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Soil pollution in the Western Balkans

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Contents

Abstract

Soil contamination in the Western Balkans is a significant challenge, hampered by inadequate legal frameworks, lack of comprehensive field data, and insufficient site investigations. This report aims to support the JRC's efforts to fill information gaps on soil pollution across the Western Balkans based on an extensive review of the current evidence base of the state of Western Balkans soils. The purpose is to identify the extent of pollution at country and regional level, but also highlighting policy areas of concern. Establishing robust monitoring networks with standardized data collection is crucial for understanding soil health and developing effective remediation strategies. Harmonized soil monitoring and testing programs, aligned with the Green Deal and pan-EU soil initiatives, are essential for cross-border collaboration and policy implementation. This work is part of the JRC project "Environment and Climate in Enlargement" and contributes to the Western Balkans Agenda on Innovation, Research, Education, Culture, Youth, and Sports, particularly in developing a soil pollution database and supporting capacity building for the Green Agenda. This work underscores the urgent need for integrated soil protection policies to ensure healthy soils and sustainable land use in the Western Balkans.

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Executive summary

Policy context

The adoption, implementation and enforcement of Chapter 27 of the EU acquis on Environment is an obligation for countries under the "Stabilisation and Association Agreement" process". The European Commission political guidelines for 2019-2024 consider the accession process as a unique opportunity to promote European Union (EU) core values and reaffirm the importance of continuing the reform process of this region while the EU Green Deal (COM(2019)640) sets out several concrete actions in the field of climate, depollution, energy, biodiversity, circular economy, among others. The European Commission has launched the EU Action Plan: "Towards Zero Pollution for Air, Water and Soil" COM(2021) 400 which aims to protect ecosystems and human health. This report is aimed at policymakers involved in environmental reforms and EU accession processes. It is relevant to current policy implementation, focusing on pressing issues like soil pollution, which poses high stakes for ecosystems and human health. This report adds value by providing updated data on soil contamination, essential for informing ongoing political debates and other related EU policies, such as the EU Soil Strategy for 2030.

Key conclusions

Inadequate legal frameworks, lack of field data and thorough site investigations, hamper addressing soil contamination in the Western Balkan. Field data are the basis for both the identification of critical situations and the development of effective and efficient policies. Therefore, the establishment of monitoring networks with sufficient data coverage in space and time and a set of analysed parameters is crucial for a comprehensive understanding of soil health and contamination levels. These networks enable the collection of standardized, high-quality data that can inform risk assessments and remediation strategies. Moreover, the harmonization of data collection methods across the region would facilitate cross-border comparisons and collaborative efforts. Implementation of a soil protection framework to ensure heathy soils is a priority for the implementation of the Green Deal across the Western Balkans. This requires coherent action across a broad policy base. Specifically, efforts must focus on unifying and integrating fragmented knowledge on soil pollution, expanding pan-EU soil initiatives to include the Western Balkans, and implementing targeted programmes like the Soil Mission to support local innovations. National policies should align with these broader developments, and harmonised soil monitoring and testing programmes should be established to meet legislative requirements and ensure consistency and reliability in data collection.

Main findings

In the Western Balkans countries, soil contamination is a significant issue resulting from over a century of industrialization. The extent of contamination in the region is difficult to determine precisely, although some countries, like Serbia, have made initial estimates. Inadequate waste management remains a significant contributor to soil pollution despite efforts to improve legislation. Agriculture, which occupies 45% of the land in the region, faces challenges from trace elements in fertilizers and pesticide residues. Additionally, emerging contaminants like microplastics, pharmaceuticals, Polycyclic Aromatic Hydrocarbons (PAHs), Persistent Organic Pollutants (POPs), and Per- and Polyfluoroalkyl Substances (PFAS) are under-researched but require attention for effective soil management strategies

- It is estimated that the area of agriculture land with failure of soil health indicator due to direct inputs of nutrient issues in agricultural systems (excluding air pollution) to be in the range of 5.20% of the total agriculture area.

— Western Balkans reported a total number of 118 contaminated sites due to mining and industrial activities, but the extent of the total area polluted is unknown. Some soils are naturally contaminated with heavy metals due to geological formations from where they have formed.

Related and future JRC work

Environment and Climate protection are essential elements of the EU Green Deal and the related Green Agenda for the Western Balkans. Healthy soils are at the basis of our economy and are key components of the climatic system. The JRC contributes to the EU Soil Strategy for 2030 and carries out a holistic investigation of the soil health in the Western Balkans by analysing a complete set of parameters: level of nutrients, content of organic carbon, erosion, pollution, soil sealing, salinisation, desertification and pressures on soil biodiversity.

Quick guide

This report addresses soil contamination in the Western Balkans, a region affected by over a century of industrialization and inadequate waste management. **Chapter 1** provides and overview of the historical context of soil contamination in the Western Balkans region. **Chapter 2** introduces the Green Agenda for the Western Balkans. **Chapter 3** describes the geomorphological and climatic context influencing soils in the Western Balkans, understanding how these factors contribute to soil degradation and pollution risks. **Chapter 4** (the core of the report) presents findings regarding soil nutrients and pollution risks at both regional and country levels. Finally, **Chapter 5** provides synthesis of findings to understand the overall regional impact of soil pollution in the Western Balkans and recommendations for policy interventions and collaborative efforts to address soil contamination and promote sustainable land management practices.

1 Introduction

On 23 June 2022, the European Union (EU) expressed its full and unequivocal commitment to the EU membership perspective of the Western Balkans and called for the acceleration of the accession process. The EU Green Deal (COM(2019)640)2 sets out several concrete actions in the field of climate, depollution, energy, biodiversity, circular economy, among others. It is part of the Commission's strategy to implement the UN's 2030 Agenda and the sustainable development goals. Considering that climate change and pollution are cross-border issues, involving EU candidates and neighbours is a prerequisite for achieving the EU Green Deal objectives. Western Balkan countries have a shared strategic objective—accession to the EU. They are in the various stage of the accession—the most advanced are Montenegro and Serbia, next North Macedonia and Albania, while for Bosnia and Herzegovina, on 12 October 2022, the European Commission recommended that candidate status be granted.

The adoption, implementation and enforcement of the EU acquis Chapter 27 on Environment and Climate Change is an obligation for accessing countries in the framework the "Stabilisation and association process". Moreover, the Guidelines for the implementation of the Green Agenda for the Western Balkans (SWD(2020) 223)3, accompanying the Economic and Investment Plan for the Western Balkans (COM(2020) 641)4, define priority areas for interventions and identify initiatives to fulfil the principles of the EU Green Deal in this region. More recently, the European Commission has launched the EU Action Plan: "Towards Zero Pollution for Air, Water and Soil" COM(2021)4005 which aims to protect ecosystems and human health. Moreover, the 'Western Balkans Agenda on Innovation, Research, Education, Culture, Youth and Sport' outlines a comprehensive strategy for regional cooperation in the six Western Balkans economies facilitating the involvement of students, researchers, innovators, and entrepreneurs in actions on sustainable socio-economic development in line with the new Horizon Europe association agreements signed by the accessing countries. The ten-year experience in the environmental and climate topics in South-East Europe and the available policy-oriented tools place the JRC in a unique position to support sustainable policies in this region.

Data to characterize the overall suite of pressures on soil are largely lacking (e.g. diffuse soil pollution), making it difficult to quantify the geographical extent of the pressure or establish quantitative trend assessments of overall soil health. Soil pollution includes both local hotspots (e.g. ex-industrial land, landfills, etc.) and more widespread contamination reflecting inputs from air pollution legacy, agricultural land use (pesticides, metals, sewage sludge) as well as from unquantified.

This report summarises for the first time the status of soil pollution in the Western Balkans, describing **current knowledge and gaps with respect to soil pollution** in order to benchmark the progress in this field, during the accession process and support the implementation of the Green Agenda for the Western Balkans with particular reference to remediation priorities. This information is also relevant for the EU Green Deal zero pollution ambition, as the pollution status in Western Balkans also affects the pollutant levels in the neighbouring EU Member States.

This report aims to support the JRC's efforts to fill information gaps on soil pollution across the Western Balkans based on an extensive review of the current evidence base of the state of Western Balkans soils. The purpose is to identify the extent of soil pollution at country and regional level.

2 The Green Agenda for the Western Balkans

The six countries and economies of the Western Balkans (Albania, Bosnia and Herzegovina, Kosovo*[1], Montenegro, North Macedonia, and Serbia) are on their way to join the European Union. Some of them are at an advanced stage and others will follow, but the goal is clear and shared by most of their citizens regarding EU membership. In this long process of EU accession, they are asked to align their legislations with the EU "acquis" the legal acts, and court decisions that constitute the body of the EU laws. The adoption, implementation, and enforcement of the EU acquis on Environment is an obligation for accessing countries in the framework of the stabilisation and association process. This implies reducing the emissions of pollutants and greenhouse gases (GHG) as priorities, which are strongly interlinked with energy, transport, and land use policies.

The Green Agenda for the Western Balkans, envisaged by the European Green Deal (EGD), details five pillars of action targeting: (1) climate action, (2) circular economy, (3) biodiversity, (4) **fighting pollution of air, water, and soil** and (5) sustainable food systems and rural areas. Digitalisation will be a key enabler for the above five pillars in line with the concept of the dual green and digital transition.

Based on the EGD targets, soil condition is recognized as a vital element of these five pillars. In particular:

- The vision for healthy soils being developed under the EU Soil Strategy 2030 and the upcoming **Soil Monitoring and Resilience Law** and Legally Binding Soil Restoration Targets that are being developed under the Biodiversity Strategy,
- the EU Climate Law notes the need for **increased sequestration of organic carbon by agricultural soils** as a major component of climate regulation and in mitigation of the effects of emissions,
- The recently adopted Nature Restoration Law (NRL) includes one criterion on **soil organic carbon** for both forest and agro-ecosystems, underscoring its relevance to the Biodiversity pillar.
- more **efficient nutrient cycles** (consequently less pollution of soil and water) and reduction in soil sealing which are explicit objectives of the Circular Economy Action Plan,
- a **Soil Pollution Watch List** together with a Clean Soil Monitoring and Outlook Report are foreseen under the **Zero Pollution Action**,
- sustainable agriculture objectives under the Farm2Fork Strategy are built on balanced soil nutrient management and the **reduction of pesticide residues in soil**,
- research and innovation challenges set by the Soil Mission under Horizon Europe.

Soil degradation is prevalent and extensive throughout the Western Balkans region (Zdruli *et al.*, 2022). Soils are under pressure, but the intensity of various soil health indicators varies between them and among the countries. It is very difficult to make a regional assessment on the extent of unhealthy soils in the Western Balkans because of the limited data availability. Data to characterize the overall state of pressures on soils in the WB region are largely lacking (e.g. diffuse soil pollution), making it difficult to quantify the geographical extent of the pressures or to establish quantitative trend assessments of overall soil health (Zdruli *et al.*, 2022). The assumption is that all soils are under pressure, even if only considering indirect pressures, from

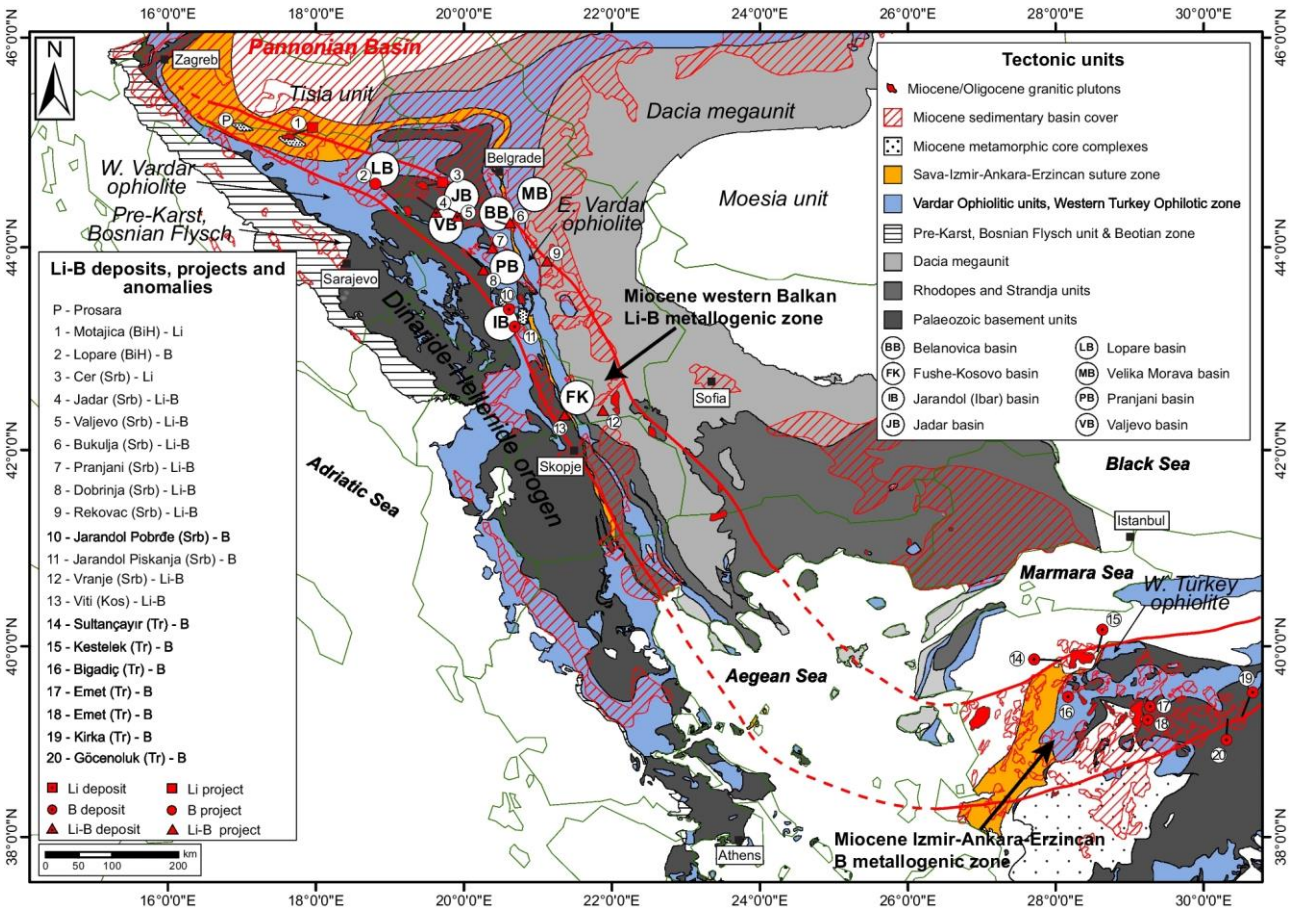
[1] This designation is without prejudice to positions on status and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

air pollution and climate change. However, soil pollution is probably one of the biggest unknowns. Soil pollution includes both local hotspots (e.g. ex-industrial land, landfills, etc.) and more widespread contamination reflecting inputs from air pollution legacy, agricultural land use (pesticides, metals, sewage sludge) as well as other unquantified sources.

3 The Western Balkans region: Geomorphological setting, climatic conditions, and associated soils

The Western Balkan region is made of a variety of landscapes, great lithological and geomorphic diversity that ultimately is reflected in the formation of very different soil types. In many cases, this soil diversity is also responsible for natural soil contamination, as in the case of soils that are formed on ultrabasic rocks that naturally are rich in heavy metals. Typical for this type of contamination are the *Smonitsa* soils, or the Chromic Vertisols spread throughout Serbia, North Macedonia, Montenegro, and Albania (Figure 1).

Figure 1 Geological map of the Balkan Peninsula



Source: (Borojević Šoštarić & Brenko, 2023)

The loess deposits of the Pannonian plain expanding largely into Serbia and to lesser extent in Bosnia and Herzegovina host some of the most fertile soils of Europe, but they are at risk of contamination due to overuse of chemical fertilisers and pesticides. It is exceptional that here some of the thickest European loess areas are recorded with depths as deep as 100 m (Koloszar, 2010; Sümegi *et al.*, 2018), preserving a quasi-continuous paleoenvironmental record extending back to the Early (Marković *et al.*, 2011; Buggle *et al.*, 2013; Schaetzl *et al.*, 2018). The research in the Middle Danube Basin has provided important contribution to loess research (Obreht *et al.*, 2017; Marković *et al.*, 2018). These loess deposits are inter merged with alluvial depositions of the Danube River within which Serbia has about 10.2% of its territory, Bosnia and Herzegovina 4.6%, while Montenegro, North Macedonia, Kosovo* and Albania less than 1%.

It is a very know fact that the Danube transports enormous quantities of nutrients and pesticide residues deriving from unsustainable farming practices. It is estimated that Nitrogen (N) emissions in the Danube River basin are currently around 500,000 tons per year, with 44% deriving from agriculture, 30% from urban areas

and 23% from forests and natural areas. About 340,000 tons enter the Black Sea, into which the Danube drains (ICPDR, 2021).

Other important geomorphologic formations are the karsts, particularly distributed in Bosnia and Herzegovina, Montenegro and to a lesser extent in Albania and North Macedonia. For instance, the Trebišnjica in Bosnia and Herzegovina is one of the largest sinking rivers in the world; one of its effluents, Ombla, springs out of a huge cave near Dubrovnik in Croatia and then drains into the Adriatic Sea.

These limestone karstic structures have been unequally uplifted with altitudes varying between 1,300 m above sea level in Kotor (Montenegro) to 200 m in the eastern part of the country. Overall, the topography in the limestone areas is karstic, heavily fractured by tectonic events with many dolines, sharp ridges, and residual reliefs in the weathered limestones. On the bottom of the dolines and karstic depressions, there are small villages, farms, and rural communities, while the highest heigh of the massive Dinaric Alps is 2,694m (Maja e Jezerces) in Albania. Furthermore, some still active glaciers were discovered in Albania on 2007, making it one of the southernmost glaciers of the European continent (Grunewald & Scheithauer, 2010; Gachev *et al.*, 2016). Overall, these pristine environments are free of any form of pollution.

The flat lands of western coastal plains of Albania form the largest alluvial plains of the Western Balkans, after the Danube basin. Other important flat lands typical of a graben formation are in the fields of Kosovo*. The flat lands all over and wherever they occur are intensively cultivated with all kinds of crops, from cereals to horticulture or fruit trees. These areas are under pressure from the overuse of chemical fertilizers and pesticides and the risks of pollution are high. The situation becomes even more complicated when these areas suffer from poor drainage and waterlogging making them even more vulnerable to pollution.

