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Mykolaiv
city on the wave

Assistance to the Development of the Mykolaiv Masterplan

Construction and Demolition Waste
Report
Final

November 2023

COWI

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Report
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Contents

List of Figures

List of Tables

List of Abbreviations

CAPEX	Capital expenditure
CDW	Construction and demolition waste
CFD	Chlorofluorocarbon
MCA	Mykolaiv City Administration
MFA	Danish Ministry of Foreign Affairs
MSW	Municipal Solid Waste
MW	Municipal Waste
OPEX	Operating Expense
UXO	Unexploded ordnances

1 Introduction

This report has been developed within the framework of the project “Technical advice to the Danish Ministry of Foreign Affairs regarding Mykolaiv - Denmark partnership” financed by the Danish Ministry of Foreign Affairs (MFA). The project, which has been entrusted COWI, is a framework contract, which, among others, includes assistance to the Mykolaiv City Administration (MCA) in developing the Mykolaiv Masterplan in close cooperation with an Italian company, One Works. Box 1-1 below provides information about COWI's contribution to the masterplan.

Box 1-1 COWI's contribution to Mykolaiv

Mykolaiv Masterplan, which has been requested by the Mayor of Mykolaiv City, has a time horizon till 2050. It provides a compass for actions to be taken by the Mykolaiv City to ensure that it will develop into a thriving city attractive to its citizens and business community.

COWI and One Works assist Mykolaiv City Administration in developing the masterplan. In this work, COWI focuses on three sectors:

- Water and wastewater
- Energy, including power, district heating and renewable energy sources
- Solid waste management.

Mykolaiv City Administration meets every week with COWI and One Works to ensure proper coordination.

COWI has established a project organization consisting of a project management team and three sector teams of professionals, each headed by a Discipline Leader. Three sectoral Focal Points are responsible for monitoring cross-cutting activities, ensuring coordination between the parties and maintaining consistency in the deliverables.

To enhance transparency in the development of the Mykolaiv Masterplan, given its significant public interest and exposure, COWI has established three sector-specific Sounding Boards inviting all potentially interested parties to take part in these.

The principal audience for this report comprises the Mykolaiv City Administration (MCA), One Works, and the waste sector Sounding Board. The report is continuously under development based on the comments and input from the stakeholders involved.

The report consists of 7 chapters, namely:

- Chapter 2 provides background of construction and demolition waste in the context of Mykolaiv city.

- Chapter 3 describes and estimates the potential amount and composition of construction and demolition waste in Mykolaiv city that can be generated during reconstruction and demolition of war-damaged buildings in the city. The results are compared with input from external sources. Hazardous waste as part of the composition is further elaborated.

- Chapter 4 lists the potentials of recycling construction and demolition waste in Mykolaiv Oblast

- Chapter 5 describes Ukrainian and EU legislative framework for construction and demolition waste management.

- Chapter 6 proposes a solution for an integrated construction and demolition waste management system, with the emphasis on the establishment of a temporary facility for handling the construction and demolition waste.

- Chapter 7 describes the expected impacts of the proposed solution for management of the construction and demolition waste in Mykolaiv.

2 Background

Handling the enormous amounts of waste from the destroyed buildings is the biggest challenge for reconstruction after wars and disasters. Accumulation of construction waste mixed with household waste, dead animals, landmines, and unexploded ordnance (UXO) etc. pose a serious risk to human health and safety. Internationally, it is well known that handling the large amounts of waste after disasters and conflicts is hampered by a lack of planning, knowledge, and consideration. In addition, there is typically a lack of space for depositing and temporary collection of the waste. It is important to take the time to sort the waste and avoid that recyclable resources are wasted.

The Mykolaiv Oblast and the city, like many, especially Eastern and South-Eastern regions of Ukraine, were subjected to shelling from the very beginning of Russia's full-scale aggression against Ukraine. In Mykolaiv city, although to a lesser extent than in, especially eastern part, of the Mykolaiv Oblast, a large number of buildings and infrastructure facilities were damaged by shelling. Some are slightly damaged and could be repaired, but many are beyond repair and need consequently to be demolished. Figure 2-1 displays pictures taken in 2023, showing examples of war-damaged buildings in Mykolaiv city.

Figure 2-1 Pictures from visits to Mykolaiv City 2023, source: Jesper Karup Pedersen, COWI.

The large amounts of Construction and Demolition waste (CDW) that is piling up in the city must be collected so as not to harm the environment or the local communities. Furthermore, the CDW holds resources that can be used to rebuild the city. It is therefore of high importance to not only collect the waste, but to collect it safely, and sort and process it properly. Since there is a risk of explosive residues and other contaminants in the waste, safety measures and legislative procedures are of high importance and must be followed.

Therefore, this report aims at 1) identifying the scale of the problem with assessment of the potential of CDW in Mykolaiv city due to war, 2) the legal frame to manage it and 3) the potentials of reusing the collected, processed and sorted material, 4) a proposal for managing the waste within the legal framework and 5) the expected impacts of the proposal.

3 Assessment of CDW Quantities and Composition

3.1 Introduction and Background

The purpose of this chapter is not to provide exact assessment of the current potential of CDW, but more relevant to gain an understanding of the scale of the problem. More precise assessment of CDW volumes and composition can be conducted at a later stage, after it becomes clear what technological solutions are possible and could be recommended for effectively addressing the issue of CDW disposal, recycling and the utilization of recycled CDW.

Many organizations were involved in assessing the scale of the problem, some at the national level and others in various regions. COWI has been informed about the following existing and on-going studies and assessments:

- In February 2022, Ukrainian Ministry of Environment compared the amount of CDW produced during the year with the amount of all solid waste generated in the entire country in an average year - about 10-12 million tonnes[1].

- Neo-Eco Ukraine, supported by the Danish NGO, Mission East have carried out CDW assessment in 70 small towns in Mykolaiv Oblast and estimated amount of CDW only in these towns to 1.7 million m³ or 2.5 million tonnes.

- According to a Property Forum report[2], citing an estimate from the MCA, the approximate amount of construction waste in Mykolaiv generated by March 2023 was 2,155 m³.

- According to the data received by a consultant from the city department on utility service for the 01.09.2023 about 7,681 m^3 CDW have been already stored.

