Physicochem. Probl. Miner. Process. 52(2), 2016, 973−990

www.minproc.pwr.wroc.pl/journal

Physicochemical Problems of Mineral Processing

ISSN 1643-1049 (print)
ISSN 2084-4735 (online)

Received January 10, 2016; reviewed; accepted February 26, 2016

MINERAL MATTER IN MUNICIPAL SOLID WASTE

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Abstract: Municipal solid waste (MSW) contains mineral materials which are seldom considered as a potential resource. Currently, the waste management sector pays attention to recyclable parts, biodegradable material, waste-to-energy fraction, and residues after waste reuse and recycle. In contrast, this study focus as on the mineral matter in MSW. The aim was to analyze and discuss the sources of mineral matter in MSW, the impact which the minerals have on waste management technologies, and finally, the possibility to recycle the mineral matter. The contribution of inorganic matter in the MSW stream is significant (about 20 wt.%). In the years 2012–2015, the average content of mineral matter in mixed MSW in Poland ranged from 16 wt.% to 36 wt.%, and the content of organic in MSW ranged from 20 wt.% to 42 wt.%. Minerals in MSW have rather negative impact on waste management technologies and their final products, and can be sorted out from the MSW stream, either in the households or in a central sorting line. However, in central collection and separation systems it is difficult to obtain a mineral matter fraction in subsequent processing steps due to technological limitations (inefficiency of devices), high degree of waste fragmentation and pollution of mineral matter with other waste. This indicates a hampered ability to separate minerals in a form available for reuse, so an effective system should be based on improved segregation at the source.

***Keywords**: mineral matter, municipal waste, separation technologies, size distribution*

Introduction

Regarding solid waste management in Europe, the Members States are requested to apply the “reduce, reuse, recycle” (“3Rs”) paradigm in accordance with the waste management hierarchy (Directive 2008/98/EC). Current municipal solid waste (MSW) handling and processing focus is on the waste reduction and resource utilization of biodegradable waste (Rigane and Medhioub, 2001; Bernstad and La Cour Jansen, 2012; Zhang et al., 2012; Adani et al., 2004), waste collection systems (Bernstad and

http://dx.doi.org/10.5277/ppmp160235

la Cour Jansen, 2012; Gallardo et al., 2011; Gomes et al., 2008), reuse and recycling of metal, glass and plastics (Troschinetz and Mihelcic, 2009; Vellini and Savioli, 2009; Cimpan et al., 2015; Ferreira et al., 2008), and thermal treatment (incineration, pyrolysis, gasification) (Bosmans et al., 2013; Surum et al., 2001; Koehler et al., 2011). In 2012, 48% of the waste in EU was still landfilled (average for 28 countries), 36% recovered/recycled (excluding energy recovery), 9% backfilled and 6% incinerated. One commonly employed method to recover the organic matter fraction is mechanical-biological treatment of mixed municipal solid waste (mMSW). In Poland, there are currently 174 regional plants for municipal waste treatment, many of which use the mechanical-biological treatment method. According to the National Waste Management Plan 2014 (KPGO 2014), future development of the waste management will primarily rely on mechanical-biological and/or thermal treatment of municipal waste. However, several of the treatment techniques used for the mixed waste are negatively affected by the content of mineral particles. Available technologies to recycle or reuse minerals in MSW, are still complex and expensive, e.g. washing with grit removal system (Rahn and Gandolfi, 2007) or waste extrusion (Schmidt, 2011), so there is an incentive to minimize the mineral matter content. Some part of the mineral matter could potentially be reused to manufacture new products (Table 1), which could be a way of reducing the problems.

