Lithuania: Municipal solid waste utilisation as fertilisers

1. Requirements for composting of Green Waste and products made from Green Waste

1.1 Requirements for composting Green Waste

The requirements for composting Green Waste are set out in Order No. D1-57 of the Minister of Environment of the Republic of Lithuania of 25 January 2007 “On the Approval of Environmental Requirements for Composting and Anaerobic Treatment of Biodegradable Waste” [2]. The technological requirements are summarized in *Table 1.1*.

Table 1.1 Requirements for the Green Waste composting process

Legislation	Biological processing				
	Biodegradable waste	Technology	Temperature, ^0C	Period	Number of turns
1	2	3	4	5	6
Environmental requirements for composting and anaerobic processing of biodegradable waste [2]	[1]Green Waste, plant waste, paper and paperboard waste	Aerobic processing	> 55 ^oC	2 weeks	Has to be periodically turned
			> 60 ^oC	1 week	
			> 65 ^oC	5 days	

[1]Note: In the case of co-composting of animal by-products, including from food and kitchen waste streams, additional requirements under Article 24 of Commission Regulation (EU) No. 1069/2009 and Commission Regulation (EU) No. apply.

Requirements for the installation of processing plants (including Composting Sites)[2]:

- waterproofing layer (impermeable coating);
- wastewater (leachate, liquid) must be collected and used for irrigation of compost or treated in accordance with the requirements of the Wastewater Management Regulation [7];
- installation in the area, taking into account the prevailing wind direction (reduce or eliminate odours and noise);
- where applicable, environmental impact assessment (EIA) procedures [5];
- Public Health Impact Assessment (PIA) where appropriate [6];
- distances to water catchment installations for which no buffer zones (zones) have been established shall be> 50 m in the direction of the groundwater flow and 25 m upstream;
- if other biodegradable waste is composted together with Green Waste: the waste must be received, stored, composted, anaerobically treated **"in an enclosed space to ensure the spread of odours, gas cleaning before discharge"**; such requirements shall not apply only to Composting Sites for Green Waste for which measures are required to prevent dust during shredding;
- detailed information on the activities of Green Waste in composting and maturing facilities, including reception of raw materials, preparation, storage of compost, measuring points and periodicity of technological bottoms must be described in detail (with diagrams and situation maps) in the Technical Regulation on Waste Recovery or Disposal - Annex to Integrated Pollution Prevention and control or permitting of contamination;
- where biodegradable waste, including Green Waste, is composted or anaerobically treated with animal by-products, it must be treated in a facility which complies with:
  - Requirements of Article 24 of Commission Regulation (EU) No 1069/2009;
  - Requirements set out in Commission Regulation (EU) No. 142/2011.

- The temperature and oxygen content must be measured and recorded periodically in the logbook, i.e. it must be ensured that the temperature specified in *Table 1.1* is reached and maintained for the required period;

- Number of tests on the compost produced: if biodegradable waste is treated ≤4000 t/year - once for every 1000 t of raw materials; >4000 t - min 4 times a year, maximum - 12 times a year;

- Fertilization plans are being drawn up for the use of compost, which must ensure that "no more than 170 kg/ha a year, 40 kg/ha of phosphorus or 90 kg/ha of phosphorus (V) oxide" enter the soil.

As Green Waste is composted in an open site, the entire open area is assessed as potentially polluted as defined in the Law on Water of the Republic of Lithuania. According to the Surface Wastewater Management Regulation [8], surface water from this potentially contaminated area must be collected and, if necessary, returned to composting or treated up to the maximum allowable concentrations in the natural environment (if the treated wastewater is further discharged into the natural environment) or up to the maximum allowable concentrations in the sewage collection networks. [7].

Controlled parameters when discharging wastewater into the natural environment [7]:

- the average annual concentration of biochemical oxygen demand (BOD_7) decreased by -23 mgO2/l, the average instantaneous concentration by 34 mgO2/l;

- the average annual concentration of suspended solids is 30 mg/l, the average instantaneous concentration is 50 mg/l;

- the average annual concentration of oil products is 5 mg/l, the average instantaneous concentration is 7 mg/l.

1.2 Requirements for fertilizer products made from Green Waste and other biodegradable waste

In 2019, an order of the Minister of Agriculture“ On the Procedure for Adding and Removing Fertilizer Products Placed on the Market of the Republic of Lithuania to the Identification List and Approving the List of Fertilizer Products Placed and Delivered on the Market of the Republic of Lithuania” [1] was approved. According to this Order, fertilizer products are divided into the following categories [1]: fertilizers (inorganic; organic; organic-mineral), starvation substances, soil improvers, growing media, inhibitors, plant biostimulants, ash, mixtures of fertilizers. Green Waste is mentioned as a raw material or a major component of a fertilizer product under the categories of fertilizer products listed in *Table 1.2*.

Compost made from Green Waste can be used as a soil improver (identification No. D.2.1.1.2) as well as a growing medium (identification No. F.2.1.1.4). Green Waste is also a very important raw material for the composting of manure, sewage sludge, food waste and the production of compost with identification number D2.1.1.1 (see *Table 1.2*).

It is very important that the content of organic matter (OM) in Green Waste compost must be ≥ 20% dry matter (DM), and in the production of compost (digestate) No. D2.1.1.1 - ≥ 25% DM (see *column 4 of Table 1.2*).

In the production of growing media, the requirements for the concentration of certain heavy metals in the products are stricter than for composting (see *column 5 of Table 1.2*), such as cadmium (Cd), zinc (Zn), copper (Cu).

A sample of 25 g of fertilizer must be free from Salmonella spp...; The concentration of bacteria of the type Enterococcaceae shall not exceed 1 000 per gram or per millilitre of product, with a maximum weed seed content of 2 units/kg.

Only in the case of soil improvers are natural and unnatural impurities analysed:

- solid natural impurities (stones, etc.) with a diameter of <5 mm must not exceed 5%;
- solid unnatural impurities (plastics, metals, etc.) with a diameter > 2 mm not exceeding 3 g/kg dry matter (DM)

Table 1.2. Fertilizer products that may contain Green Waste [1]

Product ID No.	Common name of the fertilising product	Details of production method, raw materials and main components	Minimum content of plant growth active substances (percentage by mass).	Undesirable impurities and their maximum permitted quantities
1	2	3	4	5
Category - soil improvers				
D.2.1.1.1	Compost	The product is obtained by composting manure, sewage sludge, Green Waste, plant residues, food waste, organic waste from the food industry or other similar materials suitable for use as soil improvers.	Organic matter content (dry matter) - 25%. Total amount - 2.5% ($N + P_2O_5 + K_2O$).	Solid natural impurities (stones, etc.) with a diameter of up to 5 mm - 5%. Solid unnatural impurities (plastic, metal, etc.) with a diameter of 2 mm to 3 g / kg dry matter. Weed seeds - 2 pcs / kg. • The pollutants must not exceed the following levels (mg / kg dry matter): • cadmium (Cd) – 2; • lead (Pb) – 120; • mercury (Hg) – 1; • zinc (Zn) – 800; • copper (Cu) – 300; • arsenic – 40; • nickel – 50; • Cr (VI) – 2; • 25 g the fertilizer product must be free from Salmonella spp .; • The concentration of Escherichia coli and Enterococcaceae must not exceed 1 000 cases per gram or per milliliter of D2.1.1.1 if sludge is used: PAH16 - 6; PCB7 - 0.2; - contamination with 137Cs radionuclide must not exceed 30 Bq/kg
D.2.1.1.2	Compost from Green Waste	The product is obtained by composting or recycling green plant organic matter. The product must not contain fertilizers or minerals. Compostable organic matter found in grass, fallen leaves of garden and park trees, forest biomass.	Organic matter content (dry matter) - 20%. Total amount - 1.5% ($N + P_2O_5 + K_2O$).	
Category - *growing media (other growing media)* (in which plants are grown)				
F.2.1.1.4	Compost from Green Waste	The product is obtained as a result of anaerobic exposure to organic matter, from plant materials such as aquatic biomass, bark, sewage sludge, wood residues and animal manure.	Organic matter content (dry matter) - 20%.	Weed seeds - 2 pcs / kg. Contaminants shall not exceed these amounts (mg/kg dry matter): - cadmium (Cd) – 1,5; -lead (Pb) – 120; -mercury (Hg) – 1; -zinc (Zn) – 500; -copper (Cu) – 200; -arsenic (As) – 40; -nickel (Ni) – 50; -Cr (VI) – 2; -25 g the fertilizer product must be free from Salmonella spp .; - The concentration of Escherichia coli and Enterococcaceae must not exceed 1 000 cases per gram or per millilitre of D2.1.1.1 if sludge is used: PAH16 - 6; PCB7 - 0.2; - contamination with 137Cs radionuclide must not exceed 30 Bq/kg

The required compost quality parameters according to [1] in *Table 1.3* are compared with the value indicators of compost as a fertilizer, which are evaluated in the market (Staugaitis et al., 2016).

Table 1.3. Compost quality parameters

Key quality indicators	Value of compost or anaerobic yeast as a fertilizer (Staugaitis et al., 2016)					[2] Quality criteria for fertilizer products [1]		
	Very low	Low	Average	High	Very high	D.2.1.1.2	D.2.1.1.1	[3]F.2.1.1.4
1	2	3	4	5	6	7	8	9
pH_{KCl}	<5.6	5.6-6.5	6.6-7.5	7.6-8.5	>8.5	[4]*Presented information*		
Dry matter, %	<21	21-30	31-40	41-50	>50	[4] *Presented information*		
Organic matter,% dry matter	<16	16-25	25-35	36-45	>45	≥20	≥25	≥20
Total nitrogen (N), % dry matter	<0.5	0.5-1.0	1.1-1.5	1.6-2.0	>2.0	[4] *Presented information*		
Total phosphorus (P), % dry matter	<0.21	0.21-0.40	0.41-0.60	0.61-0.80	>0.80	-	-	-
(converted to P_2O_5)	*<0.48*	*0.48-0.92*	*0.93-1.37*	*1.38-1.83*	*>1.83*	[4] *Presented information*		
Total potassium (K), % dry matter	<0.6	0.6-1.0	1.1-2.0	2.1-2.5	>2.5	-	-	-
(converted to K_2O)	*<0.72*	*0.72-1.2*	*1.3-2.4*	*2.5-3.0*	*>3*	[4] *Presented information*		
Total: N+ P_2O_5 + K_2O, % dry matter	-	-	-	-	-	≥1.5	≥2,5	-
Organic carbon, % dry matter	-	-	-	-	-	≥7.5		
Electrical conductivity, mS/cm	<0.6	0.6-1.0	1.1-1.5	1.6-2.0	>2.0[1]	-	-	-
C:N ratio	<11	11-15	16-20	21-25	>25	-	-	-
Water soluble nitrogen ($N-NH_4$+$N-NO_3$), mg/l NDM	<51	51-100	101-150	151-200	>200	[4] *Presented information*		-
Water soluble phosphorus (P), mg/l NDM	<26	25-50	51-75	76-100	>100	[4] *Presented information*		-
Water soluble potassium (K), mg/l NDM	<91	91-160	161-230	231-300	>300	-	-	-
Additional indicators:								
pH_{H2O}	<6.1	6.1-7	7.1-8.0	8.1-9.0	>9.0	[4] *Presented information*		
Water soluble calcium (Ca), mg/l NDM	<101	101-200	201-300	301-500	>500	-	-	-
Water soluble magnesium (Mg), mg/l NDM	<31	31-60	61-90	91-120	>120	-	-	-
sulphate (SO_4), mg/l NDM	<51	51-100	101-150	151-200	>200 (>300[1])	-	-	[4] *Presented information*
Chlorides (Cl), mg/l NDM	<51	51-100	100-200	201-300	>300[1]	-	-	[4] *Presented information*
Biodegradability (stability)	For example, by the concentration of dissolved organic carbon (≤ 4000 mg/kg)					-	-	-
Bulk density, g/l	It is desirable that the compost be more fluffy					[4] *Presented information*	[4] *Presented information*	-

Notes:

[1]May cause damage to sensitive plants.

[2]Quality criteria (minimum content of plant growth active substances (percentage by weight)) for a fertilizer produced from Green Waste and other biodegradable waste [1]:

- soil improver:
  - compost from Green Waste (No. D.2.1.1.2);
  - compost (decomposition) containing, among other biodegradable waste (sewage sludge, food waste, etc.) Green Waste (No. D.2.1.1.1);
- growing medium - compost from Green Waste (No. F.2.1.1.4);

[3]Information on the main constituents (containing> 10% by volume) is given in descending order. In addition to the parameters listed in the table, information may be required on the amounts of the following

plant growth regulators in the medium: calcium (Ca), magnesium (Mg), sodium (Na) and sulfur (S), which are referred to as secondary plant nutrients [1].

[4]Required product information is provided.

2. Situation of Green Waste management in Taurage district

Residents of Taurage district can compost the generated Green Waste at home or deliver it to a Green Waste Composting Site located near Taurage regional landfill, address Kaupiai village 4, Žygaičiai ward, Taurage district, where this waste is accepted from residents free of charge. In Taurage district, including the city, 925 composting boxes of different sizes are distributed to the residents of individual houses (see *Table 2.1, Picture 2.1*).

Table 2.1. Taurage Regional Waste Management Centres Compost boxes distributed to residents and the amount of waste composted at home in 2018-2020 (source: Taurage Regional Waste Management Centres (RATC), data for 2021)

City/ district	Number of compost bins distributed to the residents of Taurage Regional Waste Management Centre, units, volume			Amount of home composted Green Waste, tonnes		
	700 litres	900 litres	1000 litres	2018	2019	2020
For the city and district of Taurage	384	282	259	1167	1173	2025

Picture 2.1. Home compost bins for Green Waste

(source: RECO Baltic-21 Tech, Home composting experiment in Taurage region, 2013)

From the population living in Taurage and who do not have the conditions to compost Green Waste on their holding, Green Waste is collected in Green Waste Collection Containers (see *Picture 2.2*). Along with Green Waste, food and kitchen waste of plant origin is also collected. The service of removal of this waste in Taurage district municipality is provided by JSC Ekonovus. In 2015, 3750 Green Waste containers with a capacity of 0.24 m3 were distributed to individual households in Taurage. In 2017, an additional 200 containers were purchased and distributed. According to the data of 2021, about 4300 individual containers are used for the collection of Green Waste from individual houses in Taurage. Also, 51 units of 1.1 m^3 general use containers for the collection of Green Waste were additionally built in the public use sites. Both green and individual waste products that do not contain animal by-products, such as meat and fish or their products, can be thrown into both apartment building Green Waste containers and individual household containers.

Picture 2.2. Individual containers for the collection of Green Waste and the collection of waste in these containers

Lists of biodegradable waste allowed to be disposed of in a Green Waste container and recommended for composting under household conditions are given in *Table 22*. Small amounts of cold wood ash are also allowed in Green Waste containers. Green Waste must be free of impurities (gravel, stones, rubbish, glass, plastic, etc.). If the Green Waste is mixed with other waste, the container will not be emptied. The amount of Green Waste leaving at one time must fit in a container. Residents must bring a larger amount of Green Waste generated at the same time to the Green Waste Composting Site.

Table 2.2. Biodegradable waste is allowed to be disposed of in a container and biodegradable waste is recommended for composting.