All of this is valuable information, however, there is still no exact data regarding the quantity and composition of the CDW in the city of Mykolaiv which this chapter focuses establishing. The numbers listed above serve as a benchmark.

The most accurate method for assessing the volumes and composition of CDW would likely involve a comprehensive analysis of waste composition from various types of buildings, coupled with the passport data from each affected building. A more approximate and less accurate result may be expected from aerial photography (possibly using the drones) or by analysing satellite images. To assess the potential for handling the CDW, COWI has conducted a desk study to prepare a rough estimate on the quantities. The desk study is based on a damage assessment received from MCA in August 2023 and analysis of information from open sources.

Based on the experience from the civil war in the Western Balkans, the demolition waste is a mix of various fractions such as bricks, concrete, steel, mortar, sand, gravel, plastic, wood, gypsum, minor MW and hazardous waste. For this assessment, the waste composition and waste generation rate are based on unit rates widely used within the Danish industry today, see below. For validation purpose, the results will be compared with amounts estimated by Neo-Eco and

[1] Міндовкілля: Відходи руйнації в Україні вже можна порівняти з кількістю твердих побутових відходів, що в середньому утворюються в країні за рік | Кабінет Міністрів України (kmu.gov.ua)
[2] Construction waste in Ukraine: What's the solution? (property-forum.eu) Будівельне сміття: вирішення проблеми залежить від політичної волі та готовності впроваджувати реформи (propertytimes.com.ua)

waste composition described in the Property Forum report "Construction waste in Ukraine: What's the solution?"[3].

Table 3-1 Applied Waste Generation rate and waste distribution[4].

		Remodelling/reconstruction	Demolition5
Generation rate		50 kg/m² damaged area6	1 693 Kg/m² demolished area
Waste composition distribution	Concrete, tiles, mortar	62 %	86%
	Wood and other combustibles	26 %	6%
	Paper and cardboard	1 %	0%
	Plastic	1 %	0%
	Metal	10 %	3%
	Other non-combustibles	2 %	5%

In August 2023, MCA provided a rough damage assessment[7] that includes information on buildings that have been screened for war damage. The information includes size, ownership, location, degree of destruction, damage category (I-III), whether the building is restorable or not, number of floors, the ground level area, the damaged area etc. All the registered buildings have been categorised depending on the degree of damage. The level of damage is divided into three categories. The three categories are presented in the table below.

Table 3-2 Categories for level of damage[8].

Damage Category	Description of level of damage
Category 1	Minor damages to the bearing and enclosed structures, not violating the mechanical resistance requirements. Restoration works by repair is recommended.
Category 2	Damage to load-bearing and enclosed structures, the degree and nature of which indicates the need to perform works on partial emergency dismantling. Restoration and overhaul work, including reconstruction, is recommended.
Category 3	Damage to load-bearing and enclosed structures, the degree and nature of which indicates the danger of emergency collapse of the facility. Urgent dismantling (liquidation) of the facility is recommended.

The table below lists the total number of buildings registered in the damage assessment. The dataset is unfortunately not complete and multiple data lines (buildings) are missing one or more information. Each building should theoretically have information on both damage category, whether its restorable and a percentage of damage. As seen in the table, multiple buildings are missing information on at least one of these types of information.

[3] Construction waste in Ukraine: What's the solution? (property-forum.eu), May 2023, by Yuliya Chorna, IC Ukraine
[4] Values modified from Christensen T.H., 2011, "Solid waste technology and management". Table values are originally from Lauritzen, E.K. and Hansen T.T., 1997, "Recycling of construction and demolition waste 1986-1995"
[5] *Average value of residential and non-residential.*
[6] *Assumed unit is per damaged area as no explanation is available.*
7 Dataset includes information for over 3000 items and could be provided on request
[8] OneWorks: "Mykolaiv masterplan". 2023.

Table 3-3 Overview of registered damaged building and how many that are missing important information for the calculations (blanks).

Total # of registered damaged buildings	# of buildings registered with a damage category				# of buildings marked as restorable			# of buildings marked with a damage degree (%)	
	Cat. 1 (least damage)	Cat. 2	Cat. 3 (Most damage)	Blank	Yes	No	Blank	Yes	Blank
3,107	2,567	419	29	92	2,183	429	495	2,883	224

Despite the data gaps, it is possible to make an initial estimate of the potential construction and demolition waste, that can be generated due to the war, up to the date of the preparation of the damage assessment study.

3.2 Methodology

To estimate the quantity of potential demolition waste from war damage in Mykolaiv city, the dataset provided by the MCA and the generation rates and composition as presented in are combined. However, as shown as number of blank information in , the dataset is missing information for several of the damaged buildings. Therefore, assumptions and calculation rules have been made to either filter or fill out missing information. The applied calculation rule is shown below.

Box 3-1 Applied calculation rule

Applied calculation rule:

- Waste from restorable buildings is calculated as the damaged area multiplied by the generation rate for remodelling/reconstruction.
- Waste from non-restorable buildings (assumed demolished) is calculated as the total area of the building times the generation rate for demolition.
- For those buildings that have no information on whether it is restorable or not, they are assigned their restorability based on firstly their damage category: if the damage category is III, then they are found non-restorable (will be demolished); If the damage category is I, then they are found restorable; For buildings with the damage category II, it is unclear whether they are restorable or not based on the category description, se . As an initial estimate it is assumed that category II buildings with more than 60 % damage will be marked as non-restorable (will be demolished) and the ones below 60 % damage will be restored.

3.3 Results of CDW Quantity and Composition

Based on the calculation rule, a rough estimate of the potential demolition waste from Mykolaiv city is calculated, see below table. The table shows both the different waste fractions generated from remodelling/reconstruction and from demolition of war damaged buildings. The largest waste fraction estimated is concrete, tiles and mortar, making up to app. 86% of the total amount of waste from war damage in Mykolaiv City.

Table 3-4 Estimated waste generation (in rounded values) and waste composition of CDW from Mykolaiv City due to war damage.

