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The necessity for national guidelines for the remediation of industrially contaminated brownfields: an example of Norwegian good practice

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Subject review

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The necessity for national guidelines for the remediation of industrially contaminated *brownfields*: an example of Norwegian good practice

Brownfield areas often have industrial contamination problems and require multidisciplinary intervention for the community to be able to reuse them for the benefit of the community. In the Republic of Croatia, there are currently no regulations for dealing with industrially contaminated soil, the possibility of construction depending on certain categories of contamination, or the use of contaminated soil in construction. The paper presents a possible basis for the adoption of national guidelines, based on Norwegian national guidelines. An example of the rehabilitation of the Notodden ironworks is presented, which, due to the nature of the contamination and the location, can be an example of good practice for industrially contaminated coastal areas in the Republic of Croatia.

Key words:

brownfield areas, industrial pollution, polluter pays principle, sampling, by-product

Pregledni rad

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Nužnost nacionalnih smjernica za sanaciju industrijski onečišćenih *brownfield* područja: primjer dobre norveške prakse

Brownfield područja često imaju problema s industrijskim onečišćenjem te zahtijevaju multidisciplinarnu intervenciju kako bi ih zajednica ponovo koristila. U Hrvatskoj trenutačno nema pravilnika kojim je definirano postupanje s industrijski onečišćenim tlom, klasifikacija onečišćenja tla, mogućnosti gradnje u ovisnosti o određenim kategorijama onečišćenja ili korištenje onečišćenog tla u gradnji. U radu je prikazana moguća podloga za donošenje nacionalnih smjernica, bazirana na norveškim nacionalnim smjernicama, te je prikazan primjer sanacije željezare Notodden, koja se zbog vrste onečišćenja i lokacije može promatrati kao primjer dobre prakse za obalna industrijski onečišćena područja u Hrvatskoj.

Ključne riječi:

brownfield područja, industrijsko onečišćenje, načelo "zagađivač plaća", uzorkovanje, nusproizvod

1. Introduction

"Brownfield" areas are abandoned properties or properties that have ceased to be used for their original purpose [1]. Their emergence is most commonly associated with economic changes caused by the decline of traditional industries, processes of transformation and privatization, as well as the reorganization of the defense system. Some "brownfield" areas face contamination issues and require multidisciplinary intervention to enable their reuse by the community. An example of an identified "brownfield" area with significantly contaminated soil is the power plant within the former Jugovinil factory in the Kaštela Bay, where radioactive slag and coal were deposited during the operation of the plant, as shown in Figure 1.

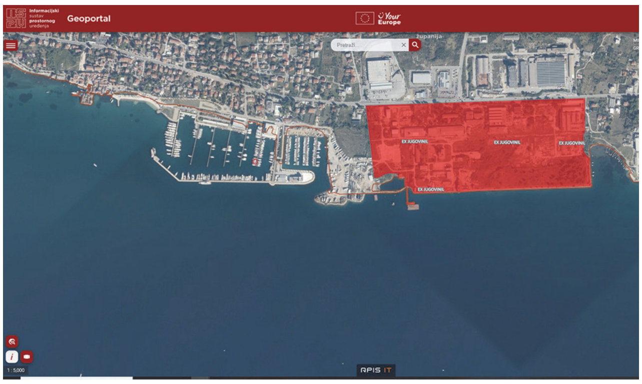

Figure 1. The area of the power plant within the former Jugovinil factory in the Kaštela Bay, marked in red (sourced from the Spatial Planning Information System)

Resolving brownfield areas involves a multidisciplinary approach and a series of steps for assessing, remediating, and redeveloping these locations for productive and sustainable use. The Republic of Croatia currently lacks a legislative and legal framework for systematically addressing the issues of industrial brownfield areas or industrially contaminated soil. In the near future, Croatia will be expected to implement the Directive on Soil Monitoring and Soil Resilience (Soil Monitoring Law) [2], which applies to all soils in EU member states and will define the methodology for classifying soil contamination and assessing risks associated with soil pollution.

Croatia has clear laws and regulations governing waste management and landfills, including procedures for declassifying waste status to enable the use of certain waste materials as secondary raw materials in other industries (explained in detail in Chapters 2.2 and 3.4). Considering that construction is one of the industries of interest where waste materials from industrially contaminated brownfield sites are often intended for use, it is essential to establish national regulations for handling contaminated brownfield areas.

As part of the project *Ecosystem-based strategies for remediation of brownfield sites (2023–2024)* [3] funded by the EEA & Norway Grants, the document *"Brownfield Remediation Roadmap"* was created as a basis for a future legislative framework. The guidelines are based on the Norwegian document *Health-based condition classes for contaminated land* [4], which forms the foundation of Norway's national legislation for remediating such areas. The guidelines were developed in collaboration with Norwegian partners and experts, including Kajsa Onshuus (GrunnTeknikk AS, Norway), Olav Berget and Janne Vaeringstad (Notodden Municipality), Kristofer Larsen and Haakon Rui (NOAH Norway), and Lasse Berntzen (University of South-Eastern Norway). Their extensive experience in remediating contaminated areas and their knowledge transfer were pivotal in shaping the guidelines presented in this work. The purpose of these guidelines is to serve as a foundation for legislative and regulatory bodies in the formation of future national regulations for managing contaminated soils, with an emphasis on health impacts. The paper includes an overview of the European and Croatian legislative frameworks for managing and addressing environmental contamination liability, the legislative framework for applying the waste hierarchy in Croatia, and guidelines for remediating brownfield and contaminated areas in Croatia, including pre-remediation actions and the implementation of remediation processes.

2. Legal framework for action

2.1. Responsibility for environmental pollution

The basic legal framework for liability for environmental damage is set out in Directive 2004/35/EC [5] of the European Parliament and Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage. The Directive is based on the "polluter pays" principle, aiming to ensure the financial responsibility of operators whose activities have caused environmental damage. The Directive applies to environmental damage caused by any of the professional activities listed in Annex III of the Directive, as well as any imminent threat of such damage. It covers activities that pose a risk of pollution or contamination and, after multiple expansions of scope, now applies to: activities in the energy industry, the production and processing of metals, the mineral industry, the chemical industry, waste management, large-scale production of pulp, paper, and cardboard, the textile industry, and the large-scale production of meat, dairy products, and food.

