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MUNICIPAL WASTE DISPOSAL IN ENERGETIC PILES IN SWECO TECHNOLOGY - SEVEN YEARS OF OPERATION AND WHAT NOW?

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UNIESZKODLIWIANIE ODPADÓW KOMUNALNYCH W PRYZMACH ENERGETYCZNYCH WEDŁUG TECHNOLOGII SWECO - SIEDEM LAT EKSPLOATACJI I CO DALEJ?

Wykonano badania pryzm energetycznych na składowisku odpadów w Zakurzewie koło Grudziądza. Badania pozwoliły odpowiedzieć na następujące pytania: czy warto jest rozkopywać pryzmy, jakie rodzaje materiałów mogą być odzyskane po rozkopaniu pryzm, jakie procesy zachodzą obecnie w pryzmach? Stwierdzono, że tworzywa, frakcja mineralna odpadów oraz frakcja przesiewowa o uziarnieniu < 10 mm stanowiły około 75-90% całkowitej masy odpadów zdeponowanych w pryzmach. Z tego względu te grupy odpadów powinny być wyselekcjonowane z masy odpadów w pryzmach. Drobne frakcje - I frakcja odpadów (o średnicy uziarnienia < 10 mm) oraz II frakcja o średnicy pomiędzy 10-40 mm stanowiły znaczący udział 50-93% całkowitej masy odpadów w pryzmach. Zawartość materii organicznej w suchej masie frakcji I była wysoka, w zakresie od 71,6 do 86,8% s.m. Frakcja ta, może być wykorzystana na składowisku jako warstwa biologiczna, nie powinna być jednak traktowana jako materiał obojętny ze względu na wysoką koncentracje zanieczyszczeń w wyciągu wodnym. Ze względu na niski procent zmniejszenia materii organicznej w pryzmach W1 - W6 dalsza fermentacja z pozyskiem biogazu jest wskazana. W celu poprawy struktury odpadów oraz zmniejszenia emisji odorów z odpadów, po rozkopaniu, a przed sortowaniem odpadów zaleca się ich suszenie.

Summary

The investigations of energetic piles on the landfill in Zakurzewo near Grudziądz were done. The study provided answers to the following questions: I - are the piles worth digging up, II - what kind of material may be recovered after that, and III - what kind of process dominates currently in piles? It has been found out that plastic, mineral fraction and fraction of waste with the particles at the diameter below 10 mm made up about 75-90% of the total mass of waste in piles. Therefore, in the future these groups should be selected from the whole mass. Small fractions - I fraction of waste (with the particles of the diameter below 10 mm) and II fraction (with the particles of the diameter between 10-40 mm) made up significant share (50-93%) of the total mass of waste in piles. Organic matter content in dry mass of I fraction was high ranging from 71.6-86.8% of d.m. This fraction can be used as a biological layer on the landfill, but should not be treated as a neutral waste for the sake of leaching of high pollutants concentration. For the sake of low reduction of organic matter further fermentation of waste from piles W1 - W6 with biogas recovery is advisable. In order to improve structural and odor features of waste, before sorting on the secondary materials, three weeks of air drying is advisable.

