, Zn, C10-C40	PCB
Z-18/2017	C10-C40	
Z-19/2017	Cr, Ni, C10-C40	

4. Paper Industry Papirpak, Čačak

Sample number	Exceeded limit values	Exceeded remediation values
Z-20/2017	As, Cd, Cr, Cu, Ni, Pb, Zn	
Z-21/2017	As, Cd, Cr, Cu, Ni, Zn	
Z-22/2017	Cr, Ni	
Z-23/2017	Cr, Ni	

5. Electronic industry, Niš

Sample number	Exceeded limit values	Exceeded remediation values
Z-24/2017		
Z-25/2017	Cu, C10-C40	
Z-26/2017	Ni	
Z-27/2017		
Z-28/2017	Cd, Cu, Ni, C10-C40	Pb
Z-29/2017	Cd, Cu, Pb, C10-C40	

6. Non-ferrous metal factory FOM, Prokuplje

Sample number	Exceeded limit values	Exceeded remediation values
Z-30/2017	C10-C40, As, Cr, Cu, Ni	Zn
Z-31/2017	As, Cu, Ni, Zn	
Z-32/2017	C10-C40, PCB, As, Cd, Ni	Cu, Zn
Z-33/2017	C10-C40, As, Ni, Zn	
Z-34/2017	PAH, Cd, Cr, Ni, Pb, Zn	C10-C40, Cu
Z-35/2017	As, Cr, Cu, Ni, Zn	
Z-36/2017	PAH, Cr, Ni, Pb	C10-C40, Cu, Zn

	Z-37/2017	PAH, As	C10-C40, Cr, Cu, Ni, Zn
	Z-38/2017	C10-C40, As, Cd	Cr, Cu, Ni, Zn
	Z-39/2017	C10-C40, As, Cd	Cr, Cu, Zn
	Z-40/2017	C10-C40, Cd, Pb	Cr, Cu, Ni, Zn
	Z-41/2017	PAH Cd, Ni	C10-C40, Cr, Cu, Zn

7. Factory of wagons, Kraljevo

Sample number	Exceeded limit values	Exceeded remediation values
Z-42/2017	PAH, Cr, Cu, Zn	Ni
Z-43/2017	PAH, C10-C40, Cr, Cu, Ni, Pb, Zn	
Z-44/2017	PAH, C10-C40, Cr, Cu, Ni, Pb, Zn	
Z-45/2017	PAH, C10-C40, As, Cd, Cr, Cu, Ni, Pb, Zn	
Z-46/2017	PCB, PAH, C10-C40, Cd, Cr, Pb, Zn	As, Cu, Ni
Z-47/2017	PAH, C10-C40, Cd, Cr, Ni, Zn	As, Cu, Pb

8. Metal Industry Magnohrom, Kraljevo

Sample number	Exceeded limit values	Exceeded remediation values
Z-48/2017	C10-C40, Cr, Cu, Pb, Zn	As, Ni
Z-49/2017	C10-C40, Cr, Cu, Ni, Pb, Zn	As
Z-50/2017	C10-C40, Cr, Cu	Ni
Z-51/2017	As, Cr, Cu, Ni	
Z-52/2017	C10-C40, Cr	Cu, Ni
Z-53/2017	C10-C40, Cr, Cu, Ni	
Z-54/2017	C10-C40, Cr, Cu	Ni

	Z-55/2017	Cr, Cu	Ni
	Z-56/2017	Cr, Cu, Ni	
	Z-57/2017	C10-C40, As, Cr, Cu, Ni	
	Z-58/2017	C10-C40, Cr, Cu	Ni
	Z-59/2017	C10-C40, As, Cr, Cu	Ni
	Z-60/2017	Cr, Cu	As, Ni
	Z-61/2017	Cu	Ni
	Z-62/2017	Cu, Ni	
	Z-63/2017	C10-C40, Ni	

9. Metal Industry Šumadija, Kragujevac

Sample number	Exceeded limit values	Exceeded remediation values
Z-64/2017	Cr, Cu, Ni	Zn
Z-65/2017	Cu, Ni, Zn	
Z-66/2017	PAH, Cu, Ni, Zn	
Z-67/2017	PAH, C10-C40, Cd, Pb	As, Cu, Ni, Zn
Z-68/2017	C10-C40, Cu, Ni, Zn	As
Z-69/2017	PAH, C10-C40, As, Ni, Zn	Cu

