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Concept of integrated municipal waste management in a selected region of the Małopolskie Voivodeship

Abstract

Based on the analysis, it was shown that is possible to increase the local efficiency of waste management by establishing a Municipal Waste Management Plant in the Sądecki Subregion in the Małopolska Voivodeship. This is due to its convenient location and environmental conditions and the proposed solution minimising the negative impact of waste on the environment. In the plant planned for waste management, the weight of mixed waste will be 323.80 Mg per day in majority. On the basis of the forecast, it was shown that the largest decrease in the mass of waste will cover mixed waste and will exceed 800.00 Mg and segregated waste per capita in the amount exceeding 96 kg cap.$^{-1}$ day^{-1}, which results from a decrease of more than 5,000 in the number of inhabitants. The possibility of producing RDF with simultaneous rational reduction in the amount of deposited waste. The proposed solution should help to reduce the amount of deposited waste.

Key words: waste management, plant, segregation, mixed waste.

Koncepcja zintegrowanego zagospodarowania odpadów komunalnych w wybranym regionie województwa małopolskiego

Streszczenie

Na podstawie analizy wykazano, że istnieje możliwość zwiększenia lokalnie efektywności gospodarki odpadami poprzez utworzenia Zakładu Gospodarki Odpadami Komunalnymi w Subregionie Sądeckim na terenie Województwa Małopolskiego. Wynika to z dogodnych uwarunkowań lokalizacyjnych i środowiskowych oraz zaproponowanego rozwiązania minimalizującego negatywne odziaływanie odpadów na środowisko. W zakładzie przewidywanym do zagospodarowania odpadów w przewadze będzie pozostawała masa zmieszanych odpadów 323,80 Mg·dzień$^{-1}$. Na podstawie prognozy wykazano, iż największy spadek masy odpadów obejmie zmieszane i przekroczy 800 Mg oraz segregowane w przeliczeniu na mieszkańca w ilości przekraczającej 96 kg·M^{-1}·dzień$^{-1}$, co wynika ze spadku liczby mieszkańców, przekraczającego 5 000. Za korzystaną uznano możliwość produkcji RDF z jednoczesnym racjonalnym ograniczaniem ilości deponowanych odpadów. Zaproponowane rozwiązanie powinno ograniczyć ilość deponowanych odpadów.

Słowa kluczowe: gospodarka odpadami, zakład, segregacja, odpady zmieszane.

1. Introduction

Waste is a growing problem in both highly-developed and still-developing countries (Hannan et al., 2015). In accordance with Polish regulation, the concept of waste means any object or substance which the holder discards, intends to get rid of or which he is obliged to dispose of (Act on waste, 2012). In addition to the general definition, the Act also indicates what should be understood under such terms as: hazardous waste, medical waste, veterinary waste, municipal waste. Waste is highly diverse in terms of chemicals and materials. There are several or even several dozen subgroups of waste that are tested for toxicity, raw material suitability or environmental impact. From the total waste, we can distinguish three main categories of waste:

- municipal waste;
- hazardous waste;
- inert waste.

Mixed waste shows significant differences in terms of morphological composition. This fraction is useful due to the content of waste with raw material properties, which indicates the need to direct this type of waste to waste management installations. Metals and plastics, multi-material packaging, paper and cardboard, glass and bio-waste (Rosik-Dulewska, 2015) show high raw material suitability that can be used in the production of products with the same or similar properties. The amount and morphological composition of municipal waste largely depend on the place where it is generated, and above all, on the wealth of the local community and the size of its consumption. The type and quantity of generated waste is also influenced by the type of area where it is generated, population density, type of development, the presence of public utility facilities, and the presence of commercial establishments and small industry or services (Przydatek, 2012).

Environmental impact is related to waste management. Impact is the connection of possible unfavourable changes in the natural environment with economic activities or the functioning of enterprises. In the Regulation of the Council of Ministers of September 10, 2019 on projects that may have a significant impact on the environment, the division is into activities that:

- can always have a significant impact on the environment;
- can potentially have a significant impact on the environment.

The efficiency of waste management is related to the collection of waste through appropriate means of transport and the dates of their collection, and then the technological system of sorting waste, both mixed and segregated, as well as composting biodegradable waste, using it for energy in thermal assembled plants, co-incineration in heat and power plants and depositing unnecessary waste (WMPMG, 2016). An important part of waste management is the regional municipal waste treatment installations (Kowalak, 2015).