INTRODUCTION

Energetic pile technology is a controlled, short-acting fermentation of organic waste in contrary to standard landfill when anaerobic biodegradation takes place, and with 25 to 5 years biogas recovering and landfill leachate recirculation [2]. During 5 years biogas should be recovered with the productivity about 10-folds higher than in the case of traditional municipal landfills. Moreover, during this time about 35-50% of waste should be transformed into biogas. SWECO technology assumed that when biochemical processes and biogas production stop, the content of energetic pile is dug up and sieved, and mineral fraction, stabilized organic one, and secondary materials (plastic, wood, glass, metal, textile) are separated [2]. Mineral fraction and secondary materials should be deposed or stored on the fields without sealing. If the legal requirements are fulfilled these materials can be agriculturally used. Stabilized organic waste may be used on the landfill area as a covering material or on municipal plantations such as parks, and any other areas. Not fully decomposed waste may be again turned back to the new pile or be briquetting and used as a RDF [14]. Decision concerning using of waste may be taken on the basis of analysis of waste quality. Uncovered waste should be sieved in order to achieve soil-similar fraction and morphological groups. Trzosińska and Podkański [14] suggested using municipal waste segregation line. Chmielewski [2] reported that waste, before supplying to the energetic piles, do not have to be selectively collected and sorted, only shredded. The waste should consist of above 50% of organic matter. Wastes are formed in prisms due to planting and compressing to the density of 600-800 kg/m3, as at traditional landfill. The basal of the prism should be sealed. At the bottom of the pile there is a gravity drainage that collects the leachate and transports it to the retention tank. The leachate should be heated up to 40°C and turned back inside the pile in order to succor biochemical biodegradation of waste. It lets obtain optimal conditions for the process: moisture 60-70%, temperature 35-55°C. After filling, the pile is covered by isolation layer - peat and soil. A covering layer should limit air penetration through the waste layer. Inside the pile there are anaerobic conditions in the whole mass of waste. In this technology degassing was expected due to the gas wells (pins) (with the diameter of 60 mm and the length of 6 m) - about 60 units per pile, gas hoses, gas collector, and pumps station. Subatmospheric pressure inside the pile should be maintained at the level of 35-50 mm of water column. It may limit fermentation gas penetration outside, and reduce the harms of the object for the environment. Recovered biogas should be burned and used for heating of the recirculated leachate, and for electricity generation. When the fermentation stops leachate recirculation and gas recovering in piles will stop [14].

Municipal waste disposal technology in energetic piles was used at the landfill in Grudziądz. After seven years of landfill operation, four piles were filled with waste, and closed, however two are still operated. In the oldest piles when technological time of the exploitation (5 years) expired the questions were asked if the piles should be dug up, and waste should be recovered, and what should be done with the separated waste.

The aim of the study was to perform the investigations that help make the decision concerning the energetic piles operation at the landfill in Zakurzewo near Grudziądz. The range of the study involves the following question: I - are the piles worth digging up, II - what kind of material may be recovered after that, and III - what king of process dominates currently in piles.

LOCALIZATION AND LANDFILL CHARACTERIZATION

Municipal landfill is situated in Zakurzewo located on the commune area of Grudziądz, about 15 km towards north from the centre of Grudziądz. The total area of the landfill is 13.5 ha, and over 2.5 ha are reserved for energetic piles [2]. Landfill in Zakurzewo was built in 1997 and it is operated on the basis of the project of SWECO company based on waste disposal in the energetic piles. This was the second landfill in Poland involving waste disposal due to this technology. Designing guidelines were based on the results from the pilotage installation in Sweden (Hagby) [13]. Economic analysis of the investment was based on the assumption of biogas generation and recovery, and selling all kind of recyclable materials (plastic, metal, glass, textiles). Moreover, it was probable to sell part of waste as a fuel [13].

First, four piles (W6, W5, W4, W3) were constructed according to the guidelines of the designer. Prepared basin as a vertical section was a turned down trapezium at a height of 3 m, as a horizontal projection was a rectangle with the measurements of 70 x 38 m. The embankment was formed to the height of 5 m. The basin was sealed by 50-centimeter layer of clay. Predictable capacity of each pile was 20 000 Mg of waste (in practice in piles there were collected wastes whose mass ranged from 19 154 Mg to 23 269 Mg, what made 96-116% of predictable capacity). The piles were filled and closed in the following order: W6, W5, W4, W3. The numerals at the letter W mean the age of pile (years). Piles filled with waste were covered by 20 cm layer of soil, and next irrigating and degassing systems were installed. Piles W1 and W2, currently almost filled, have been working alternately from 2002. The measurements of the piles expanded to 90 x 90 x 10 m. Predictable capacity of each pile was 84 000 Mg of waste (in practice in piles there were collected wastes whose mass ranged from 62 869 Mg to 89 333 Mg, what made 75-106% of predictable capacity). During the exploitation time degassing wells with the diameter of 1 m were installed. They were made of broken stone inside the perforated pipe with the diameter of 100 mm, made of PE. In five pipes there are heads joined to gas collector. From the information given by landfill service follows that in pile W1 in 2002 and 2003 year 6 700 Mg of sewage sludge with moisture about 80% was collected.