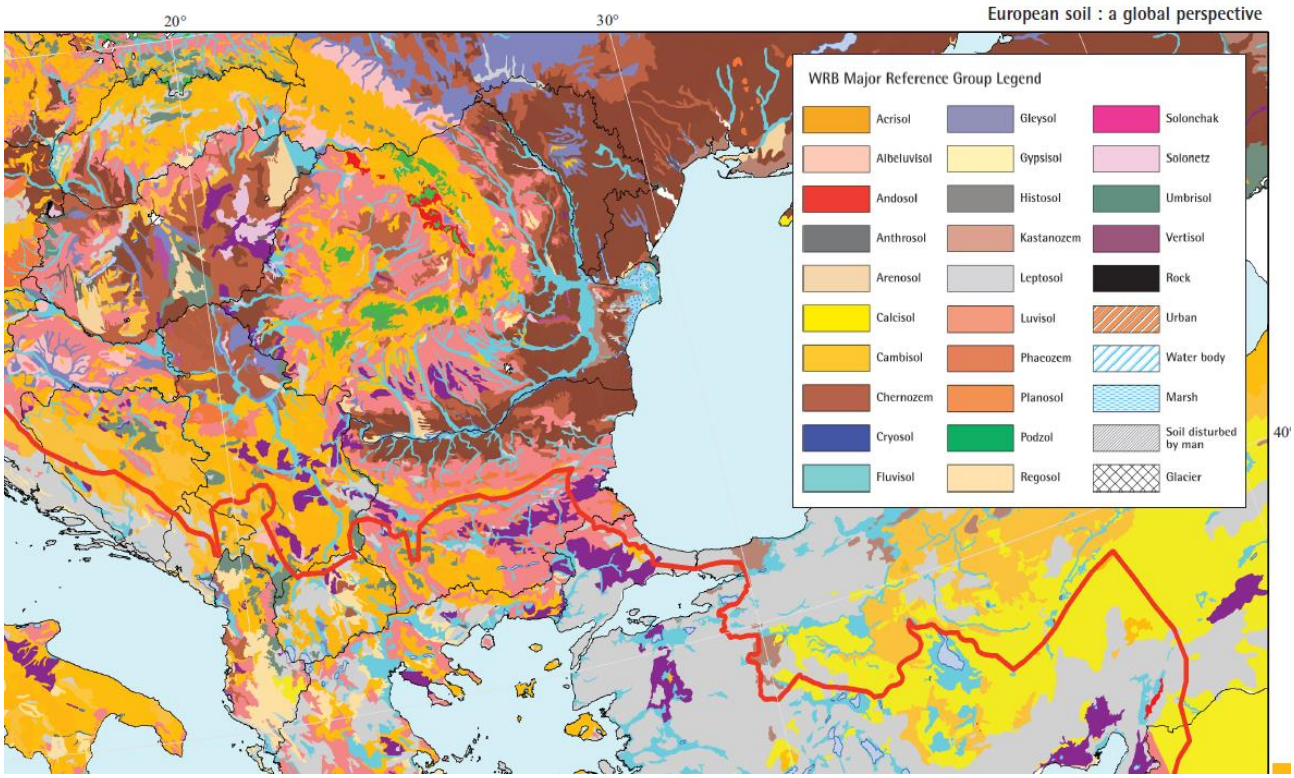
The region has also several lakes. The biggest ones are in Shkoder (bordering Albania and Montenegro), Ohrid (border between Albania and North Macedonia) and Prespa (bordering Albania, North Macedonia, and Greece).

Climate varies from typical Mediterranean along the coasts (dry and hot summers and wet mild winters) with continental climate conditions in the uplands and higher mountain ranges. It is interesting to notice the higher temperatures along the Mediterranean coast and the higher precipitation in the border between Albania and Montenegro. In Montenegro at the village of Crkvice (940 m above sea level), an annual rate of 7,000 mm has been recorded making it the rainiest place in Europe.

The impact of climate on soil contamination and pollution is reflected in the soil's capacity for carbon absorption and causes climate change though changing temperature and precipitation patterns. Therefore, environmental pollution and climate change influence each other through complex interactions. Several studies have demonstrated that soil pollution directly contributes to climate change by accelerating the emission of GHGs from the soil to the atmosphere and indirectly promoting soil respiration and adversely affecting natural carbon sinks (Chia *et al.*, 2023).

Soils of the Western Balkans are the result of the pedogenetic process dominated by lithology, topography and climate that play a dominant role in soil formation. The large diversity is represented by Cambisols, Luvisols, Chernozems, Kastanozems, Phaeozems, Umbrisols, Fluvisols, Gleysols, Histosols, Arenosols, Calcisols, Leptosols, Regosols, Vertisols, Solonchacks, Solonetz, Anthrosols, and Technosols (Figure 2).

Figure 2 General representation of the soil distribution in the Western Balkans (The red line shows the delineation of the Mediterranean watershed).



Source: Soil Atlas of Europe (European Commision, 2005)

Cambisols, Luvisols, Chernozems, Kastanozems, Phaeozems, Umbrisols, and Fluvisols are very fertile soils, typical for flatlands as well as uplands and are used mostly for cereals, horticulture, fruit trees, olives, vines, and forage crops providing higher yields even with minimum inputs. However, they are under pressure from urban expansion, soil sealing, compaction, **pollution and over fertilization causing chemical pollution.**

Leptosols and Regosols are mostly located in the uplands and the mountain regions. They are often covered with forests, shrublands and natural pastures. Erosion and landslides are a problem, exacerbated by forest fires, and overgrazing. Histosols cover relatively small areas, Arenosols usually follow the coastal sand dunes, Solonchacks and Solonetz most widely found in Albania, North Macedonia, and Serbia, while Vertisols are also evident throughout the region. Gleysols have limited extent typically found in former drained wetlands and in depressions while Calcisols usually are found in the hilly areas of Albania, Montenegro and at limited extent all over the region. Large parts of them are used for the cultivation of olive groves and vines. Finally, Anthrosols and Technosols cover limited areas compared to other soils but are widely distributed in the vicinity of large urban areas as the best testimony of the urban sprawl.

4 Soil Pollution

The Zero Pollution Action Plan's goal is that by 2050, soil pollution should be reduced to levels which are no longer expected to pose risks and which respect the boundaries our planet can cope with, thus creating a toxic-free environment.

Preventing diffuse and point-source soil pollution remains the most effective and cheapest way to ensure clean and healthy soils in the long-term. In fact, contamination should be prevented at the source (Pathway to a Healthy Planet for All, EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil', COM(2021)400 (EC, 2021a). This can be reached, for instance, by having clean industry, sustainable product design, improved recycling, waste management and nutrient recovery, more efficient fertiliser application or reduced pesticide use and risk, as well as implementing the Strategic Approach to Pharmaceuticals in the Environment (EC, 2019a) and reducing the use of antimicrobials. In this context, the Soil Strategy aims to review the rules on industrial emissions while improving and harmonising the consideration of soil health and soil biodiversity in EU risk assessments for chemicals, food and feed additives, pesticides, fertilisers and other chemicals.

A significant new development will be the establishment of a priority watch list for soil contaminants, together with an effective screening and soil pollution monitoring and outlook mechanism. Specifically addressing contaminated sites (generally ex-industrial sites) require remediation with often complex and costly techniques, although in certain cases low-cost, bioremediation techniques have been shown to be effective. Nonetheless, in some cases soils have been degraded to such an extent that they cannot be fully restored to a healthy condition at a reasonable cost. Reporting on progress in managing soil contamination 36 is currently voluntary, irregular and based on a changing methodology, different national definitions, screening values and risk assessment methodologies.

In light of this lack of level playing field, the Commission in the context of the Soil Monitoring and Resilience Directive (EC, 2023a) is proposing legal provisions to make such reporting mandatory and uniform across the EU. When efforts to prevent and control the source of pollution have failed and contaminants reach the soil and pose risks for the environment and human health, the soil must be remediated and the polluter should pay for it. The Environmental Liability Directive 2004/35/CE (EU, 2004) obliges certain operators to remediate contaminated land that poses risks for human health if pollution occurred as the consequence of activities carried out after 2007 or, if carried out before, not yet finished at that date. The Industrial Emissions Directive 2010/75/EU (EU, 2010) requests operators of certain installations to establish the state of soil and groundwater contamination at the start of operations, apply for a permit that includes conditions to prevent soil pollution through application of the best available techniques and to take necessary action upon definitive cessation to return the site to its initial status. However, for historical (contamination was caused before the entry into force of national or EU legislation) or orphan (the polluter cannot be identified, no longer exists or cannot bear the remediation cost, e.g. due to bankruptcy) contaminated sites, a common approach is lacking in the EU, which is a very important legal gaps.

After soil erosion, soil pollution remains the most important factor of soil degradation in the Western Balkans (Zdruli *et al.*, 2022). Therefore, all countries are asked to undertake actions to address soil pollution which can offer co-benefits also for other key environmental issues such as water pollution and biodiversity loss, as mentioned also in the EU Soil Strategy for 2030 (EC, 2021b) and in the proposed Soil Monitoring and Resilience Directive (Soil Monitoring Law)(EC, 2023a). As a unique and complex ecosystem, soil provides an array of goods and services that are vital for life on the planet, but soils are under pressure throughout the Western Balkans region from numerous threats, among which soil pollution is a very worrying one.

The EU Soil Strategy for 2030 identified a series of pressures that affect soil condition. These include erosion, compaction, sealing, salinization, landslides, **and pollution (both in a local and diffuse sense**). Pressures

acting on the EU and Western Balkans soils, together with their impacts, are described in numerous publications (Jones *et al.*, 2012; FAO and ITPS, 2015; Montanarella & Panagos, 2021; Vidojevic *et al.*, 2022; Zdruli *et al.*, 2022).

The EU Mission "Soil Deal for Europe" that is operative since 2021 among other objectives has also the goal to establish 100 living labs and lighthouses to lead the transition towards healthy soils by 2030 (EC, 2023b). Life on Earth depends on healthy soils, which are the foundation of food systems and at the same time provide clean water and habitats for biodiversity while contributing to climate resilience. Among the eight objectives of the mission, **reduce soil pollution** and enhance restoration is a priority.

Under this objective, the **Western Balkans countries should first identify the contaminated sites that they have within their territories and then prepare action plans for remediation and monitoring**. This could be in the form of a Living Lab to disseminate these practices, not only for the stakeholders inside the Living Lab but also for those in the vicinity areas.

Soil pollution remains a critical issue that needs major attention; despite remains largely unknown and not well documented. The main challenges at the regional and national level are related to the lack of political commitment to improve implementation of soil and related policy instruments, which are hampered by a lack of financial resources to establish a current policy relevant knowledge base. Data to characterize the overall state of contamination and pollution of soils in Western Balkan region are largely lacking (e.g. diffuse soil pollution), making it difficult to quantify the geographical extent or to establish quantitative trend assessments of overall soil health. Soil pollution includes both local hotspots (e.g. ex-industrial land, landfills, etc.) and more widespread contamination reflecting inputs from air pollution legacy, agricultural land use (pesticides, microplastics, fertilizers, manure, sewage sludge) as well as other unquantified sources.

Here we provide relevant evidence for each country and at the regional level to:

- **Examine the relevant evidence base for soil pollution in the Western Balkans** (based on scientific publications, policy reports, relevant datasets, and expert interviews)
- For all the countries, **report the area of land** (and % of any relevant area, e.g. croplands) **affected by pollution** resulting in a decline in soil condition and health.
- **Pollution (local and diffuse)** – with as much breakdown as possible, evidence also on microplastics, wherever available, and emerging contaminants in waste streams with relevance to soil.

Soil pollution is a threat to human health as soils may be polluted by Potentially Toxic Elements (PTEs) like heavy metals and metalloids, organic compounds (PCBs, PAHs, PFAs, POPs, pharmaceuticals, etc.), pesticides, biological pathogens, and plastics (from macro to nano). Pollution reduces soil's ability to produce food and it results in food and crop contamination. When soil pollutants are washed into water bodies (rivers, groundwaters, lakes, oceans, etc.), they cause water pollution. Furthermore, deforestation causes soil erosion, liberates sequestered pollutants, and generates airborne dust. Pollution of air, water, and soil is responsible for at least 9 million deaths each year globally (Münzel *et al.*, 2023). The main sources of soil pollution are associated with anthropogenic processes, including a wide variety of contaminants (organic and inorganic chemicals).

To improve the knowledge base of the Western Balkan Region, this section provides updated information on several variables related to contaminated land (diffuse contamination) and contaminated sites (local contamination).

4.1 Methodology

The methodological approach used in the preparation of this report included collection of information from various sources such as national archives and statistics, published reports, web-based datasets, and most importantly national expert interviews. Their names are recognised at the acknowledgement of this report. Previous reports published by (Zdruli *et al.*, 2022) and (Vidojevic *et al.*, 2022) were also thoroughly used. Nevertheless, it should be noted that soil pollutions data are scattered throughout the region and their availability depends on each country. There are countries like Montenegro, North Macedonia, Albania, and Serbia that have better data in terms of availability and quality. Data are less available in Bosnia and Herzegovina and especially in Kosovo*.

4.2 Results

4.2.1 Soil nutrients and Nitrate Vulnerable Zones

In the region, about 5.2 % of total agricultural land has potentially relatively large N surpluses, as this area consists of greenhouses and open field horticulture crops, which receive the largest N fertilizer doses. However, generally the fertilizer application in these countries happens to be far below average EU levels, thereby having higher chance of negative N and P budgets contributing to nutrient mining and decrease in soil fertility.

Fertilizer use is a necessity to allow farmers to maximize their yields on most conventional farms but, from a practical perspective, over-fertilizing crops can lead to unintended consequences that are followed by contamination of soil and water. Finally, there is widespread agreement that the excess use of N fertilizers is still growing at a time when the average global efficiency of its use is stagnant, and hence the surplus N that is not taken up by crops is polluting soil, surface and groundwater also causing eutrophication (Sasakova *et al.*, 2018; Zhang *et al.*, 2021).

The standard procedure for estimating the nutrient balance in the EU agriculture soils is the Gross Nutrient Balance Indicator (EUROSTAT, 2020) that provides insights into the links between the use of agricultural nutrients, their losses to the environment, and the sustainable use of soil nutrients resources (Häußermann *et al.*, 2020). It consists of the Gross Nitrogen Balance and the Gross Phosphorus Balance and is intended to be an indicator of the potential threat of surplus or deficit of two important soil and plant nutrients in agricultural land. It shows the link between agricultural activities and the environmental impact, identifying the factors determining the nutrients surplus or deficit and the trends over time.

The European Commission (EC) Nitrates Directive requires that areas of land that drain into waters polluted by nitrates to be designated as Nitrate Vulnerable Zones (NVZs). Farmers with land in NVZs must follow mandatory rules to tackle nitrate loss from agriculture. It is well known that N, apart from agriculture crops, is also vital for aquatic ecosystems, supporting the growth of algae and plants which provide food and habitat for fish and smaller organisms that live in the water. Too much N in water can result in serious environmental and human health issues.

Albania

When considering agriculture practices related to nutrient management sporadic data show that for 2019 there were deficits for: N -104.8 kg/ha , P -8.7 kg /ha and for K -134.5 kg /ha (Gjoka *et al.*, 2021) making

Albania one of the countries with the largest **soil nutrient deficit** compared to the EU and OECD (Organisation for Economic Co-operation and Development) countries. This deficit is mainly due to the application of small amounts of chemical fertilizers. Therefore, it appears that there are **no environmental pressures or potential risk of pollution** at nationwide scale. However, these risks have been documented in the greenhouses and to a lesser extent in open field horticulture crops that are over fertilized with N. Instead, Phosphorous (P) and Potassium (K) are used in much lower amounts and do not pose risks of contamination. The other issue is that farmers rely mostly on intuition when applying fertilisers. A survey carried out in 2017 (Gjoka *et al.*, 2021) with farmers that grow watermelon in open fields as well as vegetables in greenhouses revealed that only about 25% of them have carried out soil and water analysis. That is worrisome both for the long-term use of the costly greenhouses, but also for the uncertainty of fertiliser use that remains largely not scientifically based. This has increased N accumulation in the soil and groundwater inside these greenhouses. Furthermore, there are already tens of hectares of greenhouses that are experiencing increased salinisation also due to poor quality irrigation water.

Furthermore, the other issue is the inappropriate **manure storage** with nitrates' losses into water bodies. Likewise, pesticides are representing a threat for water quality, but data are missing to make the proper estimates.

Bosnia and Herzegovina

World Bank data for the fertilizer consumption in Bosnia and Herzegovina (The World Bank, 2021) pointed out that it fluctuated substantially in recent years; nevertheless, it tended to increase through 1999 - 2018 period ending at 84.8 kg ha^{-1} in 2018. Compared to the EU countries this value is far below the average use of fertilisers in the EU. As in the case of Albania, the environmental risk of **degrading soil health due to over fertiliser use in Bosnia and Herzegovina remains low**.

*Kosovo**

In 2020, Agriculture, hunting, forestry and fishery contributed by 7.4% to the total Gross Domestic Product (DEAAS, 2021). According to the data from agricultural questionnaires conducted by the Kosovo* Agency of Statistics, in 2019 were used about 76,467 tonnes of fertilizers that contain (NPK, UREA and ALN), which is higher than previous years. However, compared with the period 2012-2014 there were about 6,100 tonnes less fertilizer used, indicating lower risks of contamination.

The trend of Nitrate concentration (mg/l) in surface waters (rivers) for the period 2008-2019 shows that the nitrate concentration during this period is between 0.658 mg/l, as the lowest value recorded in 2009, and 1,181 mg/l as the highest value recorded in 2018. Year 2019, marks an increase in concentration (1,100 mg/l), compared to the previous year 2018 (0.814 mg/l). In general, the trend of this indicator for the period 2008-2019, is linear with some small changes with increasing trend for the years 2008, 2013 and 2019.

The trend of phosphorus orthophosphate concentration (mg/l) in surface waters (rivers) for the period 2008-2019 shows that the concentration during this period is between 0.118 mg/l, as the lowest value recorded in 2013, and 0.265 mg/l as the highest value recorded in 2019. Year 2019, marks an increase in concentration, compared to the previous year 2018 (0.126 mg/l). In general, the trend of this indicator for the period 2008-2019 is presented with oscillations and there is no linear flow.

The **area cultivated with vegetables and the greenhouses were considered as potentially vulnerable** and they were included in the total area of the region.

Montenegro

In 2018, fertilizer consumption for the country was 246.8 kg/ha and for the period 2009 – 2018, there was a constant tendency of increase. When compared to other countries globally, Montenegro rank at the 27th stage, which is quite high even when compared to EU countries. Despite data are not available to estimate the nutrient balance, as previously mentioned, the area **covered by greenhouses and vegetables were included in the assessments as potentially overloaded particularly with N and therefore vulnerable to pollution**.
Within the Project "Support to implementation and monitoring of water management", in Montenegro, an Action Plan to limit the land application of N fertilizers in respect to the vulnerable zones in line with the Nitrates Directive (91/676/EEC) has been developed. Delineation of 14 nitrate vulnerable zones (NVZ) together with areas of sanitary protection zones has been carried out. Out of 14 NVZ, nine are located in the Adriatic basin, and five in Danube basin. The largest is Zeta Valley comprising some 334 km^2 out of which approximately 7% belongs to large agro-complex "Plantaže". The second largest is Nikšićko polje, which comprises adjacent Šipačno polje, with some 120 km^2. The smallest are the three poljes in Orjen Mt. area, namely Ubli, Dragalj and Grahovo, all with surface areas lesser than 10 km^2. In total, all NVZ comprise 859.23 km^2 or 6.22% of the Montenegrin territory. In 2023, the government of Montenegro adopted a decision to determine vulnerable zones in the Adriatic and Danube basins.

Montenegro has the Regulation on the principles of good agricultural practice for the application of fertilizers ("Official Gazette of Montenegro", No. 29/2014). The policy tool for control of nitrate from agricultural activities involves the implementation of the Code of Good Agricultural Practice on a mandatory basis for farms that lie within a designated NVZ and on a voluntary basis for farms outside of these areas. All farmers must follow the obligatory national regulations if they use any manufactured fertilisers, manures or other materials that contain N on agricultural land in a NVZ. The Action Plan for Montenegro includes the proposal for development of a single national Action Programme for all of the designated NVZs.

North Macedonia

North Macedonia has 10,140 km² of agricultural land that includes also pastures and meadows, which is almost 39% of its territory. Half of this land is devoted to crop growing, and the other half to livestock farming. In 2018, fertilizer consumption was 60.8 kg/ha, which is one of the lowest in the region. The tendency of fertilizer use shows a constant decline since the year 2007, that, except for 2008, 2009, and 2012, the value of 60.8 kg/ha is the lowest in the last decade. Based on the data it is stipulated **that the country do not experience soil health problems related to nutrient imbalance**, rather the soil fertility of agricultural land could show signs of fertility decline due to nutrient mining.