The following waste is allowed to be dumped in a Green Waste container:	**Recommended biodegradable waste for composting:**
- cut grass; - raked leaves and grass; - small pruning branches of trees and shrubs; - uprooted indoor and outdoor flowers, vegetables, turf (after shaking the remnants of the soil); - soaked flowers (without plastic and other unnatural additives); - weeds and vegetable residues; - straw and hay; - **unfit fruits and vegetables;** - other Green Wastes from gardens and orchards; - sawdust and other small wastes from firewood preparation (without garbage); - a small amount of wood ash.	- food and kitchen waste of plant origin: • fruit and vegetable residues; • peel of fruits and vegetables; • tea, tea bags; • coffee grounds and their filters. - natural bedding of domestic rodents (hamsters, guinea pigs, etc.), - Garden and orchards waste: • unfit fruits and vegetables; • plant leaves; • cut grass; • small branches; • young weeds (without mature seeds); • straw and hay; • turf; • sawdust, - old potted soil, houseplants, flowers.

Waste is collected from Green Waste containers once every two weeks from March to November. In total, Green Waste containers in Taurage are emptied approximately 18-19 times a year, depending on the agreed schedule. Together with the containers located and serviced in the cemetery, about 2,000 to 2,300 tons of Green Waste is collected in containers in the Taurage district per year (see *Table 2.3*).

Table 2.3. Containers and quantities used to collect green and plant origin food and kitchen waste in Taurage

Quantity of containers, units	Volume of containers, m^3	Frequency rate per year	Collected Green Waste, t					
			2016	2017	2018	2019	2020	2021
4 300	0,24	18	1 891	1 814	1 983	1 850	2 291	2 005*
51	1.1	36						

* until 2021 November

Green Waste collected from the population is transported to the Taurage Green Waste Composting Site for composting. In 2020, a total of 2,688 tonnes of Green Waste collected from residents and legal entities was composted at the Taurage Green Waste Composting Site and 1,829 tonnes of compost was produced (for more details, *see Chapters 3 and 4*).

Generalization

* In the Taurage district, residents can compost the generated Green Waste at home (compost bins are distributed for this purpose) or deliver it to a Green Waste Composting Site near the Taurage regional landfill.

* Since 2015, Green Waste has been collected in Green Waste collection containers from the residents of Taurage, who do not have the conditions to compost Green Waste on their farm. Along with Green Waste, food and kitchen waste of plant origin is also collected. In Taurage, about 2000-2300 tons of Green Waste is collected in containers together with food and kitchen waste of plant origin.

* Green Waste collected from the population is transported to the Taurage Green Waste Composting Site for composting. In 2020, a total of 2,688 tons of Green Waste collected from residents and legal entities was composted at the Taurage Green Waste Composting Site, and 1,859 tons of compost was produced.

A project for the collection and treatment of food and kitchen waste, including Green Waste, is planned. The aim of the project "Development of food/kitchen waste management infrastructure in the Taurage region, including Green Waste" (hereinafter referred to as the Project) is to develop the infrastructure for the treatment of sorted food and kitchen waste (including Green Waste) in the Taurage region.

At present, biodegradable food and kitchen waste of animal origin is not collected and treated separately in the Taurage region due to the lack of a regional waste management system. Biodegradable food and kitchen waste of animal origin usually ends up in mixed municipal waste containers. Also, some of this waste can end up in Green Waste containers built on individual holdings, from which the Green Waste is composted at Green Waste Composting Sites. The project aims to create food and kitchen waste treatment (composting) infrastructure in the Taurage region.

The following activities are planned during the project:

- building (B ≈ 1500 m^2), construction and installation of food and kitchen waste treatment (1 unit),
- purchase of food and kitchen waste treatment equipment (shredder, soil sieve, compost pile cover cloth wrapper (3 unit.)).

The project is planned to be implemented with EU support. The total cost of the project is EUR 908,823.22, of which the requested amount of EU support is EUR 772,499.74. The rest will be contributed by the project partners.

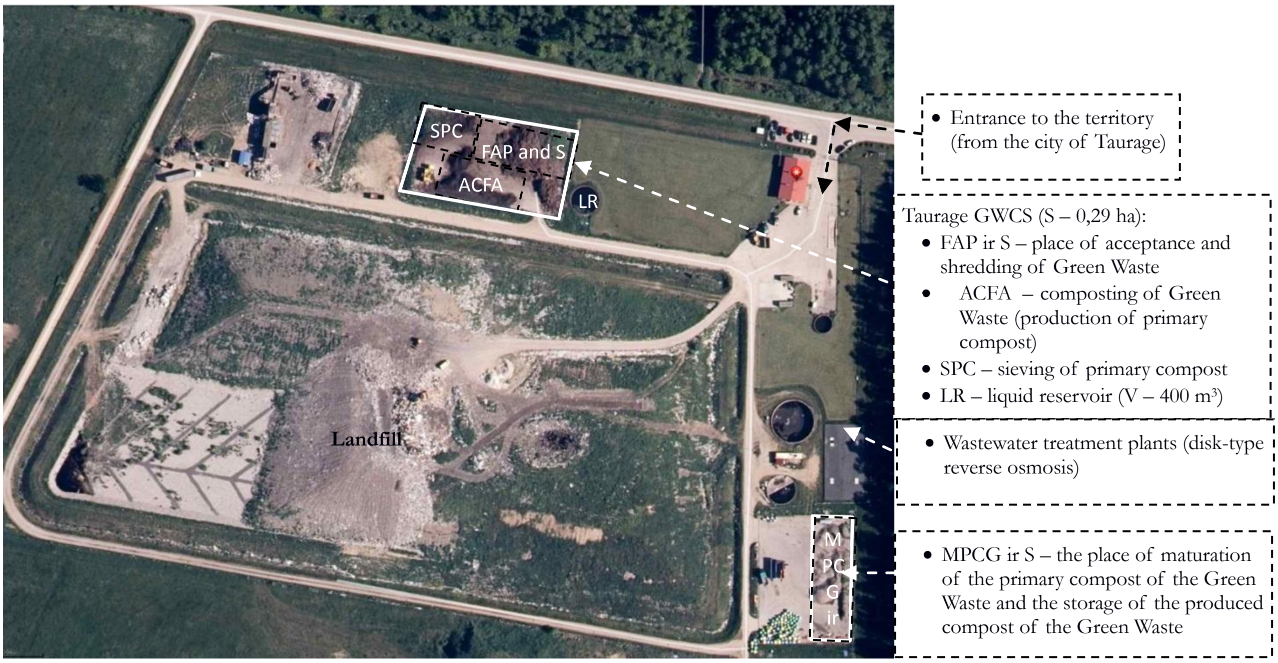
Initially, it is planned to use the existing Green Waste collection system developed in 2015, encouraging the collection of not only Green Waste, but also food and kitchen waste of plant origin in containers. It is planned to increase the collection of Green Waste to 5183 t/per year, of which food and kitchen waste of plant origin would amount to about 1183 t/per year (up to 30%/of population), the other amount would be about 4000 t/per year of Green Waste.

The collection and treatment of food and kitchen waste of animal origin will then be analysed, as intensive composting technology will be installed and absorbed in a closed building in accordance with the requirements of the Composting Rules for Biodegradable Waste [2].

3. Composting of Green Waste at Taurage Green Waste Composting Site (GWCS)

3.1 Green Waste composting process

Green Waste is collected by bypassing from Green Waste and food and kitchen waste containers of plant origin and delivered to the Green Waste Composting Site located at Kaupiai village 4, Žygaičiai ward, Taurage district (landfill area) (see Picture 3.1.). Green Waste can also be brought to the Green Waste Composting Site by residents and legal entities themselves.



Picture 3.1 Taurage Green Waste Composting Site situation map

The area of the Taurage Green Waste Composting Site is 0.29 ha. Waste management operations at the Taurage Green Waste Composting Site [10]:

- R13: Storage of wastes destined for use in operations R1 to R12 (up to 100 t);
- R12: change in the status or composition of waste before carrying out any of the operations numbered R1 to R11 (up to 5640 t)
- R3: recycling/reclamation of organic substances which are not used as solvents (including composting and other biological substitution processes) (up to 5640 t)

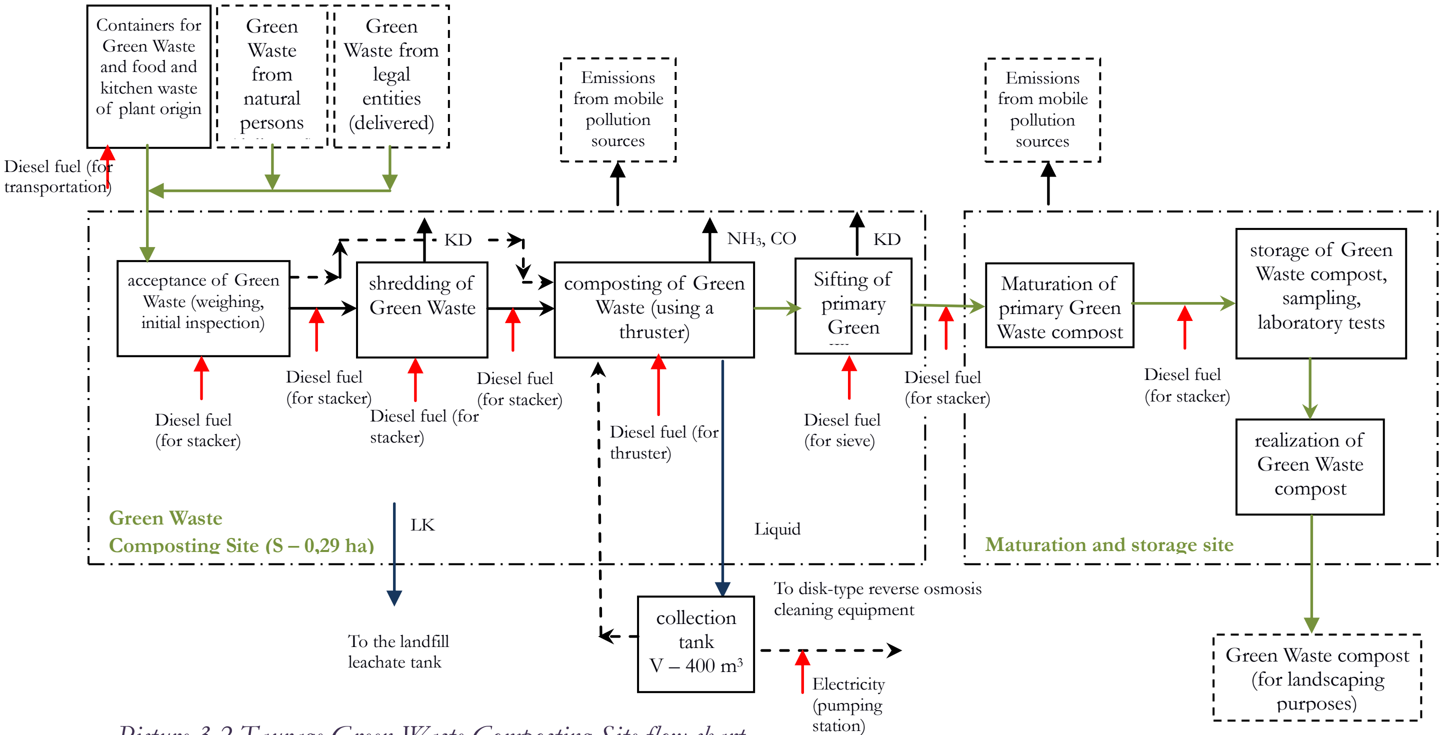
The flow diagram of the technological processes of Green Waste compost in Taurage is presented in *Picture 3.2*.

The mass of the transported waste is determined using truck scales. Green Waste is unloaded at a designated location at the Green Waste Composting Site. According to the pollution permit [10], up to 100 t of Green Waste may be stored on the site (operation R13) until treatment R12 and further R3:

- 20 03 02 marketplace waste;
- 20 02 01 biodegradable waste;
- 02 01 03 vegetable tissue waste;
- 02 01 02 animal tissue waste;
- 02 01 07 forestry waste;
- 03 03 01 wood bark and wood waste.

Prior to composting, some of the Green Waste (e.g. tree conservation waste, bark, straw and hay, etc.) is shredded in a JEZ shredder. Stacks are being formed and efforts are being made to maintain an appropriate

proportion of Green Waste of various origins. Waste is piled up using a DEUTZ-FAHR stacker. The piles are formed using a BACHUS thruster.
Primary compost is produced for up to 2 months in warm weather and up to 3 months in cold weather. At lower temperatures (less than minus 10 °C) the composting process did not take place. In this way, up to 4-5 composting cycles are performed per year.



Picture 3.2 Taurage Green Waste Composting Site flow chart

Flipping with thruster BACHUS tentatively at the following frequency:

- for the first 2 weeks - up to 2/3 times a week;
- the next period - up to 1 time per week (may be more frequent if there is a technological need).

The composting process generates liquid (theoretically up to 0.34 m3/t Green Waste [10]) which is drained into a 400 m3 liquid reservoir (DR) (see Picture 3.1). Part of the liquid is used to irrigate Green Waste heaps during dry composting. The remainder is pumped to the landfill leachate tank and further treated with the landfill leachate in disk-type reverse osmosis treatment plants. Surface (rain) wastewater collected from the Green Waste Composting Site is directed directly to the landfill leachate reservoir [10].

The primary Green Waste compost is sieved with a TERRA-SELECT sieve and transported to a maturing site on the south-east side of the landfill. In this open site, the primary compost of Green Waste is matured and stored until realization. The minimum maturation period is 2 months.

During the composting process of Green Waste, small amounts of NH3 and CO emissions are released into the ambient air in an unorganized manner. KD - dust can also be generated during the shredding of Green Waste, during the loading of Green Waste and Green Waste compost. To prevent/reduce KD and maintain process parameters, especially during the dry period, compost is irrigated.

The produced compost is periodically analysed: samples are taken, samples are formed, the main quality and pollution parameters are determined in accordance with the requirements of the Environmental Requirements for Composting and Anaerobic Treatment of Biodegradable Waste [2]. As the amount of Green Waste to be composted does not exceed 4000 t/year, the number of analyses is 1 for each 1 000 t of raw material, rounded to the next whole number.

The flows of Green Waste composted in 2019-2021 and the quantities of compost produced are presented in *Table 3.1*.

Table 3.1. Material flows at the Taurages Green Waste Composting Site for composting of raw waste and food and kitchen waste of plant origin

Process inputs / outputs	Detailing	Unit	2019	2020	2021	Average
1	2	3	4	5	6	7
Inputs						
20 02 01 biodegradable waste Gardens and parks (grass, leaves, etc.)	Green Waste is accepted from natural persons	t	93	140	123	118.7
	Green Waste was collected by bypassing from natural persons	t	1850	2291	2005	2048.7
	Green Waste is accepted from legal entities	t	223	257	355	278.3
	SUM (amount of Green Waste):	t	**2166**	**2688**	**2483**	**2445.7**
Outputs						
Product	Compost (Green Waste compost)		**1435**	**1829**	**1152**	**1472**
[3] Air pollution	NH_3 (0,66 kg/t Green Waste)		1.4	1.8	1.6	1.6
	CO (0,56 kg/t Green Waste)		1.2	1.5	1.4	1.4
Evaporates/into wastewater	Mass difference (Green Waste - Green Waste compost - air pollution)	m^3(t)	728.4	855.7	1328	970.7
	[1] Enters the collection tank and further to the cleaning reservoir:	m^3(t)	700	600	500	600
	[3] In theory, liquid arises (0,34 m^3/t)	m^3(t)	736.44	913.92	844.22	831.538

Notes:

[1] The amount of liquid incurred according to the information provided by the operator

[2] Theoretical amount of liquid generated according to the information in the Technical Regulation on the Use of Waste [10].

[3] According to the Pollution Permit, composting of Green Waste generates more methane (CH4), which is shown as Volatile Organic Compounds (code 308) - up to 0.7166 g/s (22.6 t/a year).