	Waste from remodelling/reconstruction	Waste from demolition	Total	
	[tonnes]	[tonnes]	[tonnes]	[%]
Concrete, tiles, mortar	8,900	464,000	472,900	85%
Wood and other combustibles	3,700	31,900	35,600	6%
Paper and cardboard	100	800	900	0%
Plastic	100	-	100	0%
Metal	1,400	14,400	15,800	3%
Other non-combustible	300	28,700	29,000	5%
Total Waste	14,600	539,800	554,400	100%

Theoretically, if the total amount of CDW will be removed in one batch and stored at a temporary storage area, the needed area will be in the magnitude of 8 hectares or 80,000 m² assuming storage in 4 m heigh.

It should be emphasized that the figures presented in above table are rough estimates based on 1) generation rates and waste composition distribution from another geographical area and time (Denmark in the 1990s), and 2) local dataset where some information is missing. It is not known how many of the buildings have already been reconstructed or demolished since the completion of the damage assessment. The results are therefore associated with a high degree of uncertainty.

3.3.1 Hazardous Fractions in CDW

The demolition waste risks containing all kinds of contaminations. In Ukraine, the predominant contamination is asbestos from the roof constructions. Other special fractions that need handling due to their contents of unwanted substances is presented in box below, based on experience from Western Europe.

Box 3-2 Special Fractions in Building waste (and consequently CDW)[9]

- Asbestos has earlier been used a lot for reinforcement, filler, fire inhibition and insulation, for example in roofing and ventilation channels. Asbestos fibres may be released upon mechanical force and cause risk to the human respiratory system. Asbestos must be handled separately during demolition.
- Hard PVC is used extensively for pipes, gutters, electrical installations, ceilings, decorations, windows and panels. Hard PVC contains bound chloride that may be released as acid upon incineration. Older hard PVC often contained lead and cadmium as stabilizers and pigments.
- Soft PVC is used extensively for cables, flooring and as foils. Soft PVC may usually contain high concentration of softeners such as phthalates. Lead and cadmium have been used as stabilizers and pigments.
- Mineral wool has been used for insulation. Older material may contain leachable phenols.
- Insulations foams may contain CFC-gases from the foaming process. The CFC is captured in the voids in the material but may be released by mechanical breaking or by diffusion over time. CFC gases are ozone depleting.
- Impregnated wood may contain creosote, arsenic, copper and chromium. The metals may be released during combustion and potentially also be leaching.

[9] *ref. ISWA Solid Waste Technology and Management, editor Thomas Højlund).*

- Plywood used to contain formaldehyde, which is toxic, carcinogenic and may induce allergenic reactions.
- Glazed tiles for roofing may contain lead.
- Joint filler may contain CFC and PCBs.

In addition to the abovementioned special fractions that needs special attention, the risk of mines, unexploded ordnances (UXO), pathological waste, healthcare risk waste, fuel, oil etc. possess other environmental issues that are essential for the process of cleaning up and further management and handling of the CDW.

3.4 Comparison of CDW Quantities and Composition

Mission East, Neo-Eco and UA Damage are currently working on mapping CDW in Mykolaiv Oblast excluding the city. During an interview with Neo-Eco, they estimate that Mykolaiv City could generate roughly around 350,000 tonnes of construction and demolition waste and that around 77% of the waste being concrete, tiles and mortar. Comparing the calculated figures listed in Table 4-4 with the estimate made by Neo-Eco, it is fair to assume that the figures from Table 3-4 are within an acceptable level.

From Property Forum's report[10] 's data (see below), the estimated average generation rate is 2 407 kg/m² and the sum of brick, reinforced concrete and concrete makes up 98-99% of the total waste generation. These values are higher than the generation rate and rubble percentage that have been applied for this report's results. If applying the average generation rate extracted Property Forum's report values, this report's results would change from a total CDW of app. 554 400 tons to 782,000 tons and would contain more rubble than previously estimated. The difference in generation rates and waste distribution can be due to uncertainties of the assumptions made in the estimation methods, geographical location, type of buildings etc. Despite of the listed uncertainties, the report's results are found within an acceptable level.

Table 3-5 Comparison of CDW composition and generation rates from different sources

		Demolition of a two-story small house (approximate heating area of 180 m²) [11]	Demolition of a five-story building (estimated heating area 4 368 m²) [12]	Average value of residential and non-residential demolition waste[13]
Generation rate [kg/m² demolished area]		2,737	2,077	1,693
Waste composition distribution	Brick	50%	44%	86%
	Reinforced concrete	22%	49%	
	Concrete	26%	7%	
	Metal	2%	0%	3%
	Wood	0%	0%	6%
	Glass	0%	0%	
	Other non-combustibles			5%

[10] Construction waste in Ukraine: What's the solution? (property-forum.eu)
[11] Будівельне сміття: вирішення проблеми залежить від політичної волі та готовності впроваджувати реформи (propertytimes.com.ua)
[12] Будівельне сміття: вирішення проблеми залежить від політичної волі та готовності впроваджувати реформи (propertytimes.com.ua)
[13] values modfied from Christensen T.H., 2011, "Solid waste technology and management". Table values are originally from Lauritzen, E.K. and and Hansen T.T., 1997, "Recycling of construction and demolition waste 1986-1995"

4 Potential for Recycling

As presented in chapter 3.3, the primary components of CDW are bricks, concrete, steel, wood and glass. Most materials in the destroyed buildings must be considered useful resources for reconstruction that can be used in the rebuilding and reconstruction process.

During wartime, the benefits of recycling materials are especially clear: the recycled materials are often cheaper compared to virgin materials and recycling is faster than sourcing and trucking new materials during a war, where large distance logistics can be problematic[14]. The typical application for the CDW fractions related to recycling is as follows as listed in below table.

Table 4-1 Recycling options for the different fractions from CDW.

Waste fraction	Recycling option
Concrete	After crushing, screening and sorting in different sizes, this aggregate material can be used as unbound material as substitute for virgin material in road construction. The material can also be used as aggregates for concrete or for production of concrete blocks/brick/tiles etc.
Bricks	Depending on the conditions, the bricks can be reused or crushed and recycled as unbound material in road construction.
Steel	Depending on the conditions, the steel constructions can be reused or scrapped and melted for the production of new construction steel.
Wood	Depending on the condition, the wood can be reused as construction timber. Non-painted wood can be shredded and turned into woodchips for plates or as decoration in gardens or for heating purpose.
Glass	Typically, this can be crushed and recycled for new glass production or production of insulation materials.