Table 1. Mineral components of MSW

Type of inorganic matter	MSW component	Potential reuse products
Unprocessed minerals	sand and gravel, soil	bricks, aggregate, construction materials
Processed waste, recovery materials	glass, cullet	new glass product, glass-ceramics, aggregate, fibers
Processed waste – potential recovery or as an addition	ash, slag, concrete, bricks, ceramics, porcelain	lightweight aggregate, concrete new construction materials, road pavement, soil amendment

In literature the term “mineral matter” in MSW is not used in a uniform way (Table 2). The term can be used to refer to the inorganic fraction in ionic form, heavy metals, general metals, glass, fines (part of fine “dirt” fraction <10 mm – ash, cat sand), construction and demolition waste (C&DW), stones, and soil. From literature five major classes can be distinguished:

1. The fine “dirt” fraction (< 10 mm), consisting of soil, sand, gravel and glass is entering to the waste together with green garden waste or with waste vacuum cleaner bags (Dahlen and Lagerkvist, 2008).

2. Thermal processing waste originates mainly from homes with wood or coal boilers, and consists of ash, slag, and sometimes ferrous and non-ferrous metal fragments. This fraction typically increase in the winter period (Zhou et al., 2015).

3. Unsorted construction and demolition waste (C&DW) has different composition depending on its origin, e.g. building renovation and demolition, and roads

construction, but can contain concrete, ceramics, bricks, glass and metals. Since 1st of July 2011 (Polish Law, Dz. U. 2011 nr 152 poz. 897; Directive 2008/98/EC) C&DW should be collected separately and processed in recycling and reuse units. However, it is still common, that a certain amount of C&DW enters mMSW.

Table 2. Inorganic matter in MSW

Name of mineral phase in the reference	Sub- group of mineral phase	Primary components of mineral matter	Research focus	References
inorganic matter	minerals amorphous material	quartz, calcite, glass, kaolinite, talc, illite, muscovite, zeolite, gypsum, other	refused-derived char from MSW	(Vassilev and Braekman-Danheux, 1999)
inorganic fraction	mineral compounds in ionic forms	Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, NH^{4+}, Fe^{2+}, HCO^{3-}, Cl^{-}, SO_4^{2-}	MSW leaching	(Parodi et al., 2011)
inert wastes	-	glass, mineral wastes, metals	organic waste fermentation	(Frąc and Ziemiński, 2012)
inorganic	-	metals, glass	biogas production potential of MSW	(Zhu et al., 2009)
Inert mineral waste	- -	C&DW rock dust	addition of mineral processing waste to green waste compost	(Jones et al., 2009)
non-biodegradable fractions	-	i.e. glass and stones, other (soil)	MSW pretreatment by windrow composting	(Norbu et al., 2005)
fines (< 10 mm)	inorganic material (as a part of fines)	cat sand and soil, ash	determination of household waste composition	(Dahlén and Lagerkvist, 2008)
other inorganic	-	unclassified incombustibles, other non-combustibles, miscellaneous non-combustibles, ceramics, minerals		
inorganic	glass metals aluminum inert materials	packaing and un-packaing, colour and colourles glass ferrous metals all kind of aluminum stones, ground, C&DW	determination of MSW composition	(Gidarakos et al., 2006)
mineral matter	-	ash	MSW and green waste characterization	(Hla and Roberts, 2015)
mineral residues mineral aggregate	- C&DW	fly ash from MSW icinerator, air pollution, bottom ash concrete, masonry debris	C&DW management	(Butera et al., 2015)
inorganic fraction	-	Sand	sources of heavy metals in biowaste (Cd, Cu, Pb and Zn)	(Veeken and Hamelers, 2002)

4. New regulations on separate collection of packaging and packaging waste (Polish Law, Dz. U. 2013 nr 0 poz. 888; Directive 94/62/EC) has created an incentive

to separate glass containers & bottles, glass closures and metal tins from the mMSW stream to reduce the impact on the environment. However, many households in Poland have still not adopted the practice of waste separation at source, due to reasons such as e.g. lack of awareness and efficient infrastructure to facilitate the separation. Therefore, this is still a source of both glass and metals (up to 20%; see paragraph 0).