The Directive also applies to professional activities outside those listed in Annex III when the damage is inflicted on protected species and natural habitats due to intent or negligence. According to the Directive, in cases of environmental damage, the operator must notify the competent authority and take all applicable measures to control pollutants, manage them to limit or prevent further environmental damage and adverse impacts on human health, and implement necessary remedial measures. The Directive has been transposed into Croatian law through provisions of the Environmental Protection Act [6] and the Regulation on Environmental Liability [7]. Before alignment with European regulations, the Regulation on the Method of Determining Environmental Damage [8] and the Rulebook on Measures for Remediation of Environmental Damage and Remediation Programs [9] were applied. The Rulebook is still partially in use for provisions not in conflict with the Environmental Protection Act until a new rulebook is adopted.

2.2. Waste management

The primary directive for waste management is the Waste Framework Directive [10]. This Directive establishes the waste hierarchy (Figure 2). Additionally, it emphasizes that when applying the waste hierarchy, member states must take measures to encourage solutions offering the best overall environmental outcome. This may require deviations from the hierarchy for specific waste streams when actions based on life-cycle considerations of the total impacts during the generation and management of such waste achieve the best overall environmental outcomes.

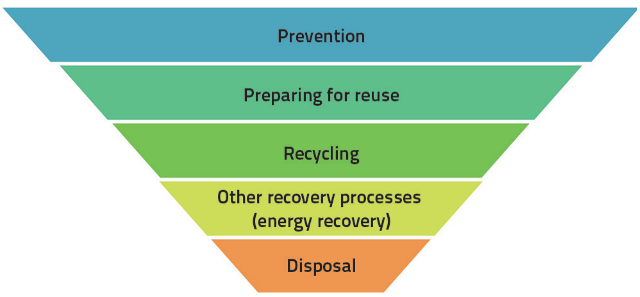

Figure 2. Waste hierarchy

According to Article 2, the scope of this Directive excludes land and/or soil (in situ), including unexcavated contaminated soil and structures permanently connected to the land. It also excludes uncontaminated soil and other natural materials excavated during construction activities, provided it is unequivocally intended to be used for construction purposes in its natural state at the site from which it was excavated.

In Croatia, waste legislation is based on European directives as well as national laws and regulations, aimed at creating a waste management system that minimizes environmental impact, promotes sustainable resource use, and ensures the protection of human health and the environment. The Directive has been incorporated into national legislation through the *Waste Management Act* [11], the *Waste Management Strategy of the Republic of Croatia* [12], and the *Waste Management Plan* of the Republic of Croatia for 2023–2028 [13]. The *Waste Management Plan for 2023–2028* [13] serves as the overarching national planning document aligning Croatia's waste management system with new European Union goals and policies in waste management while defining long-term goals and guidelines for waste management at the national level.

The document [13] emphasizes the application of the "polluter pays" principle during remediation. From 2005 to 2021, a total of 317 official landfill sites were registered and monitored. In 2021, waste was disposed of at 88 landfills [14]. The document also states that, as a result of improvements to the national system for specific waste categories, the quantities of hazardous waste have increased. Appropriate systems and capacities have been established for managing certain categories of hazardous waste; however, hazardous waste management is not systematically organized as a whole. Due to underdeveloped infrastructure, hazardous waste is largely exported from Croatia.

Section 5.4 of the document addresses the issue of hazardous waste and "black spots": "*Assessments of hazardous waste flow developments are being conducted within an ongoing project, which will result in feasibility studies for existing and required hazardous waste processing capacities and studies for identifying new locations contaminated with hazardous waste ('black spots').*" The Plan [13] identifies only eight so-called "black spots" (locations in the environment heavily burdened with waste resulting from prolonged improper management of industrial (technological) waste). A feasibility study is planned for existing and required capacities for hazardous waste processing, as well as a study for identifying new locations contaminated with hazardous waste ("black spots"). As part of identifying new "black spots," the plan aims to identify new locations contaminated with hazardous waste across Croatia, propose and elaborate criteria/mechanisms for identifying new contaminated locations, and prioritize "black spots" for remediation based on their level of risk.

To achieve Objective 11 from the aforementioned plan (R*emediating waste-contaminated sites*), three measures are defined: remediation of non-hazardous waste landfills, remediation of hazardous waste-contaminated locations ("black spots"), and remediation of sites contaminated due to uncontrolled waste disposal in the environment.

The main legal act governing the waste management system, its goals, and methods, planning documents in waste management, competencies and obligations in waste management, waste management locations and facilities, waste management activities, transboundary waste movement, the waste management information system, and administrative and inspection oversight in waste management is covered by the *Waste Management Act* [11]. The Act does not apply to land and/or soil (in situ), including unexcavated contaminated soil and structures permanently connected to the land, nor to waste generated from exploration, excavation, processing, and storage of mineral resources, or the operation of quarries.

2.3. Soil and water pollution

Healthy soils store carbon, better absorb, store and filter water, and provide food. However, soils are vulnerable to degradation such as erosion, compaction, pollution, and loss of biodiversity, often resulting from unsustainable land use and pollutant emissions. Research indicates that 60–70 % of soils in the

European Union are unhealthy, with approximately 2.8 million contaminated sites [15]. Neither Croatia nor the European Union currently has a sufficiently precise legal framework for soil protection. The Directive addresses this gap by guiding land use rules based on the nature of the area and considering its expected development. In Croatia, soil protection is partially addressed in the *Environmental Protection Act* [6]. However, aside from agricultural land regulated under the *Regulation on the Protection of Agricultural Land from Pollution* [16], there are no prescribed threshold values for pollutants in soil relative to its land use type (e.g., residential, industrial, parks, playgrounds, etc.).

Due to the lack of a legal framework and the absence of systematic data collection on soil condition and land use, it is difficult to determine changes in soil condition and, consequently, to prescribe specific preventive measures for soil protection and sustainable land management. This was confirmed in the *Report on the State of the Environment in the Republic of Croatia* [17], which emphasized the need for better soil regulation and monitoring.