It has not been possible within the timeframe of this report to conduct a detailed market survey for possible recipients of various waste fractions after sorting the CDW, but the consultant has been aware of a recent study made by Neo Eco and Mission East[15]. First of all, their study concludes that concrete from rubble from a common Ukranian Pannelka building can be used for low-carbon cement and that there is both the need and the possibility to establish a low-carbon cement plant in the region. Furthermore, their macroeconomic study provides an overview of the local companies in Mykolaiv region that have potential for collaboration for implementing circular processes, approaches and principles in the region. Here 20 companies were potentially willing to collaborate. They cover the areas: Equpment and buidling companies (eight companies), companies with alternative ways of using recycled raw materials (seven companies), wood (three companies), dry construction mixes (one company), and plastic (one company). Recycling of scrap is already common practise in the region. Here the metals are either incorporatd into manufacturing processes or exported.

Examples of recycling of rubble are shown in below textboxes.

[14] https://www.fastcompany.com/90844641/how-one-company-is-turning-50000-tons-of-rubble-into-apartment-buildings-in-ukraine.
[15] https://neo-eco.com.ua/en/project/macro-economical-study/, the full study was provided by Neo- Eco and Mission East and called "Macro-economic waste study for the reconstruction of the Mykolaiv region", 2023

Box 4-1 Neo-Eco[16],[17] pilot project for recycling of CDW in Hostomel

In 2023, Neo-Eco successfully demolished buildings in Hostomel, Ukraine, with a proven recyclability rate of more than 90% of the 50 000 tons of deconstructed rubble. The company is reusing it to construct six new buildings with 450 new apartments in the city.

Box 4-2 Experience from the Balkans re-using rubble from the cleaning-up of damaged buildings.

In Mostar, BIH, a building waste management system was donated after the ending of the civil war in the mid 90' by the Danish Ministry of Foreign Affairs. This among others consisted of provision of crusher and screener units and associated machinery. Based on a market study, it was decided to produce primarily gravel for road construction. Minor pilot projects were conducted to produce aggregates for new concrete, although the market for this was too immature.

[16] Neo-Eco – світ без відходів
[17] https://www.fastcompany.com/90844641/how-one-company-is-turning-50000-tons-of-rubble-into-apartment-buildings-in-ukraine

5 Legal Basis

It is essential to clarify the legal basis and ownership to buildings before demolition work and clean-up can commence.

As a candidate for EU membership, Ukraine must operate in accordance with the existing legislation in the country, while also be prepared to adhere the legislative framework of the EU in a near future. Both are described in the following chapters.

5.1 Ukrainian Legislation on Construction and Demolition Waste

Nationally, CDW management is regulated by Law of Ukraine “On waste management” № 2320-IX of 20/06/2022[18].

Box 5-1 Definition of demolition waste according to the Resolution No. 1073 of 27.09.2022

In the current Ukrainian context, demolition waste (according to the Resolution No. 1073 of 27.09.2022) is primarily considered as waste generated from war-related damages on buildings and structures. Demolition waste here refers to parts (debris) of damaged (destroyed) objects, as well as materials, objects that were inside or next to such objects at the time of damage (destruction) and/or the performance of dismantling works and which are completely or partially have lost their consumer properties and cannot be used in the future at the place of their formation or discovery.

From above definitions it must be assumed that what was inside or next to the building at the time of the strike, e.g. personal belongings, furniture, household appliances, and organic substances, will be part of det construction and demolition waste.

Shortly after the start of the war, Resolution No. 1073 of 27.09.2022 for the demolition waste resulting from the war (from unpredicted destructions) was adopted[19]. The procedure for implementation of Resolution No. 1073 of 27.09.2022 does not apply to management of radioactive waste, waste generated in connection with the damage (destruction) of defence and military facilities, waste generated as a result of the of economic entities' activities.

According to the resolution, organization of demolition waste management operations can be provided by:

- the owner/manager of the object, as a result of damage (destruction) of which such waste was formed, or the owner or user of the land plot within which such waste is placed;
- by an authorized body - regarding demolition waste placed on the streets and roads of populated areas, public roads, public places.

Operations for the management of demolition waste, which the owner is unable to carry out independently due to technical or economic reasons, are organized by the authorized body.

[18] https://zakon.rada.gov.ua/laws/show/2320-20#Text
[19] Resolution of the Cabinet of Ministers of Ukraine No. 1073 of 27.09.2022 "On approval of the Procedure for handling waste generated in connection with damage (destruction) of buildings and structures as a result of hostilities, acts of terrorism, sabotage or carrying out works to eliminate their consequences and making changes to some resolutions of the Cabinet of Ministers of Ukraine" https://zakon.rada.gov.ua/laws/show/1073-2022-%D0%BF#Text

Identification and accounting of demolition waste is organized by the authorized body. Accounting for demolition waste is carried out at the place of its generation or at places of temporary storage or other waste management facilities. Information on demolition waste should be submitted to regional state administrations every month as well as placed on official website of authorized body.

Resolution No. 1073 of 27.09.2022 also contains:

- Procedure on demolition waste management.
- List of components of demolition waste and possible ways of their reuse
- Requirements for arranging a temporary waste storage place. In particular, special requirements for places where combustible demolition waste is planned to be stored. Oblast state administration has responsibility to take a decision on temporary storage site location
- Reference to the document Procedure for performing works on the dismantling of objects damaged (destroyed) as a result of emergency situations, military actions or acts of terrorism[20], according to which works on the dismantling of damaged (destroyed) objects are defined
- The provision that if hazardous waste is detected at any of the stages of demolition waste management, then it must be managed in accordance with the requirements of the legislation of Ukraine
- The requirement that construction products (products) obtained using demolition waste must meet the requirements of the Technical Regulations for construction products (products)[21]
- The document specifies that the authorized body is obliged to take measures to reuse the main components of demolition waste (after their treatment/recycling - if necessary) during the implementation of construction projects for which it is the construction customer, and to promote the use of demolition waste by other construction customers.