Since the storage of Green Waste before composting, composting and maturation takes place in open sites, rainwater has a direct impact on the quantity and quality of compost produced: part of the moisture remains in the compost produced, and a large amount of nitrogen and phosphorus is planned with the wastewater.

The estimated surface wastewater (KL) from 0.29 ha of the Taurage Green Waste Composting Site is determined according to the formula in Chapter III, paragraph 8 of the Surface Wastewater Management Regulation [7]:

$W_f = 10 \times H_f \times ps \times F \times K = 10 \times 800 \times 0.85 \times 0.29 \times 0.85 =$ **1676.2 m³/a year**,

here:

H_f – average perennial precipitation in a certain area, mm (800 mm according to http://www.meteo.lt/lt/krituliai);

ps – surface leakage coefficient, ps=0.83 – for hard, waterproof coatings;

F – area of the territory, except for green areas where water collection infrastructure is not installed, ha;

K – surface runoff factor depending on whether snow is removed from the area. If the snow is removed, K=0.85.

Diesel fuel consumption in each of the technological processes is presented in Table 3.2. It is estimated that up to 10.91 l of diesel fuel is used to compost 1 t of Green Waste, including up to 27% for the stacker and up to

51.51% for shredding Green Waste. In terms of production, the consumption of diesel fuel is up to 19.72 l/t of compost produced.

Table 3.2. ²Diesel fuel consumption at Taurage Green Waste Composting Site for composting of Green Waste and plant and kitchen waste of plant origin

No.	Equipment for Green Waste composting process	Model	Diesel fuel consumption						
			2019		2020		2021		²Avarage
			l/m.	l/t Green Waste	l/a year	l/t Green Waste	l/m.	l/t Green Waste	l/t Green Waste
1	2	3	4	5	6	7	8	9	10
1	Shredder	JEZ	2125	0.98	14027	5.22	14964	6.03	5.62
2	Thruster	BACHUS	371	0.17	3685	1.37	3038	1.22	1.30
3	Sieve	TERRA-SELECT	3	0.00	3294	1.23	2182	0.88	1.05
4	Stacker (tractor)	DEUTZ-FAHR	2349	1.08	8765	3.26	6494	2.62	2.94
		Amount:	**4848**	**2.24**	**29771**	**11.08**	**26680**	**10.75**	**10.91**

Notes:

¹ The cost does not include the amount of diesel fuel used for the collection of waste from Green Waste and by-pass containers for food and kitchen waste of plant origin (see *Table 2.3*).

²As the use of other machinery in addition to the loader was very rare in 2019, the average value of the indicator of diesel fuel consumption per tonne of Green Waste treatment was estimated based on the data of 2020 and 2021.

Table 3.3. Realization of compost produced at Taurage Green Waste Composting Site

Production	2019, t/a year	2020, t/a year	2021, t/a year
1	2	3	4
Produced compost	1435	1829	1152
¹Sold	201	657	447
Realized for free (transferred)	137	246	88
Unrealized compost (percentage of production)	1097 (47.48%)	926 (50.63%)	617 (53.56%)

¹ Note: the most widely used selling price - 8.26 EUR + VAT.

3.2 Conclusions and recommendations for the improvement of the technological process

(1) The composting of Green Waste in terms of site selection and technological point of view is carried out in accordance with all the requirements for biodegradable waste composting, which are set out in the environmental requirements for composting and anaerobic treatment of biodegradable waste approved on 25/01/2007 by Order No. D1-57 of the Minister of Environment of the Republic of Lithuania (latest version – 24/11/2020 No. D1-713) [2] (hereinafter referred to as biodegradable waste composting rules).

According to the rules of biodegradable waste composting, from 1 January 2021, additional control of the technological composting process must be carried out:

- according to Chapter III, point 20.1 of the Biodegradable Waste Composting Rules, the composting of biodegradable waste <u>must ensure</u> a certain temperature regime, e.g. a temperature of at least 65 °C must be maintained for up to 5 days, if the temperature decreases, the number of storage days increases, e.g. maintain a temperature of at least 55 °C for less than 14 days;
- In accordance with the requirements set out in point 23 of Chapter III of the Biodegradable Waste Composting Rules, Taurage Green Waste Compost <u>must ensure</u> that the technological parameters

(temperature and oxygen content) are maintained by measuring them with instruments and recording them in a logbook;

- all procedures related to the maintenance of technological parameters must be described in the Technical Regulation on the Use of Waste, including information on the proportion of biodegradable waste to be mixed (compliant); measured parameters (partially compliant); measuring points, frequency, description of devices (not applicable).

Recommendation (1):

During the audit of the study organizers, by analysing the documents and analysing the results of laboratory analysis of samples of the manufactured product (see *Chapter 4*), it can be concluded that composting of Green Waste at the Taurage Green Waste Composting Site maintains all required temperature regimes. Therefore, it is only recommended to supplement and follow the relevant procedure for the control of the technological process of composting of Green Waste in the Technical Regulation on the Use of Waste.

In case the control devices have not been purchased yet, it is offered to purchase them by selecting temperature, humidity, pH measurement sensors with the transmission of readings via Wi-Fi to the computer.

Temperature, humidity, pH measurements	Temperature, humidity, pH measurements: up to 10 measurement locations with 1 sensor in 1 pile. 1 base station for connection up to 50 pcs. sensors with transmission of readings via Wi-Fi (i.e. 5 batches can be controlled) Transmitted over the Internet and recorded. RS 232 Interface. The maximum distance for the transmission of impressions - 1 km	Preliminary price for the whole system - 4,000.00 EUR

As the biodegradable waste composting requirements do not specify the installation of remote reading, the readings for temperature, humidity and pH parameters can be written off manually:

Temperature, humidity, pH measurements	Temperature, humidity, pH measuring sensors (e.g. 5 pcs. for 1 pile or 1 - every 10 m) Practical application: daily removal from measuring devices manually and recorded in a log; the sensors are removed before flipping. The flipping number can be adjusted according to the readings.	Preliminary price of the whole system for 36 piles: 600.00 EUR

(2) According to Chapter III (24) of the Biodegradable Waste Composting Rules, "in the case of compost use, sieving and other cases where there is a high risk of odours being released into the environment, odour abatement measures must be used".

Recommendation (2):

In order to optimize the composting process of Green Waste by reducing the environmental impact during composting and increasing the value of the compost produced as a fertilizer, it is proposed to use small quantities of microbiological preparations, which are also widely used as natural odour control agents (described in *Chapter 5.1*).

(3) Chapter III, point 25 of the Biodegradable Waste Composting Rules sets out the requirements for compost maturation: to avoid the formation of anaerobic conditions, such as excessive dumping, excessive drying and dust formation, etc.

Recommendation (3):

As the maturation takes place in a separate site with sufficient space, including unused space, it is proposed to carry out the maturation in heaps not exceeding 2 m in height.

(4) Section 3.2 estimates that the average consumption of diesel fuel for composting 1 ton of Green Waste is 10.91 l/t. This indicator exceeds the consumption of diesel fuel for composting of biodegradable waste according to the survey of biodegradable waste treatment facilities in Lithuania and analysing the sources of practical and scientific literature in other countries (from 1.5 to 3.2 l/t) (Staugaitis et al., 2016, Staniškis et al., 2017).

The main reasons: high fuel consumption for the shredding of Green Waste (up to 51.51%), and significant costs for the transport of primary coke of waste to the maturing site (about 27%).

Recommendation (4):

- Make optimal use of the territory of the Green Waste Composting Site and form a minimum of 2 composting piles (with the possibility to increase to 3).

According to the information provided in the technical regulation, the operating capacity of the Taurage Green Waste Composting Site R3 is up to 5640 t, currently <50% of the capacity is used.

- Carry out the maturation of the primary compost in the territory of the Green Waste Composting Site, without transporting it towards the site.
- To optimize the number of transportation trips and the procedure of waste acceptance and storage (separate the accepted waste by types, size of fractions).
- Review the need to shred most Green Waste (shredding mainly tree pruning waste).
- Using microbiological preparations suitable for composting Green Waste, speed up the composting process to 30 - maximum 40 days; this will reduce the consumption of diesel fuel for consumption (this alternative is described in detail in Chapter 5.1).

4. Quality and pollution indicators of Green Waste compost produced at Taurage Green Waste Composting Site

Samples of Green Waste compost produced at the Taurage Green Waste Composting Site were taken on 3 November 2021. For the purpose of laboratory tests, 3 samples were formed to determine the quality and contamination indicators of the produced compost in comparison with the data of previous tests and the requirements for the fertilization product according to [1] and to determine the value according to the recommendations for valuable compost (when used to enrich the soil in Lithuania), specialists (Staugaitis et al., 2015, 2016).

The tests of microbiological parameters of the samples were performed in the Kaunas branch of the National Laboratory of Public Health (NVSPL), other tests were performed in the Agrochemical Research Laboratory of the Institute of Agriculture of the Lithuanian Centre for Agrarian and Forest Sciences (LAMMC). Study protocols are provided in *Annex 1*.

The results of laboratory tests carried out in 2015-2016 on behalf of the Ministry of Environment of the Republic of Lithuania in the project "Development of Requirements (Criteria) for Biodegradable Waste Products" and samples of Green Waste compost from Green Waste Composting Sites in various Lithuanian cities were also analysed for comparison (out of 14 in total), including the Taurage Green Waste Composting Site (sample for testing was formed on 04/11/2015; the study protocol is provided in *Annex 3*.

The studied quality indicators were selected according to the recommendations of Staugaitis et al., 2016 and required for fertilization products according to [1]: pHKCl, pHH2O, organic matter (OM) content in dry matter (DM), organic carbon (C), total nitrogen (N), total phosphorus (P), total potassium (K) content in SM, water soluble nitrogen (N-NH4 + N-NO3), phosphorus (P) and potassium (K) in natural moisture (NDM), sulphides, chloride content in NDM, calcium (Ca), magnesium (Mg) content NDM, electrical conductivity, C: N ratio, biodegradability, bulk density.

Organic carbon (OM) content

The amount of OM in compost is one of the most important indicators of quality. The content of OM in compost made from Green Waste is usually very low or low - up to 25% of dry matter, i.e. the value as a soil improver is very low (see *Table 4.1, column 3*) (Staugaitis et al., 2016). In comparison, the average OM content of compost produced from the sludge of urban wastewater treatment plants when composted with Green Waste is twice as high and reaches 45.8% of dry matter (Staugaitis et al., 2016); The average content of OM in compost made from food waste (mainly from plant origin) (hereinafter - FWC) is 30% of dry matter, but it could be 80% if food waste is composted together with animal by-products (Staugaitis et al., 2016). Kliopova et al. 2019, Stunžėnas et al., 2021).

Table 4.1. Comparison of Taurage Green Waste compost quality indicators with requirements for fertilizer product [1] and determination of compost value (according to Staugaitis et al., 2016)

Compost quality indicators	**Recommended indicators for valuable compost (Staugaitis et al. 2016).**	**Quality values of tested compost: maximum and minimum, median (number of wealth samples in brackets)**			**Note on the value of compost as a fertilizer according to Staugaitis et al., 2016** *(specified value limits)*	**Comparison with requirements for fertilizer products placed on the market under [1]**
		Green Waste compost (2015-2016) (min. – max, **median**)(14)	**Taurage Green Waste compost (04/11/2015)** (1)	**Taurage Green Waste compost (03/11/2021)** (min. – max., **median**) (3)		
1	**2**	**3**	**4**	**5**	**6**	**7**
Dry matter, %	21 – > 50	47.7-81.0 **61.2** (13)	65.44	49.41-53.23 **51.58** (3)	Very high (>50)	
Organic matter, % DM	16 – >45	8.5-28.6 **20.6** (13)	24.96	23.06-26.11 **24.95** (3)	Low *(16-25)* and medium *(25-35)*	≥20 %. i.e. meets the above requirements for compost from Green Waste or growing medium
Total nitrogen (N), % DM	0.5– >2.0	0.23-1.41 **0.67** (14)	0.69	0.9-1.0 **0.96** (3)	Low *(0.5-1.0)*	($N + P_2O_5 + K_2O$) >2,5 % (2.7 to 4.1 times more, analysing only the median)
Total phosphorus (P), % DM	0.21 – >0.8	0.04-0.47 **0.14** (14)	0.19	0.37-0.44 **0.41** (3)	Average *(0.41-0.60)*	
(converted to P_2O_5)	*0.48– >1.83*		0.43	*0.84 – 1.011* ***0.93*** *(3)*		
Total potassium (K), % DM	0.6 – >2.5	0.16-1.17 **0.46** (13)	0.76	0.71-0.86 **0.78** (3)	Low *(0.6-1.0)*	
(converted to K_2O)	*0.72– >3.0*		*0.91*	*0.85 – 1.03* ***0.84*** *(3)*		
Electrical conductivity, mS/cm NDM	0.6 – >2.0*	0.4-4.32 **0.87** (9)	1.084	0.471-0.9595 **0.715** (2)	Low *(0.6-1.0)*	-
Water soluble nitrogen ($N-NO_3+N-NO_2$), mg/l NDM	51 – >200	20.0-518.1 **93.0** (9)	302.1	122-158 **138** (3)	Average (101-150) and high (151-200)	-
Water - soluble ammoniacal nitrogen ($N-NH_4$), mg/kg NDM		0.1-64.1 0.1 (11)	64.1	24-33 **27.67** (3)	Average	-
Water soluble phosphorus (P), mg/kg NDM	26 – >100	22.7-125.0 **53.6** (11)	48.7	46.1-52.8 **49.57** (3)	Low *(25-50)* and average *(51-75)*	-
Water soluble potassium (K), mg/kg NDM	91 – >300	210-6500 **1025** (4)	2712	1925-2479 **2155.67** (3)	Very high (>300)	-
Sulfates (SO_4), mg/kg NDM	51 – >300*	113-996 **457** (9)	511	325.19-338.17 **331.683** (2)	Very high (>300). but not exceeding 1000 mg / kg where it may cause damage to plants	-
Chlorides (Cl), mg/kg NDM	51 – >300*	35.8-1029 **312.5** (9)	1029	1151.71 -1202.76 **1177.24** (2)	Very high (> 300). but as> 1000 mg/kg may cause plant damage	-
Organic C, % DM		6.7-16.8 **8.9** (11)	8.64	12.00-15.60 **14.06** (3)	Average	> 7%. i.e. meets the above requirements for a soil improver
Humic acid, % DM		0.42-2.05 **1.60** (9)	2.05	4.55-5.52 **4.88** (3)	*Valuable (more than food compost)*	-
Fulvic acid, % DM		0.27-0.73 **0.56** (9)	0.73	1.05-1.29 **1.15** (3)	*Valuable (like manure compost)*	-
Calcium (Ca), mg/kg DM				16733		-
Magnesium (Mg), mg/kg DM				2747		-
Manganese (Mn), mg/kg DM				306		-
Iron (Fe), mg/kg DM				7540		-
C: N ratio	11 – >25	10.9-19.7 **13.3** (11)	12.5	13.33-15.92 **14.6** (3)	Low (11-15) or Average (16-20)	-
pH $_{KCl}$	5.6 – >8.5	7.3-7.9	7.9	7.9-8.0	High	-

Compost quality indicators	Recommended indicators for valuable compost (Staugaitis et al. 2016).	Quality values of tested compost: maximum and minimum, median (number of wealth samples in brackets)			Note on the value of compost as a fertilizer according to Staugaitis et al., 2016 *(specified value limits)*	Comparison with requirements for fertilizer products placed on the market under [1]
		Green Waste compost (2015-2016) (min. – max, median)(14)	Taurage Green Waste compost (04/11/2015) (1)	Taurage Green Waste compost (03/11/2021) (min. – max., median) (3)		
1	2	3	4	5	6	7
		7.5 (9)		**7.95 (3)**	*(7.6-8.5)*	
pH $_{H20}$	6.1 – >9.0	7.3-8.8 **8.1** (14)	8.6	8.7-8.8 **8.75 (3)**	High *(8.1-9.0)*	-
Biodegradability (stability) based on the concentration of dissolved organic carbon, mg/l DM	≤ 4000	126-846 **489** (9)	594	112-179 **150.33** (3)	High (compost stable)	-
Bulk density, g/l NDM	as fluffy as possible	625-881 **715** (11)	625	625-775 **700** (2)	Valuable *(600-700)*	-

The average OM content of Taurage Green Waste compost is 24.95% DM, i.e. low value according to this indicator. But meets the minimum requirements for compost from Green Waste or growing medium [1].