Given the lack of specific European soil legislation, the European Commission introduced a new *EU Soil Strategy for 2030* [20] as part of the *EU Biodiversity Strategy for 2030* [18], itself a component of the *European Green Deal* [19]. This strategy aims for all soils in the EU to be in healthy condition by 2050.

To achieve the goals set out in the *Soil Strategy for 2030*, the EU presented a proposal for the *Soil Monitoring Law* on July 5, 2023 [21]. This directive outlines measures for monitoring and assessing soil health, based on a common definition of healthy soil, for sustainable soil management and addressing contaminated areas. The proposed approach for contaminated soils, based on impact assessment, will enable national-level standards to adapt risk reduction measures to specific site conditions. The proposal will also enhance the application of the "polluter pays" principle and promote greater social justice by encouraging actions that benefit disadvantaged households, particularly those living near contaminated areas.

The requirements for identifying, investigating, assessing, and remediating contaminated sites will create new jobs and long-term employment opportunities (e.g., increased demand for environmental consultants, geologists, remediation engineers, etc.). Once the proposed directive comes into power, member states will have a limited timeframe to adopt the necessary measures to transpose the directive and notify the Commission. Member states will be obligated to monitor soil health in all land areas, implementing all necessary measures for soil monitoring and measurement. Soil measurements must be conducted at least every five years, with the first measurements to be carried out within four years of the directive's entry into force.

Soil descriptors listed in the directive are divided into three categories: descriptors with criteria for healthy soil conditions established at the EU level; descriptors with criteria set by member states; descriptors without established criteria.

Member states may adjust some EU-level descriptors and criteria based on specific national or local conditions and have the option to introduce additional soil descriptors and land uptake indicators. Any adjustments or additions must be communicated to the Commission.

Soil will be considered healthy if the values for all soil descriptors meet the associated criteria established at both EU and national levels (the "one out, all out" principle, meaning failure to meet any of the criteria results in a "unhealthy" soil condition). For prescribed descriptors, Annex II provides recommended standards for conducting descriptor assessments.

The Directive emphasizes the importance of registers for contaminated and potentially contaminated areas, enabling the Commission, citizens, NGOs, and other stakeholders to monitor obligations related to soil pollution. It is important to note that the Ministry of Physical Planning, Construction, and State Assets has initiated the establishment of the "Brownfield Register in the Republic of Croatia" [22] and authorized county-level spatial planning institutes to enter data on brownfield areas within their jurisdictions.

For each identified contaminated site, member states would be required to conduct site-specific risk assessments based on the current and planned land use to determine whether the site poses unacceptable risks to human health or the environment and to implement appropriate risk mitigation measures. Member states will define specific methodologies for determining risks associated with contaminated areas. They will also establish what constitutes an unacceptable risk to human health and the environment arising from contaminated areas, taking into account existing scientific knowledge, the precautionary principle, local specificities, and current and future land use.

The Water Framework Directive [23] defines comprehensive management of all water bodies in Europe through an ecosystem-based approach. Water must be managed as a whole, connecting river basins with the coastal areas into which they flow. It is necessary to integrate different categories of water: rivers, lakes, transitional, groundwater, and coastal waters. Managing water quantities, chemical composition, physical conditions, and biodiversity must also be viewed as integral parts of this approach.

The basis for determining the state of the environment must rely on scientifically recognized chemical, physical, and biological parameters. The environmental goal of "very good ecological status" is based on scientific indicators and existing natural scientific knowledge about the state and development of ecosystems. For each category of water, water regulations define specific biological quality elements, and for each element, every state must define measurable parameters with corresponding threshold values for various status classes.

In Croatia, the current *Regulation on Water Quality Standards* [24] derives from the aforementioned Directive. This regulation prescribes quality standards for surface, coastal, marine, and groundwater. It also defines specific water protection goals, criteria for establishing those goals, conditions for extending deadlines for achieving them, elements for assessing water status, water status monitoring, and reporting on water status. The regulation includes: a normative definition of water status, standards for evaluating the ecological status of surface waters, a schematic classification of surface water status, an indicative list of key pollutants, quality standards for assessing the chemical status of surface and groundwater, eutrophication indicators, assessments of human activity impacts on the state of rivers and lakes and the effects of implementing measures to achieve good status.

3. Basis for National guidelines for contaminated site remediation

3.1. Introductory notes

Before considering the remediation of industrially contaminated "brownfield" areas, it is essential to note that materials remaining in an area after industrial activity should primarily be treated as waste, and the area itself regarded as contaminated. According to the *Waste Management Act* [11], waste is any substance or object which the holder discards, intends to discard, or is required to discard. Extended producer responsibility programs define a set of measures undertaken by member states to ensure that product manufacturers bear financial responsibility or financial and organizational responsibility for managing the waste phase of a product's lifecycle.

It is crucial to classify the type of waste and determine how it should be handled, all in accordance with the *Waste Management Act* [11]. In the absence of national guidelines and regulations specific to industrially contaminated soil, if waste material remains on-site, the location should be treated as a landfill, depending on the waste category. If the generated waste is deemed to have potential applications in other industries, the waste status must be revoked following the *Regulation on the Revocation of Waste Status* [25].