10. Zastava trucks, Kragujevac

Sample number	Exceeded limit values	Exceeded remediation values
Z-70/2017	C10-C40, As, Ni, Pb, Zn	Cu
Z-71/2017	PAH, C10-C40, As, Ni, Pb, Zn	Cu
Z-72/2017	Cd, Cu, Ni, Zn	

11. Vicinity of Mining and Foundry Basin Bor, Bor

Sample number	Exceeded limit values	Exceeded remediation values
Z-73/2017	C10-C40, Pb	As, Cu
Z-74/2017		As, Cu
Z-75/2017		As, Cu
Z-76/2017	C10-C40, As	Cu
Z-77/2017	C10-C40	As, Cu
Z-78/2017	Cu	As
Z-79/2017	Pb, Zn	As, Cu
Z-80/2017	Ni, Zn	As, Cu

12. Leather-textile Combine Koža, Zaječar

Sample number	Exceeded limit values	Exceeded remediation values
Z-81/2017	C10-C40, Cu, Ni	Cr
Z-82/2017	C10-C40, Cr, Cu, Ni	As, Pb
Z-83/2017	C10-C40, Cr, Cu, Ni	As
Z-84/2017	Cu, Ni	
Z-85/2017	Cr, Cu	

13. Production of hydraulics and pneumatics Prva Petoletka, Trstenik

Sample number	Exceeded limit values	Exceeded remediation values
Z-86/2017	Cd, Cu, Ni	
Z-87/2017	C10-C40	Ni
Z-88/2017	C10-C40, Cd, Zn	As, Cu, Ni
Z-89/2017	PAH, C10-C40, Cd, Pb, Zn	As, Cu, Ni
Z-90/2017	C10-C40, As, Cr, Pb	Cd, Cu, Ni, Zn
Z-91/2017	C10-C40, As, Cr, Pb, Zn	Cd, Cu, Ni
Z-92/2017	Cu, Ni	
Z-93/2017	Cu, Ni	

14. Thermal Power Plant Morava, Svilajnac

Sample number	Exceeded limit values	Exceeded remediation values
Z-94/2017	C10-C40, As, Cu, Ni, Pb, Zn	
Z-95/2017	Ni, Pb	
Z-96/2017	As, Cu, Ni, Pb, Zn	
Z-97/2017	As, Cu, Ni, Pb, Zn	
Z-98/2017	Ni, Zn	
Z-99/2017	Ni	
Z-100/2017	As, Cu, Pb, Zn	Ni
Z-101/2017	As, Cu, Pb, Zn	Ni
Z-102/2017	As, Ni, Zn	
Z-103/2017	Cu, Ni	

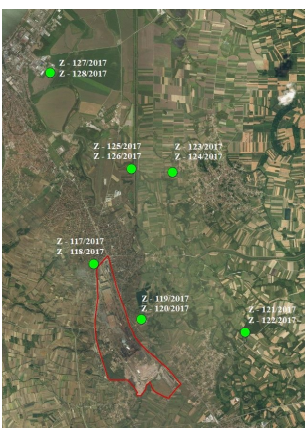
15. Mechanical Engineering Industry, Niš

Sample number	Exceeded limit values	Exceeded remediation values
Z-104/2017	C10-C40, As, Cd, Ni, Pb	Cu, Zn
Z-105/2017	C10-C40, As, Cd, Ni, Pb	Cu, Zn
Z-106/2017	PAH, PCB, C10-C40, As, Cd, Cr, Ni	Cu, Pb, Zn
Z-107/2017	PAH, PCB, C10-C40, As, Cd, Cr, Ni, Pb	Cu, Zn
Z-108/2017	Cu, Ni, Zn	
Z-109/2017	C10-C40, Cr, Ni, Pb	As, Cu, Zn
Z-110/2017	PAH, C10-C40, Cd	As, Cr, Cu, Ni, Pb, Zn
Z-111/2017	PAH, C10-C40, As, Cd, Ni	Cu, Pb, Zn

16. Battery Factory Sombor, Sombor

Sample number	Exceeded limit values	Exceeded remediation values
Z-113/2017	Ni, Zn	Pb
Z-113/2017	As, Ni	Pb
Z-114/2017	C10-C40, As, Cd, Cu, Ni, Zn	Pb
Z-115/2017	C10-C40, As, Cd, Cu, Ni	Pb
Z-116/2017	PAH, Cd, Cu, Ni, Zn	C10-C40, Pb