Organic carbon (C) content

The amount of organic carbon is the most important component of OM and depends directly on the OM in compost. On average, 14.06% of DM organic carbon is found in the dry matter of the analysed samples, i.e. the compost analysed according to this parameter is assessed as very low and low value in the same way as in the case of OM (Staugaitis et al., 2016).

Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur, partial chlorides and 5 trace elements: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (Br) - nutrients needed by plants (Staugaitis et al., 2015, 2016).

Aggregate or total nitrogen (N) content

Limits of total N content in valuable compost - from 0.5 to 2.0% DM (Staugaitis et al., 2015). The average total nitrogen content of Green Waste compost in Taurage is 0.96% DM. According to this indicator, Green Waste compost is assessed as low value compost, like other Green Waste compost produced in Lithuania (see *column 2 of Table 4.1*). For comparison, the average amount of total nitrogen produced in Lithuania: compost made from digested and unfermented sludge from municipal sewage treatment plants (MSSC) (C - 2.43% DM, compost made from separately collected food waste (SCFC) - 1.36% DM, compost made from public catering waste (PCWC) - up to 1.8% of DM (Staugaitis et al., 2016).

It is the water-soluble nitrogen (ammonia and nitrate nitrogen) that is more easily absorbed by plants. In valuable compost, the water-soluble nitrogen (N-NO4 + N-NO3) in the natural moisture content (NMC) must be between 51 and 200 mg/kg and more (Staugaitis et al., 2016). The substance tested according to this indicator is of medium and high value (up to 138 mg/kg NMC on average).

Total phosphorus (P) content

Total P in compost varies from 0.1 to 3.3% DM (Staugaitis et al. 2015). According to the rating scale, the amount of this nutrient in Taurage Green Waste compost is average - about 0.41% DM, but higher compared to other Green Waste compost produced in Lithuania (see *column 2 of Table 4.1*). This indicator is twice as high in MSSC, similar in SCFC and lower in PCWC (Staugaitis et al., 2016).

The amount of water-soluble phosphorus (P) depends on the degree of mineralization of the compost and the raw materials used to make it. In very high value compost, the water-soluble P may be above 100 mg/kg NDM. The substance tested according to this indicator is of low and medium value (up to 49.57 mg/kg NDM on average).

Total potassium (K) content

Total K in compost varies from 0.6 to 2.5% DM (Staugaitis et al. 2015). According to the rating scale, the amount of this nutrient in Taurage Green Waste compost is low - about 0.78% DM, but almost 2 times more than in other Green Waste outlets produced in Lithuania (see column 2 of *Table 4.1.)* (Staugaitis et al., 2016).

Water-soluble potassium is more easily absorbed by plants. Valuable compost must have a natural moisture content of 91 to 300 mg / kg NDM and more (Staugaitis et al., 2015). The Taurage Green Waste compost studied according to this indicator has a very high value (up to 2155 mg / kg NDM on average). It can be concluded that although the amount of potassium in this compost is low, it is all easily absorbed by plants.

It is important to note that according to the requirements for fertilizer products [1], Taurage Green Waste compost meets the minimum criteria of N + P2O5 + K2O ≥ 2.5% DM. When analysing each of the samples taken separately, the total nutrient results for N + P2O5 + K2O in the tested samples were> 2.5% DM:

- In compost No.1: 1 + 1.01+1.032 = 3.042 % DM;
- In compost No.2: 0.98 + 0.85+0.852 = 2.682% DM;
- In compost No.3: 0.9 + 0.94+0.936 = 2.776% DM;

Sulphate (SO4) content

Compost is highly valued when its sulphate content exceeds 200 mg/l NDM. In case the sulphate concentration exceeds 1000 mg/l NDM, such compost can have a negative effect on sensitive plants (Staugaitis et al., 2014). The amount of sulphates in all composts produced in Lithuania exceeds 300 mg /l NDM, the situation is similar with the compost produced at the Taurage Green Waste Composting Site.

Chloride (Cl) content

Compost is highly valued at a chloride content of about 200-300 mg/l NDM. However, if the chloride concentration exceeds 1000 mg/l NDM, such compost can have a negative effect on sensitive plants (Staugaitis et al., 2016). In 2020, the content of chlorides in the analysed HACP is extremely high (on average - up to 1177 mg/l NDM), therefore the use of such compost is not recommended when growing medium. It can be used as a soil improver, i.e. composted according to fertilization plans that set fertilization rates not only for total nitrogen (N) and total phosphorus (P), P2O5, but also for chloride (Cl).

C: N ratio

In valuable compost, this ratio should be between 11 and 25 and above. If this ratio is <10, compost mineralization occurs very rapidly, and compost as a supplement to soil organic matter for a long period of time is very poor (Staugaitis et al., 2016). According to the C: N ratio, the analysed Green Waste compost has an average value of 14.6 on average.

pH

In compost, the pH is usually determined in the water extract (pHH2O) and/or the potassium chloride extract (pHKCl). "The pH of the growing medium affects the activity of microorganisms, the mineralization of organic matter, the solubility and uptake of nutrients necessary for plants, their interconnection and blocking" (Staugaitis et al., 2016).

According to the results of agrochemical research of Lithuanian soil performed by the Agrochemical Research Laboratory of the Lithuanian Centre for Agricultural and Forest Sciences since 1999, about 40% of the area of Lithuania consists of acid soils (pH≤5.5). Therefore, in compost valuable for Lithuania, pHH2O must range from 6.1 to 9 and more, pHKCl - up to 8.5 and more. According to these indicators, Green Waste compost produced at the Taurage Green Waste Composting Site is assessed as high value compost (up to 8 according to HKCl, up to 8.8 according to pHH2O).

Biodegradability

One method of determining the biodegradability or stability of compost is to assess the concentration of dissolved organic carbon (C). A substance with a high content of readily degradable organic compounds that maintains a high activity of microorganisms is considered unstable. In case the concentration of dissolved organic carbon (C) does not exceed 4000 mg/kg, the compost is considered stable (Staugaitis et al., 2016). Assessing this indicator, it can be concluded that the process of composting Green Waste at the Taurage Green Waste Composting Site is technologically smooth, the compost produced is stable, as the concentrations of dissolved organic carbon (C) do not exceed even 200 mg/kg DM.

Table 4.2. Comparison of Taurage Green Waste Compost Contamination Indicators with Fertilizer Product Requirements and Determination of Compost Value

Contamination indicators of compost	**Recommended indicators for valuable compost (Staugaitis et al., 2016).**	**Values of quality and pollution of compost of Green Waste studied**			**Note on the value of compost as a fertilizer according to Staugaitis et al., 2016**	**Comparison with requirements for fertilizer products placed on the market according to [1]**
		Green Waste compost (2015-2016) (min. – max., **median**) (14)	**Taurage Green Waste compost (2015-11-04)** (1)	**Taurage Green Waste compost (2021-11-03)** (min. –max., **median**) (2)		
1	**2**	**3**	**4**	**5**	**6**	**7**
Indicators of heavy metal contamination						
Cadmium (Cd), mg/kg DM	1 – 2	0.15-0.39 **0.25** (14)	0.27	0.28 (1)	Valuable because the contamination with heavy metals does not reach even the minimum limit values	<2* and even <1.5** *(over 7 times less)*
Lead (Pb), mg/kg DM	50 – 100	7.4-28.1 **14.6** (14)	16.7	23.0 (1)		<120 (*over 5 times less*)
Mercury (Hg), mg/kg DM	0.4 – 1	0.00-0.081 **0.001** (14)	0.001	0.001 (1)		<1 *(practically not found)*
Chrome (Cr), mg/kg DM	70 – 100	5.6-30.9 **12.2** (14)	11.4	6.03 (1)		<70 (Staugaitis et al., 2016) (*over 11 times less*)
Cr (VI), mg/kg DM	-	not studied	not studied	not studied		-
Zinc (Zn), mg/kg DM	400 – 600	93-310 **145** (14)	184	198 (1)		<800* (<500)** (*2.5 to 4 times less*)
Copper (Cu), mg/kg DM	100 – 200	13.1-56.9 **21.7** (14)	32.6	29.1 (1)		<300* (<200)** (*6.9 to 10 times less*)
Nickel (Ni), mg/kg DM	40 – 60	3.4-15.7 **5.6** (14)	5.57	4.29 (1)		<50 (*over 11.6 times less*)
Arsenic (As) , mg/kg DM	10 – 25	Not studied	-	-		-
Organic contaminants						
PCBs, mg/kg DM	<0.2	0.001-0.022 **0.003** (9)	0.005	-	Valuable as it does not meet the minimum limits	<0.2 (*over 40 times less*)
PAHs, mg/kg DM	<4	0.38-14.89 **1.12** (9)	1.35	-		<6 (*over 4.4 times less*)
Indicators of microbiological contamination						
Faecal bowel rods (Escherichia coli), kol. sk./g	<1000	10-120000 **10** (6)	120000 (an exceedance was detected)	<10 – 80 45 (2)	Valuable as it does not meet the minimum limits	*<1000 (over 22 times less)*
Anaerobic clostridia (Clostridium perfringens), kol. sk/g	<100 000	75-16000 **345** (6)	1500	6900-20000 **13 450** (2)		<100 000 *(over 7 times less)*
Helminth eggs and larvae, pcs./kg	0	Not found (6)	Not found	Not found		Not found *(corresponds)*
Salmonella bacteria, pcs. in a sample of 25 g	0	Not found (6)	Not found	Not found		Not found *(corresponds)*
Unwanted contaminants						
[2] Glass, metals, plastics with a particle size> 2 mm	≤0.5% DM	0.0-0.0 **0.0** (7)	0	6.62-9.96 [1]8.58 g/kg DM	Valuable only according to Staugaitis et al., 2016	>3 g/kg SM Non-compliant, up to 3.3 times the limit value
Sprouting plant seeds, t. sd. of viable weeds, rhizomes	≤2 pcs./l	0.3-5.0 **1.5** (4)	0.3	Not found (3)	Valuable	≤2 pcs./kg Not found *(corresponds)*
[2] Stones, etc. up to 5 mm	≤5% DM	0.0-2.6 **0.0** (11)	0	6.39-8.475 7.25 (3)	Not valuable	>5% NDM Not suitable, up to 1.4 times the excess

Notes:

[1]The results are based on NDM, i.e. 1 kg NDM (compost No. 1, see *Annex 1*) containing up to 49.41% DM (0.4941 kg) found in 0.492% (or 4.92 g) of glass, metal, plastic particles or 9.96 g/kg DM;

[2] If the production of Green Waste compost is a growing medium, the requirements for unwanted impurities do not apply to this product: glass, metal, plastic and stones, the limit value is specified only for weed seeds - 2 pcs/kg. But in the growing medium are substances other than the soil in which the plants are grown. Due to the very high concentration of chlorides (see *Table 4.1*), Green Waste compost produced at the Taurage Green Waste Composting Site can only be considered as a soil improver and should be limited not only in terms of total phosphorus and total nitrogen but also in terms of chloride content.

Humic and fulvic acids

Humic and fulvic acids are components of organic matter. Humic acids bind with Sr, Ni, etc. to insoluble compounds and prevent the entry of heavy metals (Staugaitis et al., 2016). These acids, together with the mineral particles of the soil, form persistent organic-mineral compounds. Compared to other Green Waste compost produced in Lithuania, the analysed Green Waste compost has a higher content of these acids. This may be due to the composting of plant-based food and kitchen waste with Green Waste, which started in 2015. According to these indicators, compost is considered valuable.

The analysed Green Waste compost also has a very high content of calcium (Ca), magnesium (Mg), iron (Fe), which, as mentioned, is considered to be a nutrient. In addition, when fertilizing with the analysed compost, these elements will be well absorbed by the plants, as the pH of the available compost is> 6 and ≤8 (Staugaitis et al. 2016).

The analysis of the pollution indicators of the compost produced at the Taurage Green Waste Composting Site (see *Table 4.2*) leads to the conclusion that:

- like other Green Waste compost produced in Lithuania, the analysed compost is practically not contaminated with heavy metals and according to these indicators it can be used as a soil improver and when growing medium;
- the analysed Green Waste compost is not contaminated with persistent organic pollutants: PCBs are above 40 times the limit value [1], PAHs are above 4.4 times below the limit value [1] (but these indicators should not be assessed in the production of Green Waste compost; they were analysed specifically for Alternative 2 (see Section 5.2));
- also the analysed Green Waste compost does not show microbiological contamination;
- no seedling plants were found in the Green Waste compost samples tested;
- the samples of Green Waste compost tested contain a large number of undesirable impurities, although according to the operator, the compost is sieved before maturation and the samples were taken from a second site where maturation and storage of the compost takes place (see *Picture 3.1 MPC and S*):
  - up to 3.3 wars above the limit value (at a limit value of 3 g/kg DM [1]) for glass, metal, plastic (with a particle size <2 mm): up to 4.92 g/kg NDM or up to 9, 96 g/kg DM;
  - up to 1.4 times more solid natural impurities (pebbles, etc.) up to 5 mm in diameter (with a limit value of 5% NDM [1]).

It is important to mention that no undesirable impurities (unnatural and natural) were found in the Taurage Green Waste compost surveyed in 2015.

Conclusion:

According to the requirements for fertilizer products [1], Taurage Green Waste compost meets the following criteria:

- $N + P_2O_5 + K_2O$ ≥2.5 % DM (in the tested samples: from 2.682 to 3.042% DM);
- OM>20% DM (in the tested samples: from 23.06 to 26.11% DM);
- Organic C >7 % DM (in the tested samples: from 12,00 to 15.60 % DM);
- the concentrations of all tested heavy metals (Cd, Pb, Hg, Cr, Zn, Cu, Ni) do not exceed the limit values (from 0.001 limit value to 0.34 limit value);

- it contains no seeds of germinating plants, t. sd. viable weeds, rhizomes.

According to the requirements for fertilizer products [1], Taurage Green Waste compost does not meet the following 2 criteria:

- according to the amount of unwanted unnatural impurities (glass, metal, plastic over 2mm) (exceeds up to 3.3 times);
- according to the amount of unwanted natural impurities (stones up to 5 mm) (up to 1.4 times).

Analysing the value of compost produced as a fertilizer (Staugaitis et al., 2015, 2016) according to the main quality indicators, it is concluded that Taurage Green Waste compost:

- low value in terms of total N and total K, in terms of electrical conductivity; C: N ratio;
- the average or closer to the mean value according to the quantity of OM, the total P; water-soluble nitrogen (N-NO3 + N-NO2) and phosphorus (P);
- valuable in terms of pH, humic and fulvic acid content, organic carbon C content, water-soluble K content, sulphate (SO_4) content, stability, bulk density, dry matter content; it contains a lot of Ca, Mg, Fe;
- Due to the high chloride (Cl) content (above 1000 mg / kg NDM), this compost can only be further analysed as **a soil improver** (current product code: D.2.1.1.2 or D.2.1.1.1, if the alternatives in Chapters 5.2 and/or 5.3 are implemented).