Nevertheless, since North Macedonia devotes a considerable part of its territory to agriculture, and agriculture related activities, this sector is responsible for 89% of annual national ammonia (NH_3) emissions due to animal husbandry and manure management. In sporadic cases, there is overuse of inorganic N fertilizer and manure additions to soils. Pollution of soil and groundwater from agriculture from excessive fertilizer and manure application, and irrigation with poorly treated wastewater is expected especially in areas with high permeability karst geology. However, no monitoring has been done to confirm the assumption (UNECE, 2019a).

Serbia

Serbia is the largest country in the Western Balkans and with the largest extent of the agricultural land. The country has made progress towards adjusting its legislation with the EU. Transposition of the Nitrates Directive 91/676/EEC in the Republic of Serbia is at an initial stage with few provisions reflected in the Law on

Water. The legislative alignment will include amendments to this law in order to establish the legal basis for the designation of the vulnerable zones and the adoption of a Code of Good Agricultural Practice. Another piece of legislation in progress is the transposition of Directive 86/278/EEC on the protection of the environment, and of the soil, when sewage sludge is used in agriculture (Vidojevic *et al.*, 2022).

Though Serbia fertilizer consumption fluctuated substantially in recent years, it tended to decrease through 2009 - 2018 period ending at 72.9 kg/ha in 2018. Based on the available data the total amounts of fertilisers used in Serbia are far below the EU levels. As for the other countries data availability of their use on various crops are not available but as a general agronomic rule their excess use is often relevant for the **greenhouses and vegetables, therefore these areas were considered as potentially vulnerable and were included in the regional estimation as well as at country level.**

The quality of river water in the Republic of Serbia, concerning nitrate concentration, indicates an excellent ecological status at 89% of the measuring points. However, an unfavorable (increasing) trend of nitrates was observed at 40% (nineteen) of these points. Nevertheless, it is worth noting that the mean nitrate values at these measuring points remain low and fall within the limits of excellent ecological status.
Regarding orthophosphate levels, the quality of river water in the Republic of Serbia does not meet the criteria for a good ecological status at ten (21%) measuring points. The most concerning situation is observed at the measuring points in AP Vojvodina. Throughout all catchment areas and the entirety of the Republic of Serbia, an insignificant trend of orthophosphate was observed (SEPA, 2023).

Regional summary

This section provides a summary of the findings presented in the previous sections, synthesizing the key insights observed across the Western Balkans countries: Albania, Bosnia and Herzegovina, Kosovo*, Montenegro, North Macedonia, and Serbia. Western Balkans countries use about two times less fertilizer (N, P, K) for its agricultural production than the EU (the EU: 157.2 kg/ha of arable land in 2018; Western Balkans: 73.9 kg/ha); imports almost four times less pesticides (14.5 kg/ha vs. 3.7 kg/ha in 2019); and has a lower share of land area equipped for irrigation (18.8% vs. 11.3%), but have just less than 10% lower cereals yield than the EU (Brankov & Matkovski, 2022).

Scattered available data for the Western Balkans show that the largest amounts of fertilizers, especially N are applied in the greenhouses followed by open field horticulture crops. Based on this assumption, the total area of greenhouses and horticulture crops (Table 1) was calculated for the whole region totalling about **286,444 ha (or about 5.20% of total agriculture land)**. This was based on reported data for the years between 2016 until 2020 depending on the country's national statistics. It appears that North Macedonia has the largest surface area covered by greenhouses and open field's horticulture crops when compared with the rest of the countries.

Table 1 Total area of greenhouses and horticulture crops

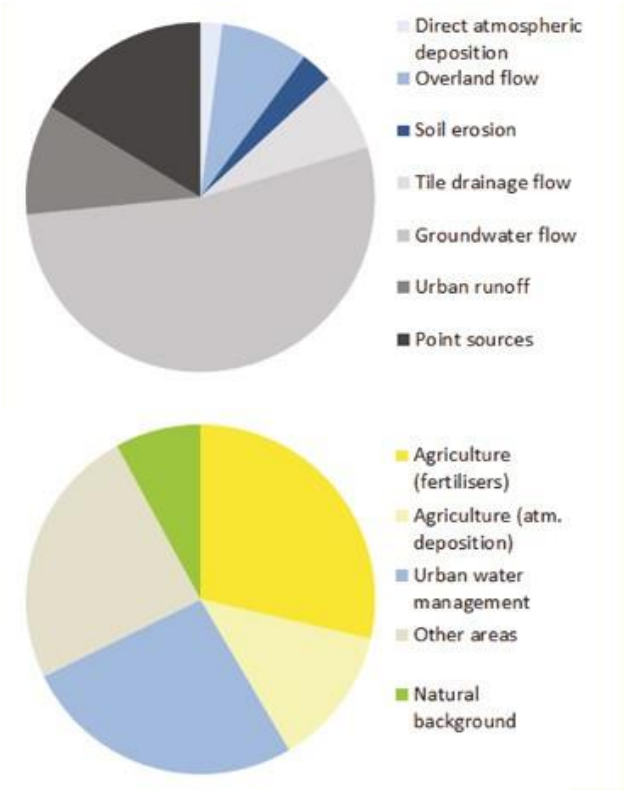
Country	Greenhouses (ha)	Horticulture crops (ha)	Total (ha)
Albania	1750	41000	42750
Bosnia and Herzegovina	715	75000	75715
Kosovo*	413	28191	28604
Montenegro	48	4125	4173

North Macedonia	6622	59000	69580
Serbia	60	69520	69580
Western Balkan TOTAL	9608	276836	286444

Other farmland uses including cereals, industrial crops such as sugar beet and sunflower, as well as forage and permanent crops (fruit trees, olives, vineyards, citrus) that cover 5,503,154 ha (or 94.85 %) of the total agriculture area of the Western Balkans but overall they are not subject of over fertilization. After numerous variations, since 2014, fertilizers efficiency has been continuously higher in the Western Balkans than in the EU. After 2009, fertilizers efficiency in the EU decreased by 19% for each ton of fertilizers produced, from 22.8 tons of cereal produced (per ton fertilizer) in 2019 to 18.5 tons of cereal (per ton fertilizer) in 2019. In the same period, fertilizers efficiency in the Western Balkans increased by 42.3%, from 19.5 to 27.8 tons of cereals produced per ton of fertilizer (Brankov & Matkovski, 2022). The general understanding is that due to economic costs, fertilizer use, especially N is used in excess primarily in greenhouses and open fields vegetable crops, and much less to other crops.

The most appropriate assessment of NVZs for the Western Balkans is to concentrate on the Danube River basin. According to several calculations, the total N emissions in the basin are about 600,000 tonnes/ha. This assessment comes from the MONERIS (MOdelling Nutrient Emissions in RIver Systems) water quality model, which has been used for the entire basin and for hydrological conditions of the period 2009-2012 to estimate spatial patterns of n emissions in the basin and assess the various contributing pathways (Gericke & Venohr, 2021). Subsurface flow is the most important pathway for N emissions, responsible for about 50% of all N emissions. Diffuse inputs dominate the basin-wide nitrogen emissions– with roughly 80% of the total load. Emissions from point sources, such as wastewater treatment plants and industrial dischargers, contribute 20% of the total load.

Figure 3 Different sources of Nitrogen load into the Danube River basin



Source: DRAFT Danube River Basin District Management Plan – Update 2015 (ICPDR, 2015)

The **main emission sources are agricultural fields with 40% of the total load**. Urban areas – such as wastewater discharges, runoff from paved surfaces and combined sewer overflows – as well as natural lands where atmospheric deposition provides nitrogen input are significant source areas as well (Figure 3). Several implemented measures have substantially reduced N inputs into surface waters and groundwater in the Danube River Basin, but further efforts are still needed. The long-term average for the period 2003-2012 of observed N river loads at the mouth of the Danube is about 500,000 tons per year. Due to the larger part of the Danube basin inside its territory, it is estimated that among the six Western Balkan countries and economies, Serbia should have the largest contribution of N discharge, which nevertheless is very limited compared to the nutrient loads coming from all other countries that drain their waters into the basin.

To further reduce N pollution, wastewater treatment plants must be upgraded with N-removal technology, however measures to introduce best practices in agriculture and land management are especially needed, since diffuse pathways make up a major part of the total N emissions. A key set of best agricultural practices related to farming and land management has been identified, which are in line with the provisions of the EU Nitrates Directive and the pillars of the Common Agricultural Policy in the EU Member States. In addition to regulatory actions to comply with basic standards, economic incentives for farmers can ensure higher efficiency and better practical performance in implementing measures. However, further efforts are needed to achieve better use of the available financial instruments and to appropriately finance and implement agricultural measures.

4.2.2 Soil Pollution risks and status

Western Balkans officially reported a total number of 118 contaminated sites due to mining and industrial activities, but the extent of the total area polluted is unknown. Some soils are considered as naturally contaminated as they show high concentrations of heavy metals due to geological formations from where they have formed.

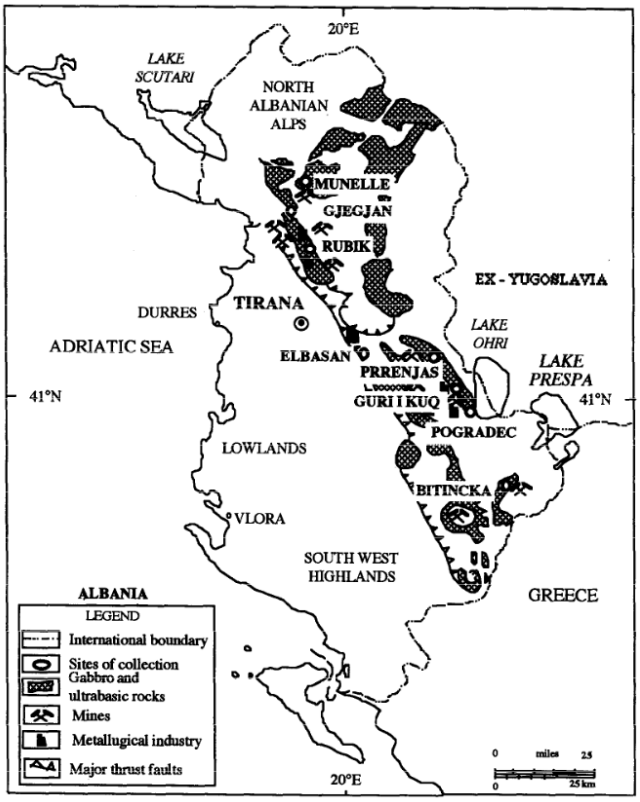
Albania

The geological formation of Albania is characterised by Quaternary sediments in the western part while on the eastern side by the basic, acid volcanic rocks and ultramafic serpentine massifs that play a crucial role in the natural contamination process. Studies (Ministry of Tourism and Environment, 2019) have shown that nickel (Ni), chromium (Cr) and Cobalt (Co) are present at high concentration at serpentine areas as well as in industrial sites located in the area. Moreover, also the surrounding soils show high levels of Cd, Copper (Cu) and Zn. Overall Albania has reported 25 contaminated sites (Annex 1).

Background levels of heavy metals were assessed in Albania to monitor soil contamination stemming from diverse human activities. Background concentrations in forest soils were larger compared to those in soils under other land use types (Gjoka *et al.*, 2021) . The largest background concentrations for Cd, Cr, Ni, Cu, Co, and Zn were found in forest soils formed on magmatic rocks, while the largest concentrations of Pb and Hg were found in soils formed on flysch and molasse. The background values and precautionary concentration values (in brackets) (mg/kg) for agricultural soils across flysch/molasses and quaternary deposits were as follow: Cd 0.24 (0.82), Cr 131.63 (527.42), Cu 41.26 (72.75), Ni 287.15 (632.70), Pb 19.11 (284.86), Zn 81.80 (113.90). The largest background values for Cd and Zn were found in Phaeozems, for Cr, Pb, and Co in Luvisols and Cambisols, and for Cu, Hg, and Ni in Fluvisols. The proposed background concentrations and precautionary values complete the picture of metal in European soils, can be used as reference concentrations for the Albanian environmental legislation, and allow the identification of potential contamination hot spots contents.

A study conducted by the Agriculture University of Tirana identified seven metals (Cd, Co, Cr, Cu, Ni, Pb and Zn) in soil samples collected on the eight sites of the serpentine zone (Table 2) (Figure 4). Each sample exhibited a high concentration in one or more metals (Laze *et al.*, 2005; Belalla *et al.*, 2010; Alikaj *et al.*, 2022). The Cd content in soils varied between 2 and 14 mg/kg dry matter (DM) and was rather high compared to the values generally observed in agricultural soils and was considered as toxic with the highest
value observed at the industrial site of Prrenjas. Cobalt and Cr concentrations in soils were also elevated because of both natural and anthropogenic sources and varied from 91 to 3,865 mg/kg DM. Again, the sample from Prrenjas exhibited the highest concentration of Co (476 mg/kg) and Cr (3,865 mg/kg). Copper concentrations in soils were lower than 73 mg/kg, except for the Rubik site where the Cu concentration was 1,107 mg/kg DM, caused by the former activity of the copper smelter factory in the area (Ministry of Tourism and Environment, 2019). High Ni and Cr concentrations were observed only at the serpentine sites where soils were derived from gabbro and ultrabasic rocks rich in Fe, Ni and Cr. The site of Prrenjas appeared the most polluted by Cd, Co, Cr, Ni and Pb. Chromium and Ni were present at high levels in the soil of Elbasan.

Figure 4 Distribution of serpentine formations and associated soils in Albania



Source: (Shallari *et al.*, 1998; Ministry of Tourism and Environment, 2019)

Table 2 Heavy metals concentrations (mg/kg) in soils of serpentine zone

Site	Cd	Co	Cr	Cu	Ni	Pb	Zn
Korce	4	184	513	6	1737	80	52
Puke	4	289	574	27	1104	87	49
Pogradec	5	259	635	8	2442	98	63
Prrenjas	14	476	3865	36	3579	172	93
Elbasan	3	130	491	14	447	80	61
Mirdite	9	338	256	1107	66	135	2495
Kukes	2	143	91	73	54	103	111

Source: (Ministry of Tourism and Environment, 2019)

The mining and ore processing industry has left behind several polluted sites, such as the one in the Elbasan metallurgical complex (Luli, 2010).

Accidental oil spills and improper disposal of wastewater used for oil extraction are also a cause of soil pollution by benzene, toluene, ethylbenzene, and xylenes (BTEX), a group of four volatile organic compounds (VOCs) or crude oil. The oil extraction industry is important to the economy of Albania, which has two of the largest onshore oil fields in Europe. In 2015, extensive pollution of neighbouring agricultural soils occurred following an incident at the Patos-Marinza oil field, which resulted in an explosion of gas, sludge, and water (Beqiraj & Topi, 2016). Furthermore, the country has two refineries that have not undergone a modernization process and therefore have limited capacity for oil treatment and refining and could have a negative impact on the environment (UNECE, 2018a).

Of the 25 sites reported by Albania in 2023, five are still considered as soil pollution hotspots. These five sites correspond to the following (Alimehmeti & Roshi, 2017):

- the pesticide-producing Durrës chemical plant, which has left a legacy of soils polluted with lindane at concentrations a hundred times higher than EU threshold levels, as well as several neighbouring waste accumulation areas with a total of more than 20,000 tonnes of lindane and other chemical residues;
- the chlor-alkali and PVC plant in Vlorë, which has caused a severe pollution of 50,000 to 60,000 m^2 with mercury at values exceeding 10,000 mg/kg, which has penetrated the soil profile up to a depth of 1.5 metres.
- the Marinzë oil field in Patos, which covers an area of 200 km^2, although the actual extent of soil pollution is unknown, the company estimates that between 20 and 40 tonnes of extracted crude oil is lost to the environment every day, along with atmospheric emissions of sulphur oxides. Values of 4-90 µg/m^3 PAHs have been reported in surrounding soils.
- the Ballsh Oil Refinery also has significant crude oil losses to the environment, estimated at 22,500 tonnes per year. As in the previous case, the oils end up in the Gjanicë River, which is a source of drinking water for the population downstream.
- And several landfills spread throughout the country. Although soil pollution has not been assessed, given the nature of the waste, pollution by trace elements, dioxins, and furans, among others, is expected.
- Agricultural production is currently a relatively less polluting source.
- Plastic pollution is also a problem with much of that accumulated along the riverbeds as well as along the coast.

Little information is available on the national priorities regarding soil pollution. The country has received funding by Global Environment Facility (GEF) to strengthen the capacity and promote sustainable soil management through integrated ecosystem restoration. The project was approved in 2016 and implemented by the United Nations Environment Programme (UNEP) (GEF, 2016). Additionally, it was reported that from 2011 until 2016 no action plan was made for the remediation of hotspots in the country (UNECE, 2018a). On the positive side, a soil monitoring network called the Consolidation of the Environmental Monitoring System (CEMSA) has been implemented, in which soil quality indicators, trace elements included, are measured in 30 fixed sites that overall are far too little for the whole country.

Alignment with EU legislation on industrial pollution and risk management is still at an early stage in Albania (European Commission, SWD(2023) 690 final) (EC, 2023c). Capacity and financial constraints are hampering progress in implementing legislation on the prevention of major accidents involving dangerous chemicals. Significant efforts are needed on the implementation and enforcement of waste management, to strengthen its administrative and inspection capacities and implement structural, cross-sectoral reforms. The legal framework for waste management is only partially aligned with EU legislation and substantial efforts to achieve full alignment are needed. Closing non-compliant landfills and dumpsites, as well as littering, remain significant challenges. Table 3 shows main drivers, sources, and location of contamination sites in Albania (For more information, please consult Annex 1).

Table 3 Drivers, sources, and location of contamination sites in Albania

Source and Drivers of soil contamination	Activities and Impacts	Area affected
Mineral Industry	Production of cement and lime	Kruja, Lezha Tirana, Elbassani

	Manufacture of ceramic products by firing, in particular roofing tiles, bricks refractory bricks, tiles, stoneware etc.	
Production and processing of metals	Metal ore roasting or sintering Production of iron or steel Processing of ferrous metals Operation of ferrous metal foundries Processing of non-ferrous metals Surface treatment of metals or plastic materials using an electrolytic or chemical process	Elbassani, Mirdita, Bulqiza, Kukes, Tropoje, Pogradec, Korçë , Berrat, Durres
Oil extraction and processing industry and energy industries	Oil extraction Refining of mineral oil and gas Combustion of fuels	Berat, Fier, Vlorë
Waste management	Disposal of urban and hazardous waste Disposal or recovery of waste in waste incineration plants Landfills Temporary and underground storage of hazardous waste	Watershed of: Buna, Mati, Erzeni, Osumi, Semani, Devolli, Shkumbini,Vsoja, Gjallica
Waste water management	Discharge of urban and industrial wastewater into rivers Discharge of urban and industrial wastewater into open environment	Watershed of: Buna, Mati, Erzeni, Osumi, Semani, Devolli, Shkumbini,Vsoja, Gjallica
Agricultural practices	Use of fertiliser Use of pesticides	Agricultural areas

Source: (Ministry of Tourism and Environment, 2019)

Bosnia and Herzegovina

Bosnia and Herzegovina do not have a national soil and land information system, and information on soil pollution is limited because of a lack of regulations on soil protection and monitoring. The only information available is on land use and structure, soil classes and ownership (UNECE, 2018b).