The aim of the article is to develop assumptions for the effective management of waste in the Mechanical and Biological Treatment of Municipal Waste (MBPOK) installation, located in three counties: Gorlicki, Limanowski and Nowosądecki, and Nowy Sącz county in the Małopolska Voivodeship.

2. Methods and materials

In order to define the assumptions of the waste management plant, it was necessary to identify the terrain conditions and define the forecast number of inhabitants for the area in question and the amount of mixed and segregated waste (including bio-waste) on an annual and daily basis, in the years 2022-2035. To determine the forecast number of people and the amount of waste in selected counties of the Sądecki Subregion, the data were obtained from the Central Statistical Office (bdl.gov.pl). The output data was for 2020. In the paper for analysis were used minimum, maximum and weighted average values.

3. Waste management plan for the Małopolska region

The Waste Management Plan for the Małopolska Region (2016) distinguishes four "regions" of waste management, including:

- the "Southern" region which includes the following counties: Tatra, Nowy Targ, Suski, Myślenice, and Limanowski;
- the "Sądecko-Gorlicki" region which includes the following counties: Gorlice, Nowosądecki and Nowy Sącz county.

The WMPMG (2016) includes planned waste management projects in the voivodeship. The paper presents the morphological composition of waste, the expected changes in the context of the amount of waste subjected to various recovery and disposal processes in mechanical and biological processing installations, divided into the so-called "Regions". The content of individual fractions separated from municipal waste was also determined, broken down into large cities with more than 50,000 inhabitants, small towns with less than 50,000 inhabitants and villages.

4. Selection of parameters for waste management installations

Characteristics of field conditions

The assumption of the location of MBPOK was adopted in the Małopolskie Voivodeship in the Nowosądecki county in the Chełmiec commune – the settlement of Klęczany, on a post-excavation site of raw stone (Figure 1), in accordance with the requirements set out in the Regulation of the Minister of the Environment of April 30, 2013 on waste landfills.