5. Recommendations for improving the quality of compost

There are 4 possible alternatives:

Process optimization:
- the use of microbiological preparations to optimize the existing composting process for Green Waste, reducing its impact on the environment and improving its performance;

Industrial symbiosis:
- mixing with dried sludge produced by Taurage wastewater treatment plants by composting (up to 25% by weight), thus improving the value of the compost produced;
- composted with food waste, including animal by-products, primary compost (if the infrastructure described in Chapter 2 is installed) *and/or*
- when maturing primary compost of Green Waste, mix it with food waste, including primary compost of animal by-products (up to 30% by weight).

Additionally offered:

- Install a shed for compost maturation and storage. This would improve one of the important parameters - the moisture content of the compost, which increases significantly during the rainy season. Other parameters for the production of Green Waste compost will increase accordingly, as no nutrients will be leached from the finished product.
- During the project of installation of food and kitchen waste treatment equipment, strictly follow the requirements for the production of fertilizer products for the production of fertilizers so that unwanted unnatural impurities (glass, metal, plastic> 2mm) are ≤ 3 g/kg DM, natural impurities (stones up to 5 mm) ≤5% NDM.

5.1 Use of microbiological preparations to optimize the existing Green Waste composting process, reducing its impact on the environment and improving value

In order to optimize the composting process of Green Waste itself, reducing its impact on the environment (reduction of diesel fuel consumption, NH3 emissions, risk of odour formation), increase the value of the product as a fertilizer (according to total N, P, K, etc.), eliminate the risk of microbiological contamination, the use of microbiological preparations (probiotics) is proposed.

The results of research conducted in 2012-2017 by researchers of the Institute of Environmental Engineering of Kaunas University of Technology showed that compost made only from Green Waste does not have high value according to many indicators, nor does it show pollution with heavy metals and persistent organic pollution, but in some cases microbiological pollution exceeds regulated More E-coli and/or Anaerobic Clostridia may be detected (Staugaitis et al., 2016; Staniškis et al., 2017). N concentration increases above 46%, total phosphorus above 43%, total potassium above 3 times (see *Table 5.1.1*), composting period shortens - during the warm period primary compost is produced in 30 days.

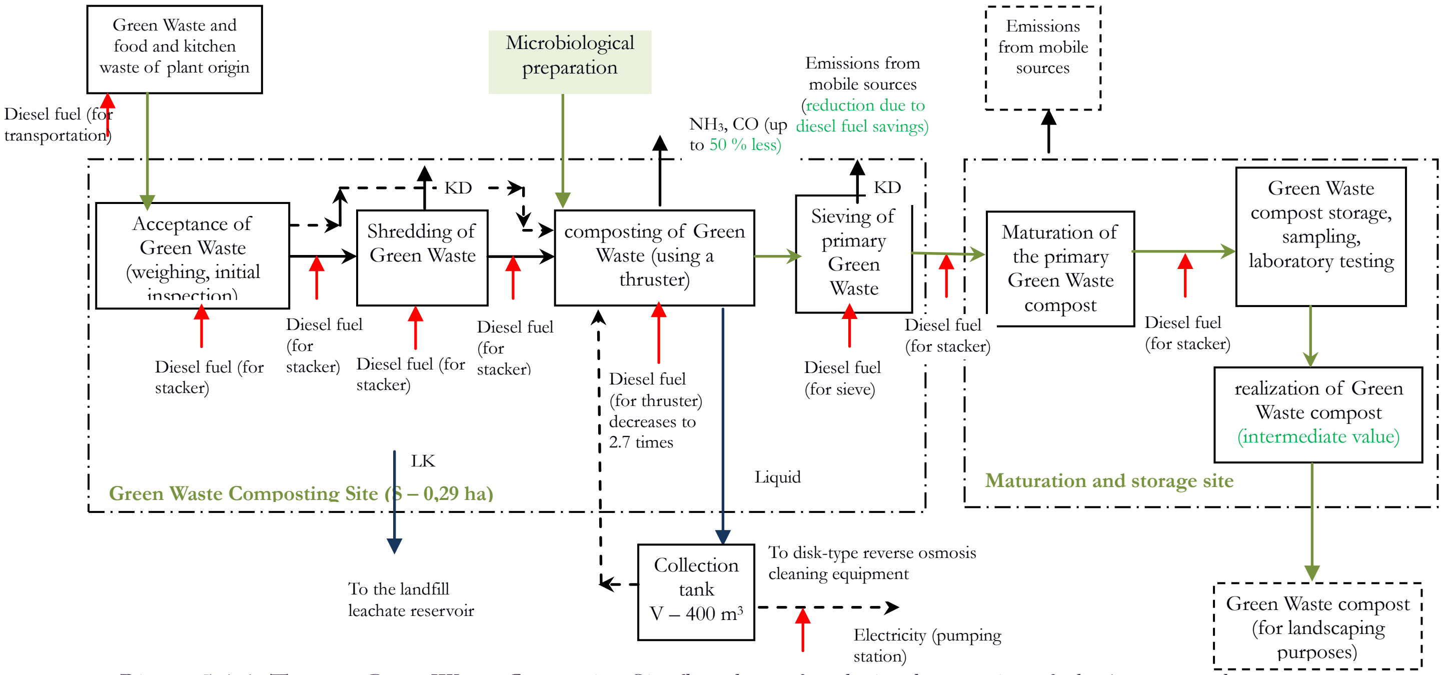
Table 5.1.1. [1]Comparative analysis of the main quality parameters of composting (composting in the classical way and with microbiological preparations)

Tested quality parameters	**Produced compost**	**Classical composting**	**Composting with microbiological preparations**	**Conclusion (increase, %)**
1	**2**	**3**	**4**	**5**
OM, **%**	Green Waste compost (at home) Green Waste compost (centralized) DC (sludge and Green Waste)	up to 22.44 up to 18.95 up to 40.39	up to 32.38 up to 25.19 up to 45.49	44.30 32.93 12.63
Total nitrogen (N), %	Green Waste compost (at home) Green Waste compost (centralized) DC	up to 0.66 up to 0.73 up to 2.03	up to 1.01 up to 1.07 up to 2.57	53.03 46.58 26.60
Total nitrogen (P), %	Green Waste compost (at home) Green Waste compost (centralized) DC	up to 0.17 up to 0.37 up to 1.06	up to 0.32 up to 0.53 up to 1.51	88.24 43.24 42.45
Total Potassium (K), %	Green Waste compost (at home) Green Waste compost (centralized) DC	up to 0.76 up to 0.44 up to 0.31	up to 1.57 up to 1.44 up to 0.44	106.58 227.27 41.94
Water soluble N, mg/l (or mg/kg) NDM	Green Waste compost (at home)	up to 123	up to 266	116.26
Water soluble P, mg/l (or mg/kg) NDM	Green Waste compost (at home) DC	up to 280 up to 104	up to 700 ik 125	150 20.19
Water soluble K, mg/l (or mg/kg) NDM	Green Waste compost (at home)	up to 1400	up to 5800	314.29
C:N	Green Waste compost (at home) SF	up to 15.88 up to 5.66	up to 23.35 up to 6.46	47.04 14.13

[1]Sources of information:

- Green Waste (at home) (RECO Baltic-21 Tech, 212-2013, Kliopova ir Stanevičiūtė, 2013; Staniškis et al., 2017)
- Green Waste (centralized) (A. Zopelienė. Optimization of Green Waste management processes by increasing product (compost) value indicators. Master's thesis. Institute of Environmental Engineering, Kaunas University of Technology, 2019)
- Sludge and Green Waste (1:1): Šleinotaitė-Kalėdė et al., 2020; Kliopova ir Budrys, 2020; Kliopova ir Dangėlaitė, 2020.

The flow chart for this proposal is shown in *Picture 5.1.1*, and the results of the benchmarking are presented in *Table 5.1.2*.



Picture 5.1.1. Taurage Green Waste Composting Site flow chart after the implementation of the 1st proposal

At the Taurage Green Waste Composting Site, the introduction of microbiological preparations for the composting process of Green Waste and food and kitchen waste of plant origin will increase the value of Green Waste compost according to the following parameters:

	The current situation (classic composting)	Planned situation (composting with a microbiological preparation (see Annex 4))	Note on value
OM, %	24.95	Up to 33	Increases from low to medium value
Total nitrogen (N), % DM	0.96	Up to 1.4	Increases from low to medium value
Total nitrogen (P), % DM	0.41	Up to 0.59	Remains of medium value (closer to high)
Total potassium (K), % DM	0.78	Up to 2.5	Increases from low to high
C:N	14.6	Up to 20	Increases from low to medium (closer to high)

Table 5.1.2. Expected environmental impact and cost savings of proposal 1: results of a comparative analysis

Analysed flows	**pcs.**	**Classic composting**	**Composting with a microbiological preparation**	**(+) Savings (decreases)/ (-) Increases**		
		Pcs./a year	**pcs./ a year**	**pcs./ a year**	**EUR/pcs.**	**EUR/a year**
1	**2**	**3**	**4**	**5**	**6**	**7**
[1] Compostable Green Waste and food and kitchen waste of plant origin	t	2445.7	2445.7	-	-	
[2] Probiotic substance	l	0	320	-320	12.00	-3840.00
[3]Water (for dilution)	m³	0.00	16-32	-16-32	0.00	0.00
[4] Diesel fuel (for flipping)	litres t	3179.41 2.67	1177.57 0.99	2001.84 1.68	1.13	2262.05
Hydraulic oil	l	16	5.9	10.1	3.60	36.36
Engine oil	l	2.5	0.9	1.6	5.00	8.00
Charge for air pollution from mobile sources (10 EUR/t diesel)	EUR	26.7	9.90	-	-	16.80
Total:						-1516.79
[2]Income for the sale of higher value compost increases, EUR/a year:						5135.97
Positive balance, EUR/a year:						**3619.18**

Notes:

[1] Compostable Green Waste and food and kitchen waste of plant origin - average in 2019-2021 (see *Table 3.1*);

[2]Consumption of probiotic materials in composting Taurage Green Waste: up to 1 l of microbiological preparation ProbioStopOdor - 1 t of organic matter (OM);

[3]Water is used for dilution of probiotic substances: 1 l to 50-100 l; instead of water suitable weight. The watering hose for probiotic spraying is technically easy to attach to the thruster and to spray/water only during the 1st application;

[4]Average consumption of diesel fuel before the introduction of the alternative: up to 1.30 l/t of Green Waste (see *Table 3.2*).

The results of the research carried out by the Institute of Environmental Engineering of Kaunas University of Technology showed that the use of microbiological preparations reduces the duration of primary compost production, the frequency of compost piles consumption:

	Current situation (classic composting)	Planned situation (composting with microbiological preparation)
Features of composting	Aerobic conditions	Semi-aerobic conditions
Week 1	number of flips - 3	number of flips - 1
Week 2	number of flips - 2	number of flips - 1
Week 3	number of flips - 2	number of flips - 0-1
Week 4	number of flips - 1-2	number of flips - 0-1
Week 5	number of flips - 1	number of flips - 0-1
Week 6	number of flips - 1	**Primary compost produced**
Week 7	number of flips - 1	-
Week 8	**Primary compost produced**	-
	Number of flips:12-13	Number of flips: 4-5 (decreases 2.7 times)

[5]Price of low value Green Waste compost in the Lithuanian market: 7.00 - 13.00 EUR/t + VAT. The price of Green Waste compost produced at the Taurage Green Waste Composting Site is 8.26 EUR/t + VAT.

The pessimistic assumption is that the compost will be sold at the average price of low-value composts - 10.00 EUR + VAT (although the implementation of this alternative would allow to increase the value of compost to medium-value compost).

Conclusion:

- The use of a microbiological preparation for the composting of Green Waste and food and kitchen waste of plant origin would allow:

- to reduce the consumption of diesel fuel for flipping (on average 2.7 times) (correspondingly, emissions to ambient air from this mobile pollution source will be reduced);

- to eliminate odours;

- to increase the value of compost as a fertilizer from low to medium (closer to high) according to the following main indicators: OM, total ratio of N, P, K, C and C: N;

- increase the sale price of compost: min. to 10 EUR/t + VAT (pessimistic assumption).

- Additional positive effects after the implementation of 1 proposal:

- expected significant reductions in NH_3 emissions (up to 40-50 percent);

- it will be ensured that microbiological contamination does not exceed the regulated limit values;

- humic and fulvic acids are likely to increase further

5.2 Compost Green Waste by mixing it with dried sludge fermentation from Taurage wastewater treatment plants

This alternative proposes the application of the principle of industrial symbiosis and composting of Green Waste with dried sludge fermentation (SF), such as dried yeast from Taurage wastewater treatment plants (after anaerobic treatment and dewatering of sludge) (Staniškis et al., 2017; Kliopova et al., 2017).

Within the framework of this project, the optimal ratio of compostable raw materials by weight has been determined:

- 75% of Green Waste, including food and kitchen waste of plant origin, is already collected in containers
- 25% SF.

In this case, there will be no additional requirements for the composting process in addition to those already applied to the composting of Green Waste, as the dried sludge fermentation (TSF) from Taurage Wastewater Treatment Plant is already a product of soil improver (D.2.1.1.1.) with a maximum limit value contamination according to [1]. (See *Table 5.2.1., column 6*, "Heavy metal pollution" and "Organic pollution").

Under this approach, the compost produced from Green Waste will be considered a high and very high value fertilizer according to many quality criteria (Staugaitis et al. 2014, 2015, 2016).

Theoretical evaluation of the obtained compost quality and pollution indicators is presented in *Table 5.2.1*.

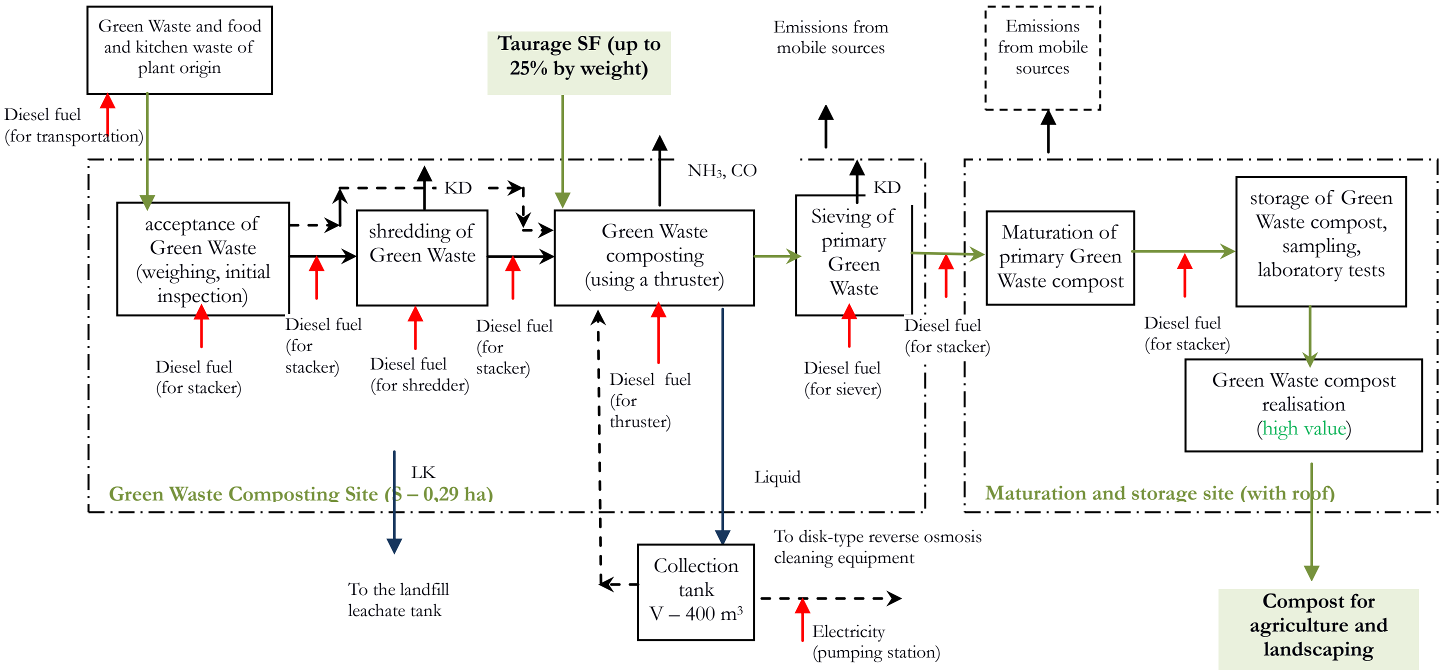
This alternative also suggests the use of microbiological preparations in composting to reduce the risk of microbiological contamination, as laboratory analysis of dried yeasts in 2015-2016 showed that they may contain more than the limit value for anaerobic clostridia (Clostridium perfringens) according to [1] (but the risk of exposure is very low).