Leachates are collected by the drainage, and gravitationally flow down to the collective well, and next are pumped to the main collector. Through the main collector leachates are gravitationally piped away to the concrete tank of the volume of 76 m^3 that is joined to a new-built tank with the working volume of about 2 500 m^3. SWECO technology recommends heating the leachate up to 40°C and next turning it back, and forcing it under the pressure in the piles. Irrigation is obtained by using elastic hoses that are put in the surface of the waste layer. It lets allows for irrigating waste independently of filling degree of pile. Currently, the system is not working according to SWECO technology; leachates are not heated and not forced into the piles. About 700 m^3 of leachates per month are taken to the wastewater treatment plant.

Each pile has its own system of biogas collection that consists of gas wells and collectors put along the pile joined to the main collectors. Main collector leads to a gas pump station. The central unit of the system of gas recovering and energy generation is electricity generator, supported by gas fuel through container pump station. Pump station involves two blowers working in dependence on the necessity. Generator at the electric power of 189 kW generates not only electricity but also heat energy used for leachate heating. Exploitation of electric engine according to the guidelines of the designer took place with breaks to 29 of November 2002. Than, the system of biogas collection and recovering from the piles was not operating.

MATERIALS AND METHODS

Waste samples preparation

Waste samples for the investigation were taken at the same place in the middle of each pile. Wells were done to the depth of 6 m in four piles from W3 to W6, and to the depth of 7.5 m in piles W1 and W2.

Collected waste samples were spread on the concrete surface covered by thick PE membrane and then was dried within three weeks to airily dry state. Waste samples on the membrane were mixed once a week by means of spade and rake. From the original dried waste the average samples of waste were separated according to [12].

Analytical procedures

Bulk density and moisture of waste using gravimetrical method were determined on the day of waste sampling and after three weeks of air drying. During air drying waste odor was defined during the following three weeks, moreover, the structure of waste was determined. Such information can be useful in the future in case of characterization of waste harms during drying, after excavating of the piles and separation of waste on fraction and morphological components. Furthermore, it can be utilized for the determination of technology of mechanical waste processing from the piles. Sieve and morphological analysis were performed following Polish Standards [7]. On this basis the possibility of secondary materials recovery from the waste collected in piles were determined. Weight of the waste samples used for sieve and morphological analysis ranged from 8.64 to 10.8 kg.

The following four granulometric fraction of waste were selected:

- the I fraction – sieving, waste passing through the sieve with the mesh of the diameter of 10 mm,
- the II fraction – waste going through the sieve with the mesh of the diameter of 40 mm,
- the III fraction – waste going through the sieve with the mesh of the diameter of 120 mm,
- the IV fraction – waste remaining on the sieve with the mesh of the diameter of 120 mm.

Each selected waste fraction was divided into morphological components and subgroups such as paper and cardboard, plastic, textiles, glass, metal, organic compounds, mineral compounds, waste from the I fraction (sieving) were determined. Selected components were weighed with the accuracy of 0.1 g. On the basis of the obtained results percentage part of morphological groups and waste fractions in the whole mass of waste were calculated. Investigation included physicochemical analysis of waste of the I fraction (sieving) in order to determine the possibility of reusing. The range of the analysis in water extract (according to [8]) was the following: moisture, organic and mineral compounds (% of dry mass) using gravimetrical method. In order to determine pollutants leaching in water extracts of the I fraction physicochemical parameters were determined: reaction pH, conductivity, soluble fraction divided into organic and mineral ones, CODCr, chlorides in accordance with Hermanowicz [5], and methodologies commonly used at water and wastewater characterization.

Analysis of biodegradable organic fraction present in waste collected in piles was done. The results were compared to municipal waste at the landfill in Zakurzewo whose characteristics were determined in 1997, 1998 and 2001 [6, 10, 11] (Tab. 5).

Biodegradation of organic matter in waste collected in piles due to fermentation in piles was determined contrary to organics contents in raw waste provided on the landfill.