3.2. Preliminary actions

Preliminary actions, typically spanning several years before the remediation phase, are key to successful remediation implementation. These actions enable a thorough understanding of the situation at the contaminated site before remediation begins. Surveys on public perception and citizen questionnaires provide insights into public awareness and concerns regarding pollution and health issues. Collaboration between various levels of authorities ensures a coordinated approach and support for remediation implementation. Urban planning and other legal documents create a legal framework for remediation activities. Continuous monitoring and laboratory analyses provide consistent data on environmental quality, allowing the tracking of remediation effectiveness. Together, these activities ensure that remediation is efficient, safe, and tailored to the community's needs and environmental protection. Preliminary actions include the following steps:

- Examining public opinion regarding issues caused by "brownfield" areas (effects on human health and the environment). Surveying the population to determine facts about the causes of contamination. Establishing cooperation between national, regional, and local authorities for site remediation (e.g., agreements to accept contaminated soil within a regional waste management center). Adopting urban plans and other legal acts necessary for remediation implementation.
- Establishing continuous monitoring for a minimum of one year, including:
  - Measuring groundwater levels,
  - Laboratory analysis of groundwater samples,
  - Laboratory analysis of surrounding water (marine or lake, if applicable),
  - Laboratory analysis of tissue from existing shellfish, placement of new shellfish samples, and tissue analysis.
- Conducting preliminary soil quality research following the standard [26], to establish historical data (baseline conditions) about the site and contamination for creating a conceptual site model that identifies the spatial distribution of contamination:
  - Homogeneous distribution,
  - Heterogeneous distribution with known locations of point sources of contamination,
  - Heterogeneous distribution with unknown locations of point sources of contamination,
  - Heterogeneous distribution without point sources of contamination.
- Defining a sampling strategy (judgmental/systematic sampling) for exploratory testing to assess contamination levels in accordance with standard [27].
- Sampling the site as part of exploratory testing and conducting laboratory analyses of all contamination descriptors for soil, surface water, and gases (for soil, all in accordance with applicable standards prescribed in the *Soil Monitoring Law* [2] or the Norwegian regulations shown in Table 1).

3.3. Implementation of remediation

Remediation is carried out following the development of a remediation plan, which is prepared based on the results of preliminary actions:

- Zoning the area according to urban plans to enable phased remediation (the size of the zone should not exceed 25.000 m^2).
- Determining the number of samples and the sampling strategy in accordance with standard [28] or standard [29].
- In the absence of Croatian regulations for determining the number of samples, Norwegian recommendations (TA2553-2009 *Health-based condition classes for contaminated land* [4]) can additionally be used, depending on the type of contamination detected during preliminary actions, as specified in Tables 2 to 4.

Table 1. Categories of Contaminated Soil Conditions in Relation to Acceptability for Human Health (concentration expressed in mg/kg dry matter)

Substance \ Condition category	1	2	3	4	5
	Very good	Good	Moderate	Poor	Very poor
Arsen	< 8	8-20	20-50	50-600	600-1000
Lead	< 60	60 -100	100-300	300-700	700-2500
Cadmium	< 1,5	1,5-10	10-15	15-30	30-1000
Mercury	< 1	1-2	2-4	4-10	10-1000
Copper	< 100	100-200	200-1000	1000-8500	8500-25000
Zinc	< 200	200-500	500-1000	1000-5000	5000-25000
Chromium(III)	< 50	50-200	200-500	500-2800	2800-25000
Chromium (VI)	< 2	2-5	5-20	20-80	80-1000
NIckel	< 60	60- 135	135-200	200-1200	1200-2500
∑PCB7 [2)]	< 0,01	0,01-0,5	0,5-1	1-5	5-50
DDT [2)]	< 0,04	0,04-4	4-12	12-30	30-50
∑PAH16 [2)]	<2	2-8	8-50	50-150	150-2500
Benzo(a)pyrene	< 0,1	0,1-0,5	0,5- 5	5 -15	15-100
Aliphatic C8-C10 [1)]	< 10	< 10	10-40	40-50	50-20000
Aliphatic > C10-C12 [1)]	< 50	50- 60	60-130	130-300	300-20000
Aliphatic > C12-C35	< 100	100-300	300-600	600-2000	2000-20000
DEHP [2)]	< 2,8	2,8-25	25-40	40-60	60-5000
Dioxins/Furans	< 0,00001	0,00001-0,00002	0,00002-0,0001	0,0001-0,00036	0,00036-0,015
Phenol	< 0,1	0,1-4	4-40	40-400	400-25000
Benzene [1)]	< 0,01	0,01-0,015	0,015-0,04	0,04-0,05	0,05-1000
Trichloroethylene	< 0,1	0,1-0,2	0,2-0,6	0,6-0,8	0,8-1000

[1)] For volatile substances, gas as an exposure pathway will result in low threshold values for human health. If gas in buildings is not a relevant exposure pathway, a site-specific risk assessment should be conducted to calculate location-specific acceptability criteria.
[2)] Meanings: ∑PCB7 - Total indicative content of polychlorinated biphenyls (∑PCB7); ∑PAH16 - Total content of polycyclic aromatic hydrocarbons (∑PAH16);DDT – Dichlorodiphenyltrichloroethane; DEHP - Di-(2-ethylhexyl) phthalate

- Sampling the site as part of a detailed investigation in accordance with standard [27] and conducting laboratory analysis of all descriptors of soil contamination, surface water, and gases (for soil, all analyses follow the applicable standards prescribed in the *Soil Monitoring and Resilience Directive* [2] or Norwegian regulations presented in Table 1).
- Developing a general remediation plan for the entire area based on data collected from preliminary actions.

In cases where exceptionally large sites (> 100 000 m^2) are tested, the general rule of increasing the number of samples to 1000 m^2 above 10.000 m^2 may be deviated. This is decided on a discretionary basis in each individual case.

Table 2. Minimum number of surface samples at sites of different sizes with dispersed or homogeneous contamination

Planned land use \ Size of site [m^2]	< 500	1000	2000	3000	4000	5000	Increase in the number of samples every 1000 m^2 for areas from 5000 to 10.000 m^2	Increase in the number of samples per 1000 m^2 at > 10.000 m^2
Residential areas	4	8	10	12	14	16	2	1
City center, offices and shops	4	8	8	10	12	14	2	1
Industrial and transport areas	4	8	8	8	10	12	2	1

Table 3. Minimum number of surface samples at sites of different sizes with point sources of known location

Planned land use \ Size of site [m^2]	< 500	1000	2000	3000	4000	5000	Increase in the number of samples every 1000 m^2 for areas from 5000 to 10.000 m^2	Increase in the number of samples per 1000 m^2 at > 10.000 m^2
Residential areas	4	8	12	16	20	24	4	2
City center, offices and shops	4	8	8	12	16	20	4	2
Industrial and transport areas	4	8	8	8	12	16	4	2