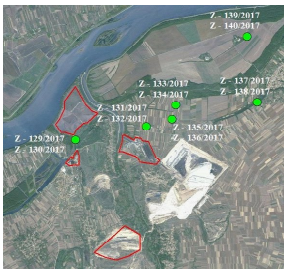
17. Vicinity of Železara Smederevo, Smederevo



Sample number	Exceeded limit values	Exceeded remediation values
Z-117/2017	Ni, Pb	
Z-118/2017	Ni, P	
Z-119/2017	Ni	
Z-120/2017	Ni	
Z-121/2017	Cr, Ni	
Z-122/2017	Cr, Ni	
Z-123/2017	Cr, Ni	
Z-124/2017	Cr, Ni	
Z-125/2017	Ni	
Z-126/2017	Ni	
Z-127/2017	C10-C40, Ni	
Z-128/2017	C10-C40, Cr, Ni	

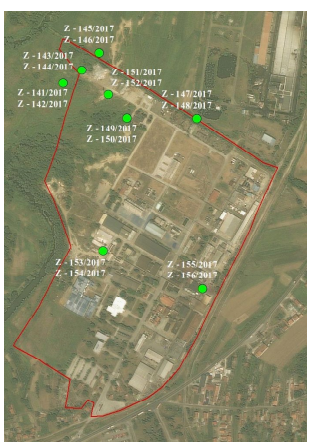
18. Thermal Power Plant Kostolac, Kostolac

Sample number	Exceeded limit values	Exceeded remediation values
Z-129/2017	Ni	
Z-130/2017	Ni, Pb	
Z-131/2017	Cu, Ni, Pb, Zn	
Z-132/2017	Cu, Ni, Pb, Zn	



Z-133/2017	Ni	
Z-134/2017	Ni	
Z-135/2017	Cr, Cu, Ni	
Z-136/2017	Cr, Ni, Pb	
Z-137/2017	Cu, Ni, Zn	
Z-138/2017	Cu, Ni	
Z-139/2017	Cr, Cu, Ni	
Z-140/2017	Cr, Ni	

19. Chemical Industry Župa LTD, Kruševac



Sample number	Exceeded limit values	Exceeded remediation values
Z-141/2017	Cr, Ni, Zn	
Z-142/2017	Cr, Cu, Ni	
Z-143/2017	C10-C40, Hg, Cd, Pb	Cr, Cu, Ni, Zn
Z-144/2017	Cr, Cu, Zn	Ni
Z-145/2017	Cr, Cu, Zn	Ni
Z-146/2017	Cr, Cu	Ni
Z-147/2017	PAH, C10-C40, Cr, Cu, Ni, Zn	Hg
Z-148/2017	Cr, Cu, Ni, Zn	Hg
Z-149/2017	PAH, C10-C40, Cd, Pb	Cr, Cu, Ni, Zn
Z-150/2017	C10-C40, Cd, Cr, Pb	Cu, Ni, Zn
Z-151/2017	C10-C40, As, Ni	Hg, Cr, Cu, Pb, Zn
Z-152/2017	C10-C40, Ni, Pb	Cr, Cu, Zn
Z-153/2017	As, Cr	Cd, Cu, Ni, Pb, Zn
Z-154/2017	Cd, Cr	Cu, Ni, Pb, Zn
Z-155/2017	C10-C40, Cu, Ni, Zn	Cr
Z-156/2017	Cr, Ni, Zn	As, Cu, Pb

20. EPS-TENT A, Obrenovac

Sample number	Exceeded limit values	Exceeded remediation values
Z-157/2017	Cr, Ni	
Z-158/2017	Cr, Ni	
Z-159/2017	Cr, Ni	
Z-160/2017	Cr, Ni	

21. EPS-TENT B, Obrenovac

Sample number	Exceeded limit values	Exceeded remediation values
Z-161/2017	Ni	
Z-162/2017	Ni	
Z-163/2017	C10-C40	
Z-164/2017		

22. MB Kolubara Prerada, Lazarevac

Sample number	Exceeded limit values	Exceeded remediation values
Z-165/2017	Ni	
Z-166/2017	Ni	
Z-167/2017	Ni	
Z-168/2017	Ni	
Z-169/2017	Ni	
Z-170/2017	Ni	
Z-171/2017	As	
Z-172/2017		

23. MB Kolubara Veliki Crljeni, Lazarevac

Sample number	Exceeded limit values	Exceeded remediation values
Z-173/2017	Ni	
Z-174/2017	C10-C40, Ni	
Z-175/2017	Ni, Pb, Zn	
Z-176/2017	Ni	
Z-177/2017	Ni	
Z-178/2017	As, Cr, Ni	
Z-179/2017	Cr, Ni	
Z-180/2017	Cr, Ni	