The following morphological groups of waste made up total biodegradable organics: 30% of textiles, 100% paper, 100% organic waste, and 100% of organic part of the I fraction.

Potential unit biogas production was determined according to [1] on the basis of the assumption that conversion of volatile substances (VS) - residue after ignition - into gas is 0.5 m^3/kg dry mass.

RESULTS

Water content (moisture) in waste was determined twice: on the day of waste sampling from the wells, and three weeks after the first sampling. Water content in waste on the day of sampling ranged from 34.9 to 60.9%, and depended on waste age. Water content after 1-2 years of waste collection (55.6-60.9%) was higher than as for older waste from 3 to 6 years old piles which ranged from 34.9 to 40.7% (Tab. 1).

Table 1. Water content (moisture), bulk density of waste collected in piles on the landfill in Zakurzewo near Grudziądz in 2004, and changes during drying

No. of waste sample	Closing time of pile	The age of pile	Water content					Bulk density				
			day of sampling from the hole	after 3 weeks of air drying		loss of water after 3 weeks air drying		day of sampling from the hole	after 3 weeks of air drying		change after 3 weeks air drying	
		years	%	%	% of the initial value	difference	% of the initial value	kg/m^3	kg/m^3	% of the initial value	kg/m^3	% of the initial value
W6	1998	6	40.7	15.3	40.4	25.4	59.6	643	441	70.1	201	29.9
W5	1999	5	34.9	15.6	45.6	19.3	54.4	738	574	77.0	163	23.0
W4	2000	4	36.1	17.5	48.4	18.6	51.6	539	418	77.5	122	22.5
W3	2001	3	39.6	15.4	42.0	24.2	58.0	599	422	71.5	177	28.5
W2	work	2	55.6	32.8	57.5	22.8	42.5	603	409	68.6	194	31.4
W1	work	1	60.9	37.7	61.8	23.2	38.2	781	468	63.8	312	36.2

Water loss in waste was similar in the range of 18.6 to 25.4%. Higher water loss was observed in the older piles (W6 - 59.6%, and W4 - 51.6% of the initial value) contrary to the youngest piles (W1 - 38.2%, and W2 - 42.5% of the initial value) (Tab. 1).

Bulk density ranged from 539 to 643 kg/m^3, and merely in waste from W5 (after 5 years of collection) it was higher, on the level of 738 kg/m^3. After three weeks of air drying bulk density of waste due to loss of waste decreased by 122 to 312 kg/m^3. The highest weight of volume on the level of 574 kg/m^3 was observed in waste from pile W5. In other samples of waste the weight of volume was similar, and ranged from 409 to 468 kg/m^3 (Tab. 1).

In order to determine waste harms for the environment during drying and separation on morphological fraction, odor changes in the following weeks of drying were checked.

On the day of waste sampling, waste from all piles, excluding waste from W5, was characterized by ammonia odor with different intensity (Tab. 2). Furthermore, putrid odor was detected in waste from piles W4, W2 and W1. Waste from pile W5 possessed chemical odor. After one week of drying odor intensity decreased, ammonia odor resigned in aid of putrid odor. Chemical odor of waste from pile W5 did not change. After three weeks of drying waste from pile W5 was still characterized by chemical odor, and odor nuisance of waste from other piles was not observed (Tab. 2).

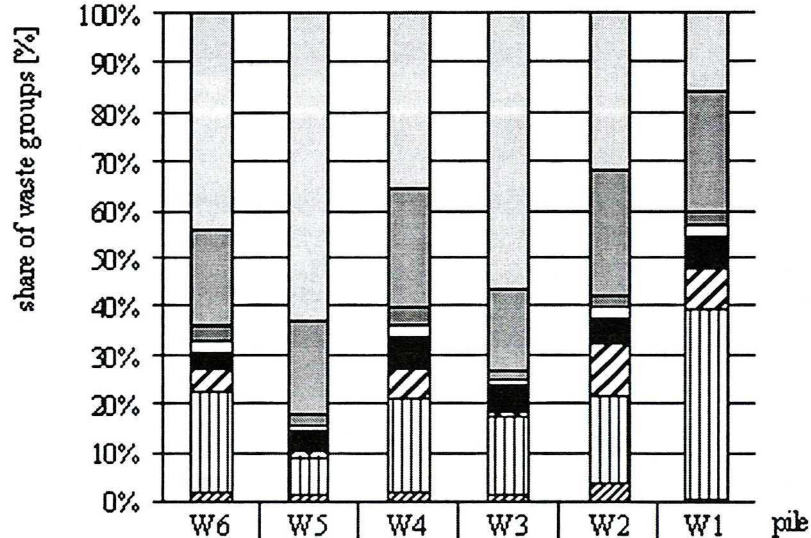
Table 2. Odor structure of waste collected in piles on the landfill in Zakurzewo near Grudziądz in 2004, changes during drying