Table 4 .Minimum number of surface samples at sites of different sizes with point sources of unknown location

Planned land use \ Size of site [m^2]	< 500	1000	2000	3000	4000	5000	Increase in the number of samples every 1000 m^2 for areas from 5000 do 10.000 m^2	Increase in the number of samples per 1000 m^2 at > 10.000 m^2
Residential areas	4	8	16	24	32	40	8	4
City center, offices and shops	4	8	14	20	26	32	6	3
Industrial and transport areas	4	8	8	12	16	20	4	2

3.3.1. Remeditaion procedures under the Norwegian guidelines

Table 5 shows the relationship between planned land use and condition categories at different depths. The relationship between condition category and land use indicates that a lower category denotes a lower level of soil contamination, making the soil suitable for sensitive land uses. For example, land with condition category 2 or lower in the upper soil layer will be appropriate for residential construction, kindergartens, and playgrounds. On the other hand, land with condition category 3 or lower will be acceptable for city centers without residential buildings, such as areas with streets, squares, shops, or offices.

The *Norwegian Pollution Control Authority* (NIKO) has deemed it appropriate to work with the designations surface layer and deeper soil layer. The boundary between these layers is set at a depth of 1 meter. The surface soil layer is the cultivation zone, excavation zone for technical installations, and the zone for substance replacement. The first meter is the most critical concerning human exposure. Therefore, stricter requirements for contamination levels must apply to this layer compared to the soil beneath.

In deeper soil layers, based on health assessments, higher condition categories may be permitted. However, assessments of potential spread must be conducted if there is a risk of contamination spreading to surrounding receptors. Keeping this in mind, NIKO has compiled a list of recommended land uses for condition categories based on their impact on health, presented in Table 5. The condition categories are linked to the intended use of the area, particularly when construction, excavation, or cleaning will take place on it. Land use refers to the purpose outlined in city development plans or municipal plans for the area's future use.

Table 5. The relationship between the planned use of land and the condition categories at different depths

Planned land use	Category of surface layer condition (< 1 m)	Category of condition in deeper soil (> 1 m)
Residential areas	Condition category 2 or lower. Land for cultivation next to a residential building and green nurseries: Here, the soil used for the cultivation of vegetables must meet condition category 1 for the substances PCB_{sum7}, PAH_{sum16}, benzo(a) pyrene, cyanide and hexachlorobenzene.	Condition category 3 or lower. For aliphates C8-C10 and C10-C12, benzene and trichloroethene, condition category 4 may be accepted, if the risk assessment for spreading and degassing can demonstrate that the risk is acceptable.
City center, offices and shops	Condition Category 3 or lower	Condition category 3 or lower. Condition category 4 may be accepted, if the spread risk assessment can document that the risk is acceptable. Condition category 5 can be accepted if the health and spread risk assessment can document that the risk is acceptable.
Industrial and transport areas	Condition category 3 or lower. Condition category 4 may be accepted, if the spread risk assessment can document that the risk is acceptable.	Condition category 3 or lower. Condition category 4 may be accepted, if the spread risk assessment can document that the risk is acceptable. Condition category 5 can be accepted if the health and spread risk assessment can document that the risk is acceptable.

Table 6. Backfill material: Intended use and proof of properties

BACKFILL MATERIAL		
Intended use	**Proof of harmlessness to the environment and human health**	**Document for proving the properties of backfill material**
Filling in accordance with the construction project or technically recognized professional standards	Values of the examined parameters must be less than or equal to the limit values shown in Table 8, and the testing conducted through an authorized laboratory.	Report on testing in accordance with the special regulation of the relevant authority for construction, prepared in accordance with the requirements from the construction project or technically recognized rules of the profession + Declaration of conformity on the form from Annex II of this Regulation
Filling for performing works that can be carried out without a building permit and main project in accordance with the regulation prescribing simple and other structures and works.	Values of the examined parameters must be less than or equal to the limit values shown in Table 8, and the testing conducted through an authorized laboratory.	Statement by the responsible person that the substance or object will be used in accordance with professional rules and their use will not lead to significant harmful effects on the environment or human health + Contract with the investor for the construction of simple and other buildings or execution of works with established necessary quantities of materials and/or notification of the start of construction of simple and other buildings/execution of works.

Table 7. Recycled aggregate: Intended use and proof of properties

RECYCLED AGGREGATE			
Intended use	**Properties and essential features**	**Proof of harmlessness to the environment and human health**	**Documents for proving the properties of recycled aggregate**
Concrete aggregates	According to harmonized technical specifications or *Croatian technical specifications***	The proof that the use of recycled aggregate will not cause a greater risk in terms of hazardous properties than the risk that exists with the application of aggregate produced from natural minerals, and the value of the tested parameters must be less than or equal to the limit values shown in Table 8.	Declaration of performance in accordance with special regulations governing construction products and accompanying reports confirming that the sample of construction material resulting from the recovery of waste with key numbers from tables 3.1 and/or 3.2 of the Regulation on the abolition of waste status (NN 55/2023) [25] meets the conditions of the appropriate standard for intended use + Declaration of conformity on the form from Annex II of the Regulation[25]
Aggregates for mortar			
Aggregates for railway embakement			
Stone revetments			
Recycled asphalt aggregates			
Light aggregates for concrete, mortar, and grout			
Light aggregates for bituminous mixtures and surface treatments and for use in unbound and bound mixtures			
Aggregates intended for use in roads and other engineering structures			
For use in accordance with the design project			
Aggregates intended for use in roads and other engineering structures			
For use in accordance with the design project	According to the requirements from the design project	The proof that the use of recycled aggregate will not cause a greater risk in terms of hazardous properties than the risk that exists with the application of aggregate produced from natural mineral.	Report on testing in accordance with the special regulation of the competent authority for construction + Declaration of conformity on the form from Annex II of the Regulation [25]

* Harmonized technical specifications have the meaning defined by a special regulation governing the determination of harmonized conditions for placing construction products on the market (meaning harmonized standards and European harmonization document).
** Croatian technical specifications have the meaning defined by a special regulation governing construction products in the non-harmonized area (meaning technical regulation, Croatian standard referred to by the technical regulation, and Croatian assessment document).