Table 5.2.1. Planned quality and contamination indicators of Green Waste compost after the implementation of the 2nd proposal: comparative analysis

Quality and contamination criteria	**Taurage Green Waste compost** median (3)	**Taurage sludge fermentation** Avarage (2)	**Taurage Green Waste compost 75%+ Taurage SF 25%**	**Change, %**		**Value of received compost according to Staugaitis et al., 2015, 2016**	**A note on value**
1	2	3	4	5		6	7
Quality criteria							
Dry matter content, %	51.58	93.115	61.96	increased	20.13	Very high	has not changed
Organic matter, % DM	24.95	65.385	35.06	increased	40.52	High	increased from low to medium to high
Total nitrogen (N), % DM	0.96	5.61	2.12	increased	121.09	Very high	increased from low to very high
Total phosphorus (P), % DM	0.41	3.535	1.19	increased	190.55	Very high	increased from medium to very high
Total potassium (K), % DM	0.78	0.45	0.70	decreased	-10.58	Low	has not changed
Organic C, % DM	14.06	29.05	17.81	increased	26.65	High	increased from low to high
Humic acid, % DM	4.88	5.94	5.15	increased	5.43	High	has not changed
Fulvic acid, % DM	1.15	0.6	1.01	decreased	-11.96	High	has not changed
Electrical conductivity, mS/cm NDM	0.715	2.435	1.15	increased	60.14	Medium	increased from low to medium
Water soluble nitrogen; $N-NO_3+N-NO_2$), mg/l NDM	138	4237.25	1162.81	increased	742.62	Very high	increased from medium to very high
Water soluble phosphorus (P), mg/kg NDM	49.57	1194	335.68	increased	577.18	Very high	increased from low to very high
Water soluble potassium (K), mg/kg NDM	2155.67	2751.5	2304.63	increased	6.91	Very high	Has not changed
Sulphates (SO_4), mg/kg	331.683	14160.5	3788.89	increased	1042.3	-	can be harmful

NDM						
Chlorides (Cl), mg/kg NDM	1177.24	2550.5	1520.56	increased 29.16	-	can be harmful
pH KCl	7.95	7.55	7.85	decreased -1.26	High	has not changed
pH H20	8.75	7.75	8.50	decreased -2.86	High	has not changed
Calcium (Ca), mg/kg DM	16733	51041.5	25310.13	increased 51.26	Very high	increased
Magnesium (Mg), mg/kg DM	2447	8208.5	3887.38	increased 58.86	Very high	increased
Heavy metal contamination					**Limit value (LV)[1]**	**LV part**
Cadmium (Cd), mg/kg DM	0.28	0.835	0.42	increased 49.55	2.00	0.21
Lead (Pb), mg/kg DM	23	23.55	23.14	increased 0.60	120.00	0.19
Mercury (Hg), mg/kg DM	0.001	0.025	0.01	increased	1.00	0.01
[1]Chrome (Cr), mg/kg DM	6.03	32.9	12.75	increased 111.40	[1]- 70 (Staugaitis et al.. 2016)	[1]- 0.18
Zinc (Zn), mg/kg DM	198	810	351.00	increased 77.27	800.00	0.44
Copper (Cu), mg/kg DM	29.1	190	69.33	increased 138.23	300.00	0.23
Nickel (Ni), mg/kg DM	4.29	19.45	8.08	increased 88.34	50.00	0.16
Contamination by organic pollution						
PCBs, mg/kg DM	0.005	0.031	0.01	increased 130.00	0.20	0.06
PAHs, mg/kg DM	1.35	3.455	1.88	increased 38.98	6.00	0.31

[1] Note: Restricted only to Cr (VI) - ≤2 mg/kg DM, which was not detected in Taurage Green Waste compost and Taurage SF in 2015-2016.



Picture 5.2.1. Taurage Green Waste Composting Site flow chart after the implementation of the 2nd proposal

Conclusion:

- Composting Green Waste and food and kitchen waste of plant origin with mixed sludge fermentation (TSF) from Taurage wastewater treatment plants (3: 1 ratio) would increase the value of the compost produced from low to medium to high and very high according to many quality indicators. It is very important that the value as a fertilizer increases according to the main quality criteria of the fertilizer product, such as OM, total N, P, water-soluble N and P, organic C content. The reduction of certain valuable properties does not reduce the value of the final product according to these indicators.

- In this case, a fertilizer product with the code - D.2.1.1.1 would be produced (soil improver - compost, the production of which contains Green Waste, sludge from domestic sewage treatment plants).

- Concentrations of heavy metals (Cd. Pb, Hg, Cr, Zn, Cu, Ni) in the compost produced will not exceed the limit values for fertilizer products (from 0.01 to 0.44 limit value) due to 25% TSF, no germination seeds, direct sowing of viable weeds, rhizomes; only the amount of other unwanted impurities can be reduced.

- The amount of TSF in the production of Green Waste compost must be reduced to 15% if a "green procurement" tender is used.

- It is advisable to install a roof for the maturation of the primary compost and the storage of the produced Green Waste compost, as this will reduce the environmental impact on the quality of the product produced.

5.3 Composting of Green Waste with municipal food waste, including animal by-products

Food waste - nitrogen-rich composting feedstock; in food waste, in which animal by-products predominate, the C: N ratio does not exceed 10-15: 1, if mainly waste of plant origin, then the C: N ratio increases to 15-20: 1 (Staniškis et al., 2017).

In the event that the project described in Chapter 2 for the implementation of closed composting technology for food waste, including intensive composting with geosynthetic film, is implemented at the Taurage Green Waste Composting Site, the planned building will be able to compost not only food and kitchen waste but also animal by-products products. In this case, Green Waste will play the role of a structural carbon-rich substance (C).

The C:N ratio of Green Waste depends on the origin, for example, less carbon is present in cut grass, unusable fruits and vegetables (10-20:1), more - in tree leaves, hay (30-40: 1), significantly more in tree pruning waste (above 100:1), for example in sawdust - above 300:1 (Staniškis et al., 2017).

In case food and kitchen waste will be biologically treated in the planned new facilities, it is recommended to compost food waste with Green Waste, mixing the raw materials in the following ratio (by weight) (Staugaitis et al., 2016):

- 60% - food waste (and food and kitchen waste of plant and plant origin) (we assume that their C:N ratio will be about 15:1);
- min. 40% - Green Waste (mainly cut grass, tree leaves, hay, etc., with a C:N ratio of 30:1); the amount of Green Waste can be increased to 50%.

The amount of Green Waste must be reduced to approx. 20% (by weight) if shredded wood waste is composted.

Theoretical evaluation of the quality and pollution indicators of the obtained compost, if up to 40% of Green Waste and up to 60% of food and kitchen waste are composted, is presented in *Table 5.3.1*.

Table 5.3.1. Planned quality and pollution indicators for Green Waste compost (FWC) after the implementation of the 3rd proposal: comparative analysis

Quality and contamination criteria	**Taurage Green Waste compost** Median (3)	[1]**FWC** Average (6)	**Taurage Green Waste compost 40%+ FWC 60%**	**Change, %**		**Value of received compost according to Staugaitis et al., 2015, 2016**	**Note on value**
1	2	3	4	5		6	7
Dry matter content, %	51.58	57.56	55.17	increased	6.96	Very high	Has not changed
Dry matter, % DM	24.95	39.05	33.41	increased	33.91	Average	increased from low to average
Total nitrogen (N), %	0.96	2.07	1.63	increased	69.38	High	increased from low to high

Quality and contamination criteria	Taurage Green Waste compost Median (3)	[1]FWC Average (6)	Taurage Green Waste compost 40%+ FWC 60%	Change, %		Value of received compost according to Staugaitis et al., 2015, 2016	Note on value
1	2	3	4	5		6	7
DM							
Total phosphorus (P), % DM	0.41	1.08	0.81	increased	98.05	Very high	increased from moderate to very high
Total potassium (K), % DM	0.78	0.82	0.80	increased	3.08	Low	has not changed
Organic C, % DM	14.06	17.6	16.18	increased	15.11	Average	increased from low to average
Humic acid, % DM	4.88	3.38	3.98	decreased	-18.44	High	has not changed
Fulvic acid, % DM	1.15	0.54	0.78	decreased	-31.83	High	has not changed
Electrical conductivity, mS/cm NDM	0.715	1.93	1.44	increased	101.96	Average	increased from low to average
Water soluble nitrogen; N-NO$_3$+N-NO$_2$), mg/l NDM	138	384.48	285.89	increased	107.17	Very high	increased from average to very high
Water soluble phosphorus (P), mg/kg NDM	49.57	204.2	142.35	increased	187.17	Very high	increased from low to very high
Water soluble potassium (K), mg/kg NDM	2155.67	2170.5	2164.57	increased	0.41	Very high	has not changed
Sulfates (SO$_4$), mg/kg NDM	331.683	1799.33	1212.27	increased	265.49	Very high (>300)	exceeding 1000 mg/kg may cause harm to plants
Chlorides (Cl), mg/kg NDM	1177.24	369.395	692.53	decreased	-41.17	Very high (>300),	Decreased and now <1000 mg/kg
pH $_{KCl}$	7.95	5.13	6.26	decreased	-21.28	Average	decreased from high to average
pH $_{H20}$	8.75	7.48	7.99	decreased	-8.71	Average	decreased from high to average
Heavy metal contamination						**Limit value (LV)[1]**	**LV part**
Cadmium (Cd), mg/kg DM	0.28	1.097	0.77	increased	175.07	2.00	0.39
Lead (Pb), mg/kg DM	23	25.17	24.30	increased	5.66	120.00	0.20
Mercury (Hg), mg/kg DM	0.001	0.01	0.01	increased	540.00	1.00	0.01
[1]Chrome (Cr), mg/kg DM	6.03	21.05	15.04	increased	149.45	[1]- 70 (Staugaitis et al.. 2016)	0.21
Zinc (Zn), mg/kg DM	198	350	289.20	increased	46.06	800.00	0.36
Copper (Cu), mg/kg DM	29.1	56.05	45.27	increased	55.57	300.00	0.15
Nickel (Ni), mg/kg DM	4.29	11.03	8.33	increased	94.27	50.00	0.17
Contamination by organic pollution							
PCBs, mg/kg DM	0.005	0.007	0.01	increased	24.00	0.20	0.03
PAHs, mg/kg DM	1.35	2.261	1.90	increased	40.49	6.00	0.32

Note: information sources (Staugaitis et al., 2016; Stunžėnas et al., 2021)

Conclusions:

- In the event that the planned food and kitchen waste treatment project is implemented and composting of food and kitchen waste of not only vegetable but also animal origin is started, Green Waste will be technologically necessary for the optimal composting process.

- If cut grass, tree leaves, hay predominate among Green Waste, the mixing ratio of this waste is recommended: min 40 percent Green Waste + 60 percent food and kitchen waste.

- If tree pruning waste (wood waste) predominates among Green Waste, a mixing ratio is recommended: up to 20% Green Waste + 80% food and kitchen waste.

- In this case, a product with the code D.2.1.1.1 would be produced (soil improver - compost, the production raw materials of which contain food waste and Green Waste).

- The compost produced will have a very high and high value in terms of total N, P, water-soluble N, F, K, humic and fulvic acids, average value in terms of organic matter, organic C, pH and electrical conductivity.

- Taurage Green Waste compost is characterized by high levels of chlorides (Cl) and sulphates (SO4); co-composting of Green Waste and food and kitchen waste will reduce chloride (Cl) content (<1000 mg / kg) but increase sulphate (SO4) levels, so recommendations for composting should suggest that fertilization plans set standards not only for total nitrogen (N) and total phosphorus (P) or P2O5 but also sulphate (SO4).

- Concentrations of heavy metals (Cd. Pb, Hg, Cr, Zn, Cu, Ni) in the compost produced will not exceed the limit values for fertilizer products (limit value from 0.01 to 0.39), further reducing the likelihood that such compost may the emergence of seedlings of germinating plant seeds, t. sd. viable weeds; only the amount of other unwanted natural impurities can be reduced; special attention must be paid to plastic and glass impurities that may be present in the food waste stream (due to packaging).

5.4 Maturation of the produced primary Green Waste compost together with the primary compost from food waste

The resulting primary waste compost can be used as a Green Waste compost improver, especially if it is made from food waste collected from cafes (catering establishments).

In the case of this alternative, it is proposed to co-mature the produced primary Green Waste compost and primary food waste compost, for example, Green Waste compost - up to 70-75 percent + FWC - up to 25-30 (Stunžėnas et al., 2021). This would increase the value of the product as a fertilizer according to many quality criteria: from existing low and average to average and high and very high.