5. Similarly, unsorted electric and electronic waste (Polish Law, Dz. U. 2015 nr 0 poz. 1688; Directive 2002/96/EC) in mMSW is a result of inefficient source separation, as electric and electronic waste should be collected and treated in separate installations. This type of waste contains ferrous and non-ferrous material, plastics, glass, wood, cables and other waste (Cui and Forssberg, 2003; Widmer et al., 2005).

When mixed municipal waste is processed, the inorganic material passes to the biological, waste-to-energy and ballast fractions at different ratios depending on their size and the techniques employed. There is a need to critically analyze the composition of the mineral matter and how this changes in the processing chain to identify possibilities to minimize disturbances caused by this fraction, and also potentially increase the recovery of minerals.

The aims of this study were therefore to: i) identify and analyze types and size distribution of mineral matter in MSW and how this changes through mechanical-biological waste processing, ii) discuss the impacts of mineral matter on the outcomes of the mechanical-biological waste management technology, and iii) discuss the possibilities to recycle or reuse these valuable resources. One large MSW plant in Northern Poland was selected as a case study.

Materials and methods

Municipal solid waste characterization

Municipal solid waste (MSW) was sampled from the Waste Treatment Plant in Gdansk (ZUT) in northern Poland in November of the years 2012, 2013 and 2014. From November 2014 to Nov 2015, additional samples of the ofMSW were collected every three months to analyze the inter-annual variation in waste composition and size distribution of the waste sent to composting.

Three different kinds of samples were taken (Fig. 1): 1) untreated mixed municipal solid waste (mMSW) without pre-selection, 2) organic fraction of municipal solid waste (ofMSW) sieved through 100 mm mesh size, and 3) MSW compost, derived from aerobic treatment of the ofMSW fraction for 21 days intensive composting and 90 days maturation.

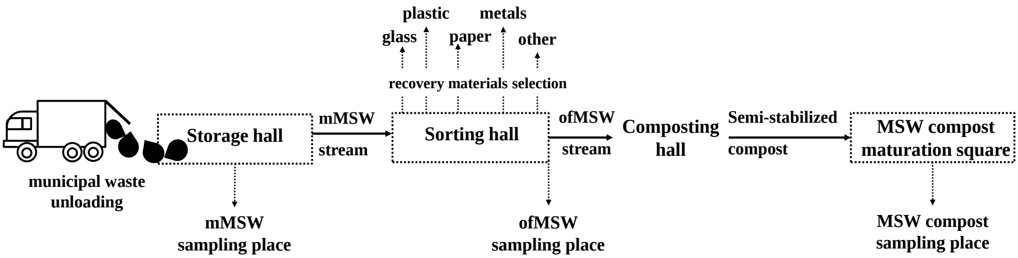

Fig. 1. Scheme of waste sampling places in the Waste Treatment Plant in Gdansk

In the plant, the collected mMSW is sorted manually and mechanically into materials for reuse or recycling and a biodegradable fraction (ofMSW) that is further processed through composting. The mechanical treatment is based on optical, ballastic and magnetic separation, drum sieving and manual sorting (Fig. 2).