3.4. Waste recovery process in construction

If it is proven that the material is inert waste that could find applications in other industries, such as construction, it is necessary to comply with the *Regulation on the Revocation of Waste Status* [25]. The Regulation prescribes specific criteria for revoking waste status, including technical and environmental criteria for using waste as recycled aggregate and/or as backfill material.

The Regulation specifies details of the criteria for revoking waste status for certain substances or objects, the method of implementing EU regulations that define criteria for revoking the status of specific types of waste, the manufacturer's report on revoking waste status, and the content of the declaration of conformity for substances or objects registered in the Registry for Revoking Waste Status.

Appendix I of the Regulation provides specific criteria for revoking waste status. The criteria for recycled aggregate and backfill material are defined, including the types of waste that can be processed in the recovery procedure to produce recycled aggregate and backfill material, recovery process criteria, and quality criteria that recycled aggregate and backfill material must meet after the waste recovery process. Additionally, the permitted uses of recycled aggregate and backfill material resulting from the revocation of waste status are specified (Table 6 and Table 7).

It is necessary to emphasize that this Regulation specifies the limit values for the parameters of the eluate/leaching test of recycled aggregate and backfill materials, as well as additional parameters that must be met if the waste is to be used as new material (Table 8).

Table 8. Limit values of the parameter of eluate/leaching test of recycled aggregate and backfill material (L/S = 10 l/kg indicates the liquid to solid ratio)

Parameter	**L/S = 10** [l/kg] [mg/kg] **dry substance**
As	0,5
Ba	20
Cd	0,04
Cr Total	0,5
Cu	2
Hg	0,01
Mo	0,5
Ni	0,4
Pb	0,5
Sb	0,06
Se	0,1
Zn	4
Chloride	800
Fluoride	10
Sulfate	1000
Phenolic index	1
Additional parameters that need to be met	**Value** [mg/kg]
BTEX (Benzene, toluene, ethylbenzene, and xylenes)	6
PCB (Polychlorinated biphenyls, 7 related compounds)	1
Mineral oil (C10 do C40)	500
PAH (Polycyclic aromatic hydrocarbons)	10

- Analyze the eluate must be prepared in accordance with standards [30, 31], or the leaching test in accordance with standard [32]. The recovered waste can have its waste status revoked and be used as recycled aggregate, or as a material for embankment if a report on testing conducted in accordance with a special regulation of the competent authority for construction proves compliance with project requirements or conformity with technically recognized rules of the profession.

The recovered waste can have its waste status revoked if the values of eluate parameters or the leaching test are less than or equal to the limit values shown in table 8. The recovered waste can have its waste status revoked and can be used as recycled aggregate if the actions of assessment and verification of constancy of performance according to harmonized technical specifications or Croatian technical specifications have been carried out, and a declaration of performance has been issued in accordance with special regulations governing construction products, and an analysis has been conducted proving that the use of recycled aggregate will not cause a greater risk in terms of hazardous properties than the risk existing with the application of aggregate produced from natural minerals. Only after it has been proven according to the Regulation on the Revocation of Waste Status that the waste material meets all technical and environmental criteria, can the revocation of waste status and the possibility of using the material be considered. In accordance with legal provisions, to handle a substance or object as a by-product, it is necessary to:

- Conclude a contract between the holder of the substance or item for which registration in the By-product Register is sought and the future user of that substance or item (for example, with an economic entity from the construction industry).
- Create a specification for the future user of the substance or item for which registration in the By-product Register is sought (for example, specify the properties or requirements that the substance meets to be considered suitable for use for a specific purpose). It is necessary to consider both technical and environmental specifications.
- Prove that the substance or item for which registration in the By-product Register is requested meets the attached specification.
- Submit an application for registration in the By-product Register.
- Obtain a certificate of registration in the By-product Register.

4. Example of good Norwegian practice – remediation of the Notodden steelworks

4.1. Location and pollution description

Approximately 90 kilometers east of Oslo, there is the town of Notodden with approximately 12,000 inhabitants by Lake Heddalsvatnet. The far southeast of Notodden is called Jernverkstomta and is the site of a former ironworks, covering an area of 50,000 m^2 right next to the Tinnelva River, which flows into Heddalsvatnet. Today, it is used as a temporary storage for construction waste and parking, while one part has been very successfully remediated and is used as an residential area.

Historical maps from 1904 and 1910 indicate that a large southern part of Jernverkstomta was submerged. An islet can also be seen right next to the Tinnelva River, and the channel that formed the islet was filled in. The area was utilized at the beginning of

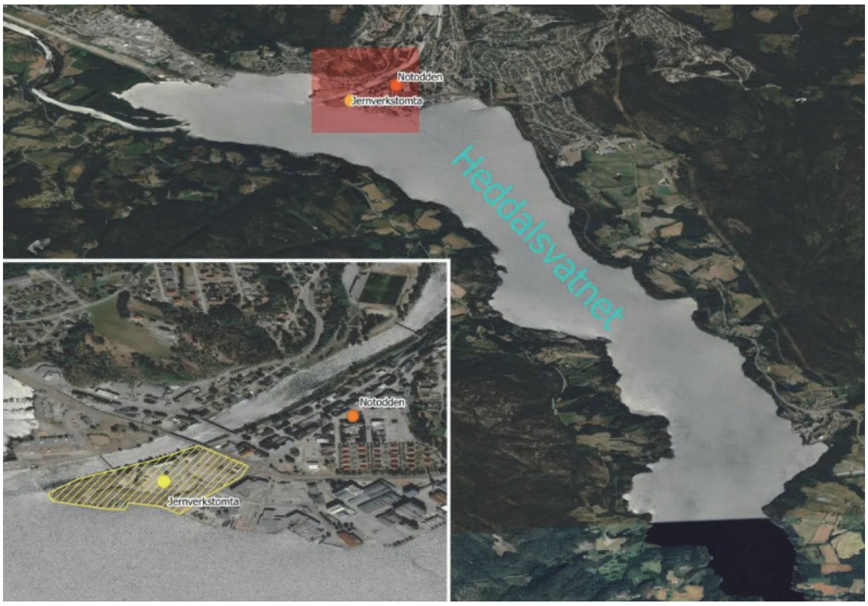

Figure 3 Accommodation of "brownfield" areas in Notodden, Norwayj [33]

the 20th century for the construction of an ironworks owned by Tinfos Jernverk AS, which produced pig iron until 1927. After that, it was reoriented to the production of ferroalloys (ferrosilicon and ferrochrome) and silicon manganese alloys. In 1963, gas cleaning equipment was installed, and in 1974, wastewater treatment was introduced. Tinfos Jernverk AS also owned a calcium carbide factory (Notodden Calsiumkarbidfabrikk) located east of Jernverkstomta, which operated from 1900 to 1952. The ironworks was closed in 1986, leaving behind by-products of iron, ferroalloy, and carbide production.