No. of waste sample	Odor			Structure		
	day of sampling from the hole	after air drying		day of sampling from the hole	after air drying	
		1 week	3 weeks		1 week	3 weeks
W6	ammonia	putrid, faint ammonia	soil	friable, wetness	friable, wetness	friable
W5	chemical, ammonia	soil, chemical	soil, chemical	friable, wetness	friable, wetness	friable
W4	putrid, ammonia	putrid, faint ammonia	soil, faint putrid	friable, wetness	friable, wetness	friable
W3	strong, ammonia	putrid, faint ammonia	soil	friable, wetness	friable, wetness	friable
W2	putrid	soil	soil	friable, wetness	friable, wetness	friable
W1	putrid, ammonia	ammonia	soil, faint ammonia	semisolid	semisolid	friable, wetness

In order to determine the possibility of mechanical selection of waste from the piles its structure and changes during drying process were described. On the day of waste sampling but also after one week it was shown that most samples were characterized by friable structure, but they had high water content. After three weeks the structure of most waste samples was friable and waste easily passed through the sieves (Tab. 2). In contrary, within one week waste from pile W1 had semisolid structure. After three weeks of drying wastes from pile W1 were characterized by friable structure, but still had high water content.

In order to determine the possibility of secondary materials recovery from waste collected in the piles sieve and morphological analysis were done. Results are shown in Figures 1 and 2.

Waste of 10 group - fraction of waste with the particles of the diameter below 10 mm (the I fraction) made up the highest share in total mass of waste in most piles (Fig. 1). The share significantly (the level of significance was $p < 0.05$; the statistic F-value was 23.32 and the computed probability was 0.0001) changed from 15.8% in pile W1 to 62.9% in pile W5. As for other groups plastics significantly (the level of significance was $p < 0.05$; the statistic F-value was 5.83 and the computed probability was 0.015) changed from 15.8 to 38.8% (in pile W5 - merely 7.6%), and mineral fraction made up from 17.1 to 25.9%.



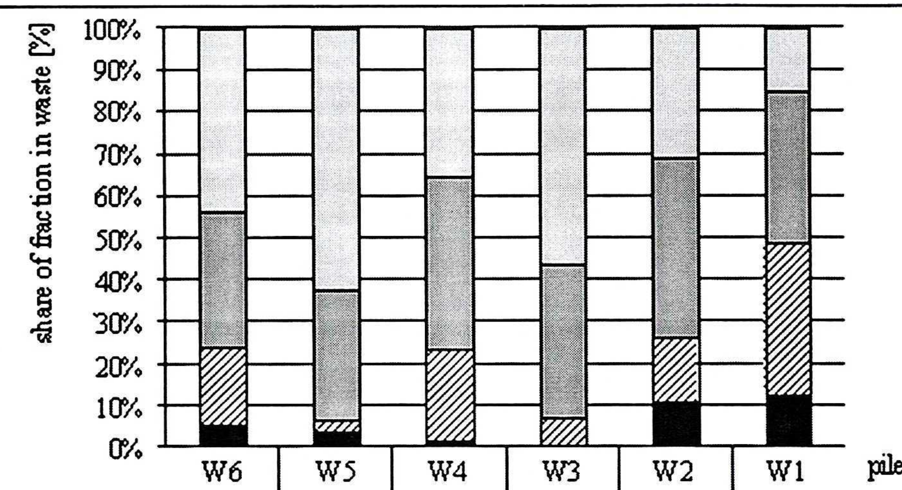
	W6	W5	W4	W3	W2	W1
<10 mm	44,2	62,9	35,4	56,6	31,6	15,8
mineral compounds	19,7	19,6	25,0	17,1	25,9	24,5
organic compounds	3,0	2,0	3,3	1,4	2,4	2,7
metals	2,9	0,8	2,7	1,2	2,3	2,7
glass	3,3	4,5	6,1	5,3	5,4	6,5
textiles	4,8	1,2	6,7	1,5	10,8	8,5
plastic	20,2	7,6	19,1	15,8	18,2	38,8
paper	1,8	1,4	1,7	1,2	3,2	0,5