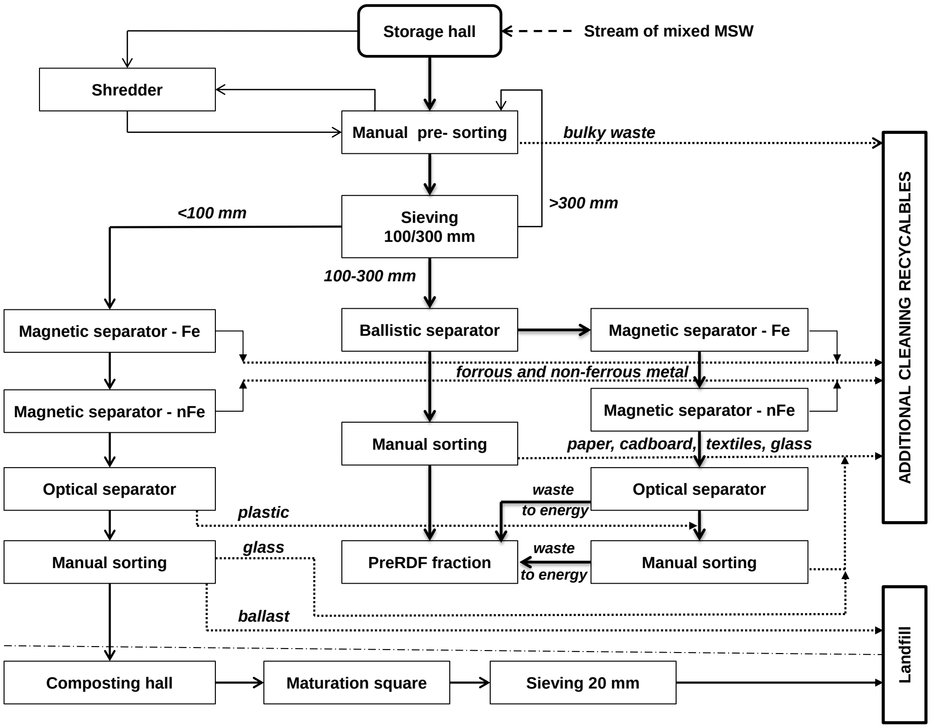

Fig. 2. Mechanical MSW treatment in the Waste Treatment Plant in Gdansk in 2014

In 2015, the sorting line was modernized. The mesh sizes of the sieving drums were changed from the previous 100 and 300 mm to a sequence of 80/160/300 mm in order to get a homogeneous composition of each granulometric fraction. Additionally, the transporting lines were extended, thereby providing better distribution of material on the belt and a more efficient mechanical separation. Manual employees are changing their workplace depending on seasonal variations in the composition of the collected waste, to have a better control of the sorting line.

In this investigation, the methodology for determination of waste composition was based on the Polish standard PN-93-Z15006 where municipal waste is classified into 9 main categories. The methodology was modified so that the waste samples were sorted into 19 sub-categories, plus the organic and inorganic fractions <10 mm, which were all grouped into 5 main categories (Table 3).

Table 3. Categories used to characterize mixed MSW and the organic fraction of MSW from Waste Treatment Plant in Gdansk

Waste category		Waste category*	Category components (19 sub-categories)	Characterization
BIODEGRADABLE	Bio	1 and 2	Kitchen residues	vegetable and fruits scraps
		1	Garden waste	plant material (leafs, branches), grass
		2	Animal-derived food waste	bones and skin
		3	Paper	office paper, kitchen towels, commercial flyers
		3	Cardboard	package cardboard
		1	Wood	wooden scraps, processed wood
		8	Other organic (>10mm)	food scraps
		-	Organic fine *“dirt”* fraction <10 mm	food scraps, plant material
NONBIODEGRADABLE	Mineral	-	Inorganic fine *“dirt”* fraction <10 mm	complex composition (ash, sand, gravel, glass)
		6	Clear glass	clear, brown and green fine particles of packaging glass
		6	Colored glass	
		9	Construction and demolition waste	concrete, ceramics, gypsum plasterboards
	Synthetic	4	Plastics – HD (high density)	packaging and toys, containers, etc. PET, HDPE, PS, PP
		4	Plastics – LD (low density)	packaging PE foils
		5	Textiles	natural and synthetic origin textiles
		4	Multimaterial waste	Packaging Tetra Pak, packaging bags
		4 and 5	Human hygiene waste	diapers, tampons, cotton pads, other
		4	Rubber	disposable gloves
	Hazardous	5 and 7	Hazardous materials	battery, pharmaceuticals and other
	Metal	7	Ferrous metals	caps, cans and other
		7	Non-ferrous metals	

*waste category according to Polish Norm PN-93-Z15006

Waste samples preparation

mMSW and ofMSW samples

To analyze the composition of the mMSW and ofMSW, the quartering method was used. To ensure representativeness, 30 m^3 samples were divided into quarters and then two opposite parts were mixed to form a new portion, whereas the other two portions were discarded. The quartering procedure was continued until a 10 kg sample remained (Fig. 3).