4.2. Remediation

The fundamental problems of local authorities regarding industrial pollution during most of the 19th century became visible in the mid-20th century. Deficiencies in legal regulations and the level of professional knowledge prevented effective preventive health protection. Only with major changes in the 1970s and 1980s did the removal of industrial pollution from the responsibilities of local self-government begin. Through the Norwegian Pollution Control Authority as the central supervisory body, the Norwegian Institute of Public Health as a research-based expert center, the Norwegian Pollution Act, and the Health and Social Services Act, it became possible to deal with these complex environmental and health issues on a professional level. The remediation of the steel plant area in Notodden began in 2000 with a contract between the company TinfosAS and the Municipality of Notodden, and in 2008, the responsibility for remediation was taken over by the company Eramet, which also purchased the polluted land. To date, about 25 % of the total area has been remediated, where business and residential buildings have been constructed, and the remediation of approximately 50 % of the areas is ongoing. The plan is to complete the remediation of the entire area by 2030.

In geological terms, the area contains river deposits primarily: sand, gravel, and pebbles. The embankment on the basic geological substrate consists of production remnants: ash, concrete, bricks, and waste. During the excavation of test pits, remnants of concrete floors and structures in the soil were observed, which remained after the demolition of the building. Measurement established the groundwater level at approximately 5-6 meters below the surface. Soil sample analysis revealed high contamination of PAHs and some heavy metals in the soil (e.g., Ba, Cu, Zn, Cd), while the level of contamination in the groundwater was low, likely caused by the constant flow of groundwater under the influence of the Tinnelve River.

Figure 4 Remediated "brownfield" areas Nottoden in Norway [33]

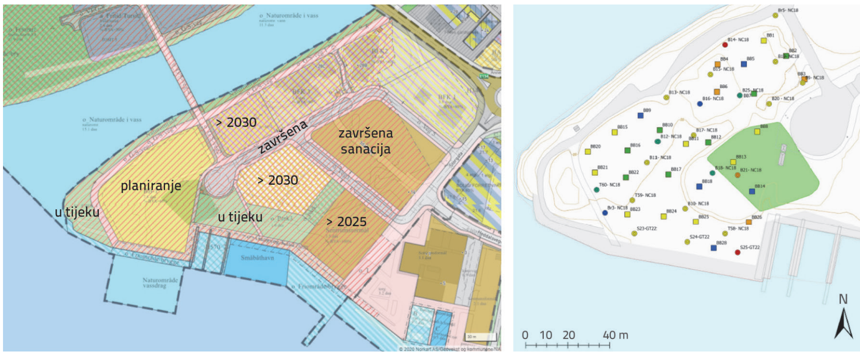

Figure 5. Example of zoning areas according to urban planning with the aim of phased remediation (left) and the positions of soil sampling in the area of the steel plant zone which is in the process of remediation planning (right) [36]

In the context of the remediation program, samples were taken from various plan positions and at multiple depths where laboratory tests were conducted. The samples were classified according to Table 1 into condition categories ranging from very good to very poor, as shown in Figure 5. To date, approximately 34000 tons of contaminated soil classified in categories 4 and 5 have been removed from the site and disposed of at the Noodden landfill. The total cost of remediation to date has amounted to 1.82 million EUR. In the future, it is estimated that an additional 70000 tons will need to be excavated with an estimated cost of 3.04 million EUR.

5. Conclusion

One of the key problems in Croatia is the lack of centers for the disposal of large quantities of highly contaminated soil, for example, category 4 and/or 5 from table 1, which should not be located near people or generally in the environment due to their extreme harmfulness. The only option for disposing of such soil, under current circumstances, is sealing it at the site of contamination (in waterproof concrete containers, etc.) or exporting it to countries that have such systems (e.g., the Norwegian company NOAH). Croatia is currently at the very beginning of solving the extremely complex problem of "brownfield" area remediation, and a long way lies ahead before an efficient system is established. The Soil Directive partially provides guidelines, so it would be necessary to further regulate the remediation of "brownfield" areas through national legislation based on this directive. Greater coordination of various professions at the state level is required to create a legislative framework, expert guidelines, recommendations, and standards related to the remediation of "brownfield" areas. Simultaneously, it is necessary to encourage (through tax incentives and subsidies) the interest of private companies in the field of remediation of contaminated areas (including brownfield areas), related to the development of remediation plans, innovative technical remediation solutions, and the development of technologies for the disposal of contaminated soil. It is also necessary to encourage scientific institutions and universities to develop new knowledge and technologies in the field of remediation through funding special scientific programs and campaigns (via, for example, the Croatian Science Foundation, Hamag Bicro, etc.).

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REFERENCES

[1] Matković, I., Jakovčić, M.: Brownfield prostori i njihova regeneracija; Definicije i pristupi, Prostor : znanstveni časopis za arhitekturu i urbanizam, 27 (2019) 2.