Fig. 1. The share of the morphological groups of waste collected in piles on the landfill in Zakurzewo near Grudziądz in 2004

As secondary material, besides plastic, mass of the glass made up from 3.3 to 6.5%, and textiles from 1.2 to 10.8%. Metal content ranged from 0.9 to 2.9%, and paper and cardboard from 0.5 to 3.2% (Fig. 1).

Sieve analysis shown that in most piles small particles - the I fraction of waste with the particles of the diameter below 10 mm and the II fraction with the particles of the diameter of 10-40 mm made up the highest share of total waste mass in piles from 74 to 93%. The lowest value was observed in pile W1 on the level of 50%.

Fraction of waste with the particles at the diameter below 10 mm (10 groups in morphological analysis) was treated in the additional investigations. It resulted from the fact that the fraction made up the highest share in the total mass of waste from all piles. Moisture, dry mass, mineral and organic fraction concentrations were determined in dry mass of waste of the I fraction. Moreover, analysis of leaching pollutants (using water extract) and physicochemical analysis were done.



	W6	W5	W4	W3	W2	W1
fraction I	44,2	62,9	35,4	56,6	31,6	15,8
fraction II	32,2	30,7	41,3	36,6	42,6	35,5
fraction III	18,5	2,9	21,7	6,8	15,7	36,2
fraction IV	5,1	3,4	1,7	0,0	10,2	12,6

Fig. 2. The share of the waste fractions in total mass of waste collected in piles on the landfill in Zakurzewo near Grudziądz in 2004

Moisture of the I fraction of waste after three weeks of air drying was low in all samples and ranged from 10.3 to 14.9% (Tab. 3). The concentration of mineral fraction in dry mass of waste was low and the share made up 13.3-28.4% d.m. of I fraction. Thus, organics (accessible for microorganisms) in dry mass of the I fraction changed from 71.6 to 86.7% (Tab. 3).

Table 3. Characterization of the I fraction of waste (with the particles of the diameter below 10 mm) collected on the landfill in Zakurzewo near Grudziądz in 2004 after three weeks of air drying, with parameters of ANOVA at the significance level ($p < 0.05$)

No. of waste sample/ parameters of ANOVA	Moisture	Dry mass	Mineral fraction	Organic fraction	Potential unit biogas production according to [1]
	%	%	% d.m.	% d.m.	m^3/Mg d.m. of I fraction
W6	14.9	85.1	17.3	82.7	352.1
W5	10.5	89.5	16.1	83.9	376.6
W4	10.3	89.7	13.3	86.7	371.8
W3	10.7	89.3	16.7	83.3	389.0
W2	13.7	86.3	14.0	86.0	370.7
W1	13.2	86.8	28.4	71.6	311.8
Statistic F-value	0,6	0,6	2,48	2,48	1,83
Computed probability	0,699	0,699	0,121	0,121	0,213

High concentration of pollutants was observed in water extract from the waste of the I fraction. Total soluble substances concentration was on the level of 1 372.5-2 197.5 mg/dm^3, and COD concentration varied from 651.6 to 809.4 mg O_2/dm^3 (Tab. 4). Despite the fact that organics made up 80-88% of waste they are sparingly soluble in water and water extract contains mainly mineral substances (68.7-78.6% of total concentration of leaching substances). Chlorides concentration in the I fraction of waste was not high, and the value ranged from 16.8 to 27.0 mg/dm^3. Probably easily soluble chlorides were leaching from the piles during the initial years of its operation. Water extract was characterized by low conductivity ranging from 1.5 to 2.2 mS/cm. All samples of waste were alkaline from 7.5 to 7.8 pH what provides stable methanogenic fermentation conditions in piles (Tab. 4).