Each sample was then separated into two fractions using 10 mm screen. The oversize was manually sorted into 19 waste sub-categories (see Table 3). The undersize was sorted manually into biodegradable and non-biodegradable components. The results were expressed as a percent of the wet mass to guarantee scale invariability and to facilitate comparison. Analyses were performed in duplicate and averaged.

MSW compost samples

MSW compost samples were taken from stabilized compost piles which were intensely treated for 21 days and maturated for about 3 months. Afterwards, stabilized compost was sieved by 20 mm – opening rotating screen. After random sampling from 10 different sites compost prism, the samples were mixed, and quartered until 2 kg sample remained, according to the Polish standard PN-Z-15011-1:1998. Subsequently, the compost sample was dried at 105°C formed lumps – disintegrated and screened using a 2 mm mesh size. Impurities such as glass, ceramics, stones and plastic fragments were sorted out manually. The total amount of hand-picked inorganic material impurities (bigger than 2 mm) was sieved by using 8.0, 6.3, 4.6, and 2.0 mm screens to determine the particle size distribution.

Physico-chemical analyses

After determining the mMSW and ofMSW composition, the waste categories were mixed and a 2 kg sample was dried at 105°C (until constant weight). Subsequently samples were ground below 4 mm (see Fig. 3). The pH of the extract was recorded after reaching a constant value, which usually took place after 1,5 h of mixing (Polish standard PN-Z-15011-3). The dried and ground sample was used for determination of total solids (TS), volatile solids (VS), total organic carbon (TOC), calorific value (Q) and moisture content (MC).VS was determined by measuring the weight loss of 2 g sample in a muffle furnace at 550°C (Polish standard PN-93/Z-15008/03). MC and TS were measured as weight loss after drying at 105°C. TOC was analyzed by oxidizing the samples with potassium dichromate according to the Polish standard PN-Z-15011-3. Solid waste samples were mineralized in sulfuric acid for 1h at ambient temperature, then heated and oxidized for 5 minutes. Afterwards, the amount of residual dichromate was measured by titration with Mohr salt (iron(II) ammonium sulfate). The calorific value was measured using bomb calorimeter (KL 12 Calorimeter).