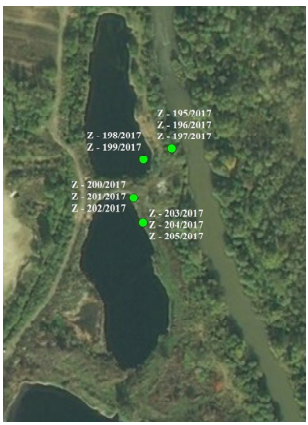
24. Copper Rolling Mill Sevojno, Užice

Sample number	Exceeded limit values	Exceeded remediation values
Z-181/2017	Cd, Cr, Ni	Cu, Zn
Z-182/2017	Cu, Ni, Zn	
Z-183/2017	Cd, Cr, Ni	Cu, Zn
Z-184/2017	Cd, Cr, Ni	Cu, Zn
Z-185/2017	Cu, Zn	Cr, Ni
Z-186/2017	C10-C40, Cr, Cu, Zn	Ni

25. Chemical Industry Zorka, Subotica

Sample number	Exceeded limit values	Exceeded remediation values
Z-187/2017	Cu	
Z-188/2017	Cd, Ni	As, Cu
Z-189/2017	As, Cd, Cu, Ni	Zn
Z-190/2017	PAH, Cd, Cu, Pb, Zn	
Z-191/2017	Cu, Ni	
Z-192/2017	Cu, Ni	
Z-193/2017	PAH, Cd, Cr, Ni, Pb, Zn	As, Cu
Z-194/2017	Cu	

26. Packing Paper and Packaging Factory FOPA, Vladičin Han



Sample number	Exceeded limit values	Exceeded remediation values
Z-195/2017	Cd, Cu, Ni, Pb, Zn	
Z-196/2017	Cd, Cu, Ni, Pb, Zn	
Z-197/2017	As, Cu, Ni, Pb, Zn	
Z-198/2017	C10-C40, Cd, Cr, Cu, Ni, Pb, Zn	
Z-199/2017	C10-C40, Cu, Ni, Zn	
Z-200/2017	C10-C40, Cd, Cu, Ni	
Z-201/2017	As, Ni, Zn	
Z-202/2017	As, Ni, Zn	
Z-203/2017	C10-C40, As, Cr, Cu, Ni, Zn	
Z-204/2017	As, Ni, Zn	
Z-205/2017	Ni	

27. Foundry Sand Landfill Mačkatica, Surdulica

Sample number	Exceeded limit values	Exceeded remediation values
Z-206/2017	PAH, Cu, Ni, Zn	
Z-207/2017		
Z-208/2017		
Z-209/2017		
Z-210/2017		
Z-211/2017	Ni, Zn	
Z-212/2017	As, Cu, Ni, Zn	
Z-213/2017	PAH, Ni	
Z-214/2017	C10-C40, Ni	
Z-215/2017	Ni	
Z-216/2017	Ni	
Z-217/2017		
Z-218/2017		
Z-219/2017		
Z-220/2017		

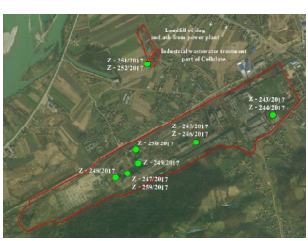
28. Chemical Industry PKS Latex, Čačak

Sample number	Exceeded limit values	Exceeded remediation values
Z-221/2017	Cu	Ni
Z-222/2017	Ni, Zn	Ni
Z-223/2017	As, Cu, Zn	Ni
Z-224/2017	As, Cu, Zn	Ni
Z-225/2017	As, Cu, Zn	Ni
Z-226/2017	Cr, Cu, Zn	Ni
Z-227/2017	Cr, Cu	Ni

29. Chemical Industry Elixir, Prahovo

Sample number	Exceeded limit values	Exceeded remediation values
Z-228/2017	Cu, Ni	fluorides and phosphates
Z-229/2017	C10-C40, As, Cd, Cu, Ni, Zn	fluorides and phosphates
Z-230/2017	Hg, Cd, Cu, Ni, Zn	
Z-231/2017	Ni	
Z-232/2017	Ni	
Z-233/2017	As, Ni	
Z-234/2017	Cu, Ni	
Z-235/2017	Cu, Ni	
Z-236/2017	As, Ni	
Z-237/2017	Cu, Ni	
Z-238/2017	As, Ni	
Z-239/2017	As, Ni	
Z-240/2017	As, Ni	
Z-241/2017	Ni	As
Z-242/2017	As, Ni	