Table 4. The average value of the pollutants concentration in water extract from the I fraction of waste selected from the piles on the landfill in Zakurzewo near Grudziądz in 2004, with parameters of ANOVA at the significance level ($p < 0.05$)

No. of waste sample/ parameters of ANOVA	Determination						
	Reaction	Conductivity	COD	Chlorides	Soluble fraction	Mineral fraction	Organic fraction
	pH	mS/cm	mg O_2/dm^3	mg/dm^3	mg/dm^3	mg/dm^3	mg/dm^3
W6	7.6 ± 0.2	2.2 ± 0.4	809.4 ± 251.2	27.0 ± 9.7	1982.5 ± 872.7	1460.0 ± 725.3	522.5 ± 171.7
W5	7.5 ± 0.1	1.7 ± 0.6	705.3 ± 569.1	16.8 ± 6.7	1532.5 ± 449.8	1205.0 ± 467.7	327.5 ± 149.7
W4	7.5 ± 0.1	1.7 ± 0.3	762.2 ± 109.1	18.2 ± 1.1	1620.0 ± 241.8	1235.0 ± 216.9	385.0 ± 72.3
W3	7.6 ± 0.3	1.5 ± 0.4	763.3 ± 322.1	24.2 ± 13.4	1372.5 ± 577.9	942.5 ± 399.9	427.5 ± 176.3
W2	7.6 ± 0.1	2.2 ± 0.3	651.6 ± 162.2	26.4 ± 5.5	2197.5 ± 688.2	1607.5 ± 503.5	590.0 ± 202.8
W1	7.8 ± 0.2	2.1 ± 0.6	701.8 ± 181.8	26.2 ± 11.8	2020.0 ± 14.1	1395.0 ± 261.6	625.0 ± 247.5
Statistic F-value	1,49	1,97	0,18	1,07	1,16	0,92	1,66
Computed probability	0,235	0,126	0,967	0,404	0,372	0,491	0,200

DISCUSSION

It was proved that water content in waste collected in piles was significantly lower than is characteristic for waste typically used for disposal in energetic piles, i.e. 60-70% [2] and bulk density of waste on the day of sampling in most cases was similar to the value given by designer on the level of 600-800 kg/m [14]. Due to air drying for three weeks water content decreased to the value ranging from 15.3 to 37.7% what made up from 40.4 to 61.8% of the initial value of the water content (Tab. 1). At such low moisture of waste after drying biochemical reaction should decrease, and waste does not become fouled. This fact allows for an easy waste processing (i.e. mechanical selection) from technical point of view, and moreover, it is safe from the viewpoint of the landfill service. The time needed for elimination of odor nuisance of waste is three weeks. In pile W5, for the sake of no recessive strong chemical odor, before making the decision concerning pile closing, specific analysis of waste as for harmfulness and toxicity, and gas is prescribed.

Investigation revealed that sort of waste such as plastic, mineral fraction and fraction of waste with the particles of the diameter below 10 mm made up about 75-90% of the total waste mass in the piles. Therefore, in the future these groups should be selected from the whole mass. Selection and recovery of glass, textiles, metals and paper should be treated as supplemental and insignificant. It does have no matter at waste management on the landfill. In the case of piles processing the I and the II fraction should be selected firstly because of it's very high share in total wastes mass ranging from 74 to 93%.

At high concentration of easily accessible organic fraction, moisture can significantly influence microorganisms' activity taking part in fermentation. One of solutions of using the I fraction of waste is biogas production. A few estimations of gas production have been proposed. Detailed estimation of methane or landfill potential can be obtained from the equation presented by [3], but waste composition needs to be known at a very detailed, stechiometric level. More easily volatile solids (VS) can be an indicator of gas potential. Volatile solids may include plastics, and lignin, both of which are not significantly degradable under anaerobic conditions on landfill. Despite, on account of simple determination this parameter can be used [9]. On the basis of [1], potential biogas production of the I fraction ranged from 310 to 390 m^3/Mg of d.m.