[20] Resolution of the Cabinet of Ministers of Ukraine dated April 19, 2022 No. 474
[21] Resolution Cabinet of Ministers of Ukraine No. 1764 of December 20, 2006

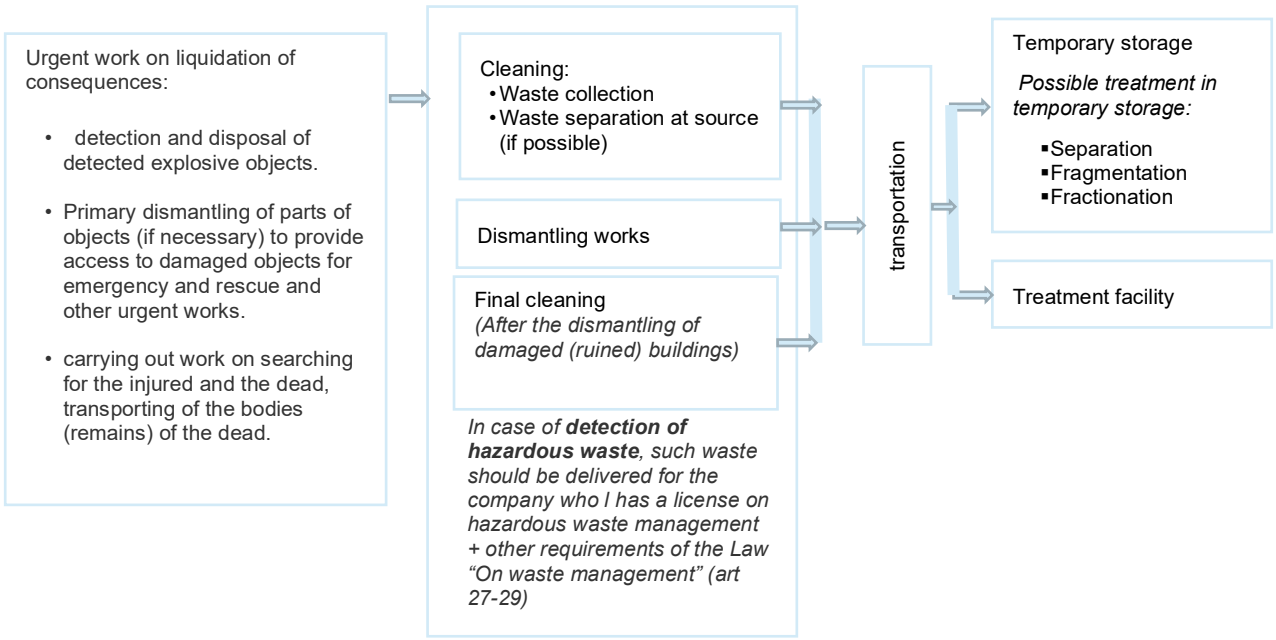

Figure 5-1 Scheme of demolition waste management according to the requirements of Resolution of the Cabinet of Ministers of Ukraine No. 1073 of 27.09.2022

EU Legislation on Construction & Demolition Waste

Directive 2008/98/EC[22] defines CDW waste and reuse and recycling targets across EU member states. Across EU, construction and demolition waste (CDW) is defined as waste generated by construction and demolition activities (according to Directive 2008/98/EC[23]). For CDW a target for the material recovery of non-hazardous construction and demolition waste has been set at as 70%, which must be achieved by the Member States by reference year 2020. After latest amendments to the Directive 2008/98/EU a new target on preparing for re-use and recycling targets for construction and demolition waste and its material-specific fractions should be installed by 31 December 2024.

Every EU country should report on regular base on targets achieving according with the rules established by the Commission Implementing Decision (EU) 2019/10043 and based on rules and calculation methods set out in Commission Decision 2011/753/EU2.

To support implementation of the best practices on CDW management across the EU member states, two documents have been developed in 2018:

- Construction and Demolition Waste Management Protocol - non-binding guidelines on how to properly handle this waste stream;
- Guidelines for audits before demolition of building - guidance on best practices for the assessment of construction and demolition waste prior to demolition or renovation of buildings and infrastructures.

[22] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705
[23] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705

The main idea behind these documents is to separate CDW as much as possible at source to make recycling or recovery possible.

All other activities on CDW management related to the general requirements is defined by the Directive 2008/98/EU and Directive 1999/31/EU[24]. Here the main points are:

- Waste hierarchy implementation
- Requirements to have a permit to treat waste

Waste that cannot be recovered after pre-treatment can be landfilled. Landfilling must be separate, meaning non-hazardous waste can only be landfilled in landfills for non-hazardous waste, inert waste can only be landfilled in landfills for inert waste, and hazardous waste can only be landfilled in landfills for hazardous waste.

[24] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01999L0031-20180704

6 Description of the Proposed CDW Management System

For Mykolaiv City, the Consultant proposes the following three-step approach for a CDW Management system in Mykolaiv city:

1 Regulatory and administrative system

2 Demolition and clean-up

3 Establishment of a CDW facility, with the following phases:

- Phase 1 - A temporary CDW facility to handle the waste as an emergency handling;
- Phase 2 - A permanent CDW facility, to be established after the cease of the war actions, to handle the waste generated in the building and construction sector.

The primary goal of the proposed CDW management system is to increase and ensure recycling of CDW, and to provide support in rebuilding of the city.

The primary objective with step 1, is to ensure that the legislation is in place and that the full administrative system is in place to conduct and implement the entire CDW management system.

The objective with step 2 is to ensure that the demolition and clean-up can be done in an organised and safe manner, and that as mush of possible of the CDW can be reused and recycled.

The objective of step 3 is the physical setup of the facility to handle the waste in the best possible manner, converting waste to valuable resources. With phase 1 of step 3, the objective is to swiftly implement a system in accordance with the Ukrainian legislation. This process shall ensure that it can handle the vast amount that is accumulated within the City that hinder the reconstruction and can attract pests etc. This involves setting up a semi-mobile system that both can be established at a temporary location, but also can be moved to a dedicated and more permanent location, where the amount available justifies it. After completion of the hostilities and handling of the accumulated CDW has been finally handled, a more long-term set-up shall be established. The distinction between the phase 1 and phase 2 configuration of the CDW facility is that the phase 2 configuration is fixed to a permanent location, which is deemed relevant for the City of Mykolaiv. Further to this is that the permanent CDW facility is equipped with more sorting equipment, screens, magnet separators, crushers, etc.

In the figure below is presented a diagram to illustrate the proposed CDW Management process.