30. Chemical Industry Viskoza, Loznica



Sample number	Exceeded limit values	Exceeded remediation values
Z-243/2017	As, Cr, Cu, Pb	Ni, Zn
Z-244/2017	As, Cu, Ni, Pb, Zn	
Z-245/2017	As, Cu, Pb, Zn	Ni
Z-246/2017	As, Cu, Pb, Zn	Ni
Z-247/2017	As, Cu, Ni, Pb, Zn	
Z-248/2017	Cu, Ni, Pb, Zn	
Z-249/2017	Cu, Ni, Pb, Zn	
Z-250/2017	C10-C40	
Z-251/2017	As, Cd, Cu, Pb, Zn	Ni

	Z-252/2017	Cu, Ni, Zn	
	Z-259/2017	Cr	As, Cd, Cu, Ni, Pb, Zn

31. Zorka non-ferrous metallurgy, Šabac

Sample number	Exceeded limit values	Exceeded remediation values
Z-253/2017		As, Cd, Cr, Cu, Pb, Ni, Zn
Z-254/2017		
Z-255/2017	Ni	As, Cd, Cu, Pb, Zn
Z-256/2017	PCB, C10-C40, Cr	DDE/DDD/ DDT, As, Cd, Cu, Ni, Pb, Zn
Z-257/2017	C10-C40	DDE/DDD/ DDT, As, Cd, Cu, Ni, Pb, Zn
Z-258/2017		DDE/DDD/ DDT, PAH, As, Cd, Cu, Ni, Pb, Zn

32. Production of auto parts 21. Oktobar, Kragujevac

Sample number	Exceeded limit values	Exceeded remediation values
Z-260/2017	As, Cr, Cu, Pb, Zn	Ni
Z-261/2017	Cr, Cu, Zn	Ni
Z-262/2017	C10-C40, Cr, Pb	Cu, Ni, Zn
Z-263/2017	C10-C40, cyanide complex, As, Cd, Pb	Cr, Cu, Ni, Zn
Z-264/2017	C10-C40, As, Cd, Cr, Pb	Cu, Ni, Zn

Location sorted by priority	Remediation technologies
1.(19) Chemical Industry Župa LTD, Kruševac	1) combination of excavation, displacement to a safe location and solidification with stabilization 2) electrokinetic separation
2.(16) Non-ferrous metal factory FOM, Prokuplje	1) stabilization/solidification (in situ) 2) phytoremediation
3.(31) Zorka non-ferrous metallurgy, Šabac	Zone contaminated by inorganic pollutants: 1) stabilization/solidification (in situ) 2) electrokinetic separation Zone contaminated by organic waste 1) excavation and incineration 2) thermal reduction
4.(30) Chemical Industry Viskoza, Loznica	1) stabilization/solidification 2) excavation, displacement to a safe location and solidification
5.(5) Electronic Industry, Niš	1) excavation, displacement to a safe location and solidification 2) stabilization/solidification (in situ)
6.(15) Mechanical Engineering Industry, Niš	1) electrokinetic separation 2) stabilization/ solidification (in situ)
7.(12) Leather-textile Combine Koža, Zaječar	1) stabilization/solidification (in situ) 2) phytoremediation
8.(29) Chemical Industry Elixir, Prahovo,	1) stabilization/solidification (in situ) 2) excavation, displacement to a safe location and solidification 3) phytoremediation
9.(7) Factory of wagons, Kraljevo	1) stabilization/solidification (in situ) 2) excavation, displacement to a safe location and solidification
10.(9) Šumadija, Kragujevac	1) stabilization/solidification (in situ) 2) electrokinetic separation
11.(16) Battery Factory Sombor, Sombor	1) excavation, displacement to a safe location and solidification 2) stabilization/solidification (in situ)
12.(3) Radijator LTD, Zrenjanin	1) excavation and incineration 2) thermal reduction
13.(26) Packing Paper and Packaging Factory FOPA, Vladičin Han	1) stabilization/solidification 2) phytoremediation
14.(8) Magnohrom, Kraljevo	1) stabilization/solidification (in situ) 2) electrokinetic separation

Table 2.Priority List and Proposed Remediation Technologies (CIOPH, 2018)

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