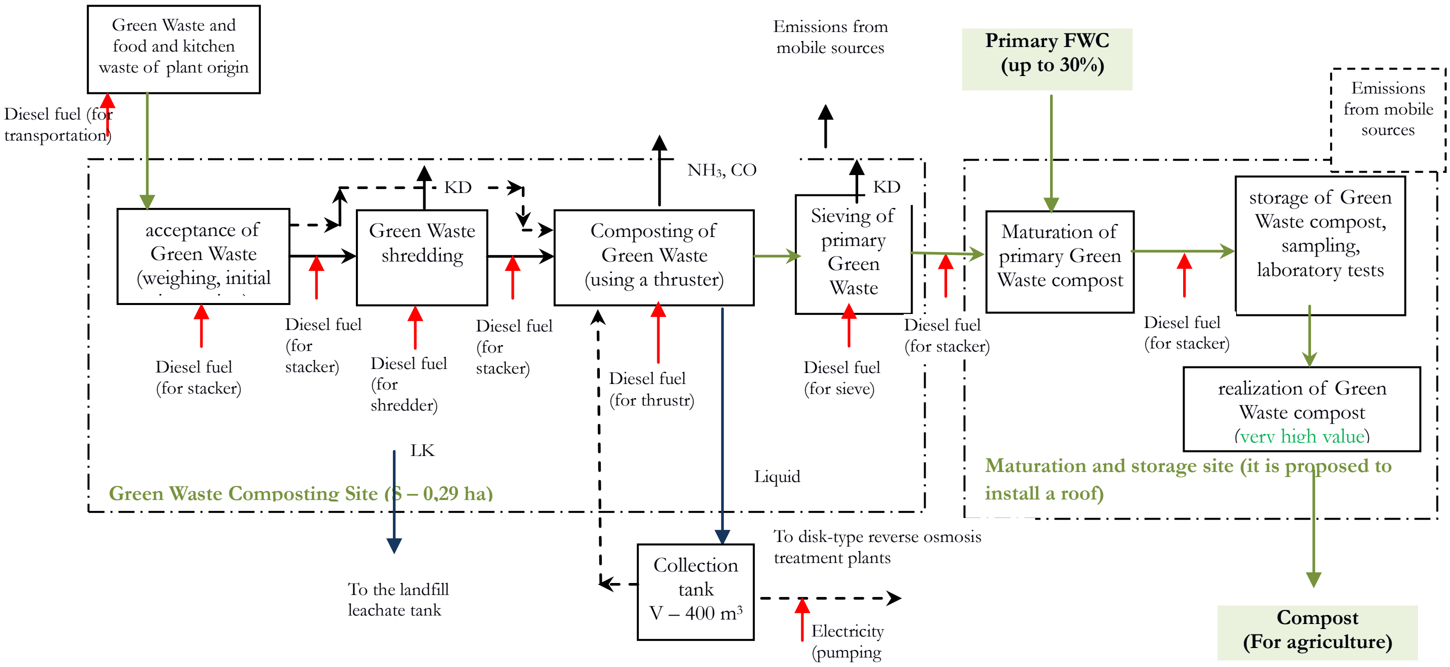
As a very valuable compost would be produced in this case, as in Alternative 2, it is proposed to install a shed for the maturation and storage of the produced compost, thus reducing the leaching of nutrients during the rainy season.

Table 5.4.1. Quality and pollution indicators of Green Waste compost are planned after the implementation of proposal 4: comparative analysis

Quality and contamination criteria	**Taurage Green Waste compost** median (3)	[1]**FWC** Average (3)	**Taurage Green Waste compost 70%+ FWC 30%**	**Change, %**		**Value of received compost according to Staugaitis et al., 2015, 2016**	**A note on value**
1	2	3	4	5		6	7
Dry matter content, %	51.58	57.56	53.37	increased	3.48	Very high	has not changed
Organic matter, % SM	24.95	88.15	43.91	increased	75.99	High	increased from low to high
Total nitrogen (N), % DM	0.96	2.04	1.28	increased	33.65	Average	increased from low to average
Total phosphorus (P), % DM	0.41	0.53	0.45	increased	8.54	Average	increased from average to average
Total potassium (K), % DM	0.78	1.24	0.92	increased	17.69	Low	has not changed
Electrical conductivity, mS/cm NDM	0.715	5.56	2.17	increased	203.29	Very high	increased from low to very high
Water soluble nitrogen; $N\text{-}NO_3+N\text{-}NO_2$), mg/kg NDM	138	1031.67	406.10	increased	194.28	Very high	increased from average to very high
Water soluble phosphorus (P), mg/kg NDM	49.57	5612	1718.30	increased	3366.41	Very high	increased from low to very high
Water soluble potassium (K), mg/kg NDM	2155.67	2170.5	2160.12	increased	0.21	Very high	has not changed
Sulphates (SO_4), mg/kg NDM	331.683	1298.67	621.78	increased	87.46	Very high (>300)	may harm

Chlorides (Cl), mg/kg NDM	1177.24	8730.67	3443.27	increased	192.49	Very high (>300), but in excess of 1000 mg / kg may cause harm to plants	increased
pH KCl	7.95	5.6	7.25	decreased	-8.87	Average	decreased from high to average

Note: Source of information (Stunžėnas et al., 2021)



Picture 5.4.1. Taurages Green Waste Composting Site flow chart after the implementation of the 4th proposal

Conclusions:

- In case the planned food and kitchen waste treatment project is implemented and composting of food and kitchen waste not only of vegetable but also animal origin is started, it is proposed to compost animal by-products of cafes (catering establishments) in a separate heap and thus produce high value compost, for agriculture.

- In this case, direct the proposed part of the produced primary FWC (as compost-enhanced) to maturation together with the primary Green Waste (mixing ratio by weight: 70% Green Waste compost + 30% FWC).

- The implementation of this proposal would lead to the production of a product with the code D.2.1.1.1 (soil improver - compost, the raw materials for the production of which contain food waste and Green Waste).

- The compost produced will have a very high value in terms of water-soluble N, P, K, humic and fulvic acids, sulphate content, electrical conductivity, high OM content, average N and P value, pH.

- The guidelines for such composting produced should propose to set fertilizer plans not only for total nitrogen (N) and total phosphorus (P), P2O5 but also for chlorides (Cl), as their concentration is> 1000 mg/kg NDM.

- It is advisable to install a roof on the site for the maturation of the primary compost and the storage of the produced Green Waste compost; this would reduce the environmental impact of the quality of the compost produced (no leaching of nutrients).

6. Mixing possibilities of Green Waste and food / kitchen waste for compost production. Recommendations for the production process

(See Chapter 5.3, in which proposal 3 is analysed).

7. Advertising measures to ensure the demand for compost and its smooth realization

Demand for compost and smooth realization are possible only if the value of compost as a fertilizer is increased. Compost currently produced, although meeting the requirements for Green Waste compost [1], is of very little or no value in terms of many quality indicators (Staugaitis et al., 2016). Nevertheless, Taurage Green Waste compost is more valuable in terms of quality compared to other Green Waste compost produced in Lithuania. For example, the amount of organic matter that varies from 23 to 26 percent DM, while Green Waste compost is usually ≤20 percent DM. This compost is also valuable in terms of humic and fulvic acids, which is highly valued by farmers. The main reason is that not only Green Waste but also food and kitchen waste of plant origin is already being composted at the Taurage Green Waste Composting Site.

Tips, including promotional materials, for the smooth realization of compost:

- Write a product standard, taking into account the requirements [1], which provides for periodic determination of value (recommended periodicity for each batch produced, i.e. up to 4-5 tests per year) and comparison with the value indicators given in *Table 1.2* of this study.

- Compost made from Green Waste (product identification No. D.2.1.1.2 according to [1]) for sale with a description in [1]promotional material, the description must include information:

  - on the main quality criteria for marketed Green Waste compost that are valuable (starting from the average value), indicating their concentrations (e.g. OM content ≥25% DM, total content of essential nutrients (N + P2O5 + K2O) - ≥2.5 percent DM (for Taurage Green Waste compost - 2.7 to 4.1 times higher), organic carbon content - ≥7 percent DM (for Taurage Green Waste compost - 2 times higher);

  - on additional quality criteria discussed in this study, such as water-soluble N, P and K, which are more readily available to plants, as well as humic and fulvic acid content, trace elements required by plants and characterized by Taurage Green Waste compost (zinc (Zn), iron (Fe), manganese (Mn), copper (Cu));

  - on pollution parameters that do not exceed the LV according to [1], which makes compost for Green Waste also valuable,

  - with recommendations for fertilization or with prepared fertilization plans in which it is advisable to specify restrictions not only for total N (≤170 kg/ha/year) and total P (≤40 kg/ha/year) or phosphorus (V) oxide (P2O5) (≤ 90 kg/ha/year), but also for chlorides (C_l) and sulphates (SO_4).

[2]For example, if the total nitrogen concentration in Green Waste compost is 0.96% DM, the DM content is 51.58%, then the compost fertilization rate by nitrogen is 34.34 t/ha or 3.344 kg/m^2.

[2]For example, if the total P concentration of Green Waste compost is 0.41% DM, the DM content is 51.58%, then the compost fertilization rate by nitrogen is 18.91 t/ha or 1.891 kg/m^2.

[2]Estimated compost fertilization rate based on chlorides (C_l) at a concentration of 1177.24 mg/kg NDM: 13.17 t/ha or 1.317 mg/m^2

[2] Estimated fertilization rate of compost based on sulphates (SO_4) with a concentration of 331.683 mg/kg NDM: 56.75 t/ha or 5.675 mg/m^2

It is concluded that Taurage Green Waste compost, which is currently produced, must be regulated according to chlorides, i.e. the fertilization rate is up to 13.17 t/ha.

- Pay special attention to the pH of the compost produced (especially if the Green Waste is composted together with food waste, which can lower the pH). Although alkaline compost has a higher value due to soil acidification, there are plants with optimal yields in very, moderately and low acid soils (See *Table 7.1*).

Table 7.1. Plants with high, average and low acidity soils are used to achieve optimal yields

(Mačiukas, A. Soil acidity. AgroZinios.lt)

Optimal pH for the crop	Examples of plants
3.5 – 4.5	cranberries, blueberries
4 – 4.5	rhododendrons, vetches, heather, azaleas, heath, hydrangeas, orchids, daisies
4 – 6.5	Canadian pine, mountain pine, western redcedar, carp birch, mahogany, blizzard, silver bush
4.5-5.5	flax, myrtle, ferns, cyclamen, primrose, bromeliads, camellias, fuchsia, anthers, ferns
5-6	barley, oats, lilies, calathea, sorrel
5.5 - 6	winter rye, stevia
5.5 – 6.5	Potatoes, corn, lily of the valley, most houseplants: cyclamen, geraniums, abutilon, asparagus, begonia, calceolaria, primrose, sipiderwort, ficus
5.5 - 7	carrots, parsley, celery, radish

- Communicate the importance of organic matter, humic and fulvic acids in agriculture. These substances are not included in the composition of inorganic fertilizers, they can be obtained mainly only with compost (although humic and fulvic acids can also be obtained as bio-fertilizers).
- Include in the compost microorganisms (plant growth-promoting bacteria, microbiological preparations (see Chapter 5.1) that improve the uptake of nitrogen and phosphorus and communicate this extensively in an advertising company.
- Communicate articles that state that compost reduces the amount of artificial fertilizer. For example, after enriching 300 kg/ha of compost with 88 kg/ha of artificial nitrogen fertilizers and Pseudomonas fluorescens, the maize yield was the same as using twice the amount of inorganic nitrogen fertilizers (175 kg/ha) (Ahmad et al., 2008).
https://www.tandfonline.com/doi/abs/10.1300/J064v31n04_05
- Communicate scientific articles that substantiate the benefits of compost. As an example, the intensive use of compost and the addition of organic matter to the soil can reduce the fuel consumption of agricultural machinery by up to 25%. Using compost at a lower intensity can reduce fuel consumption by a significant 14% (Peltre et al., 2015).
- To recommend to municipalities and other contracting authorities in the Taurage region to carry out green procurement for compost and to apply the environmental protection criteria established for soil improvers approved by Order No. D1-508 of the Minister of Environment of the Republic of Lithuania of 28 June 2017 Order No. D1-672), as amended.

[1] Advertising media available:

– booklets,
– calendar (in which the pictures must be linked to the production and use of this compost),
– TV and radio advertising,
– Packaging (especially when high and very high value compost is produced)

[2] Explanation of fertilization rates:
The formulas used to estimate the fertilization rate are (Staugaitis et al., 2016):

$$M_{K/NDM} = (DM \times M)/10, \quad [7.1]$$

here

$M_{K/NDM}$ – content (K) of nutrients (nitrogen or phosphorus) per tonne of natural moisture (NDM), kg/t;

DM – dry matter content of compost, %;
M – nutrient content of compost DM, %;

For example, in the case of nitrogen:

$M_{K/NDM} = 51{,}58 \times 0{,}96 \,/\, 10 = 4{,}95$ *kg/t NDM*

$$K_{M/NDM} = LV/M_{K/NDM} \quad [7.2]$$

here

$K_{M/NDM}$ - maximum fertilization rate of compost according to the nutrient to be analysed, t/ha;
LV – limit value for the incorporation of nutrients into the soil, kg/ha;

$M_{K/NDM}$ - the amount of nutrient (nitrogen or phosphorus) per tonne in the compost, kg/t NDM.

For example, in the case of nitrogen:

$N_{M/NDM}$ = 170 kg/ha / 4,95 kg/t =34,34 t/ha

$P_{M/NDM}$ = 40 kg/ha / 2,115 kg/t =18,91 t/ha

$SO_{4\ K/NDM}$ = 18,84 t/ha / 0,332 kg/t NDM = 56,75 t/ha, or 5,675 kg/m²;

$Cl_{K/NDM}$ = 15,50 t/ha / 1,177 kg/t NDM = 13,17 t/ha, or 1,317 kg/m².

8. Recommendations for home composting, proposal of incentives

It is recommended to maintain appropriate composting parameters and to strive to increase the value of the compost produced as a fertilizer. Some tips are given in *Table 8.1.*

Table 8.1. Tips for home composting

Target indicator	Advices
The moisture content of the composting process depends on the moisture content of the waste and the compost bin (open or closed). Optimal humidity - 50-60 %.	When Green Waste is not sufficiently moist, it must be irrigated, for example by spraying. Special garden sprayers or watering equipment can be used for this purpose, thus simulating rain (it is not advisable to take water directly from the bucket or from the watering hose). When biodegradable waste is wet, it must be mixed with dry biodegradable waste, such as felling waste, food of plant origin and kitchen waste. Therefore, logging waste (or a multi-chamber compost bin should be selected for composting) near the Composting Site.
Optimal C:N ratio: 20-30:1	Prior to composting, the waste must be mixed according to the nitrogen and carbon content, e.g. when composting green food waste or green garden waste rich in nitrogen (compared to other Green Waste), it is mixed with tree leaves, hay, straw, waste from wood, paper and cardboard rich in carbon.
Size of the fraction of biodegradable waste to be composted. Structural materials must be added (>40 mm)	Green Waste must be shredded before composting, e.g. by cutting, grinding, chopping, etc. In this case, their surface area increases and the nutrients they contain become more readily available to biodegradable waste decomposers. In order to prevent the onset of an anaerobic process, small amounts of structural material, such as logging waste, hay, etc., must be added (>40 mm)
size of biodegradable waste heap (non-composter composting)	The height of the heap will depend on the Green Waste, its moisture content, the degree of shredding, and the initial density. Optimal - up to 1.5 m. At a higher heap height, an anaerobic process begins (no air enters the lower layers), at a lower heap height, the thermophilic process may not start and the correct temperature will not be reached.
pH (evaluation pH>7)	Compost Green Waste and food and kitchen waste of plant origin, compost pH is usually alkaline (>8). Compost Green Waste and food and kitchen waste of plant origin, compost pH is usually alkaline.
OM content in the produced compost	In order to increase the amount of OM when composting Green Waste, it is worth noting about the food and kitchen waste of plant origin that is generated in the household; wood sawdust can also be added (increased organic carbon). Recommended for increasing OM: • [1] use of microbiological preparations by dilution with water and spraying (particularly effective during summer and/or • [2] to add dried sludge fermentation (SF) produced in sewage treatment plants in small quantities (up to 10-15% by volume);
Increasing the concentration of nutrients in the compost produced	Generally, home-made Green Waste compost does not have a high content of total N, P or K, but is characterized by a sufficiently high content of water-soluble N, P, K, i.e. although these nutrients are not abundant, they are all easily assimilated by plants. The use of 1 microbiological preparations and/or [2]SFs is also recommended to increase nutrient concentrations.
Duration of composting in Lithuania	From April to November. The compost produced is better to use next spring.

[1] Recommendation for the use of a microbiological preparation (eg probiotic substances (see Annex 4)):
For 1 household - up to 1 l of probiotic substances per season (up to 15 EUR), diluted with water (e.g. 1 stopper of 10 l of water).
Results of practical research (See *Table 5.1.1*):

- The amount of OM increases above 40 %;
- The total N content increases above 50% (less NH3 is formed, more N remains in the compost);
- The total P also increases 3 times and the total K increases two times;
- Water-soluble N and P increase more than 2 times,
- Water-soluble K increases by more than 3 times;
- Other advantages: no flies, the risk of odours is eliminated, and the compost produced is not contaminated with microbiological contamination.