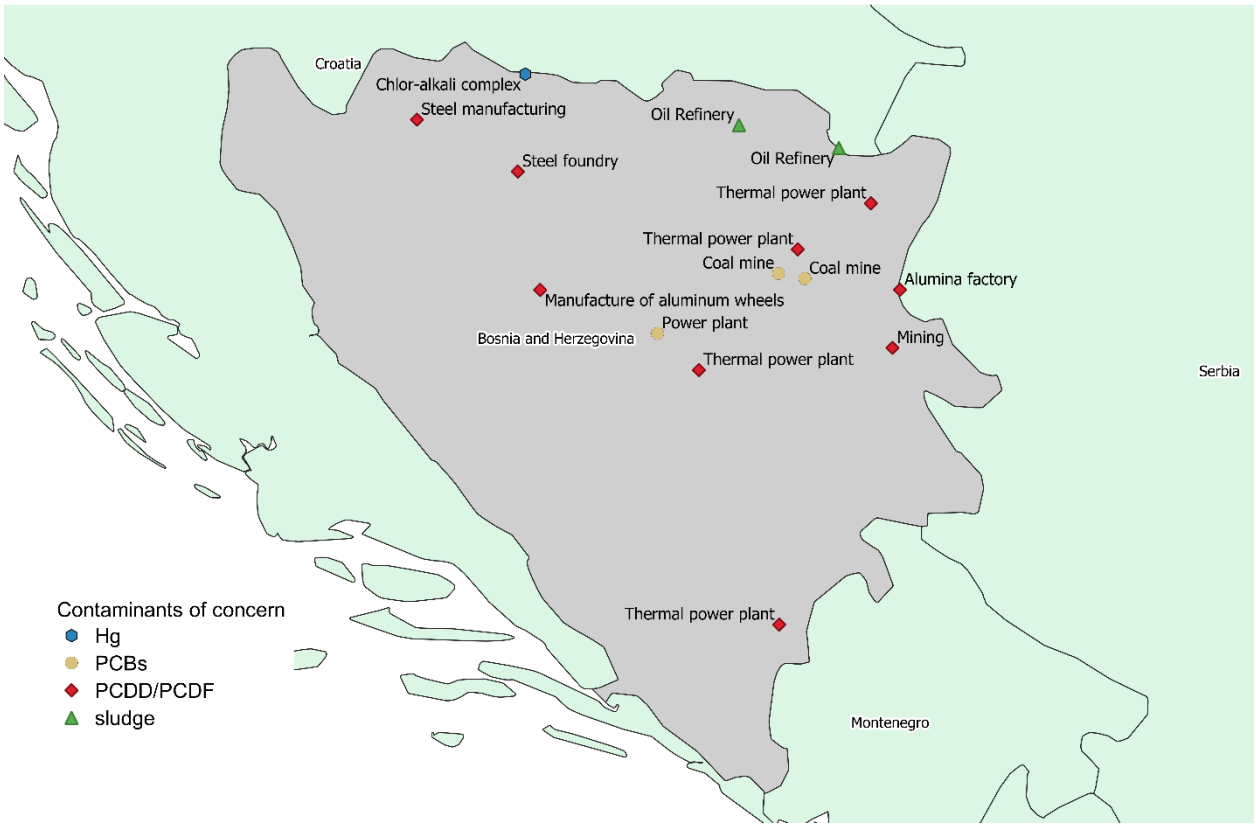
Overall, an estimated 300,000 ha are polluted (Andersen, 2000). As reported in 2017, 109,100 ha corresponds to mining areas. According to the latest data, Bosnia and Herzegovina has reported 16 contaminated sites with the potential for greater impact on the environment and threat to public health (Annex 1). There are no estimates on the area polluted by POPs, but many, including fire-fighting foams and polychlorinated biphenyls (PCBs), are still in use or have been buried without any contention measure, as it is the case for PCB-containing capacitors (UNECE, 2018b).

At least three sites are potentially polluted with PCBs in the country. Seven sites potentially polluted with POPs pesticides were identified corresponding to farmland, orchards, vineyards, and a tobacco processing plant. The preparation study for the development of the National Implementation Plan for the Stockholm Convention included the collection of data and investigation of sites potentially polluted with key POPs (Figure 5) (Institute for Protection and Ecology of Republika Srpska, 2015).

Landfills in Bosnia and Herzegovina are responsible for extensive soil pollution through leachates containing organic compounds and trace elements that seep into soil and ultimately groundwater due to the existence of underdeveloped municipal solid waste treatment facilities in urban areas. For example, groundwater pollution occurs after the landfill leaching through soil at the Banja Luka's municipal landfill, despite low soil permeability. Furthermore, there are 340 illegal dumpsites in the country (UNECE, 2018b).

According to the study on “Capacity Development for Soil Contamination Management Related to Mining in the Former Yugoslav Republic of Macedonia” (JICA, 2008), other places are to be included as shown in Figure 5. Such as the 340 registered illegal landfills and many others that may exist but have not yet been identified, coal mines and deposits of coal, and metal and military industries. Sixty five percent of electric power is generated by coal/lignite-fired plants, which do not follow any procedure to reduce pollution from the waste generated from combustion (UNECE, 2018b).

Figure 5 Hot spots of soil pollution in Bosnia and Herzegovina and the major contaminants of concern as identified in the National Implementation Plan of the Stockholm Convention.



Source: UN 2020, modified with data from the (Institute for Protection and Ecology of Republika Srpska, 2015)

Bosnia and Herzegovina needs to ensure an even, country-wide harmonized and consistent approach and alignment with the EU acquis in the field of waste management (EC, 2023d) (European Commission, SWD(2023) 691 final). To align with the Landfill Directive, Bosnia and Herzegovina needs to close down or rehabilitate non-compliant landfills. Awareness-raising measures are required to reduce waste generation and promote reuse and recycling. There is no progress on alignment with the acquis on industrial pollution control and risk management. The pollutants release and transfer register (PRTR) protocol to the Aarhus Convention still needs to be ratified. This includes the obligation to report to PRTR at the country level, enabling public access to and integration of the collected data and its transmission to the EU institutions. Bosnia and Herzegovina still needs to further align with the directives on industrial emissions.

*Kosovo**

The Kosovo* Parliament approved the first law on environmental protection in 2001 emphasizing the same importance of chemical pollution as for soil erosion. The 2001 Law was drafted from an analysis of legislation in various European countries under consultancies with the World Bank and the United Nations Environmental Programme (The Parliament of Republic of Kosovo*, 2011).

There are in addition several institutions under the Academy of Sciences, various public Universities and the Ministry of Agriculture that deal with environmental monitoring and research studies, but often deprived from adequate financial resources. In the same year, Parliament also passed the Law for Soil Protection with the established legal aspects to be followed by all governmental structures in the country. Unfortunately, such legislation was not able to halt soil degradation due to a lack of policy enforcement and implementation.

The Law "On Environmental Protection" adopted in 2011 determined the five stages of environmental protection applied in Kosovo*:

- Gradual reduction of pollution, degradation and environmental damage and the prevention of those aspects of economic and other activities that pose a significant threat to human health and the environment.
- Protection of biodiversity and general ecological balance of Kosovo*.
- Rational and sustainable utilization of natural resources and agricultural land and protection of natural genetic stocks.
- Protection of valuable natural resources.
- The preservation of the diversity, cultural and aesthetic values of the landscape.

The law's goals were prevention and reduction of pollution, conservation of biodiversity, rational management of natural resources, and avoidance of over-exploitation, ecological restoration of damaged areas, and maintenance and improvement of the environment. The law could have significant impacts on environmental and human health since it requires an environmental impact assessment (EIA) for all projects and activities. However, there was minimal enforcement of it for many reasons including also governmental transitions.

Soil monitoring in terms of the environmental aspects of pollution is under the responsibility of the Kosovo* Hydrometeorological Institute (KHMI), according to the provisions regulated by Law 06/-035 on Hydrometeorological Activity, which also specifies soil monitoring. Currently, KHMI does not monitor soil due to the lack of relevant staff (Kosovo Environmental Protection Agency, 2022). Based on data from the "Environmental Hotspots in Kosovo" report (Kosovo Environmental Protection Agency, 2011), the total area of these hotspots continues to be approximately 9.94 km² or 0.09% of Kosovo*'s territory. The most sensitive environmental locations, "environmental hotspots" have been created mainly as a result of past industrial activity, caused by mining activities from old unmanaged landfills, by chemicals deposited, from waste oils, pesticides, herbicides, etc. The most affected municipalities by these hotspots in Kosovo* are Gllogovc, Mitrovica, Suhareka, Zveçan, Graçanica, Novo Berdo, Obiliq, Lipjani, Gjakova, Stantergu and Leposaviç, as a result of the industrial activities that have been performed in these areas.

Ecological problems in Kosovo* have accumulated over decades because of the uncontrolled use of natural and mineral resources, a growing industrial production with a high level of pollution, and a lack of appropriate policies, laws, and institutions that could treat and solve the problems. As a result, the environment in Kosovo* has been degraded, and severe negative impacts on the health of the population have already occurred. However, the public's knowledge in Kosovo* about environmental issues is very limited. Industrial development that does not comply with environmental standards is the main source of pollution.

There are six municipal and regional landfills in the territory of Kosovo*, which are considered as potential hotspots, and are located in Prizren, Podujevë Obiliq, Mitrovicë, Gjilan and Peja. Most of the places that are identified as hotspots for hazardous chemicals are in the region of Peja. Radioactive substances are concentrated in two industrial cities, Mitrovica and Hani i Elezit, but more than half of them are in Hani i Elezit city as a result of ex-factory for asbestos-cement production.

In the entire territory of Kosovo*, about 110 sensitive spots are evidenced (Kosovo Environmental Protection Agency, 2013), whereas, 33 sites with the potential for greater impact on the environment and threat to public health have been identified and presented (Annex 1). Chemical waste in Kosovo* has been deposited without any prior treatment, without complying with the permitted standards and applicable legislation, they have been accumulated in various places in Kosovo*, such as warehouses, garages or basements, thus causing hazardous locations for the health of the population and the environment. The chemical waste of different compositions is a product of industrial generation.

One of the main sources of contamination derives from industrial pollution that took place for decades in the radius of Mitrovica (TREPCA) smelting plant. A soil and plant test has proved that farmlands within 25 km radius of Mitrovica are contaminated with Pb, Hg, and Cd with serious implications on human health. The soil and water contamination of garbage wastes is the other environmental threat, especially when it comes to landfill sites, where percolation of chemicals and heavy metals into the soil and water is likely.

Another source of pollution are the Obiliq power generation plants in the Kastriot Municipality near the capital of Prishtina (Figure 6). (Sallahu, 2017) evaluated the total heavy metals concentrations pollution in different soil types in the Commune of Kastriot in the region of Prishtina. Soil samples were collected at the depth of 0-30 cm in an agricultural area of about 5,000 ha divided in three circles (2, 4, and 6 km distance from the Power Plants). A total of 40 geo-referenced samples were collected, 35 in the study area and 5 in the control zone 25 km far from the plants. Results showed that contamination is higher at the third circle indicating that pollution is spreading in larger areas. These results were contrasted against the permissible threshold values set by the EU, revealing higher levels. Particular focus was placed on identifying contaminated zones deemed unsuitable for human habitation, livestock rearing, or urban/rural expansion. Recommendations for mitigation measures across these polluted regions were proposed. However, no action has been taken since then.

Special attention was devoted to the delineation of contaminated areas that should be off limits to humans, livestock, and urban/rural development. Mitigation techniques were suggested to be applied throughout the polluted areas. Nevertheless, nothing was done since then.

Figure 6 The huge lignite excavation site at Obiliq that fuels two huge power plants inside the Kastriot Municipality. This is the major source of electricity for Kosovo*.

Source: Zdruli, 2016

Coal-fired thermal power plants are major emitters of multiple contaminants into the environment. The ashes deposit in the soils near the plants, resulting in pollution by trace elements and radionuclides such as uranium or thorium (UNECE, 2019b). Uncontrolled emissions from the combustion of lignite in Kosovo*'s power plants result in the annual average release into the environment of some 2 million tonnes of ash, more than 11 tonnes of arsenic, 1 tonne of cadmium, 351 tonnes of nickel, 492 tonnes of titanium, 191 tonnes of manganese, and 0.48 tonnes of vanadium (Daci *et al.*, 2011). These obsolete highly polluting coal-fired power plants, Kosova A and B, nurture Kosovo's energy needs, and both have associated two big dump areas (Kosovo Environmental Protection Agency, 2018; ITA, 2020).

Wastewater treatment remains very rare in Kosovo*, and given its expansive sewerage networks, it is both a logical next priority for the sector to invest in and develop, as well as a requirement under the Water Framework Directive. Sewerage systems are one source of pollution, but Kosovo* has important point polluters in form of landfills, and heavy industry as well as local mining operations. These require strong licensing, regulation, and prohibitions on destructive actions. Besides addressing point source pollution this requires the conservation and protection of the aquatic ecosystems and the determination and enforcement of Ecologically Acceptable Law (The World Bank, 2018).

Little progress has been made in Kosovo* in the assessment, monitoring, reporting, and remediation of polluted soil. Industrial and mining waste and dumpsites are the main sources of pollution although the extension of soil affected is still to be determined (EC, 2019b). There are about 1,572 illegal landfills in Kosovo and 4 municipal non-sanitary landfills that may be posing a high risk to the environment and human health (Ministry of Environment and Spatial Planning - Kosovo* Environmental Protection Agency, 2019). Additionally, the major municipal landfill, Mirash landfill, is close to the capital Pristina and receive waste from 450,000 people but is poorly managed and it is leachates are posing a high risk (Morina *et al.*, 2017).

There is some progress in aligning the waste management legislation in Kosovo* with the EU acquis, but the unsustainability of the system still needs to be addressed (EC, 2023e). Kosovo* should, in particular, increase the waste collection coverage and address effectively the issue of illegal dumpsites. Kosovo* made limited progress in aligning with the acquis on industrial pollution and risk management. Hazardous mine waste,

industrial discharge into rivers, and industrial dumpsites continue to pose serious threats to soil, water, and health.

Montenegro

Montenegro has reported only three contaminated sites with the potential for greater impact on the environment and threat to public health (Annex 1). However, there are about 20 industries including mines, coal power and aluminium plants that are causing point-source pollution that require advanced chemical treatment of their waste and wastewater to avoid further impacts on the surrounding environment. High concentration of PAHs was detected in soils at Srpska village affected by the Aluminium Plant Podgorica (UNECE, 2015a). The remediation of polluted sites in Montenegro occurs within the waste management plans that have been produced so far. The waste management plans include activities such as the remediation and closure of dumpsites and the remediation of locations called "black points", which are sites with large quantities of disposed waste (UNECE, 2015a).

The mining sector in Montenegro has produced large quantities of toxic waste and is a relevant source of soil pollution. An open pit mine for coal exploitation has produced about 70 million tonnes of waste, whereas 3.9 million tonnes of tailings from the Pb and Zn mines were deposited on the bank of the Ćehotina River, after changing the river's course (UNECE, 2015a). Montenegro has now a project to restore the watercourse of the river after the excavation of the toxic waste (Environment South East Europe, 2021), which will need to be properly treated to avoid further pollution offsite.

Metal production has long been a tradition in Montenegro, however lately there has been a decline in smelting plants in favour of food, wood, and paper processing plants. There is an urgent need in the country for the proper treatment of waste generated from past industrial production, as the red mud from the aluminium industry KAP that covers an area of 420,000 m² is disposed in two basins (UNECE, 2015a).

The Government of Montenegro, the United Nations Development Programme (UNDP) and the Organization for Security and Co-operation in Europe (OSCE) implemented the "Capacity Development Programme for Small Arms and Light Weapons (Conventional Ammunition) Demilitarization and Safe Storage for Montenegro (MONDEM)**"** programme between 2007 and 2018. It aimed to reduce the exposure and risk of the population and environment from stockpiles of weapons and ammunitions originating from the Kosovo* conflict. The program resulted in the disposal of 3,300 tonnes of weapons and 128 tonnes of toxic substances, the reconstruction of an ammunition depot and the partial demilitarisation of 1,806 tonnes of obsolete ammunitions (UNDP, 2019).

Montenegro has an ongoing project on the identification and disposal/treatment of the remaining PCBs in the country (amount estimated not less than 900 tonnes between equipment and waste) funded by GEF and implemented by the United Nations Development Programme (UNDP). The aim is to improve regulations concerning PCBs, the creation of PCBs inventories, but also the development of an environmental sound management to deal with hazardous waste such as PCBs in the future (UNDP/GEF, 2022). Regarding persistent organic pollutants, Montenegro together with Serbia participated in a GEF-funded project implemented by UNEP, to support the implementation of the Stockholm Convention, assist the countries in meeting up with the obligations of the Convention and strengthen their capacity to manage POPs (GEF, 2019). A recent GEF-funded project targeting POPs was dedicated to the environmentally sound management and final disposal of PCBs. The aim was to reduce and eliminate PCB releases and exposures by establishing safer management practices and disposal of 200 tonnes of PCBs in an environmentally safe manner. The project has been very effective in achieving its results and outcomes. The project has managed to establish a full online dynamic inventory of PCB in the country, develop guidelines for Environmentally Sound Management (ESM) of PCB, train relevant stakeholders, adjust national legislation, and draft a national PCB management plan. Targets for sampling were exceeded, as well as those for waste disposal (UNDP/GEF, 2022).

Environmental monitoring in Montenegro encompasses the assessment of various parameters, including the presence of dangerous and harmful substances in the soil. However, there is currently a deficiency in an

appropriate legal framework for soil monitoring near landfills, roads, industrial zones, as well as populated areas, including children's playgrounds.

In 2022, the determination of hazardous and harmful substance levels in the soil was conducted at 13 locations in seven urban settlements in Montenegro (Montenegro Environmental Protection Agency, 2023). The soil pollution monitoring analyses inorganic, organic and pesticide pollution, but only for point-source pollution and not for diffuse sources. Despite the monitoring system, Montenegro seems to be lacking plans on how to deal with point-source pollution and the development of an inventory of the polluted sites. Although conducting regular soil quality surveys, there is very limited information on the treatment and management of polluted sites (UNECE, 2015a).

Significant efforts are still needed in Montenegro in the implementation and enforcement of waste management. Montenegro should in particular adopt and start implementing the Waste Management Law and the national waste management plan (EC, 2023f). No significant progress was registered on industrial pollution control and risk management; Montenegro's national legislation remains partially aligned with the EU acquis. The European Commission notes that the ecological reconstruction plan for the Pljevlja coal power plant will not address the core issues. Montenegro needs to step up its efforts to permanently close the plant to meet EU emission standards.

North Macedonia

The legal framework governing soil management is encompassed within the Law on Environment ("Official Gazette of the Republic of Macedonia" no. 42/14), which addresses the identification of contaminated sites and establishes a management plan, including those involving state property, based on the "polluter pays" principle. Additionally, the Law on Waste Management, covering both non-hazardous and hazardous waste and its handling, along with various other laws and strategies, contribute to this framework (EEA, 2021). A draft law on soil protection was prepared in 2014 but it was not adopted, largely due to financial implications (UNECE, 2019b). There is no legislation to address historic pollution of soils. The country did not perform soil monitoring systematically. The City of Skopje carried out a series of soil monitoring campaigns in the Skopje region focusing on heavy metals pollution. These activities were concluded in 2012 and the results made publicly available on the website of the City of Skopje. A Soil Law is Being developed as part of a GEF project (GEF, 2017). Various ministries hold roles and responsibilities within this framework. Although the law was not passed for a variety of reasons, including its financial implications, it still suggests that soil is part of the national political agenda (UNECE, 2019a).