It can be concluded that the I fraction of piles contains high concentration of organics (80-88%), and constitute potential source of water environmental pollution. Organic substances in waste are slowly biodegradable and there is a slow leaching to the leachate but they are hazardous for water environment for many years.

In 1997-2001 morphological analysis of waste was done three times. Wastes were collected in piles W6 - W3, and were characterized by high content of organic fraction - 38.8%, paper - 17.1%. It means that biodegradable organic fraction made up 60% of total mass of waste (Tab. 5). For the reason of organics content on the level of 50% of weight, waste collected on the landfill in Zakurzewo can be disposed in energetic piles [2]. It was proved that organic matter content of piles W3 - W6 in contrary to raw waste was not high and ranged from 11.9 to 42.6% (Tab. 6). There results may be compared with sewage sludge fermentation. Heidrich and Nieścier [4] reported that at the reduction of organics on the level of 50% sewage sludge is stabilized and acid fermentation cannot be obtained. However, waste collected in piles W3 - W6 was not stabilized, and further fermentation was advisable, due to the technological guidelines. In the case of piles W1 and W2, for the sake of young age, they were considered not to be stabilized, and further fermentation with biogas recovery was advisable.

Table 5. Morphological groups in waste collected on the landfill in Zakurzewo in 1997-2001 [6, 10, 11]

Morphological group	Share of morphological group in waste [%]	Comment
Metal	4.7	Non biodegradable wastes 41.5%
Glass	11.2	
Mineral waste and small fraction	13.7	
Plastic	6.8	
Textiles	7.3	
Paper	17.1	Biodegradable wastes 58.1% *
Organic waste	38.8	
Other	0.4	
Sum	100	

* - sum of weight of 30% textiles, and 100% paper and organic waste

Table 6. Biodegradable organics content in waste collected in piles on the landfill in Zakurzewo near Grudziądz in 2004, and percentage reduction due to fermentation contrary to organics concentration in raw waste

No. of waste sample	Biodegradable organics content in waste [%]	Reduction [%]
The average from waste collected in 1997–2001	58.1	
W6	37.5	35.5
W5	51.2	11.9
W4	33.3	42.6
W3	47.3	18.7
W2	32.3	–
W1	16.0	–

CONCLUSIONS

Waste from 10 groups - fraction of waste with the particles of the diameter below 10 mm had the highest share in total mass of waste in most piles. The share changed in the range of 32% to 63%. Organic matter content in dry mass of the I fraction was high ranging from 71.6-86.8% of d. m. This fraction can be used as a biological layer on the landfill, but should not be treated as a neutral waste for the sake of leaching of high pollutants concentration. Groups 4, 9 and 10 (plastic, mineral fraction and fraction of waste with the particles of the diameter below 10 mm) made up about 75-90% of the total waste in piles. Therefore, in the future these groups should be selected from the whole mass.

Plastic made up the biggest share of the secondary materials ranging from 7.6 to 38.8%, and the way of this waste disposal should be found. The investigation did not reveal a high content of glass (3.3-6.5%) and textiles (1.2-10.8%), metal (0.8-2.9%), paper and cardboard (0.5-3.2%). Selection and recovering of these groups of secondary materials should be treated as a supplemental and insignificant for waste management.

Small fractions - the I fraction of waste (with the particles of the diameter below 10 mm) and the II fraction (with the particles at the diameter between 10-40 mm) made up a significant share (50-93%) of the total mass of waste in piles. Selection and recovery of these groups of secondary materials should be treated as a supplemental and insignificant one.

For the sake of low reduction of organic matter, further fermentation of waste from piles W1 - W6 with biogas recovery is advisable.

In order to improve structural and odor features of waste, before sorting on the secondary materials, air drying is advisable. It was proved that time needed for elimination of odor nuisance of waste is three weeks.

In the case of waste characterized by strong chemical odor (pile W5), before making the decision concerning pile closing, specific analysis of waste for harmfulness and toxicity, and gas is prescribed.

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