[2] Europska komisija: Prijedlog Direktive Europskog parlamenta i Vijeća o praćenju i otpornosti tla (Akt o praćenju tla) (Soil Monitoring Law), COM(2023) 416 final 2023/0232(COD); https://www.europarl.europa.eu/doceo/document/A-9-2024-0138_HR.html

[3] Projekt Strategije cjelovitog oporavka obalnih brownfield područja (2023.-2024.); Fond za bilateralne odnose EGP i Norveškog financijskog mehanizma za razdoblje 2014.-2021.; https://cbr.grad.hr/hr/

[4] TA25532009 Health-based condition classes for contaminated land (Kategorije stanja onečišćenog tla na temelju njihovog utjecaja na zdravlje), na norveškom i hrvatskom https://cbr.grad.hr/hr/norwegian-regulations)

[5] Europski parlament i Vijeće Europske unije: Direktiva 2004/35/EZ Europskog parlamenta i Vijeća od 21. travnja 2004. o odgovornosti za okoliš u pogledu sprečavanja i otklanjanja štete u okolišu

[6] Hrvatski sabor: Zakon o zaštiti okoliša (NN 80/13, 153/13, 78/15, 12/18, 118/18)

[7] Vlada Republike Hrvatske: Uredba o odgovornosti za štete u okolišu (NN 31/17, 50/20)

[8] Vlada Republike Hrvatske: Uredba o načinu utvrđivanja šteta u okolišu (NN 139/08)

[9] Ministarstvo zaštite okoliša, prostornog uređenja i graditeljstva: Pravilnik o mjerama otklanjanja šteta u okolišu i sanacijskim programima (NN145/08)

[10] Europski parlament, Vijeće Europske unije: Direktiva (EU) 2018/851 Europskog parlamenta i Vijeća od 30. svibnja 2018. o izmjeni Direktive 2008/98/EZ o otpadu

[11] Hrvatski sabor: Zakon o gospodarenju otpadom (NN 84/21, 142/23)

[12] Hrvatski sabor: Strategija gospodarenja otpadom Republike Hrvatske (NN 130/2005)

[13] Vlada Republike Hrvatske: Plan gospodarenja otpadom Republike Hrvatske za razdoblje 2023. - 2028. godine, NN 84/2023, https://narodne-novine.nn.hr/clanci/sluzbeni/2023_07_84_1334.html

[14] Ministarstvo gospodarstva i održivog razvoja: Pregled podataka o odlaganju i odlagalištima otpada za 2022. godinu, https://isgo-portal.mingor.hr/hr/nacionalna-izvjesca

[15] European Commission, Directorate-General for Research and Innovation, Veerman, C., Pinto Correia, T., Bastioli, C., et al., Caring for soil is caring for life, Ensure 75 % of soils are healthy by 2030 for food, people, nature and climate : report of the Mission board for Soil health and food, Publications Office, 2020, https://data.europa.eu/doi/10.2777/821504; EU project Achieving Remediation And Governing Restoration of contaminated soils; now https://aragorn-horizon.eu/

[16] Ministarstvo poljoprivrede: Pravilnik o zaštiti poljoprivrednog zemljišta od onečišćenja (NN 71/19)

[17] Vlada Republike Hrvatske: Izvješću o stanju okoliša u Republici Hrvatskoj za razdoblje od 2013. do 2016., 2019,https://mingo.gov.hr/UserDocsImages/GLAVNO%20TAJNI%C5%A0TVO/Strategija,%20planovi%20i%20ostali%20dokumenti/IZVJ_OKOLIS_2013-2016.pdf

[18] Europska komisija: Strategija EU-a za bioraznolikost do 2030., COM(2020) 380 final

[19] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_hr,

[20] Directorate-General for Environment: EU soil strategy for 2030, https://environment.ec.europa.eu/publications/eu-soil-strategy-2030_en

[21] Europska komisija: Prijedlog Direktive Europskog parlamenta i Vijeća o praćenju i otpornosti tla (Akt o praćenju tla) (Soil Monitoring Law), COM(2023) 416 final 2023/0232(COD)

[22] Informacijski sustav prostornog uređenja, https://ispu.mgipu.hr/ (pristupljeno: 11. studenog 2024. godine).

[23] European Parliament and of the Council European Union: Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Official Journal L 327 , 22/12/2000 P. 0001 - 0073

[24] Vlada Republike Hrvatske: Uredba o standardu kakvoće voda NN 96/2019, NN 20/2023

[25] Ministarstvo gospodarstva i održivog razvoja: Pravilnik o ukidanju statusa otpada (NN 55/2023)

[26] Hrvatski zavod za norme: HRN ISO 18400-202:2019 Kvaliteta tla - Uzorkovanje - 202. dio: Preliminarna istraživanja

[27] Hrvatski zavod za norme: HRN ISO 18400-203:2019 Kvaliteta tla - Uzorkovanje - 203. dio: Istraživanje potencijalno onečišćenih lokacija

[28] Hrvatski zavod za norme: HRN ISO 18400-104:2019 Kvaliteta tla - Uzorkovanje - 104. dio: Strategije

[29] Hrvatski zavod za norme: HRN EN 14899:2007 Karakterizacija otpada - Uzorkovanje otpadnih materijala - Okvir za pripremu i primjenu plana uzorkovanja

[30] Hrvatski zavod za norme: HRN CEN/TR 16192:2020 Otpad - Upute za analize eluata

[31] Hrvatski zavod za norme: HRN EN 14039 Karakterizacija otpada - Određivanje sadržaja ugljikovodika od C10 do C40 plinskom kromatografijom

[32] Hrvatski zavod za norme: HRN EN 12457 - 4 Karakterizacija otpada - Izluživanje - Provjera izluživanja zrnatoga otpadnog materijala i muljeva - 4. dio

[33] Berget, O., Væringstad, J.: Polluted areas form the perspective of local administration (Notodden municipality); presentation at the case study Coastal brownfield remediation, 2023, Dugi Rat

[34] Lov om vern mot forurensninger og om avfall (forurensningsloven); https://lovdata.no/dokument/NL/lov/1981-03-13-6

[35] Lov om kommunale helse- og omsorgstjenester m.m. (helse- og omsorgstjenesteloven); https://lovdata.no/dokument/NL/lov/2011-06-24-30

[36] Onshuus, K.: Experiences in remediation of the former ironworks in Nottoden (Norway), presentation at the case study Coastal brownfield remediation, 2023, Dugi Rat