A study was conducted on hot spots as part of the national waste management plan, resulting in a risk-based ranking of these areas. Several input parameters were considered for this ranking, including risk assessment, hazardousness of pollutants, site extent, hydrogeology, location sensitivity, and waste quantity. The identification of contaminated sites, as well as clean-up and pollution management, has been carried out through several projects since 2001. North Macedonia still encounters several challenges, including issues related to terminology, overlapping responsibilities among agencies, lack of regulatory provisions during privatization processes, absence of a legal framework and established standards for remediation, and insufficient monitoring and financing mechanisms. While the National Waste Management Plan 2021-2030 addresses contaminated sites, its implementation is hindered by the lack of adequate financial support.

The main emission sources in North Macedonia are most likely metallurgic activities, power plants and mining activities. Soil pollution is mainly due to trace elements such as Cd, Pb and Zn in the vicinity of mines in north-eastern parts of Macedonia (Zletovo, Toranica, Sasa), as well as in the central part of the country (smelter in Veles) (MOEPP, 2017). High concentrations of trace elements exceeding reference levels have been detected along the Kiselica and Zletovska rivers and are associated with an old emission following the breaking of mine tailings (JICA, 2008). In addition, the use of low efficiency technologies employing the use of other organic

compounds for the extraction of trace elements contributes to soil pollution also by organic contaminants such as PCBs (MOEPP, 2017).

Therefore, special studies were performed in the areas with the highest heavy metal pollution, including air or soil pollution (Stafilov, 2014). A detailed study was performed on the environmental impacts of the Pb-Zn-Cd smelter plant in the city of Veles and detected soil pollution with possibly harmful elements (As, Cd, Cu, Hg, In, Pb, Sb and Zn) exceeding the intervention values and leading to high contamination of air with particles, and high contents of these metals in food produced in this area. The study also detected pollution of water and sediment of the Vardar River. Similar effects were detected in an area with ferronickel metallurgical activities near the city of Kavadarci regarding the contamination of soil and more significant air pollution with dust rich in Ni, Co and Cr.

A detailed study of the impact of the copper mining and flotation plant "Bucim" near the town of Radovich was also performed, showing the amount of soil or air pollution using moss biomonitoring, lichen species biomonitoring or attic dust. There are three active Pb-Zn mines and flotation plants situated in the eastern part of the country, and their activities pollute the environment with Pb, Zn, Cd and some other heavy metals, which can be found in the soil, the air, and the river water and in sediments.

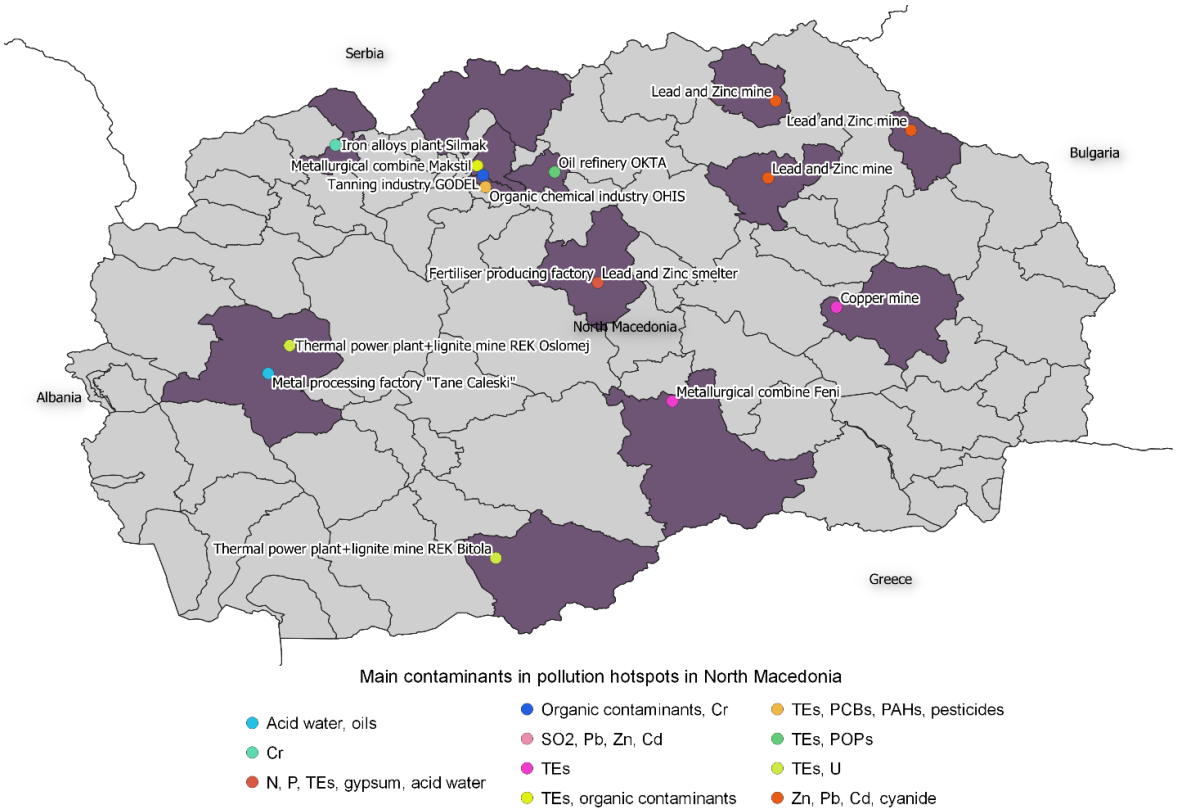
Studies also found an influence of the thermoelectric power plant near the city of Bitola, producing about one million tons of fly ash per year, deposited on the surface close to the plant. This plant pollutes soils with Pb and Zn as well and air with radioactive fly ash containing Uranium (U) and Thorium (Th) as well as As, Pb and Zn. Soils in the capital, Skopje, are heavily polluted. An area of about 200 ha is covered with landfills that can potentially pollute the soil beneath them.

Out of 70 contaminated sites covering 429.6 km^2, 16 of them have been of major concern in the previous period as shown in Figure 7. According to the latest data, North Macedonia has 11 contaminated sites with the potential for greater impact on the environment and threat to public health (Annex 1).

Open-pit coal mines and power plants in Bitola and Oslomej have contributed to the poor air quality of the capital Skopje, listed by the World Health Organization (WHO) as one of the most polluted capital city in Europe (Martinez *et al.*, 2018; Bennett, 2019). Those mines are also partly responsible for the enrichment in trace elements such as Pb and As in the surrounding soils (Stafilov, 2014; Stafilov *et al.*, 2018). However, the Oslomej plant has taken a big step towards decarbonisation and thus emission reductions by transforming it into a photovoltaic power plant (Bennett, 2019). In the city of Skopje, soil monitoring campaigns were carried out in 2012 to analyze concentrations of trace elements (UNECE, 2019b).

After a two-year project in collaboration with the Food and Agriculture Organization (FAO) Global Soil Partnership (GSP), North Macedonia launched the Macedonian Soil Information System (MASIS) in 2015, which is publicly available online (FAO, 2015). MASIS includes a variety of layers for the country's soils based on historical research and limited sampling in the field. The system provides limited information on polluted sites within the Macedonian Environmental Information Centre (Aksoy *et al.*, 2020). North Macedonia lacks a comprehensive soil pollution monitoring system.

Figure 7 Major pollution hotspots in North Macedonia.



Source: UN, 2020 modified with data from (MOEPP, 2017).

High concentrations of trace elements were detected in drinking water and wheat associated with mining activities near residential and agricultural areas, posing a high risk to local populations (JICA, 2008). Measures to avoid health consequences should be taken to prevent leaching from mining tailings dams into the soil and the consequent transfer of contaminants from soil to crops and water. Mining rehabilitation is not practiced in the country although the 2012 law on mineral resources requires a financial guarantee for rehabilitation and waste management of mining projects. The country has no practical experience in land rehabilitation because until now, when a mining concession ended, the Ministry extended the concession.

Since 2010, North Macedonia has devolved many efforts to improving the management of chemicals by working on the Strategic Approach to International Chemicals Management. New laws on waste management, such as the National Waste Management Plan and the National Waste Prevention Plan, are expected to be adopted since 2020. Laws such as the Packaging waste and E-waste are currently being drafted. The advancement in the sound management of chemicals, besides reinforcing policies, has also contributed to the development of remediation plans of contaminated sites from waste (UNECE, 2019b). Additional research has been conducted in phytoremediation with promising results (Silvana *et al.*, 2018).

To address the long-standing problem of hexachlorocyclohexane (HCH) waste (lindane and its isomers) historically deposited at the OHIS plant site, the Ministry of Environment and Physical Planning through its Project Unit for POPs is in the process of implementing the project “Removal of Technical and Economic Barriers to Initiating the Clean-up Activities for Alpha-HCH, Beta-HCH and Lindane Contaminated Sites at OHIS”. As a result of preparatory activities in the past period, works are being carried out on the decontamination of a small dump located in OHIS. The United Nations Industrial Development Organization (UNIDO) is the implementing agency for selecting the best solution/technology.

Box 1 Project "Removal of Technical and Economic Barriers to Initiating the Clean-up Activities for Alpha-HCH, Beta-HCH and Lindane Contaminated Sites at OHIS"

The project for remediation of the former Organic Chemical Industry "Naum Naumovski-Borce" (OHIS) site, which is contaminated with lindane and hexachlorocyclohexane (HCH), was initiated in 2014. Approximatively 50,000 tons have to be treated. Before the actual treatment and remediation, a certain amount of preparatory work had to be done. Most of the preparatory work was completed by mid-2018: the adoption of legal acts for the management structure and by-laws (rulebooks) to introduce them into the national legislation, preparation of technical tools; detailed site investigation and public procurement for the remaining works is the next step. The project also includes the elaboration of a feasibility study, cost-benefit analysis, risk analysis and communications plan for public awareness raising on this specific issue and project. The project itself will cover the treatment and removal of 10,000 tons of contaminated soil, while further funds need to be ensured for the removal and treatment of the remaining 40,000 tons. The experience gained through this project will serve as an example for further clean-up activities in North Macedonia and other countries, which is why a methodology was prepared as part of the preparatory work. To facilitate knowledge-sharing and raise professional and public awareness, the Instructions for the sustainable management of contaminated sites in the country were published in May 2018 in three separate books: "Assessment of Contaminated Locations", "Remediation of Contaminated Sites" and "Standard Operating Procedures".

Significant efforts are still needed in North Macedonia to reduce industrial pollution. The law on industrial emissions is yet to be adopted. In the area of waste management in North Macedonia, the first (2022-2028) national plan for waste prevention was adopted in September 2022, setting out regulatory, policy and practical measures to be taken by various stakeholders across the public and private sectors. The process for closing non-standard landfills in the eastern regions is ongoing (EC, 2023g).

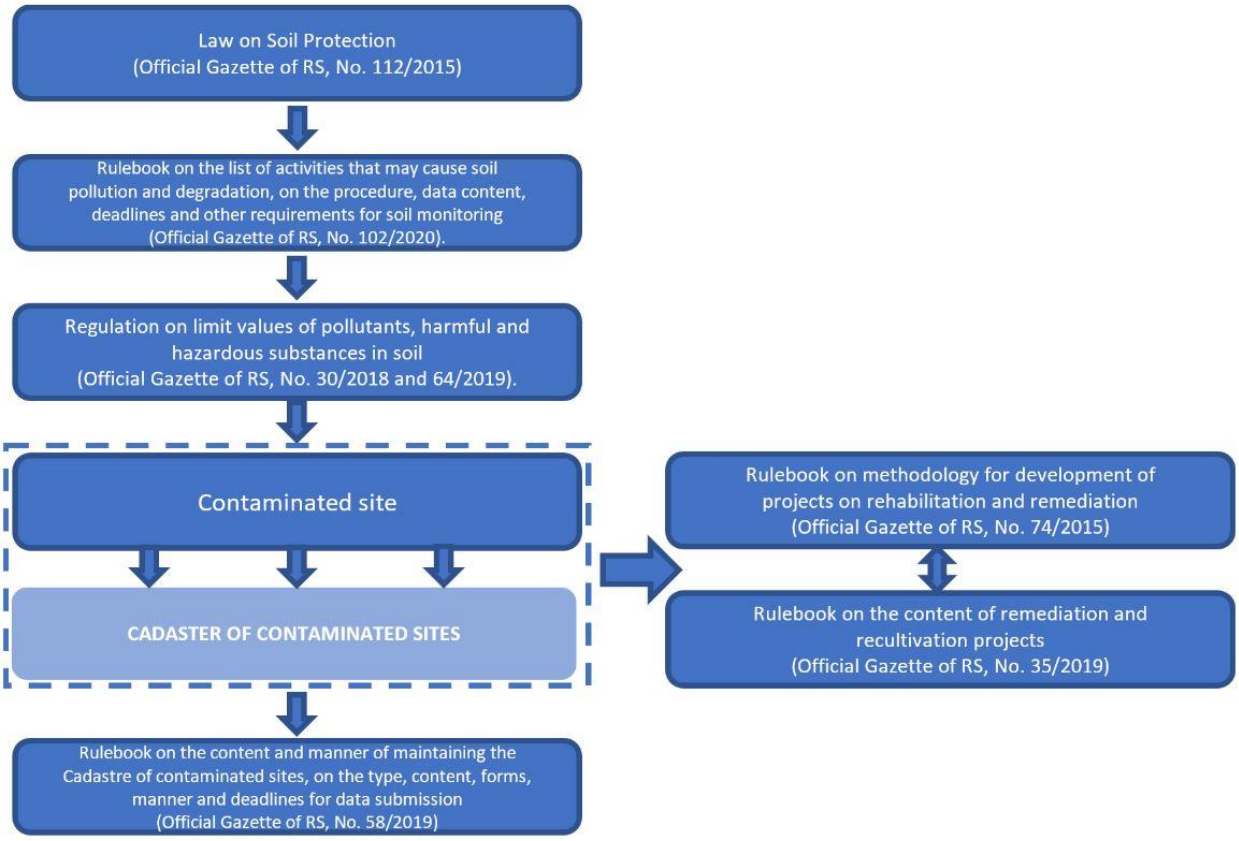
Serbia

The Republic of Serbia stands out as the only country in the region to have established a legal framework for monitoring local soil pollution and maintaining a cadastre of contaminated sites. This cadastre comprises data on endangered, polluted, and degraded lands. Cadastre is an integral component of the Soil Information System managed by the Serbian Environmental Protection Agency (SEPA). A set of indicators, listed in the National List of Environmental Protection Indicators, are used to assess the risks of soil degradation. The indicators that refer to the management of contaminated sites provide information on the progress made in the management of polluted sites but also give information on what types of remediation measures should be implemented. Nevertheless, Serbia does not conduct any regular soil monitoring, and the existence of reports on polluted hot spots is due to pilot projects with the involvement of external donors (UNECE, 2015b).

The Republic of Serbia has adopted a considerable number of environmental laws, which are helping her to make considerable progress towards the objective of "approximation" to the EU legislation. The primary authority responsible for environment management and policy at the national level in Serbia is the Ministry of Environmental Protection. Under the jurisdiction of the Ministry is the Serbian Environmental Protection Agency (SEPA) and the Inspectorate while on the territory of the Autonomous Province of Vojvodina jurisdiction has also the Provincial Secretariat for Urban Planning and Environmental Protection.

The main principles of EU environmental laws are already transposed into Serbian legislation. In order to improve the management of contaminated sites in Serbia, the Ministry of Environmental Protection in the period 2015-2021 adopted the legal framework that enables progress in the management of contaminated sites (Figure 8).

Figure 8 Legal framework for contaminated sites management in Serbia



Source: Serbian Environmental Protection Agency.

Based on the data submitted to the Cadastre of contaminated sites, 213 potentially contaminated and contaminated sites were identified in the Republic of Serbia in 2020. Activities that are carried out on those sites are listed in the Rulebook on the list of activities that may cause soil pollution and degradation, on the procedure, data content, deadlines, and other requirements for soil monitoring ("Official Gazette of RS", No. 102/2020). Out of the total number of reported sites, the reports on soil monitoring in the period 2020-2022 were submitted by 21 companies in 2020, 36 companies in 2021, and 32 companies in (SEPA, 2021, 2022, 2023). SEPA reported that total of 850,000 tonnes of municipal waste was landfilled at twelve sanitary landfills in Serbia, covering 42% of the population of Serbia in 2021. This is a significant increase in accessibility to sanitary disposal of solid municipal waste, compared with 2016, where sanitary landfilling was available only for 14% of the population. Despite such great progress in the population's accessibility to sanitary landfills, a considerable amount of waste is still disposed on dumpsites. Those sites have the largest share in the identified contaminated sites (71.83%).

In terms of the activities involving the rehabilitation, closure, and recultivation of unsanitary landfills from 2019 to 2022, it can be observed that only 10-15% of locations are currently undergoing work (SEPA, 2023).

In the Vojvodina Region, the Provincial Secretariat for Urban Planning and Environmental Protection examined the degree of endangerment of non-agricultural land from chemical pollution in 30 municipalities and cities, at 113 illegal dumpsites. A total of 1,130 soil samples were analyzed (SEPA, 2021; Vidojevic & Jevtic, 2022). The analysis of heavy metal content in soil samples showed that remediation values were exceeded for Cd, Zn, Cu, Ni, Hg and As. Analysis of the pesticide content and their metabolites in soil samples showed that remediation values were exceeded for dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE), dichlorodiphenyldichloroethane (DDD) and atrazine. Concentrations of total PCBs, PAHs and mineral oils exceeded the limit values but did not exceed the

remediation values. Analysis of the content of phthalate esters show values greater than the remediation value in 319 out of a total of 1,130 samples. The analyses were conducted in accordance with the Regulation on limit values of pollutants, harmful and hazardous substances in soil ("Official Gazette of RS", No. 30/2018 and 64/2019).

Preliminary health risk assessment methodology application in Serbian contaminated sites:

Considering the abundance of contaminated sites, financial challenges, and lack of overall institutional capacity to perform comprehensive risk assessments, the lack of well-established mandatory methodologies for risk assessments in the legal framework is also the case in the Republic of Serbia (Matic *et al.*, 2022). In the absence of such methodologies, comparative risk assessment is a preferred approach for risk-based assessment and prioritization of contaminated sites. In Serbia, data acquired during the contaminated site investigation process is a task facilitated by national strategies for soil protection that provide guidelines for soil sampling and information gathering. The integration of such data could support the application of comparative (preliminary) risk assessment methodologies, allowing for the incorporation of risk criteria in site prioritization.

To streamline decision-making on management actions, a preliminary risk assessment methodology, "PRA.MS - Preliminary Risk Assessment Model for the identification and assessment of problem areas for Soil contamination in Europe," was applied in Serbia to prioritize the industrial locations as a pilot study. The PRA.MS methodology, a system for preliminary risk assessment for the individual locations in order to set a priority list of contaminated sites, is developed in the framework of the project "Towards an EEA Europe-wide assessment of areas under risk for soil contamination" from 2005 (Altieri *et al.*, 2004). This preliminary risk assessment model was adopted by the European Information and Observation Network (EIONET) and represents a review of 27 existing and documented international methodologies for preliminary and simplified risk assessment of (potentially) contaminated sites. It was applied in several EU member countries and overseas at the national or regional level for the prioritization and planning of soil remediation and protection programs. The PRA.MS methodology was developed to support national, regional, or local programs for the rehabilitation and remediation of contaminated sites (Gentile *et al.*, 2005).

This approach was applied in the Republic of Serbia within the UNEP/GEF project "Enhanced cross-sectoral land management through land-use pressure reduction and planning" co-financed by the Italian Ministry of Environment, Land and Sea, on 32 industrially contaminated sites that were explored and surveyed in the period 2015-2018. The goal was to establish a prioritized list based on the relative risk to human health and the environment, providing methodological support for data processing, systematization, and informed allocation of financial resources for location management (Kukobat *et al.*, 2018; UNEP, 2023).