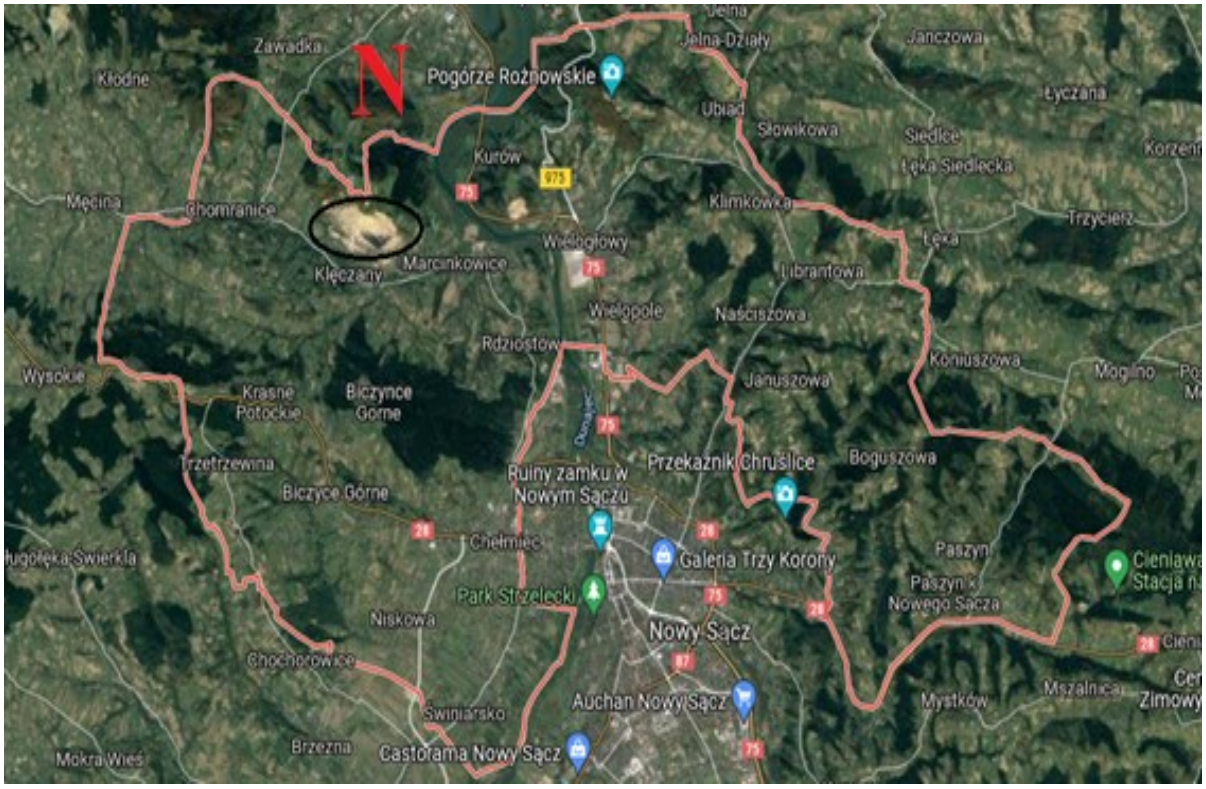

Figure 1. The place of investment in the Chełmiec commune area (Souther Malopolska Voivodeship – Poland)

In the area of Klęczany, the window series of the Silesian Nappe is revealed from under the Magura Strata. It is formed in the form of Krosno layers, consisting here of mid-lane fine-grained mica and calcareous sandstones (Program, 2004).

There are natural monuments (3) and the South Małopolska Protected Landscape Area in the vicinity of the indicated place, the closest point of which is approximately 250 metres from the border of the investment. In the case of natural monuments, the distance is approximately 400 metres. The analysed area is located in the Dunajec river catchment area. From the south, about 100 metres from the site of the plant, the "Smolnik" stream flows into the Dunajec River (geoserwis.gdos.gov.pl). Near the indicated place, there are the country road with the numbers 1544K and 1552K.

5. Waste quantity forecast in the Sądecki Subregion

Forecast of the number of inhabitants

The assumptions of the MBPOK are aimed at improving waste management in the Sądecki Subregion, due to the fact that the landfill in the nearest location, i.e., in Nowy Sącz county, is practically close to capacity, which makes it advisable to choose a new location.

The forecast of the population in the Sądecki Subregion in the years 2022-2035 is determined on the basis of the formula:

$$P_g + P_l + P_n + M_{NS} = \text{Total amounts of inhabitants} \quad (1)$$

where:

P_g – population from the Gorlice county (town + village)
P_l – population from the Limanowa county (town + village)
P_n – population from the Nowosądecki county (village)
M_{NS} – population from Nowy Sącz (town) county.