[2]Recommendation on the use of dried sewage sludge: up to 10-15% by volume when mixed with compostable Green Waste. It should be noted that the sludge produced by Taurage sewage treatment plant already meets the requirements for a fertilizer product under [1] (see *Table 5.2.1*), i.e. heavy metal contamination, organic pollution, microbiological contamination do not exceed the limit values for compost (yeast) containing wastewater sludge. For example, the content of heavy metals does not exceed 50% of the limit value (LV). Mixing dried yeast with Green Waste and composting it will further reduce the concentration of heavy metals. However, the amount and concentration of OM in the total N and P will increase (OM - over 30 percent, N - 1.9 times, P - 2.5 times).

Recommended measures to encourage home composting:

- Free distribution of home composting containers/boxes (if there is a demand among the population: to purchase part of the funds for the collection of food and kitchen waste, indicating that food waste of plant origin will also be composted among the Green Waste);
- Free distribution of dried yeast from Taurage wastewater treatment plants (with the results of laboratory tests already performed periodically);
- Announce competitions - who is better at composting (possible prizes: new composting box; probiotics; free setting of basic compost parameters);
- Take interviews from people who successfully compost, which means that they make a real contribution to the realization of the Circular Economy in the country and to the reduction of climate change (due to the reduction of greenhouse gases);
- Evaluate the possibility of applying a lower variable part of the local fee to those residential facilities that compost bio-waste at home and do not provide a separate collection service for Green Waste and food waste.
- Other (See Chapter 7).

9. Indicators of severe quality and contamination of compost at the Taurage Green Waste Composting Site

The burden of composting is a by-product that is identified as problematic in the scientific literature. As the number of composting plants increases, the size of this flow becomes just as significant. The scientific literature states that composting of the organic fraction of mixed municipal waste generates between 75 and 100 litres of leachate, while composting of Green Waste between 5 and 50 litres, and sewage sludge generates about 100 litres of leachate from biodegradable waste (Roy et al. 2018). Academics note that there is a lack of efficient technologies for the treatment of leachate from composting (Roy et al., 2018).

The compost currently formed is collected in a 400 m³ tank near the site and sent to a disk-type reverse osmosis unit for treatment. If necessary, for example, in the warm season part of the heavy is used in the composting process (irrigation).

On average, heavy loads are 500-600 m³ per year (see *Table 3.1*). The resulting compost is collected in a 400 m³ tank near the site and sent for cleaning. If necessary, for example, in the warm season, part of the heavy is used in the composting process (irrigation).

Table 9.1. Liquid at the Taurage Green Waste Composting Site

Tested sewage parameters	**Liquid at Taurage Green Waste Composting Site**	**Limit value according to the Wastewater Management Regulation (WMR)**			**Note**
1	**2**	**3** Into the natural environment	**4** Into wastewater networks	**5** *** LV into the sewer	**6**
pH	7.0	6.5-8.5	6.5-9.5		Wastewater according to pH is suitable for discharge into the natural environment
Suspended matter, mg/l	424	50	-		Do not discharge into the environment without cleaning
BDS_7, mg O_2/l	488	40 (instantaneous)	800		Does not exceed the limit value to the sewer according to WMR (Table 3); cannot be released into the natural environment without cleaning
Bichromatic oxidation (ChDs), mg O_2/l	1236	125			Not regulated, releasing (<5 m³/d.)
ChDs/ BDS_7	2.53		<3		Sewage is non-toxic according to WMR Table 3 reference 3
Oil Products, mg/l	0.83	5	25	5	Does not exceed the limit value for the natural environment according to Annex 2 of the WMR (B, B1)
Dry residue, mg/l	4102				*not regulated
Total nitrogen (N), mg/l	270		100	50	Exceeds limit value for sewer
Kjeldahl nitrogen (NK), mg/l	269				*not regulated
Nitrogen nitrate ($N\text{-}NO_2$) + nitrate ($N\text{-}NO_3$), mg/l	270				
Total phosphorus (P), mg/l	26		20	10	Exceeds limit value for sewer
Potassium (K), mg/l					*not regulated
Specific electrical conductivity, µS/cm	4290				
Organic matter,%	37				
Sulphates (SO_4), mg/l	47	300	1000	300	Does not exceed the limit value for sewage according to Annex 2 of WMR (B; B2)
Chlorides (Cl), mg/l	284	1000	2000	1000	
Cd, mg/l	0.001	0.04	0.1	-	Does not exceed the limit value to the natural environment in accordance with Annex 1 of the WMR
Pb, mg/l	0.005	0.1	0.5	0.1	Does not exceed the limit value for the natural environment according to Annex 2 of the WMR (A)
Ni, mg/l	0.039	0.2	0.5	0.1	
Cr, mg/l	<0.02**	0.5	2	0.4	Does not exceed the limit value for the natural environment according to Annex 2 of the WMR (B; B1)
Cu, mg/l	0.06	0.5	2	0.4	
Zn, mg/l	0.73	0.4	3	0.6	Does not exceed the limit value for sewage according to Annex 2 of the WMR (B; B1)
Fe, mg/l	6.58				*not regulated
Mn, mg/l	1.30				
Ca, mg/l	231				
Mg, mg/l	74.6				

* Not regulated but tested for evaluation of alternatives to industrial symbiosis

** Less setting limits

***Compared to the limit value to the landfill for the purpose of assessing the possibility of transferring waste water to a landfill operated by other persons (in accordance with point 33[1] of Chapter V of the WMR).

The study of the main parameters of contamination was performed in the Agrochemical Research Laboratory of the Agricultural Institute of the Lithuanian Centre of Agrarian and Forest Sciences (LAMMC). The study protocols are presented in *Annex 2* and are summarized in *Table 9.1* in comparison with the requirements of the Wastewater Management Regulation [8].

Studies of severe composting quality in an accredited laboratory and a comparison of the values obtained with the maximum allowable concentrations (MAC) and limit values (LV) of the Wastewater Management Regulation (WMR) have shown that there is no specific contamination that could reduce its potential use. According to the Wastewater Management Regulation, this wastewater would be classified as industrial wastewater because the zinc concentration (0.76 mg Zn/l), according to Annex 2, List B1 of the Regulation, exceeds the maximum permissible concentration to the natural environment of 0.4 mg/l. Also, the concentrations of total nitrogen (270 mg/l) and total phosphorus (26 mg/l) in Annex 2, List B2, exceed the maximum permissible concentrations in the sewage collection system. Although the heavy biochemical oxygen demand over 7 days was 488 mg O2/l, this value is likely to exceed 500 mg/l on hot summer days, and above 500 mg O2/l, wastewater is also classified as industrial. Although heavy would be classified as industrial effluent, difficult quality requirements would meet the MWR. For example, industrial effluents are required to have a pH in the range of 6.5-9.5, ChDS/BDS7 ratio of no more than 3 and a BDS7 value of up to 800 mg O2/l.

According to the study on the heavy quality of composting, possible alternatives for the management of heavy compost are evaluated. Technical proposals, their advantages and disadvantages are presented in *Table 9.2*.

Table 9.2. Technical offers for the recovery or management of liquid at the Taurage Green Waste Composting Site: advantages and disadvantages

Technical proposal	Advantages/disadvantages
1	2
Liquid cleaning in a disc-type reverse osmosis unit	Advantages: • A high degree of purification is achieved; • Existing landfill infrastructure is used. Disadvantages: • The purification of liquid of composting in a disk-type reverse osmosis unit results in a concentrated stream that is returned to the landfill. The total amount of filtrate in the landfill and treatment plant system is increasing; • Such a return further degrades the quality of the landfill leachate. Increased filtrate conductivity in the plant may require a reduction in water recovery in the future (Nowak and Włodarczyk-Makuła, 2020). • Nutrients such as nitrogen phosphorus are immobilized. • Cleaning in a disc-type reverse osmosis unit with relatively uncontaminated streams such as liquid of composting is not economically viable.
The use of composting liquid as a substrate for the production of bacterial species Bacillus. These species are considered to promote plant growth when used in combination with fertilizers (Badillo et al., 2019)	Advantages: • Composting liquid is a potential source of carbon for microorganisms; • Reduces the cost of cultivation of microorganisms (due to cheaper raw material); • High density of *Bacillus megaterium* and *Bacillus subtilis* cells is achieved by mixing the diluted composting grit with the yeast used and fermenting. Also, as many as 98% of vegetating *Bacillus subtilis* cells formed spores when *Bacillus megaterium* reached 95%. Spore formation is very important in the production of fertilizer mixtures with microbiological preparations. • High density of *Bacillus megaterium* and *Bacillus subtilis* cells is also achieved by mixing the diluted composting liquid with whey permeate and fermenting. Meanwhile, spore formation was 90% for *Bacillus megaterium* and 89% for *Bacillus subtilis*.

Technical proposal	Advantages/disadvantages
1	**2**
	• The creation of a microbiological manufacturer could lead to an Industrial Symbiosis between a Composting Site, a probiotic manufacturer and a brewery or dairy. Disadvantages: • Microorganisms grow better in the dilute filtrate than in the undiluted filtrate; • During the fermentation, in the cell density study, the worst results were observed in the case of the dilute filtrate, using a separate mixture of nutrients, diluted filtrate, diluted filtrate mixture with 3% brewer's yeast and diluted filtrate mixture with 23% whey permeate; **Conclusion:** It is technically feasible to have a microbiological plant in the region, as a milk processing plant already exists.
Use of liquid for plant fertilization [6].	Advantages: • Both water and nutrients in the water are used; • The alternative does not require investments; Disadvantages: • The Green Waste liquid must be diluted 100 to 500 times; • A quality test should be performed on each batch of liquid to allow farmers to self-assess the dilution; • The degree of dilution should always be assessed according to the fertilized plant; • Compost liquid can only partially replace liquid fertilizer (liquid); • The undiluted liquid is phytotoxic to plants due to its high salinity, ammonia, and low molecular weight organic compounds (Sanadi et al., 2019); • In some cases, the fluid needs to be treated to reduce COD and raise the pH; • The substances in the system and their concentrations are highly variable parameters that depend on the biodegradable waste and the age of the compost; **Conclusion:** technically feasible, but requires strict quality control, recommendations on how to use the liquid, advertising companies to engage users.
Production of biogas from liquid	It is not technically feasible as ChDS concentrations should be any 20 times higher. Even in this case, the biogas produced would only be enough to raise the effluent temperature from 20 °C to mesophilic (35 °C) (University of Florida, 2021).
Transmission of liquid to Taurage city wastewater treatment networks	Advantages: • Existing wastewater treatment infrastructure is used; • No need to build additional wastewater treatment plants in the already limited area of the Green Waste Composting Site; • No liquid cleaning required in a disk-type reverse osmosis unit that is expensive to operate; Disadvantages: • The Green Waste Composting Site and the city's wastewater treatment plant are far enough apart. This can lead to high transportation costs. • The city's wastewater treatment plants are operating at almost twice the capacity planned. The additional wastewater treatment plant cannot accept it now. **Conclusion:** Technically feasible, but only when additional capacity for urban wastewater treatment plants is developed.

Technical proposal	Advantages/disadvantages
1	2
Installation of a biological wastewater treatment plant	Advantages: • The composting liquid is cleaned in a cheaper way than with a disk-type reverse osmosis unit; • Substances in the liquid accumulate in the sludge, where they can reverse the composting of Green Waste; • Directing sludge to composting Green Waste would enrich the compost with nitrogen, phosphorus, potassium; • Wastewater treatment plants are installed underground, so there is no need to designate a special area for them; • Domestic wastewater could be diverted to the plant, thus increasing the amount of sludge generated; Disadvantage: • Additionally, probiotics may be needed to control pathogens; • Additional infrastructure investments. **Conclusion:** Technically feasible with good integration into existing infrastructure (due to further use of sludge in composting).

The analysis of the possibilities for the management of composting liquid at the Taurage Green Waste Composting Site leads to the conclusion that the treatment of the liquid in the biological treatment plant is the easiest alternative to date, so this solution is analysed in detail.

Although the alternative of biological treatment is easy to implement, it is also financially viable compared to treatment in a disk-type reverse osmosis unit. Due to the expensive operation of a disk-type reverse osmosis unit (equipment manufacturer RoChem estimates that it costs € 0.00883 to produce 1 litre of permeate (Cook, 1998)), the installation of a biological treatment plant would save the company € 3.856 per year (see Table 9.3).

Due to the relatively high contamination of the filtrate with total nitrogen (270 mg/l) and phosphorus (26 mg/l), biological treatment plants with a higher degree of purification are selected, for example, August's cleaning equipment meet the required specifications. The combined nitrogen and phosphorus removal efficiencies of these equipment are 93.2% and 93.3%, respectively. The use of such equipment would allow the requirements of the Wastewater Management Regulation to be met for total nitrogen (instantaneous MAC <25 mg/l) and phosphorus (instantaneous MAC <5 mg/l).

As 600 m^3 of liquid is generated per year (1.64 m^3/d), the 1.8 m^3/d August AT15 equipment is selected (August, 2021). The price of such equipment would be about 3400.00 EUR, and the installation works would cost about 450.00 EUR. The total investment in the project would be 3850.00 EUR. As the savings from the introduction of the alternative would amount to 3856.00 EUR per year, the investment would pay for itself within one year.

Table 9.3. Results of the environmental and economic evaluation of the biological liquid cleaning alternative.

Flows at process (equipment) input and output, flow dimension	Costs before project implementation			Costs after project implementation			+ Savings (decrease) - Increase	
	Pcs./a year	EUR/pcs.	EUR/a year	Pcs./a year	EUR/pcs.	EUR/a year	Pcs./a year	EUR/a year
1	2	3	4	6	7	8	10	11
DTRO operating price, m^3 permeate	450	8.83	3973.50	0	0	0	450	3973.50
DTRO concentrate for landfill, m^3	200	0	0	0	0	0	200	
Electric power, kWh	0	0	0	803	0.146	117.2	-803	-117.2
Wastewater sludge 5%, t	0	0	0	14.8	0	0	-14.8	0
Total N back to composting, kg	0	0	0	151	0	0	+151	0
Total phosphorus back to composting,	0	0	0	14.6	0	0	+14.6	

Flows at process (equipment) input and output, flow dimension	Costs before project implementation			Costs after project implementation			+ Savings (decrease) - Increase	
	Pcs./a year	EUR/pcs.	EUR/a year	Pcs./a year	EUR/pcs.	EUR/a year	Pcs./a year	EUR/a year
1	2	3	4	6	7	8	10	11
kg								
							Total:	**3856.30**

One of the biggest advantages of using the entire wastewater stream is that the water returns to the natural cycle, and organic and nutrients are used to compost and increase the value of the compost. Although recoveries of nitrogen (151 kg) and phosphorus (14.8 kg) are minimal, it is far better to direct these materials with a disk-type reverse osmosis unit, where they are immobilized in the form of a concentrate in a landfill.

Note: The flow diagram referred to in point 19 of the Integrated Pollution Prevention and Control Permit No. 179901854 shows that surface effluents from a certain area, such as Composting Sites (0.26 ha), are also diverted to leachate treatment facilities [10]. This generates an additional wastewater flow of 1502.8 m^3/a year, which could be mixed primarily with composting heavy and diverted to biological wastewater treatment only after mixing. In this way, the liquid contamination of compost would be diluted and less efficient wastewater treatment plants could be chosen, which would also be cheaper.