Beyond presenting the results and relative-risk-based priority list, the application of PRA.MS methodology on 32 contaminated sites in the Republic of Serbia aimed to examine the logistical and economic feasibility of applying comparative risk-based methodology to other contaminated sites in the Cadastre of Contaminated Sites of the Republic of Serbia for prioritization regarding relative health and environmental risk. Secondly, it assesses whether the results obtained, including exposure paths and relative risk values, can serve as relevant risk communication tools (Vidojević *et al.*, 2021).

A debate in Serbia that involves the public opinion, scientific experts and politicians is on the association with depleted uranium from the NATO bombing in 1999 and cancer incidence, especially in children. In 2018, the Serbian Parliament approved a law proposal for an Inquiry Commission to carry out a two-year investigation programme to determine the effects of DU on the health of the Serbian citizens and the environment. The programme was officially signed and agreed by the ministries of environmental protection, health, defence, education, and science and technological development and the complete results were foreseen to be published in 2020 (Simić, 2018) but not yet public. In 2019, for the 20th anniversary from the bombing, a second international symposium on the "Consequences of the bombing of the Federal Republic of Yugoslavia" was held in Nis, Serbia (Kukin, 2019).

Republic of Serbia made progress by continuing to increase environmental funding and investments, in the waste management. Regarding waste management, Serbia has a good level of alignment with the EU acquis, but implementation should be further strengthened. As regards industrial pollution and risk management, alignment with most of the EU acquis is at an early stage across industry, including as concerns the Industrial Emissions Directive. In 2022, Serbia allocated funds to clean 233 illegal dumpsites, added video monitoring to prevent waste disposal, and improved cooperation with local authorities. About 20% of the municipal waste generated in Serbia is still dumped in illegal dumpsites. The remediation of the Belgrade landfill and the construction of a waste-to-energy facility continued in the reporting period (EC, 2023h).
The results of improved legislation and cooperation between different UN Agencies and ministries in the projects related to contaminated sites on the territory of the Republic of Serbia include the improved contaminated sites data management and developed capacity for the investigation of contaminated sites. Inadequate waste disposal still represents the most significant localized source of soil pollution in the Republic of Serbia.

Regional summary

Most soil contaminants in the Western Balkans come from industrial processes and mining, poor waste management, unsustainable farming practices, accidents ranging from chemical spills to environmental disasters, and armed conflicts that devasted the region after the breakdown of former Yugoslavia.

Soil pollution is widely present in the region as mentioned in the state of the Environment in Europe report SOER2020 that also recognises the complexity of the problem (Payá Pérez & Rodríguez Eugenio, 2018; EEA, 2019). Nevertheless, the chain reaction effects are still unknown for many substances entering into the soil especially those related to microplastics. The most common pollution sources include petrochemical plants and petrol stations, landfills, pesticide contamination, POPs, microplastics, veterinary products/pharmaceutical, and emerging concerns such as Per- and Polyfluoroalkyl Substances (PFASs), heavy metals, and pollutants from sewage sludge spreading in agricultural soils. Furthermore, the percentage of landfilling remains very high and exceeds 90% in all cases except for Albania (EEA, 2019).

The mining industry represents a major source of soil pollution in the region, especially in Albania, which was (is) one of the world's leading chromate producers (Egerer *et al.*, 2010). Furthermore, illegal dumping and open landfills are a common waste management practice in many countries. In North Macedonia for instance, some 200 hectares are occupied by landfills and illegal dumps that are abundant although their impact and extent have not been fully elucidated (MOEP, 2021). Hazardous waste is frequently buried in urban landfills. A common concern is also the e-waste management, which still needs improvement as most of the e-waste is disposed in landfills and the recycling and recovery activities are poorly managed causing significant resource losses. This leads to a high risk for human health and the environment. However, initiatives are taking place mainly in the private recycling sector (Baldé *et al.*, 2017).

The war that devastated the region between 1991 and 1999 has caused extensive soil pollution, especially from landmines, categorizing for instance Bosnia and Herzegovina as one of the most landmine-polluted countries in the world. To date, the country counts about 1,366 landmine polluted settlements, of which 1,168 (86%) are in rural communities, which causes a limitation to agricultural and livestock activities (Musa *et al.*, 2017). In addition, intensive warfare in the region left a legacy of trace element pollution in soils, including antimony (Sb), arsenic (As), lead (Pb), mercury (Hg), and zinc (Zn), as observed by (Vidosavljević *et al.*, 2013).

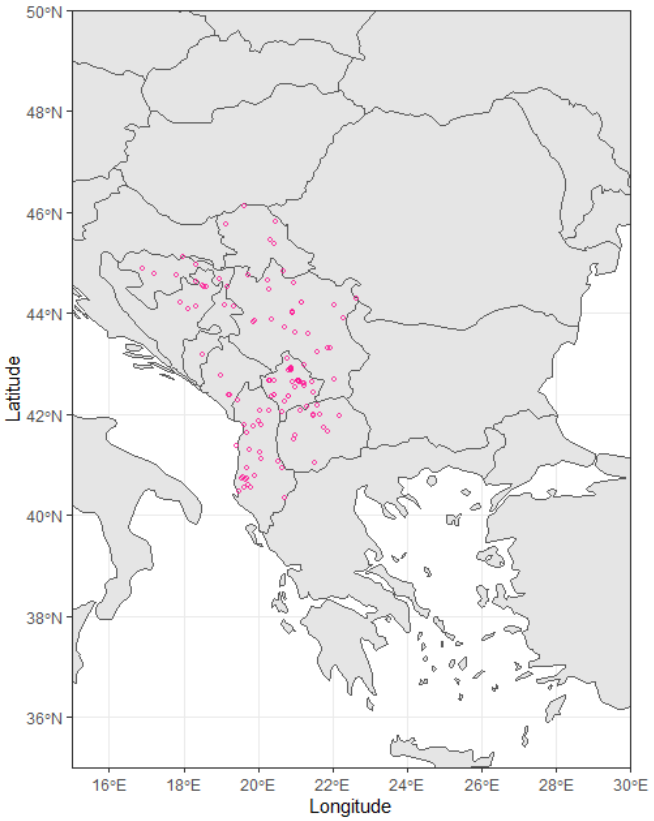
Moreover, depleted uranium (DU) penetrators were also used in the Kosovo's* conflict, which have left a trail of DU-polluted soils. Southern Serbia and Kosovo* were the regions most affected by the 1999 air strikes, in which 11 tonnes of depleted uranium ammunition and 30,000 depleted uranium shells were used in military actions in the Kosovo* conflict (Di Lella *et al.*, 2003; Milačić *et al.*, 2004). It has been observed that soil pollution is very heterogeneous in affected areas and that DU pollution is higher when penetrators are burned after reaching a certain target. Currently, four locations in Serbia are routinely tested in order to monitor DU contamination (UNECE, 2015b). After the war, Serbia and Kosovo* have experienced a significant

increase of malicious tumours, with more than 30,000 people diagnosed with haematological malignancies in the first 10 years since the bombing and between 10,000 and 18,000 of them died (Latifi-Pupovci *et al.*, 2020).

The estimation of the extent of pollution in the **agriculture sector** is very difficult to be made due to lack of data. We assume that the area of organic farming, which is very small compared with other farming types, as "risk free" the area of organic farming. However, it should be noted that the application of manure in organic farming might potentially increase the concentrations of antibiotics and copper in soils.

The next step is to estimate the extent of contamination at **country level** and consequently region wide. To do so, the total number of contaminated sites per country were collected as given in Table 4, Figure 9.

Figure 9 Location of the contaminated sites in the national inventories (Annex 1)



Source: own elaboration

Table 4 Number of contaminated sites in the national inventories (Annex 1)

Country	Identified polluted or potentially polluted sites	Date when information was provided
Albania	25	2023
Bosnia and Herzegovina	16	2020-2022
Kosovo*	33	2024
Montenegro	3	2024
North Macedonia	11	2024
Serbia	30	2024
Total	**118**	

Source for Albania: Programi Kombëtar i Monitorimit të Mjedisit 2024 (National Programme of Environmental Monitoring) National Agency of Environment, Ministry of Environment and Tourism Nr. 6708/2 Prot. Date 20.11.2023;

Source for Bosnia and Herzegovina (Federation Bosnia and Herzegovina): Project: Models of protection and remediation of soil contaminated with heavy metals in industrial areas of the Federation of Bosnia and Herzegovina, Environmental Protection Fund of the Federation of Bosnia and Herzegovina, Sarajevo 2020;

Source for the Republic of Srpska: Environmental Protection Strategy of the Republic of Srpska, 2022;

Source for Kosovo: Annual Report on the State of the Environment for 2021, Kosovo* Environmental Protection Agency, 2022; Hydrometeorological Institute Kosovo*;*

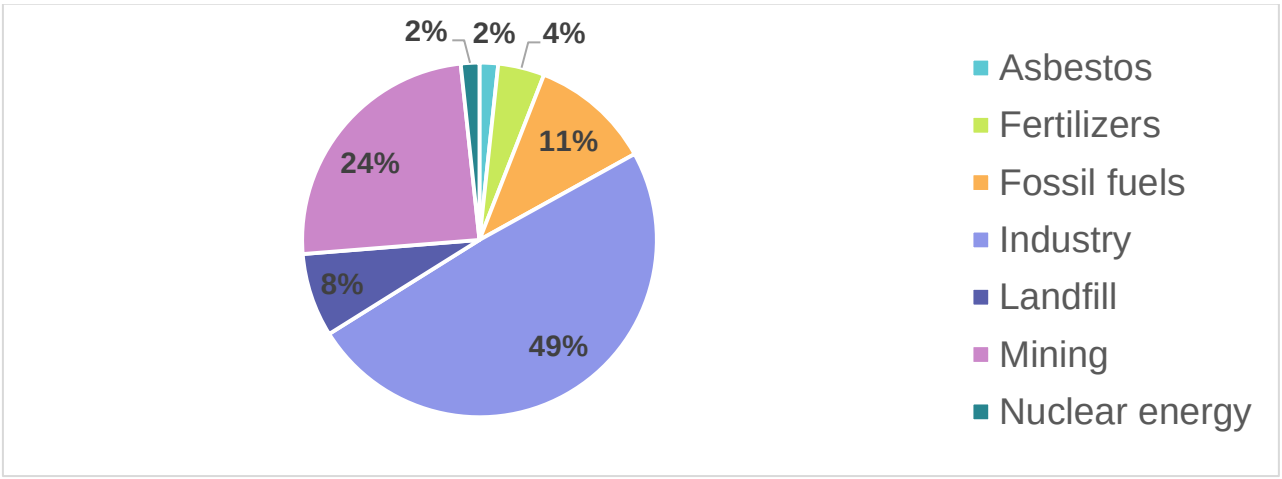
Source for North Macedonia: State Statistical Office of the Republic of Macedonia, Environmental statistics, 2013 ISBN 978-608-227-132-3; Ministry of Environment and Physical Planning;

Source for Montenegro: Environmental Protection Agency of Montenegro;

Source for the Republic of Serbia: Serbian Environmental Protection Agency;

Contamination activities (Annex I) were standardized and compiled in accordance with the most common ones (asbestos, fertilizers, fossil fuels, industry, landfill, mining, and nuclear energy). Industry is the largest contributor to localized soil pollution with 58 sites. Mining follows with 29 sites, indicating a significant impact on soil pollution. Fossil fuels account for 13 sites. Landfill sites contribute to soil pollution in nine locations. Fertilizers are identified in five polluted or potentially polluted sites. Asbestos and Nuclear energy each account for two polluted or potentially polluted sites. The data highlights that industrial activities and mining are major sources of soil pollution, while asbestos and nuclear energy have a relatively lower number of identified polluted sites (Figure 10).

Figure 10 Share of main localised sources of soil pollution in the total number of identified sites (%)



Regarding the type of contamination, heavy metals have the highest count of 69 locations, predominantly in Serbia and Kosovo*. Mix materials are present in 33 locations, with the highest count in Kosovo*. Organic materials are present in 14 locations, mostly in Albania. Asbestos is found in two locations across two countries (Bosnia and Herzegovina – Republic of Srpska and Kosovo*) (Figure 11).

Figure 11 Identified contaminated sites based on the type of contamination

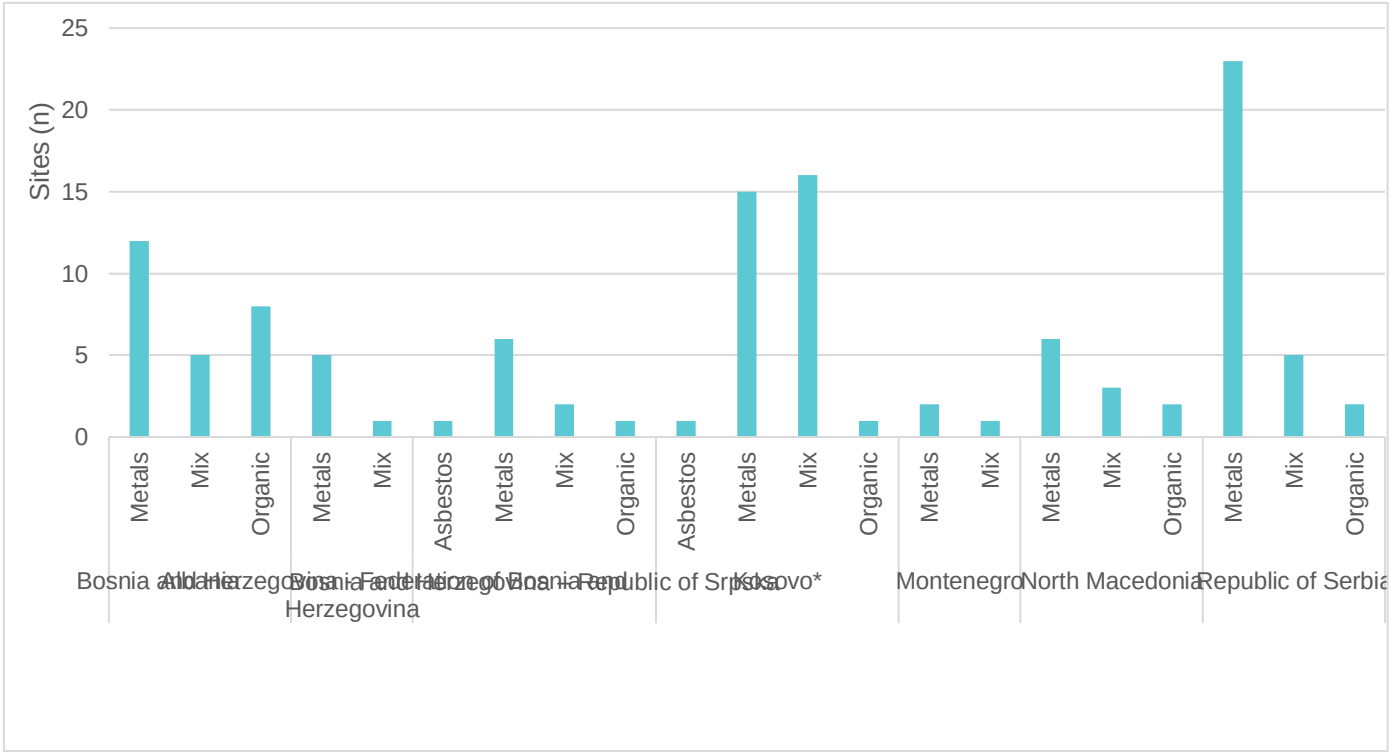
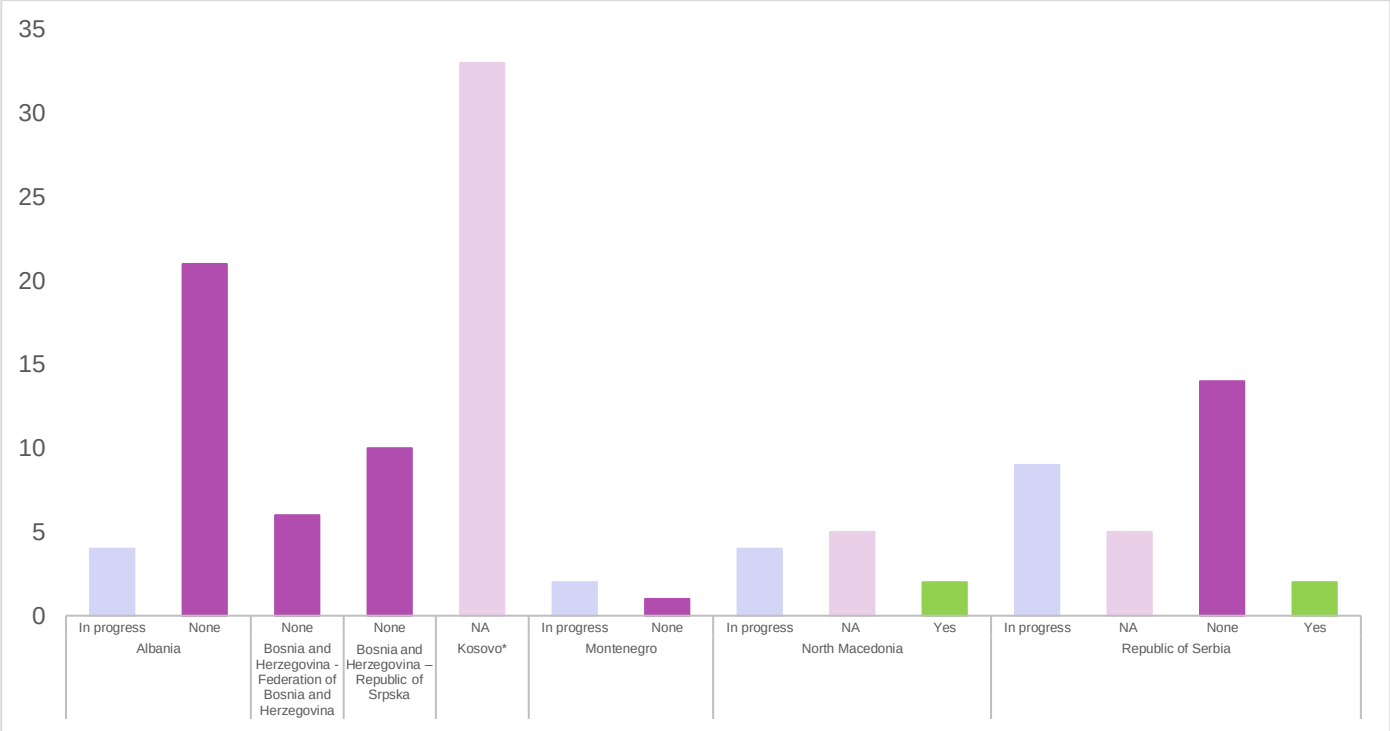


Figure 12 presents a breakdown of identified contaminated sites based on the status of remediation efforts. Among the entries, 19 sites are currently undergoing remediation processes, while 43 sites have no available information regarding their remediation status. Additionally, there are 52 contaminated sites where no active remediation efforts are reported. Only four of the identified contaminated sites have successfully undergone remediation. This highlights the ongoing challenges in addressing environmental contamination, underscoring the importance of continued vigilance and action in environmental stewardship.

Figure 12 Remediation efforts in the identified contaminated sites by country.