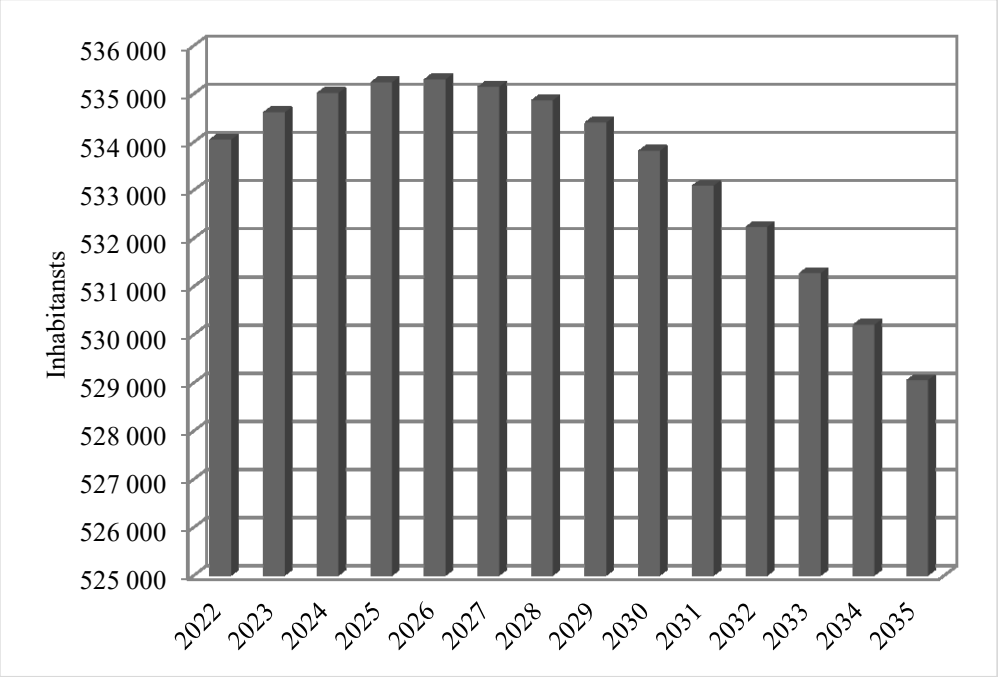

Figure 2. Population forecast for the area of the Sądecki subregion

The maximum value of the population in the Subregion in the analysed period is estimated at 535,303 in 2026. In the years 2022-2035 a noticeable decrease in the number of inhabitants occurred of more than 5,000.

It should be noted that the assumed installation should cover a 4.5 times higher value than the minimum required for the regional installation for mechanical and biological waste treatment.

Waste quantity forecast

The largest amount of waste was recorded in Nowy Sącz county (5,891.81 Mg), and the lowest in Gorlice county (3,047.66 Mg) with a total value of 18,012.16 Mg. It should be noted that the daily amount of waste generated in the Sądecki Subregion is 50 Mg (Table 1).

Table 1
Value of collected mixed municipal waste in the Sądecki Subregion in 2020

County	Quantity of collected mixed waste [Mg]
Gorlicki	3,047.66
Limanowski	3,977.61
Nowosądecki	5,891.81
Nowy Sącz	5,095.08
Total	18,012.16

Table 2
Amount of separately collected municipal waste in the Sądecki Subregion in 2020

County	Quantity of selectively collected waste [Mg]				
	Plastics	Metals	Paper and cupboard	Glass	Organic
Gorlicki	2,546.03	7.12	519.67	1,154.87	1,449.92
Limanowski	1,315.92	11.66	230.83	1,682.72	900.73
Nowosądecki	4,378.84	7.38	793.01	3,797.09	2,069.64
Nowy Sącz	1,379.89	0.00	1,162.40	1,105.40	5,830.77
Total	9,620.68	26.16	2,705.91	7,740.08	10,251.06

The amount of waste collected selectively ranged from 0.00 Mg in the case of metals to 5,830.77 Mg of organic waste in Nowy Sącz county. In general, the highest amount of organic waste was collected in the amount of 10,251.06 Mg, while the lowest amount was of metals – 26.16 Mg.

Table 3
Amount of separately collected municipal waste per capita in the Sądecki Subregion in 2020

County	Quantity of selectively collected waste [kg·cap^{-1}· year^{-1}]				
	Plastics	Metals	Paper and cupboard	Glass	Organic
Gorlicki	24	0.1	4.9	10.9	13.7
Limanowski	10.2	0.1	1.8	13.1	7.0
Nowosądecki	20.4	0.03	3.7	17.7	9.7
Nowy Sącz	16.5	0	13.9	13.2	69.7
Weighted Average	20.04	0,08	4.2	13.47	15.42

The amount of segregated waste per capita reached the highest value of 69.7 kg·cap^{-1}· year^{-1} in Nowy Sącz county at the weighted average 15.42 kg·cap^{-1}· year^{-1} in relation to organic waste. On the other hand, the lowest accumulation rate of waste per capita, with the value of 0 kg cap^{-1}·year^{-1} in case of metals at the weighted average 0.08 kg·cap^{-1}· year^{-1}. This concerned the area of Nowy Sącz county.

The calculation of the amount of waste generated by the inhabitants was based on the results of the population forecast according to pattern:

$$A_{inb} * Waste_{2020} = Waste_{20XX} \quad (2)$$

where:

A_{inb} – population from a specific year in a specific area (county)

$Waste_{2020}$ – the amount of waste collected per inhabitant of a specific county in 2020

$Waste_{20XX}$ – expected amount of collected waste that year.