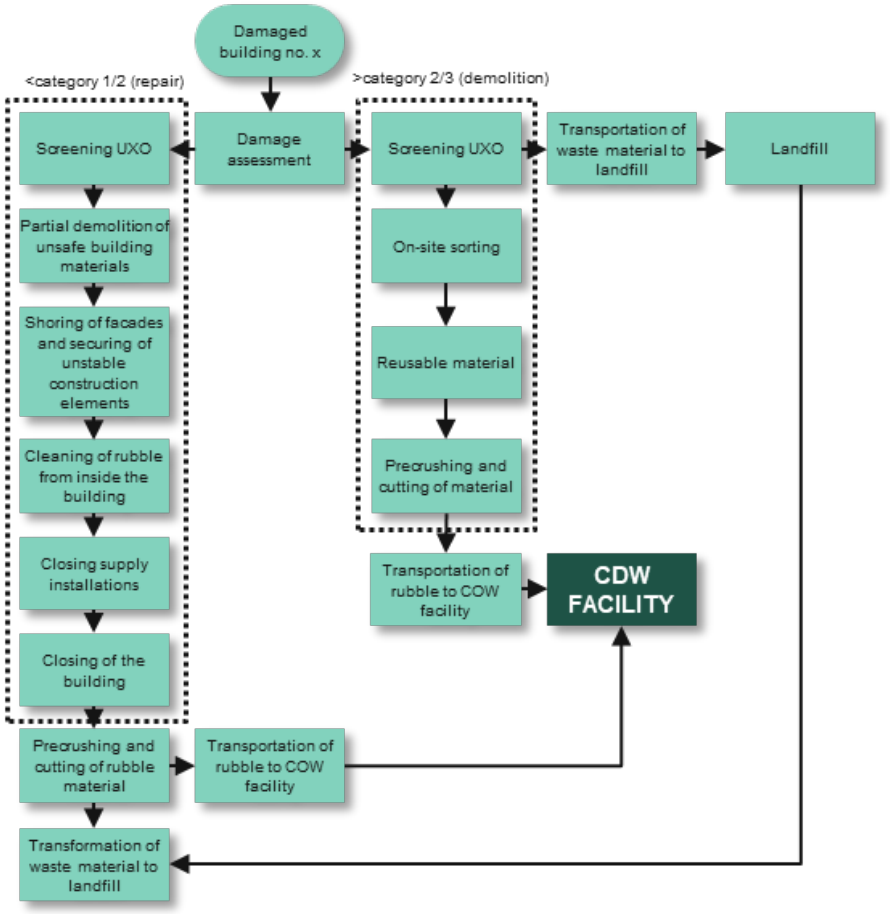

Figure 6-1 Process diagram for demolition, repair and recycling of CDW with highlight of the CDW facility in the process chain. (Source: COWI).

The three-step approach is described in the following with special attention to the establishment of the CDW facility.

6.1 Regulative and Administrative System

The regulations related to demolition on EU level and national level has been described in chapter 5.

Before commencement of any work at a specific land plot of a residential or non-residential building, private as well as public building, it is crucial to ensure this is done in accordance with current national and regional regulation. In the case of Mykolaiv city, multiple building types are destroyed, and multiple types of owners are affected.

Property rights of building and landowner together with lack of administrative instruments are barriers to effective expedient removal and management of debris and other kind of waste accumulated at a land plot.

The purpose of the step 1 is to ensure full transparency in which regulation to be applied, and the responsibility of the entire process from cleaning up, processing to ownership of the processed

valuable materials. It should also be clarified, the responsibility of any environmental damage occurred at a land plot.

This step 1 will require legal consultations and dialogue between various stakeholders. Specific sub-tasks are under development.

6.2 Demolition and Clean-up

The purpose of this step 2, is to ensure the land plots can be cleaned up, allowing reconstruction or rebuilding. In addition to this, the purpose of this step 2 is also to ensure that the demolition can take place in a structured and safe manner, collecting as much as possible of the valuable material for recycling. Furthermore, it is important also to ensure that structures are secured after removal of rubbles and other waste fractions, so that the building will not deteriorate further.

During step 2, the following tasks are suggested:

- Damage assessment. A full damage assessment must be completed prior to demolition and cleanup. With the damage assessment previously prepared, we have an early overview of the social infrastructure buildings most severely damaged and recommended for demolition. This needs to be further developed and updated for the purpose of prioritizing buildings for demolition and clean-up of the site.

- Development of tender documents

- Tendering

- Procurement

- Contracting

- Implementation

The tendering, procurement and contracting procedures must comply with EU standards and safety protocols. For tendering, the following suggestions are made:

- The cleaning-up of buildings, especially buildings being medium damaged that shall remain and only be repaired, will need to be done by an engineering firm and by a contractor being able to perform engineering design to ensure full stability of the building, both during cleaning and after closure.

- All transportation related to waste material and rubble can be tendered to local transportation companies.

- The cleaning-up of public buildings including the final demolition shall be performed by skilled workers, thus the works should be tendered to pre-qualified contractors with the relevant proven experience and prober equipment and machinery available. Procurement for the lack of equipment may be considered.

- All transport of material should be tendered to the local transport companies, providing sufficient transportation exists.

- All operations related to the demolition, shall be performed fulfilling a high level of Health and Safety measures. See section 6.3.

The below section describes the suggested processes for demolition.

6.2.1 Demolition and clean-up process

Demolition of structures and buildings should ideally be performed in a controlled manner, via a selective demolition or during a de-construction process. Prior to the demolition, all problematic and hazardous waste components and all reusable and recyclable materials should firstly be removed and handled separately to the extent possible. This includes safe asbestos management. Subsequently, a final demolition of the remaining structures can take place, generating a homogenous waste stream which is rather uncomplicated to further process. Unsorted waste may be further processed at the CDW facility. The handling of the waste can take place at the construction site at the damaged building or at a site dedicated receiving and processing the vast amount of waste.

At a construction site for renovation and/or re-construction the following operations shall take place[25].