The report by the Health and Environment Alliance (HEAL) on the impact of coal-fired power plants on children in Bosnia and Herzegovina, Serbia and Montenegro reveal worrying data (HEAL, 2015). Elevated levels of mercury (Hg), above the limit of 0.58 µg/g, were detected in around 17% of human hair samples from Serbia. Elevated levels of cadmium (Cd) were found in 25% of samples and 33% of samples from Montenegro showed high levels of lead. 17% of studied Bosnian children had elevated levels of lead (Pb) (HEAL, 2015).

A survey conducted in the Western Balkans on public awareness of environmental issues, such as pollution, shows that there is widespread acceptance that environmental degradation is a necessary step towards prosperity and that a large part of the population does not minimise their impact on the environment through their consumption choices (RCC, 2019). However, even the most environmentally conscious citizens have limited options to reduce their environmental impact. In terms of pollution, two-thirds of the interviewed population considered pollution a threat, while 35% considered it a serious issue. Respondents from Montenegro are the least concerned about the state of the environment, with only 47% showing concern, while 82% of respondents from North Macedonia indicated that they were very concerned about pollution, maybe because Skopje is considered one of the most air polluted cities in the world. Furthermore, 59% of respondents were willing to pay more to buy environmentally friendly products, with Albania and Montenegro having the most environmentally conscious shoppers at 63% (RCC, 2019).

Figure 13 Distribution of identified polluted or potentially polluted sites based on varying levels of public awareness.

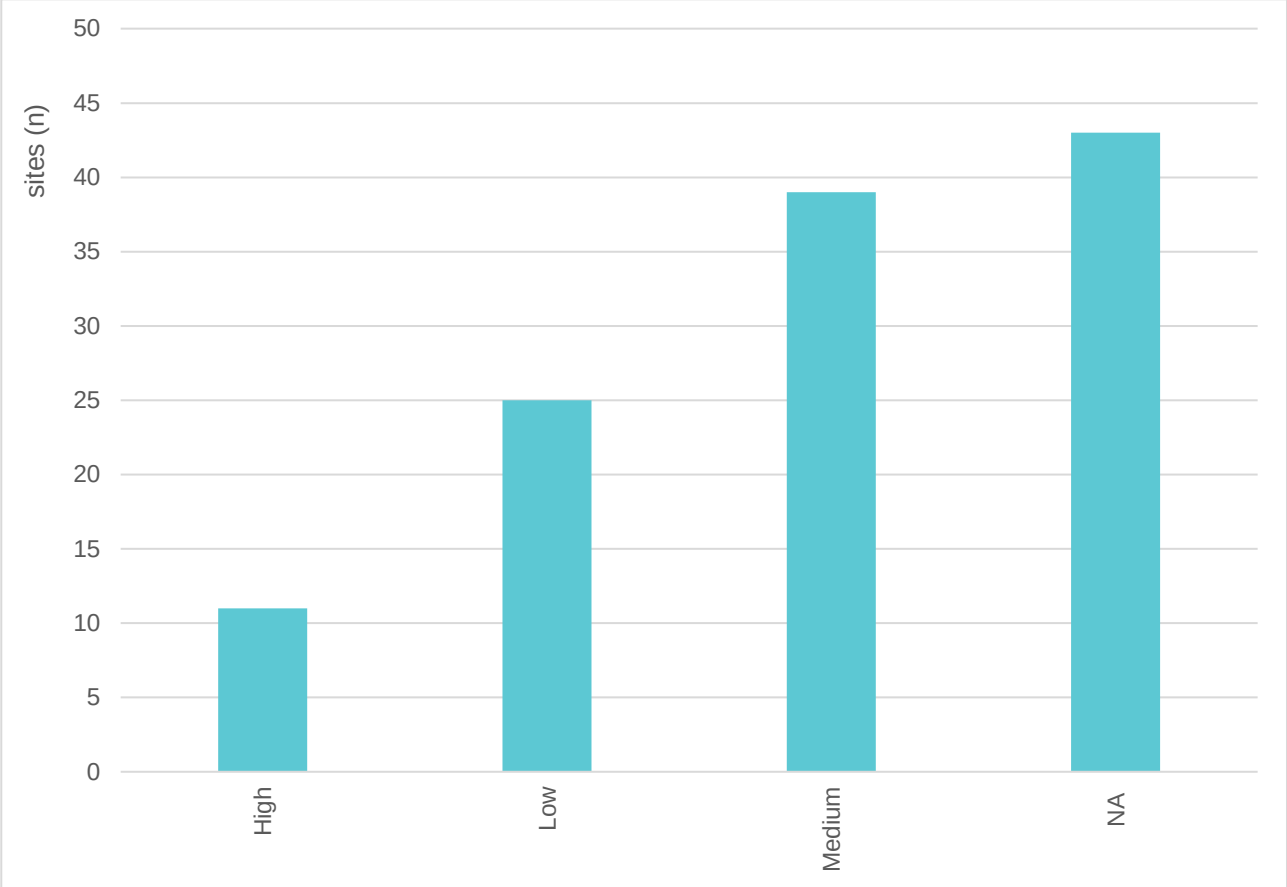


Figure 13 summarizes the distribution of identified polluted or potentially polluted sites based on varying levels of public awareness. Of the 118 sites identified, 11 (9.3%) are associated with high public awareness, indicating a relatively small portion of the sites are well known to the public. In contrast, 25 sites (21.2%) are linked with low public awareness, and a significant number, 39 sites (33.1%), are associated with medium public awareness. Notably, the largest category, with 43 sites (36.4%), falls under the 'Not Available' (NA) category for public awareness, suggesting that a considerable number of sites lack clear data on public awareness levels.

Diverse policies refer to soil pollution and the need for data on pollution sources is high. However, there is a lack of binding measures, e.g. to build and publish registers of polluted sites or to assess and apply harmonised definitions and critical thresholds for contaminants in soils. Progress towards sustainable development in the Western Balkans will be possible only if land and soil resources are properly addressed.

5 Conclusions

Due to over 100 years of industrialization, soil contamination is a widespread problem in Western Balkans countries. The main contaminants associated with these industrial activities are mineral oils, trace elements (such as As, Cd, Pb, Ni, or Zn) and organic contaminants such as halogenated and non-halogenated solvents, PCBs and PAHs. Huge efforts should be done to estimate the number of sites where contamination takes place. Some countries have made preliminary estimates (the Republic of Serbia), but further analysis should be carried out to get aggregated data for the region. Even though, due to strict legislation, some progress has been made as regards adequate waste management in the region, recent estimates have shown that inadequate waste management is still an important source of soil pollution. Diffuse soil contamination is one of the specific threats to soils in Western Balkans. Agriculture is traditionally the main land use activity in Western European countries, having a share of 45% of the total land use. Trace elements from fertilisers (e.g., Cd from mineral fertilizers) and some fungicides (mainly Cu) and pesticide residues are the contaminants of major concern in the region in agricultural soils. Contaminants of emerging concern, such as microplastics, pharmaceuticals and PFASs, are still poorly studied in the region, and require further attention.

Addressing soil contamination in the Western Balkans is hampered by inadequate legal frameworks, insufficient funding and staffing, and a lack of thorough site investigations. To identify contaminated sites and principal polluters, it is essential to start with accessible, high-quality information, with primary criteria focusing on the absence of significant risks to human health and the environment. Pre-established hot spot identification criteria must align with overarching strategies and goals, singling out sites that present very high or high risks, while other less risky sites might influence land value during land use changes. Building a registry of contaminated sites requires clarity on which types of sites to include, with agreed identification criteria that are consistent with strategic targets. The process should begin with the most concerning sites, progressively including every site that handles substances posing health and environmental risks, and deciding which entities are responsible for data collection and registry management.

In this report, every effort was made to collect the best information available for soil pollution in the region. Nevertheless, results should be taken as preliminary and not final due to the data quality and their availability.

Recommendations:

- **National soil surveys programmes should be launched without delay**

  The Western Balkans countries are relying on obsolete soil data for soil assessments and monitoring. This has created a considerable gap between the status of soil health in the region when compared with EU countries. Therefore, there is an urgent need to embark in a soil monitoring system that must be robust and able to provide reliable data for updating soil policies, which are also required by the Sofia Declaration for the Western Balkans. Inspiration should come also from the LUCAS soil survey when these data would be available, and the second round of LUCAS should be also implemented.

- **Soil pollution indicators must be clearly defined and comparable throughout the region and compatible with those implemented in the EU Member States**

  This would require the definitions of indicators, and how they are determined (sampling, analysis, evaluation method). These indicators should be identical between the countries and in line with LUCAS Soil sampling procedure or defined according to the needs of each country. In addition, the national soil survey programmes could implement standard soil survey procedures that better fit national conditions.

— **Soil monitoring should provide the necessary framework for drafting policies for soil protection and management**

  Reliable data must be generated to depict spatially explicit policy-relevant indicators for developing harmonization procedures, and for enhancing the region-wide use of harmonized indicators. The resolutions of this corresponding indicator will depend on the national and regional plot densities, but they should be INSPIRE compatible

— **Implementation of a soil protection framework to ensure heathy soils** is a priority for the implementation of the Green Deal across the Western Balkans. Robust legal frameworks supported by extensive field data and rigorous site investigations can lead to the development of targeted interventions and sustainable land management practices that protect both the environment and public health in the Western Balkans. This requires coherent action across a broad policy base:

  - Knowledge on soil health and factors causing pressures on soil conditions across the region is disjointed and fragmented.
  - Pan-EU soil initiatives, such as LUCAS, the EU Soil Observatory, Clean Soil Outlook, should be expanded to cover the Western Balkan Regions.
  - The Soil Mission should implement a targeted programme to support the implementation of lighthouses and living labs in the Western Balkans.
  - National policies should take note of the developments described above.
  - Harmonised soil monitoring and testing programmes should be established.

— Apart from national data sources, **innovative proximal and remote sensing and monitoring techniques should be further developed** to allow rapid but accurate measurements.

— Additionally, **building local capacity through training and the provision of resources** for soil monitoring can enhance the ability of national and regional authorities to respond promptly to emerging contamination issues. Effective communication and collaboration between government agencies, academic institutions, and local communities are essential to foster a shared commitment to soil health.

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List of abbreviations and definitions

Abbreviations	Definitions
As	Arsenic
BIPHENYLS	PCBs, polychlorinated biphenyls
BTEX	benzene, toluene, ethylbenzene, and xylenes concentrations
Cd	Cadmium
CEMSA	Consolidation of the Environmental Monitoring System
Co	Cobalt
Cr	Chromium
Cu	Copper
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DM	Dry Matter
DU	Depleted uranium
EC	European Commission
EGD	European Green Deal
EIA	Environmental impact assessment
EIONET	European Information and Observation Network
ESM	Environmentally Sound Management
EU	European Union
FAO	The Food and Agriculture Organization

Abbreviations	Definitions
GEF	Global Environment Facility
GHG	Greenhouse gases
GSP	Global Soil Partnership
HCH	Hexachlorocyclohexane
HEAL	Health and Environment Alliance
In	Indium
K	Potassium
KHMI	Kosovo* Hydrometeorological Institute
LUCAS	Land Use/Cover Area frame statistical Survey
MASIS	Macedonian Soil Information System
MONERIS	MOdelling Nutrient Emissions in RIver Systems
N	Nitrogen
Ni	Nickel
NVZs	Nitrate Vulnerable Zones
OECD	Organisation for Economic Co-operation and Development
OSCE	Organization for Security and Co-operation in Europe
P	Phosphorous
PAHs	Polycyclic aromatic hydrocarbons
Pb	Lead
PCBs	polychlorinated biphenyls
PFAS	Polyfluoroalkyl Substances

Abbreviations	Definitions
POPs	Persistent organic pollutants
PRA.MS	Preliminary Risk Assessment Model for the identification and assessment of problem areas for Soil contamination in Europe
PRTR	The pollutants release and transfer register
Sb	Antimony
SEPA	Serbian Environmental Protection Agency
Th	Thorium
U	Uranium
UNDP	The United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNIDO	The United Nations Industrial Development Organization
VOCs	Volatile organic compounds
WHO	World Health Organization
Zn	Zinc

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Annexes

Annex 1. Summary of the contaminated sites in the Western Balkans

Country	No	Name of Location	Municipality (LAU– local administration unit)	Activity	Type of soil contamination	Amount of accumulated waste/deposited material	Gravity of soil contamination	Water contamination	Public health risk	Public awareness	Remediation action
Albania	1	Metallurgical complex Elbasan	Elbasan	Metal industry	Ferronickel and ferro chromate	1,5-2 million tons	High	Shkumbin river	High	Medium	None
	2	Cooper mine Rreshen	Mirdite	Cooper mine	Arsenic and cooper	N/A	High	Mat and Fan rivers	High	Low	None
	3	Cooper mine Kurbnesh	Mirdite	Cooper mine	Arsenic and cooper	N/A	High	Mat and Fan rivers	High	Low	None
	4	Cooper mine Reps	Mirdite	Cooper mine	Arsenic and cooper	N/A (high production level 350,000 tons per year)	High	River Fan	High	Low	None
	5	Cooper mine Fushe Arrez	Puke	Cooper mine	Arsenic and cooper	N/A (high production level 320,000 tons per year)	High	Surface contamination	High	Low	None
	6	Ferronickel mine Pogradec (Guri i Kuq and Bitinske	Pogradec	Ferronickel mine	Ferronickel	N/A	High	Lake Ohrid	High	Low	None
	7	Ferronickel mine Prrenjas	Librazhd	Ferronickel mine	Ferronickel	N/A	High	Surface contamination	High	Low	None
	8	Cooper mine Rehove	Kolonje	Cooper mine	Arsenic and cooper	N/A	High	River Osum	High	Low	None
	9	Cooper mine Kalimash, Kukes, Gjegjan	Mirdite	Cooper mine	Arsenic and cooper	N/A	High	River Drin	High	Low	None
	10	Hydrocarbon and fossil fuels areas of Ballsh, Kucove, Patos Marinez	Fier	Fossil fuels	Petrol	Only in Ballsh 20,000 tons of petrol has been disbursed in the surrounding areas	High	River Gjanica and surface contamination	High	Medium	None
	11	Lushnje PVC waste, Mercury	Lushnje	Chemical waste	PVC waste, Mercury	N/A	Medium	Surface contamination	Low	Low	None

	12	Vlore PVC waste, Mercury	Vlore	Chemical waste	PVC waste, Mercury	5-6 ha contaminated	Medium	Surface contamination	Low	Low	None
	13	Fier Nitrous ammonia	Fier	Fertilizer waste	Nitrous Ammonia Factory	850 m^3 liquid waste	Medium	Surface contamination	Low	Low	None
	14	Tirana landfill	Tirane	Landfill	Landfill of Shara	N/A	High	Surface contamination	Medium	High	Some action
	15	Lac super-phosphate	Kurbin	Fertilizer waste	Super phosphate factory	30,000 tons of iron waste	High	Surface contamination	High	Low	None
	16	Lezhe paper waste	Lezhe	Paper waste	Paper factory	N/A	Low	Surface contamination	Low	Low	None
	17	Balez, Elbasan Chemical waste	Elbasan	Chemical waste	Accumulation of chemical waste	216 tons of dichloromethane, arsenic, ammonium nitrate, ammonium hydroxide	High	Surface contamination	High	Low	Some action, in 2010, 10 tons of chemical waste was shipped in Germany, Belgium and Greece
	18	Porto Romano, Durres Chemical waste	Durres	Chemical waste	Accumulation of chemical waste hegza cloroclozan, chromate	N/A	High	Surface contamination	High	Medium	78,000 ha reclaimed and another 60,000 were partially reclaimed
	19	Bajze, Shkoder Sodium fluorosilicate	Shkoder	Chemical waste	Sodium fluorosilicate	80 tons of waste	High	Surface contamination	High	Low	Some waste was shipped in Germany and Great Britan
	20	Mbrostar, Fier fossil fuels	Fier	Fossil fuels	Hydrocarbon and fossil fuels	Petrol	N/A	Surface contamination	High	Medium	None
	21	Kozare, Perondi Kucove fossil fuels	Kucove	Fossil fuels	Hydrocarbon and fossil fuels	Petrol	N/A	Surface contamination	High	Medium	None

	22	Ballsh, Greshicë, Hekal, Qendër, Mallakaster fossil fuels	Fier	Fossil fuels	Hydrocarbon and fossil fuels	Petrol	N/A	Surface contaminatio n	High	Medium	None
	23	Zharrëz, Patos fossil fuels	Mallakaster	Fossil fuels	Hydrocarbon and fossil fuels	Petrol	N/A	Surface contaminatio n	High	Medium	None
	24	Kuman, Roskovec fossil fuels	Mallakaster	Fossil fuels	Hydrocarbon and fossil fuels	Petrol	N/A	Surface contaminatio n	High	Medium	None
	25	Vllahinë, Selenicë fossil fuels	Vlore	Fossil fuels	Hydrocarbon and fossil fuels	Petrol	N/A	Surface contaminatio n	High	Medium	None
Bosnia and Herzegovina - Federation of Bosnia and Herzegovina	1	Thermal power plant	Tuzla	Coal mine	heavy metals, sulfur,...(ash and slug)	N/A	Medium	N/A		Medium	None
	2	Thermal power plant	Kakanj	Coal mine	heavy metals, sulfur (ash and slug)	N/A	Medium	N/A		Medium	None
	3	ArcelorMittal	Zenica	Iron ore processing	heavy metals	N/A	Medium	N/A		Medium	None
	4	Global Ispat Coke Industry Lukavac (GIKIL)	Lukavac	Production of coke, maleic anhydride, ammonium sulfate, calcium ammonium nitrate, crude benzene and crude tar	Sulfur oxides, nitrogen oxides, carbon oxides, dust particles, polycyclic aromatic compounds, PAHs and heavy metals	N/A	Medium	N/A	high	Medium	None
	5	Şişecam Soda Lukavac	Lukavac	Production of synthetic soda	Wastewater from the soda production process is drained to the "White Sea" ("Bijelo more") settling tanks The waters that are drained to the "Bjelo More" sedimentation	Estimation of several million tons of sedimentary material, and the area of the "White Sea" is approx. 560.000 m2	High	High	High	Medium	None

					tanks mostly contain: dissolved substances (CaCl2, NaCl, Na2SO4), and suspended matter (CaCO3, CaSO4, Ca(OH)2, SiO2, MgCO3, Al2O3 and Fe2O3)						
	6	Iron mine	Vareš	Iron mine	Heavy metals	N/A	Medium	N/A	N/A	Medium	None
Bosnia and Herzegovina – Republic of Srpska	1.	Thermal power plant	Ugljevik	coal mine	heavy metals, sulfur,...(ash and slug)	N/A	Medium	N/A	N/A	Medium	None
	2.	Thermal power plant	Gacko	Coal mine	heavy metals, sulfur,...(ash and slug)	N/A	Medium	N/A	N/A	Medium	None
	3.	Thermal power plant EFT	Stanari	Coal mine	heavy metals, sulfur,...(ash and slug)	N/A	Medium	N/A	N/A	Medium	None
	4	ArcelorMittal	Prijedor	Iron mine	heavy metals	N/A	Medium	N/A	N/A	Medium	None
	5.	"Boksit" Milići	Milići	Bauxite mine (aluminium industry)	Al and other heavy metals (red mud)	N/A	Medium	N/A	N/A	Medium	None
	6.	Gross" doo	Srebrenica (Sase)	Lead (Pb) and Zinc (Zn) mine	Pb, Zn and other heavy metals	N/A	Medium	N/A	N/A	Medium	None
	7.	Oil refinery	Modriča	Oil refinery	gudron, heavy metals	N/A	Medium	N/A	N/A	Medium	None
	8.	Oil and petroleum refinery	Brod	Oil and diesel refinery	gudron, heavy metals	N/A	Medium	N/A	N/A	Medium	None
	9.	"Incel" business zone	Banja Luka	Cellulose (paper production plant)	POPs	N/A	Medium	N/A	N/A	Medium	None
	10.	Petrovo, asbestos mining	Petrovo	Asbestos exploitation, No exploitation at the moment	Asbestos mud	N/A	Medium	N/A	N/A	Medium	None