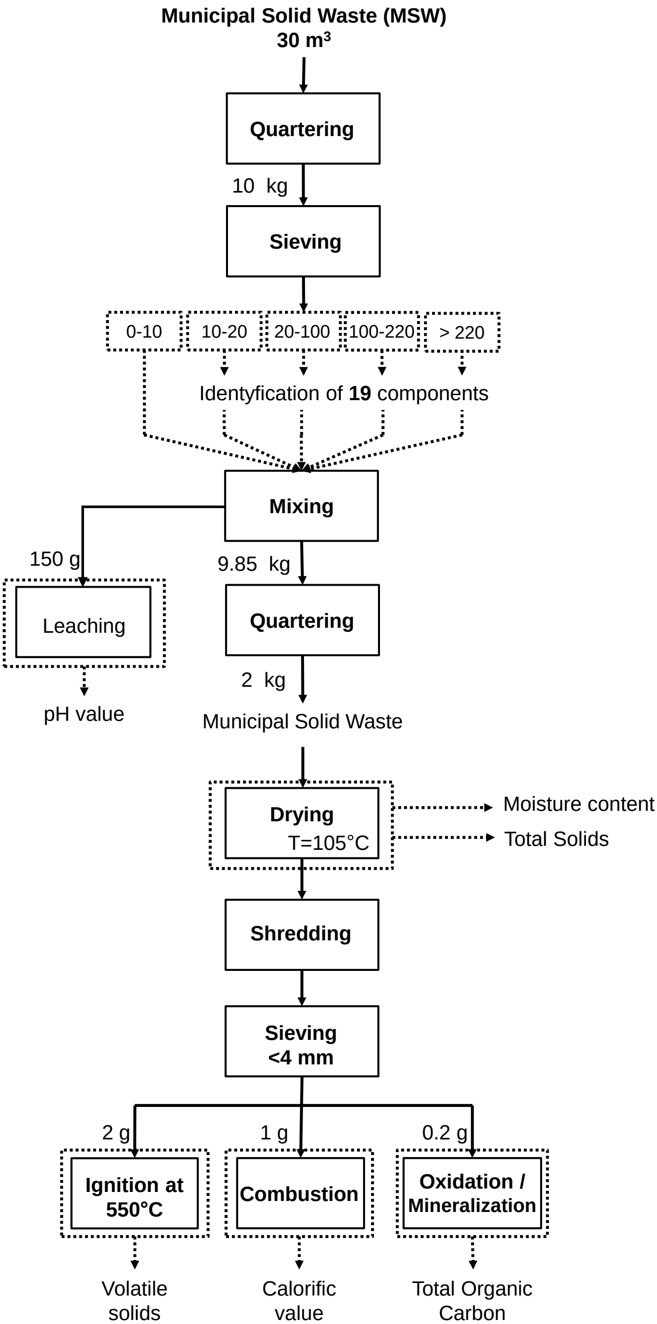

Fig. 3. Scheme for samples preparation and physiochemical characterization of mMSW and ofMSW from the ZUT company

Results

mMSW composition

No major fluctuations in the five main waste categories (bio-, synthetic, hazardous, metal and mineral) can be observed over the analyzed four years (Fig. 4A). The organic waste was the predominant fraction of mMSW, amounting to 47, 43, 50 and 35 wt.% in the years 2012, 2013, 2014, 2015, respectively. Variation can be observed within the group of minerals. Inorganic components amounted to 12-36% of the total weight in the four years. The amount of mineral waste in 2015 increased up to three-fold compared to other analyzed years.

The main inorganic components present in mMSW were glass, C&DW and the fine "dirt" fraction <10 mm. Glass waste (mainly packaging glass) contributed about 13 wt.% (2012), 10 wt.% (2013), 7 wt.% (2014) and 19 wt.% (2015) of the total waste. In 2015 the amount of glass increased significantly to the level from 2012 and reached 19 wt.% (Fig. 4B). Glass present in mMSW origins from households which are not following segregation rules regarding glass packaging. The fine "dirt" fraction varied significantly between the years and amounted to 3.5–12 wt.% of the total weight, whereas very low amounts of inert materials, such as C&DW, were found. C&DW presence has increased even 40-fold from 2014 to 2015.

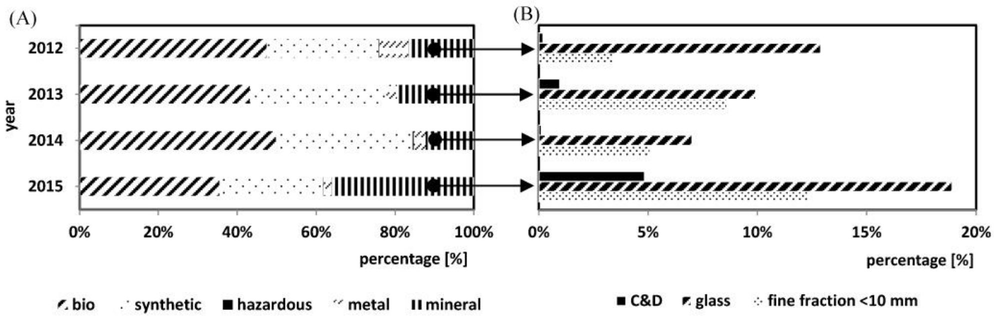

Fig. 4. Composition of mMSW in November (A), and the specific composition of the inorganic fraction (B) in MSW from the ZUT company