Table 4

Planned amount of mixed and segregated municipal waste in the Sądecki Subregion in 2022-2035

Year	Mixed waste [Mg·year^{-1}]	Mixed waste [Mg·day^{-1}]	Segregated waste [Mg·year^{-1}]	Segregated waste [Mg·day^{-1}]
2022	80,871.72	323.49	28,241.67	127.39
2023	80,918.87	323.68	28,600.16	127.50
2024	80,945.33	323.78	28,601.13	127.56
2025	80,950.09	323.80	28,592.15	127.56
2026	80,935.85	323.74	28,574.41	127.53
2027	80,896.03	323.59	28,545.06	127.44
2028	80,841.16	323.37	28,509.00	127.32
2029	80,765.71	323.06	28,463.72	127.15
2030	80,674.66	322.7	28,411.34	126.97
2031	80,567.41	322.27	28,351.63	126.74
2032	80,445.15	321.78	28,285.47	126.48
2033	80,311.51	321.25	28,214.28	126.21
2034	80,163.60	320.66	28,136.51	125.91
2035	80,007.39	320.03	7,782.98	31.13
Average	80,663.89	322.66	26,950.68	120.21
Max	80,950.09	323.80	28,601.13	127.56
Min	80,007.39	320.03	7,782.98	31.13

The assumed amount of municipal waste generated per day ranges from 127.56 Mg (segregated) to 323.80 Mg (non-segregated). In turn, the annual breakdown, it will be from 7,782.98 Mg (segregated) to 80,950.09 Mg (non-segregated). During the 14 analysed years, the largest decrease in the mass of mixed waste, exceeded 800 Mg, and segregated waste per capita 96.26 kg·cap^{-1}·day^{-1}, is noticeable.

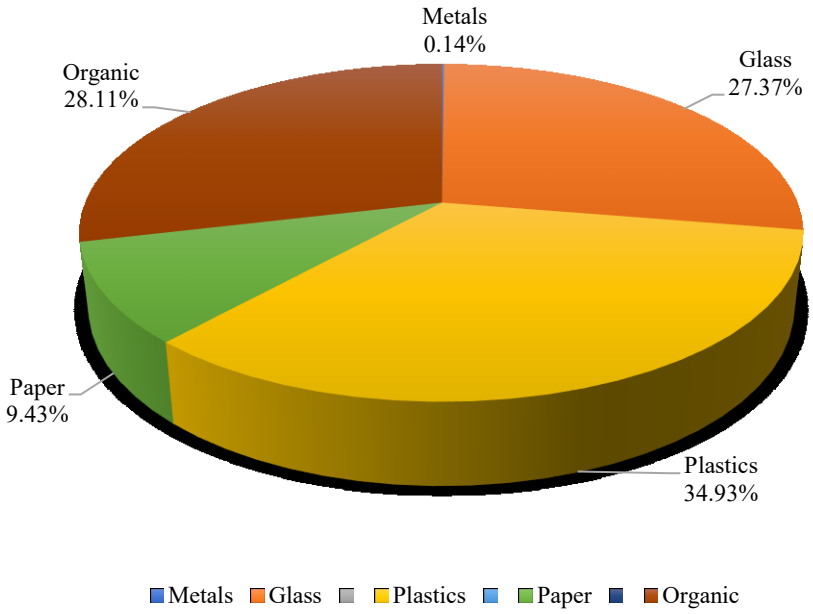

Figure 3. Projected share of the waste fraction intended for recovery

Przydatek and Gancarczyk (2020) showed a lower value of the index of 40.30 kg in a rural commune. The largest share of 34.93% in the mass of segregated waste will fall on plastics, and the lowest of metals at the share of 0.14% (Figure 3).

6. Concept of waste recovery and neutralisation solution

Assumptions:

Calculated annual processing value: 6,746 Mg

The assumed daily processing amount: 321 Mg

Figure 4. Layout of buildings and facilities of the planned Waste Management Plant in the Sądecki Subregion

Explanation:
1. Sorting plant for mixed and selective waste.
2. A composting plant for selective and separated organic waste in the mixed waste sorting process.
3. Dryer for the RDF combustible fraction.
4. Landfill (black lines indicate the division into quarters).
5. The administrative building of the landfill with a garage for operating machines.
6. Wastewater treatment plant.
7. Planned biogas plant for landfill gas after the basin is closed.
8. Hazardous waste warehouse.
9. The plant's office building.

7. The process of sorting municipal waste

When selecting the installation, the size of the waste, the inlet flow and the expected capacity should be taken into account. The purpose of the sorting installation for waste is to obtain the highest degree of purity fraction so that the recipient receives a product of guaranteed quality (Wandrasz, Hryba, 2009).