Kosovo*	1	Agricultural waste disposal facility	Suharekë - Shirokë	Warehouse for hazardous agricultural waste	Chemical substances	0.04 ha	N/A	N/A	N/A	N/A	N/A
	2	Industrial chemicals storage facility	Pejë	Disposal of hazardous industrial chemicals	Chemical substances	0.12 ha	N/A	N/A	N/A	N/A	N/A
	3	Sanitary landfill	Podujevë	Landfill for urban waste		8.72 ha	N/A	N/A	N/A	N/A	N/A
	4	Sanitary landfill	Sferk të Thatë-Pejë	Landfill for urban waste		4.85 ha	N/A	N/A	N/A	N/A	N/A
	5	Sanitary landfill	Gjilan	Landfill for urban waste		20.50 ha	N/A	N/A	N/A	N/A	N/A
	6	Sanitary landfill	Prizren	Landfill for urban waste		20.94 ha	N/A	N/A	N/A	N/A	N/A
	7	Sanitary landfill	Obiliq	Landfill for urban waste		33.65 ha	N/A	N/A	N/A	N/A	N/A
	8	Sanitary landfill	Mitrovicë	Landfill for urban waste		3.60 ha	N/A	N/A	N/A	N/A	N/A
	9	Factory for the production of tires and tapes - Balkani	Suharekë	Oil residue and soil contamination		17.17 ha	N/A	N/A	N/A	N/A	N/A
	10	Çikatovë e re (NewCo Ferronikeli Complex L.L.C)	Gllogoc	Ferronickel slag waste	Heavy metals	24 ha Zona e ndikimit 71.37 ha	N/A	N/A	N/A	N/A	N/A
	11	The mine dump near the dam of Lake Badovci-Kishnica	Graçanicë	Content of Pb, Zn, Gold	Heavy metals	2.85 ha	N/A	N/A	N/A	N/A	N/A
	12	The landfill of sterile material, waste from the Kishnica mine	Graçanicë	Content of Pb, Zn, Gold	Heavy metals	10.23 ha	N/A	N/A	N/A	N/A	N/A
	13	Landfill of Lead and Zinc (Marec 1 and March 2)	Miniera Artanë		Heavy metals	2.38 ha	N/A	N/A	N/A	N/A	N/A
	14	Mitrovica Industrial Park	Mitrovicë	Heavy metal waste from zinc metallurgy, jarosite process, fertilizer plant, battery, zinc	Heavy metals	115.10 ha	N/A	N/A	N/A	N/A	N/A

				electrolysis, pyrite burning and phosphogypsum waste							
	15	The landfill in Kelmend	Mitrovicë	Heavy metal dump		23.78 ha	N/A	N/A	N/A	N/A	N/A
	16	Mitrovica Industrial Park - Trepce	Mitrovicë	Storage of radioactive materials of Thorium Nitrate	Heavy metals	0.04 ha	N/A	N/A	N/A	N/A	N/A
	17	Mitrovica Industrial Park (Tunnel I)	Mitrovicë	Deposit of radioactive materials	Strontium, Thorium and Americium	0.03 ha	N/A	N/A	N/A	N/A	N/A
	18	Industrial landfill	Zveçan	Heavy metal dump	Heavy metals	62.28 ha	N/A	N/A	N/A	N/A	N/A
	19	Industrial landfill	Leposaviq	Heavy metal dump	Heavy metals	20.31 ha	N/A	N/A	N/A	N/A	N/A
	20	The ash landfill from the Kosova A thermal power plant	Obiliq	Ash disposal	chemical substances and used oils	181.97 ha	N/A	N/A	N/A	N/A	N/A
	21	The ash landfill from the Kosova B thermal power plant	Obiliq	Ash disposal	chemical substances and used oils	192.92 ha	N/A	N/A	N/A	N/A	N/A
	22	Phenol tanks, TEC	Obiliq	Phenolic tanks	chemical substances and used oils	177.64 ha	N/A	N/A	N/A	N/A	N/A
	23	Flotation of the chrome mine in Deve	Gjakove	Heavy metal dump	Heavy metals	5.23 ha	N/A	N/A	N/A	N/A	N/A
	24	Mining in Golesh	Lipjan	Mining of magnesium and heavy metals	chemical substances and used oils	15.13 ha	N/A	N/A	N/A	N/A	N/A
	25	SharrCem Industrial Complex	Hani I Elezit	Two landfills with asbestos materials	Heavy metals, chemicals	0.60 ha	N/A	N/A	N/A	N/A	N/A
	26	GC Metal	Lipjan	Metal production	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	27	Sharrtex factory	Dragash	Textile factory (no activity)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	28	Sole Coral	Fushë Kosovë	Cooling machinery	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	29	"Swiss General Group Shpk" - Former Leather Factory	Pejë	Leather production (no activity)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	30	Eurosteel	Pejë	The company deals with the collection and recycling of iron, paper and glass waste	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	31	Jatex	Gjakovë	Textile production	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	32	Metaliku	Gjakovë	Steel production sector (no activity)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	33	Former textile production factory "Emin Duraku", now "Emin Duraki i Ri" (Devolli Corporation)	Gjakovë	Textile production (no activity)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
North Macedonia	1	OHIS A.D	Skopje	Organic chemical industry, Abandoned	Dumpsite of HCH	252.200 m^3	High	High	Yes	Yes	Yes
	2	Zletovo mine	Probishtip	Lead and zink mining site, Active	Mining dumpsite	1.115.000 m^3	Medium	Medium	N/A	N/A	The municipality proposed the site for the Solar thermal power plant.
	3	Lojane	Lipkovo	Former chromium, arsenic, antimony mining site, Abandoned	Cr, As, Sb	1.000.000 m^3	Medium	Medium	N/A	N/A	According to the Law on Mineral Resources, the Ministry of Economy started the procedure for

											concession, due to the interest of investors in reusing the metal.
	4	Silmak ferro-silicon plant	Jegunovce	Ferro-silicon plant (former HEK Jugohrom) Iron alloys plant, not active	Ferro -silicon	851.000 m^3	Medium	Medium	N/A	N/A	The wastewater treatment plant works for the remediation of chromium six
	5	MHK Zletovo	Veles	Lead and zinc smelter, Abandoned	Pb, Zn	14.000.000 m^3	High	High	N/A	N/A	Under concession
	6	REK Bitola	Bitola	Lignite mine and thermal power plant, Active	Termal power plant and lignite mine	11.000.000 m^3	Medium	Medium	N/A	N/A	Yes, the company takes measures. Under IPPC permit.
	7	MHK Zletovo Fertilizer Plant	Veles	Plants for fertilizers production, private, not active	fertilizers	3.700.000 m^3	Low	Low	N/A	N/A	N/A
	8	REK Oslomej - ESM	Kichevo	Thermal power plant and lignite mine, Active	TP plant and coal mine	2.000.000 m^3	Low	Low	N/A	N/A	N/A
	9	Godel Tannery	Skopje	Tanning industry, Abandoned	Leather processing plant	5.600 m^3	Low	Low	N/A	N/A	N/A
	10	OKTA Rafinerija AD	Ilinden	Oil refinery, not Active		3.000 m^3	Low	Low	N/A	N/A	N/A
	11	Tane Calevski	Kicevo	Metalprocessing factory, Abandoned		10 m^3	Low	Low	N/A	N/A	N/A

Montenegro	1.	KAP Solid Waste Dump Site Podgorica	Podgorica	The aluminum production	A number of different waste fractions which were deposited adjacent to the plant. The site contains both hazardous and non-hazardous waste	529,773.87 m^3	High	The KAP is located between two rivers, the Morača River and the Cijevna River and located above Lake Skadar. Also, the Morača River passes near the KAP site and flows into Lake Skadar, a large National Park, which is located on the Albanian border. The potential Area of Influence would involve these surface water resources	High	High	Remediation technical documentation prepared.
	2.	KAP Red Mud Basins	Podgorica	The aluminum production	Red mud	7-8 million tons	High	The KAP is located between two rivers, the Morača River and the Cijevna River and located above Lake Skadar. Also, the Morača River passes near the KAP site and flows into Lake Skadar, a large National Park, which is located on the	High	High	Remediation technical documentation prepared.

								Albanian border. The potential Area of Influence would involve these surface water resources			
	3	Halda Landfill	Nikšić	Historical waste landfill	A number of different waste fractions were deposited adjacent to the plant. The site contains both hazardous and non-hazardous waste	12.5 ha	High	River Gračanica	High	High	None
Republic of Serbia	1	Electronics Industry Niš	Niš	Energy industries	Heavy metals (Pb)	5t chemical waste	Medium	River Nišava	Medium	Low	Some action
	2	Machinel Industry Niš	Niš	Processing of ferrous metals	Heavy metals (Cu, Zn, Pb, Ni, As, Cr)	3t of different types of waste	Medium	River Nišava	Medium	Low	None
	3	Non-ferrous metal factory - Prokuplje	Prokuplje	Processing of non-ferrous metals. Predominant - Processing of copper and copper alloys	Heavy metals (Cr, Cu, Ni, Zn) and C10-C40	10 t hazardous waste	Medium	River Toplica	Medium	Low	None
	4	HI Župa - Kruševac	Kruševac	Production of inorganic chemicals	Heavy metals (Hg, Cr, Cu, Ni, Zn, Pb, As, Cd)	930 t of dangerous chemicals	High	River Rasina	High	Medium	None
	5	Prva Petoletka - Trstenik	Trstenik	Manufacture of plasticized seals products	Galvanic sludge and waste digesters (degreaser) in an amount of several tons.	N/A	Medium	River Zapadna Morava	Medium	Low	None

					At the complex is registrated the presence of other types of waste, above all, plasticizers in seals and used waste oils. In the old tempering plant, cyanides and cyanide salts are used in the production process. Heavy metals (As, Cu, Ni, Cd, Zn)						
	6	Wagon factory Kraljevo	Kraljevo	Production of locomotives and rail vehicles	Heavy metals (Cu, Pb, Ni, As)	53t waste color and sludge 9 t Packaging waste	Medium	Rivers Ibar, Zapadna Morava	Mediu m	Low	None
	7	Toza Marković - Kikinda	Kikinda	Manufacture of ceramic products	Heavy metals (Zn)	N/A	Medium	Nakovački channel	Mediu m	Low	None
	8	a.d. Radijator - Zrenjanin	Zrenjanin	Industry-Production of boilers and heating radiators	PCB	300t (2015)	Low	No	Mediu m	Medium	Yes
	9	TE Morava - Svilajnac	Svilajnac	Electricity production	Heavy metals	4,5 mil t ash with slag	High	River Morava	High	Medium	Some action
	10	Battery factory Sombor	Sombor	Other activities - Battery factory	Heavy metals (Pb) and C10-C40	N/A	Law	No	Mediu m	Medium	Some action
	11	Šumadija d.o.o. - Kragujevac	Kragujevac	Production and	Heavy metals (As, Cu, Ni, Zn)	N/A	Medium	No	Mediu m	Low	None

				processing of metals							
	12	Zastava trucks - Kragujevac	Kragujevac	Commercial vehicles - sales, parts and equipment, services	Heavy metals (Cu)	100t paints and varnishes	Medium	River Lepenica	Medium	Low	None
	13	HI Zorka - Subotica	Subotica	Chemical industry	Heavy metals (As, Cu, Zn)	N/A	Low	Lake Palićko	Medium	High	Some action
	14	KTK Koža - Zaječar	Zaječar	Leather and Textile Processing Factory	Heavy metals (Cr, As, Pb)	N/A	Medium	River Crni Timok	Medium	Medium	None
	15	IHP Prahovo -	Negotin	Mineral Fertilizer Industry	Heavy metals (As)	N/A	Medium	River Dunav	Medium	Medium	None
	16	PKS Latex - Čačak	Čačak	Production of organic chemicals	Heavy metals	25000t chemicals 49700t TNG	Low	River Zapadna Morava	Medium	Medium	None
	17	21. oktobar - Kragujevac	Kragujevac	Manufacture of other parts and accessories for motor vehicles	Heavy metals (Cr, Cu, Ni, Zn)	35t hazardous waste	Medium	River Lepenica Lake "Bubanj" River Bresnica	Medium	Low	None
	18	HI Viskoza - Loznica	Loznica	Chemical industry, Manufacture of cellulose fibers	Heavy metals (As, Cd, Cu, Ni, Pb, Zn)	40t carbon disulfide	High	River Drina	High	High	Some action
	19	Zorka – Non-ferrous metallurgy complex - Šabac	Šabac	Manufacture of lead, zinc and pewter	Heavy metals (As, Cd, Cr, Cu, Pb, Ni, Zn) and PAH, DDE/DDD/DDT Pyrite burnt dumpsite (waste from the production of phosphoric acid)	N/A	High	River Sava	Medium	High	Some action

	20	Mei Ta Europe d.o.o. - Barič	Barič	Metal industry	PCB	N/A	Medium	River Sava	N/A	Medium	N/A
	21	HBIS GROOP Serbia Iron & Steel d.o.o. Beograd, Smederevo- Radinac	Smederevo	Production and processing of metals	Heavy metals Cd, Ni, Ba, Hg (2020) Heavy metals Pb, Zn, Ba (2021)	N/A	Medium	No	Mediu m	Law	
	22	Serbia Zijin Copper d.o.o. - Bor-ogranak TIR	Bor	Exploitation of other black, ferrous, precious and other metal ores - Copper production	Landfill with pyralene waste. Heavy metals Cu, As, Cd (2020) Heavy metals Cu, Zn, As, Cd, Hg (2021) Heavy metals Cu, Pb, As, Zn, Ni, Cd and PCB (2022)	N/A	High	Borska River	High	High	Some action
	23	Copper mill a.d. - Sevojno	Užice	Processing of secondary raw materials and copper slag.	Heavy metals Pb, Ni, Zn, Cu (2020) Heavy metals Cu, Zn (2021) Heavy metals Cu and PCB (2022)	850t (2015)	High	River Đetina	Mediu m	Medium	None
	24	IMPOL SEVAL Aluminium Mill a.d. Sevojno	Užice	Processing of aluminium	Heavy metals Ni, Cu (2020) Heavy metals Cu, Ni, Zn (2021)	N/A	Low	River Đetina	N/A	Medium	N/A
	25	HIP-Petrohemija a.d. - Pančevo, Pančevo	Pančevo	Chemical industry	Heavy metals: Hg (2020) Heavy metals: Hg (2021) Heavy metals: Hg (2022)	N/A	High	River Dunav	N/A	High	Yes
	26	HIP-Petrohemija a.d. - Pančevo, The *synthetic rubber plant*, Elemir	Zrenjanin	Chemical industry	Heavy metals: As, Zn	N/A	Low	Lake Okanj	N/A	Medium	N/A
	27	ENERGETIKA d.o.o. Kragujevac	Kragujevac	Energy industries	Heavy metals: As, Zn, Cu, Ba	N/A	Medium	River Lepenica	N/A	Medium	N/A

	28	Joint Stock Company „Elektroprovreda Srbije“ Branch Nikola Tesla power plant Beograd-Obrenovac, location Power Plant Morava	Svilajnac	Energy industries	Heavy metals Ni (2021) Heavy metals Ni, Cr (2022)	N/A	High	River Velika Morava	High	Medium	Some action
	29	Joint Stock Company „Elektroprovreda Srbije“ Branch Nikola Tesla power plant - Beograd-Obrenovac, lokacija TE Kolubara A	Beograd-Obrenovac	Energy industries	Heavy metals: As	N/A	High	River Sava	High	High	Some action
	30	Packing Paper and Packaging Factory (FOPA), Vladičin Han	Vladicin Han	Paper Industry	C10-C40, Cd, Cr, Cu, Ni, Pb, Zn	N/A	High	River Juzna Morava	High	Medium	None

* This designation is without prejudice to positions on the status and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo Declaration of independence.

N/A Data Not Available

Source for Albania: Source: Programi Kombëtar i Monitorimit të Mjedisit 2024 (National Programme of Environmental Monitoring) National Agency of Environment, Ministry of Environment and Tourism Nr. 6708/2 Prot. Date 20.11.2023;

Source for Bosnia and Herzegovina (Federation Bosnia and Herzegovina): Project: Models of protection and remediation of soil contaminated with heavy metals in industrial areas of the Federation of Bosnia and Herzegovina, Environmental Protection Fund of the Federation of Bosnia and Herzegovina, Sarajevo 2020;

Source for the Republic of Srpska: Environmental Protection Strategy of the Republic of Srpska, 2022;

*Source for Kosovo**: Annual Report on the State of the Environment for 2021, Kosovo* Environmental Protection Agency, 2022; Hydrometeorological Institute Kosovo*, 2024;

Source for North Macedonia: State Statistical Office of the Republic of Macedonia, Environmental statistics, 2013 ISBN 978-608-227-132-3; Ministry of Environment and Physical Planning, 2024;

Source for Montenegro: Environmental Protection Agency of Montenegro, 2024;

Source for the Republic of Serbia: Serbian Environmental Protection Agency, 2024;

Annex 2. Synthesis of final methodology and metadata for spatial evidence

After a careful collection of available existing information and its critical review the methodology was finalized and applied during the assessment process. Following a standard procedure, the risk of soil pollution was assessed and analysed in detail and their extent at country and regional level estimated. It should be noted however that data availability is overall poor, and its quality depends on country specifics, for instance is much better in North Macedonia, Serbia, Montenegro, and Albania and rather problematic in Bosnia and Herzegovina and particularly in Kosovo*. Therefore, the methodology remains largely based on educated expert assessments and the inputs provided by national experts.

Table 1. Overview of soil pollution threat and indicators investigated in this report

Soil pollution			
Cropland	Exceedance of screening values for critical risk from heavy metal pollution	Cd, Cu, Pb and Zn by country [mg/kg]	Country-specific values vary broadly and are not necessarily comparable Stratification by land use and soil texture

Source: Soil monitoring in Europe Indicators and thresholds for soil quality assessments Version 24, September 2021 for review. EEA ETC/ULS Report 2021. Editors: Rainer Baritz (EEA), Gundula Prokop and Marco Trombetti (ETC/ULS)

Table 2 Metadata sources

	Albania	**Bosnia& Herzegovina**	**Kosovo***	**Montenegro**	**North Macedonia**	**Serbia**
Pollution	EEA reports, national reports, UN reports, research publications.	EEA reports, national reports, UN reports, research publications.	EEA reports, national reports, UN reports, research publications, Kosovo* Environmental Protection Agency.	EEA reports, national reports, UN reports, research publications, Environmental Protection Agency of Montenegro.	EEA reports, national reports, UN reports, research publications, Ministry of Environment and Physical Planning.	EEA reports, national reports, UN reports, research publications, Serbian Environmental Protection Agency.

It is suggested that apart from national data sources innovative proximal and remote sensing and monitoring techniques should be further developed to allow rapid but accurate measurements.

Thresholds values used by Western Balkan countries for heavy metals

Montenegro: Rulebook on permitted amounts of hazardous and harmful substances in soil and methods of investigation ("Off. Gazette of Montenegro", No. 18/97).

Serbia: Regulation on limit values of pollutants, harmful and hazardous substances in soil (“Official Gazette of RS”, No. 30/2018 and 64/2019).

Bosnia and Herzegovina: Rulebook on permitted quantities of hazardous and harmful substances in agricultural land and water for irrigation and methods for their testing (Official Gazette Republic of Srpska, No.)

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