- Cleaning for UXO and mines
- Temporary scaffolding
- Partial demolition of unsafe building elements
- Shoring of facades and securing of unstable construction structures
- Cleaning of rubble from inside the buildings
- Closing of supply installations such as water, electricity, gas etc.)
- Closing of buildings
- On-site sorting of waste and separation of hazardous materials
- Crushing/cutting of rubble material
- Transportation of reusable material to a dedicated location for storage and processing
- Transportation for disposal of waste

At the construction site for the complete demolition of the buildings and structures due to the degree of damage (>category 2), the following operations shall take place:

- Screening for UXO and other hazardous waste and substances
- On-site sorting in recyclable materials and waste for landfill
- Complete demolition of the remaining building and structure
- Pre-crushing and cutting the rubble on-site
- Transportation of the recyclable material to the CDW facility and waste for the landfill.

[25] *According to "Rebuilding Mostar – Reconstruction in a War zone", by John Yarwood.*

6.3 CDW Facility

6.3.1 Phase 1 – Temporary CDW Facility

A pre-condition for a well-functioning CDW Management system, is to ensure the waste from the cleaning up of the damaged buildings can be safely temporarily stored and that facilities are in place for processing of this material. Prior to implementation of the CDW facility, a feasibility study (e.g. CAPEX, OPEX, market analysis, institutional setup) should be conducted to assess the proper size, materials and machinery for the CWD facility. This also includes assessing optimum uses of the recyclables and end-users.

At the location for the storage and handling of the CDW the following processes shall be implemented:

- Pre-sorting and cutting (down-sizing) the rubble material
- Crushing the material
- Manual sorting (e.g. removal of plastic and hazardous materials). Metal is out sorted by use of magnet separators
- Screening the concrete material into specific grainsizes.
- Storage of processed material
- Transport of waste to the landfill.

Handling and treatment of the CDW shall take place at a dedicated facility area of a sufficient size to accommodate the amount of waste being delivered, area for pre-sorting (manually and by machine), an area for the machinery for processing and storage area for the processed material as well as management and staff facilities and workshops as required.

The purpose of the temporary CDW facility, is to be able to swiftly to setup the facility necessary to process the materials collected from within the Mykolaiv City.

For the CDW facility in the temporary configuration the following equipment is foreseen for the Mykolaiv City;

- Front-end loaders of various sizes and capacities and associated equipment, 2 pc. Medium sizes
- Excavators with various equipment mounted e.g. cutting devices, 2 pc.
- Sorting and screening equipment
- Crushers (jaw crushers and impact crushers), 2pc. Each 120 tonnes/hour
- Manual sorting bands and cabins
- Magnetic separators

Examples of relevant machinery are given in the figures below.

Figure 6-2 Figure to the left: Example of a semimobile crusher unit, source Meldgaard Handel. Figure to the right: Example of excavator with special cutting cutter equipment, source RGS Nordic Copenhagen.

One of the lessons learned from similar projects after e.g. natural disasters, where donations have included crusher and sorting equipment, is that it is of outmost importance to secure the logistics (with trucks available for transporting material between the demolition/construction site and the CDW facility and the landfill). Service and maintenance of the machinery and equipment is a precondition for a long-term operation. Last, but not least, proper training of the staff for handling the machinery is important for the integrity of the machinery and the quality of the produced crushed products and for the health and safety of the workers.

6.3.2 Phase 2 – Permanent CDW Facility

The detailed configuration of the CDW facility shall be designed to meet the market demand for the crushed material. From a desk study of the market, it is assumed that the predominant product to produce is for unbound subbase for roads and secondary for aggregates for concrete and asphalt. The CDW facility shall meet the technical requirements for these elements. Other applications for the processed concrete waste are backfilling of excavations and filler in asphalt concrete.

The dominant use is as an unbound aggregate substituting virgin resource for road constructions. The aggregate size is often in the range of 5-40 mm, but subject to the national norms and standards in Ukraine.

Below, a principal setup of a CDW facility receiving mixed and pre-sorted waste is illustrated and the different logistic elements of the process areas.

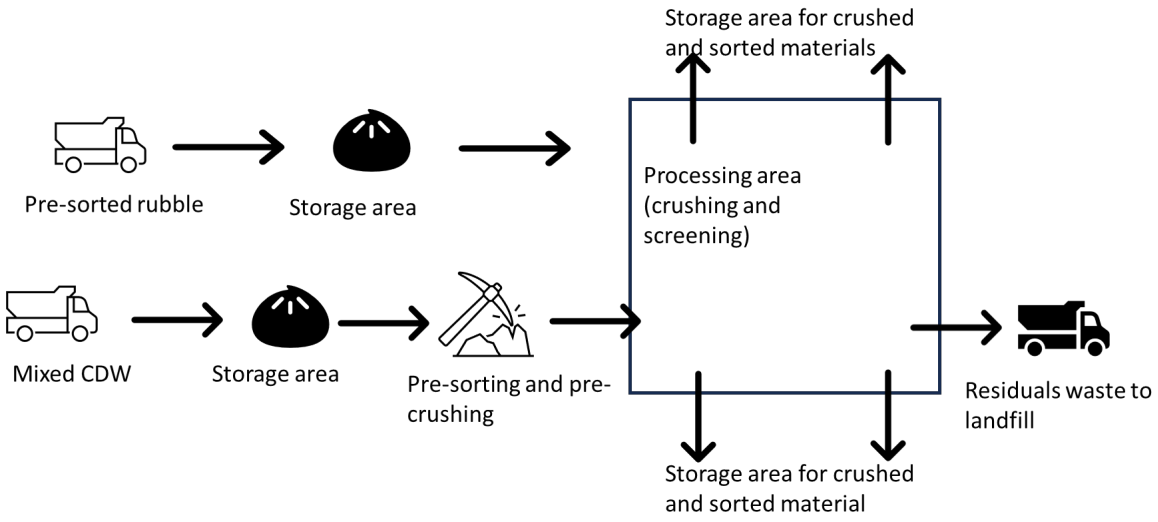

Figure 6-3 Principal layout of the facility.

The best quality product will be produced using a homogenous input material, which means well sorted construction waste without impurities (except for iron bars for the reinforcement). Upon reception of the waste at the CDW Waste facility, it is important to distinct between well-sorted waste and waste needed for sorting.

1 The well sorted construction waste can be unloaded directly to the crusher;

2 The mixed waste shall undergo a pre-sorting on site before feeding unto the vibrating feeder prior to feeding the crusher. To some extend this waste will be required to undergo a manual sorting.