Separated and unsorted waste, due to its diversified composition, will require technological advancement that will ensure the rational recovery of secondary raw materials, including bio-waste contained in mixed waste. The importance of installations in the local waste management system is crucial due to the hierarchy of waste management and the selection of process technologies for machines and devices that are used to sort and manage individual waste fractions with the final destination for material recycling (Przydatek, Smaga, 2016).

Installation of organic waste management

Bio-waste includes:

- kitchen waste (peelings, noodles, food scraps – excluding bone, meat and fish remains, and cooking oil – or unfit for consumption parts of fruit and vegetables);
- green waste from mostly urban areas (mowed grass) in the spring and summer season, fallen leaves in autumn season, remnants of hedge trimming, weeds from the care of flower beds and branches and boughs from the care of park stands, alleys and squares, waste from deciduous wood and coniferous and other green waste – delivered from individual customers who rented a container to remove them, e.g. allotment gardens, when users do not compost or their amount simply exceeds the processing capacity, as well as from owners of single-family houses who, for various reasons, do not compost and provide organic fractions as selectively collected waste (Rosik-Dulewska, 2015).

The composting process takes place in four successive phases: mesophilic, thermophilic, cooling and maturation (Gajewska, Miszczyk, 2004). The simplest and, at the same time, the earliest composting method is the course of the process carried out on piles, with periodic mixing of waste (Czekała et al., 2013). The first stage of composting, after transporting, unloading and selecting bio-waste, is the stabilization process (thermophilic process). The next stage will be composting in a closed system.

Alternative fuel (RDF)

The fuel derived from municipal waste consists of the main parts (fractions): the combustible part that can be separated from the bio-waste (it can be wood, e.g., in the form of branches, but the wood will be ground and mixed with the bio-waste input to provide carbon for the thermophilic process and improving the composition of minerals). The production of alternative fuel (RDF) will be a valuable raw material for cement plants and the power industry as an energy source in the processes of incineration or co-incineration of waste (Rayski, 2019). The concept of the plant should take into account the possibility of producing RDF together with drying to reduce the amount of deposited waste.

Landfill for the residue waste after sorting process

In accordance with the resolution of the Minister of Environment of 30th April 2013 on landfills (Journal of Laws of 2013 item 523) the landfill cannot be located particularly on the area of protected reservoirs of underground water, in the zones of landslides and sinkholes as well as on an area whose slope is more than 10º, areas of protection zones of national parks and nature reserves and on the protected areas. This regulation indicates that the distance of a landfill from buildings should be determined pursuant to the report on the influence of the undertaking on the environment, which should be subjected to social consulting as a part of the assessment of environmental impact. To mitigate the threat of a negative impact of waste on the environment, it is recommended to use shutters which insulate the ground and side walls with filtration indicators showing a considerable reduction of effluent migration. It should be emphasised that synthetic insulation, designed in a way that takes into account the chemical composition of waste and geotechnical conditions of disposal, complements a natural and artificial geological barrier.

The landfill should be equipped with a drainage system for leachate intake. Its reliable functionality should include exploitation and a post-exploitation period of 30 years after the landfill is closed (Przydatek, Pietrzak, 2016).

Environmental monitoring

Before and after the entire period of exploitation of the landfill and after its closing, the condition of the natural environment should be monitored within its area. The role of the monitoring is to evaluate the impact of such a municipal facility on the environment. Pursuant to the resolution of the Minister of Environment of 30th April 2013 on landfills, the monitoring includes three stages:

- before exploitation;
- during exploitation;
- post exploitation.

8. Conclusions

The assumptions of the Municipal Waste Management Plant clearly indicate the possibility of improving the waste management system in three counties and Nowy Sącz county, both technologically and in terms of energy efficiency, taking into account local environmental conditions.

In the assumed installation, mixed waste will predominate in the daily amount of 323.80 Mg during processing. It will also be possible to significantly decrease the mass of non-selectively collected waste exceeding 800 Mg and segregated waste per capita by 96.26 $kg \cdot cap^{-1} \cdot day^{-1}$ with the highest share of 34.93% of plastics waste. This is due to a significant drop in the number of inhabitants by more than 5,000. The fact that RDF is allowed to be produced should be considered beneficial. This should reduce the amount of deposited waste. The selected location of the plant, including the landfill infrastructure, should minimise the negative impact of waste on the environment.

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