6.3.3 Health & Safety

For demolition it is key to ensure safe approaches are followed to control buildings for unexploded remnants of war and possibly mining, using personnel with the right expertise and equipment, and following the International Mine Action Standards (IMAS)[26]. This means proper engineering design for demolition of the individual buildings, trained staff for demolition and ensuring a high level of protecting clothing including respiratory protection equipment, filters and fresh air equipment in the machinery.

At the CDW facility, the same precautions should be observed with machinery fully equipped with fresh air installations and the manual workers equipped with protection clothing and respiratory equipment especially at the manual sorting band. Other occupational health aspects such as sufficient lightning at the manual sorting area should be secured. As manual sorting is considered as physically monotonic work or repeated heavy burdens from lifting and pushing, it is up to the management to ensure sufficient breaks or shifting of working positions etc.

[26] International Mine Action Standards: IMAS

6.4 Localisation of the CDW Facility

A separate part of the Mykolaiv city landfill, placed west of the city (see Figure 6-5), has already been designated as a temporary storage site for the CDW in accordance with the order of the Mykolaiv Regional Military Administration[27]. This has been done as a temporary action.

Figure 6-4 Current temporary storage of CDW at Mykolaiv city landfill, both pictures were taken during visit to Mykolaiv in 2023. source: Jesper Karup Pedersen, COWI.

Figure 6-5 Separate place at the landfill for temporary CDW storage (1 ha area).

[27] Order of the Mykolaiv Regional Military Administration of 25.01.2023 No. 26 -p.

The landfill for municipal waste of Mykolaiv city, wherein the temporary storage site for the CDW is placed, has a very short remaining lifetime. The small plot where CDW is currently stored can serve as a temporary solution.

MCA can dedicate an area for storage and processing of the CDW for the permanent CDW facility. At this stage the authorities have not yet been able to identify a suitable area for long term storage and treatment for the CDW.

It should be mentioned that an ongoing similar project is current being developed in the Shevchenko municipality in the Mykolaiv Oblast by the Neo-Eco and Mission East. In this project, agreements are currently being settled to develop a site for setting up a CDW facilities for the Oblast. For the economy of scale and for reducing the overall costs, cooperation between the Oblast and the City of Mykolaiv should be considered.

The optimal location of the permanent CDW facility is in the centre of gravity of the generated CDW. However, as such facility requires a substantial area and further requires certain environmental considerations to limit the environmental impact, a site in the outskirts of Mykolaiv can be considered.

The site-specific requirements for the site preparation prior to commencement of the operation of the facility are:

3 A solid and level base or cover. It can be concrete, asphalt, or compacted soil covered with layer of geomembrane of at least 1.5 mm thickness, protected from mechanical damage by a layer of minimum 0.5 m sand.

4 The waste storage area must have an entrance and access roads that ensure the unhindered passage of vehicles, including free passage for fire and other special equipment.

It should be considered how the ownership of the temporary CDW facility shall be distributed. It is suggested that the ownership of the CDW facility should be the City of Mykolaiv and operated by the entity within the City Administration being responsible for waste Management. As an alternative can the ownership be another institutional authority.

7 Perspectives and Impacts

The EU taxonomy establishes a system to identify what is environmentally sustainable economic activity. The EU Taxonomy aims to help scale up investments in projects and activities that are necessary to reach the objectives of the European Green Deal. The six environmental objectives of the EU Taxonomy are addressed, to the extent possible.

The six objectives are: (1) climate change mitigation, (2) climate change adaptation, (3) sustainable use and protection of water and marine resources, (4) transition to a circular economy, (5) pollution prevention and control, and (6) protection and restoration of biodiversity and ecosystems.

To be taxonomy aligned the project must 1) Substantially contribute to one objective, 2) not significantly harm another objective, 3) Comply with Minimum Social Safeguards. The EU taxonomy compass lists the screening criteria to comply to Substantially contribute to the climate change mitigation or climate adaptation objectives and the criteria to the other objectives to do No Significant Harm.[28] The criteria to substantially contribute to the other objectives have not yet been implemented in the compass tool but are instead published in a recent delegated regulation[29].

Hereof activities from the proposed steps are expected to have substantial contribution to the environmental objectives (1) or (4). The expected impacts are listed below with inspiration from the EU taxonomy. A full screening and assessment of the project's compliance to the EU taxonomy objectives have not been performed due to time limitations.

(1) Climate change mitigation, or (4) transition to a circular economy: the CDW facility's main goal is increased recycling and substitution of virgin products. The system thereby helps conserve resources and prolong the lifespan of materials. The system is further contributing to the overall objective of optimizing the capacity of controlled landfills and sanitary landfills, as valuable materials for recycling and reuse will be diverted from the landfill areas. The CDW facility is expected to contribute to the overall objective of reducing CO_2 as the exploitation of virgin materials can be the major contributor to generation of CO_2. In the EU taxonomy compass, screening criteria have been developed for the relevant objective (1) Climate change mitigation. According to the compass, the criteria to substantially contribute to climate mitigation for an activity of Material recovery from non-hazardous waste, like the CDW facility, is that at least 50 %, in terms of weight, of the processed separately collected non-hazardous waste are turned into secondary raw materials that are suitable for the substitution of virgin materials in production processes. With the expected recycling rate of the facility, the project is aligned with these criteria.

The proposed project is not expected to significantly harm the objectives (2), (3), (5) and (6). However, to fully assess whether the project does not significantly harm another objective, the following assessment must as minimum be performed: 1) a climate risk and vulnerability assessment, 2) An Environmental Impact Assessment (EIA) or screening. It will require additional time to perform the assessments, and thus in this report, it cannot be concluded whether the

[28] EU taxonomy for sustainable activities, European commission, https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en
[29] 2013/2486, Commission delegated regulation of 27 June 2023, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302486

project does comply with the criteria of not significantly harm another objective. The project should additionally comply with Minimum Social Safeguards to align with the EU taxonomy.

Lastly, and additional to the EU taxonomy screening, the CDW facility in Mykolaiv can, once implemented, function as a pilot project applicable in all other cities and areas of Ukraine that have been affected by the war in similar ways. Providing available capacity of the CDW facility, inter-municipal cooperation can be established to assist in the cleaning-up of the neighbouring municipalities.