The total amount of MSW (code 20 in the Waste Catalogue of the Environmental Protection Agency, 2002) collected by the ZUT company in 2014 was about 14% greater than in 2012 (Fig. 5). During this time, the amount of separately collected waste increased from 3.2 to 26 Gg annually, which constituted up to 76% of the total increase of waste amount from 2012 to 2014. Biodegradable kitchen and canteen waste belongs to this group, and a dual waste collection system introduced in 2013 allows for separate collection of some of this waste. The amount of garden and park wastes decreased about the same amount (three-fold decrease).

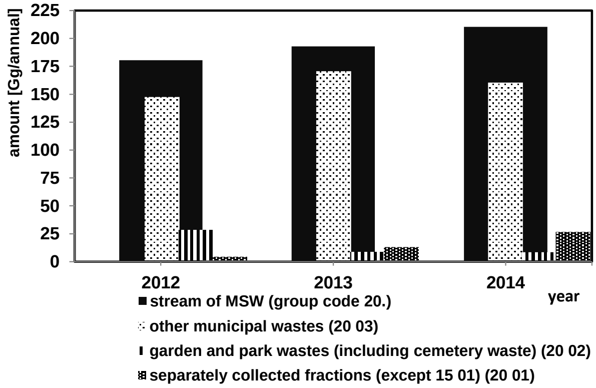

Fig. 5. Amounts of total MSW and some of separate waste fractions collected and processed by the ZUT company

MSW size distribution before and after sorting hall

In the sorting hall, inorganic components larger than 100 mm (2012-2014) and 80 mm (2015) are removed from the organic matter, which is then composted. It is, however, apparent that some fragments greater than 100/80 mm were also passing through to the compost process (Fig. 6B). The size distribution analysis revealed that the dominant amount of glass in mMSW was of the size from 10 to 20 and from 20 to 100 mm (Fig. 6) resulting in about 7% glass in the composted ofMSW treated. There was relatively minute C&DW in mMSW, though the major part of it (20-100 mm) passed to the ofMSW, making up around 3% in 2015, and negligible before that. Synthetic waste was found in all size fractions, and a significant amount passed to the ofMSW, and actually made up the largest part of the impurities - around 13%. After the change of the screening drum (80 mm openings) in 2015, the share of synthetic waste in ofMSW dropped to around 7% and was similar to the glass fraction (10%). However, the amount of fine “dirt” fraction increased to almost 30%, or more than double of that in 2012.

In total, the mineral waste in the 0-100 mm fraction of mMSW amounted to 15% of the total waste in 2012 and 33% in 2015, which indicates that this stream is a part of ofMSW in 20.4 wt.% and 42.6 wt.% of total amount in 2012 and 2015. Moreover, if the total amount of glass in mMSW was 11.4 wt.% (2012) and 15.5 wt.% (2015) and in ofMSW amount of glass was 6.8 wt.% (2012) and 10.4 wt.% (2015), which means that during mechanical processing only 40.4% (2012) and 32.9% (2014) of glass was recovered. The rest of glass, as deeply fragmented fraction, reported to the organic fraction.

The content of organic (bio-) waste in the fraction used for composting (see ofMSW in Fig. 1) varied considerably between the months, from 45 to 57 wt.% (Fig. 7). The largest amount of fine material (25 wt.%) was found in February and November 2015. This could coincide with an increase in ash and slag from coal incineration in stoves. C&DW amounted to a maximum of 5%. The amount of glass was highest in May (19 wt.%) and August (25 wt.%), coinciding with the period with highest beverages consumption. The proportion of synthetic waste was relatively stable being around 9.0 wt. percent.

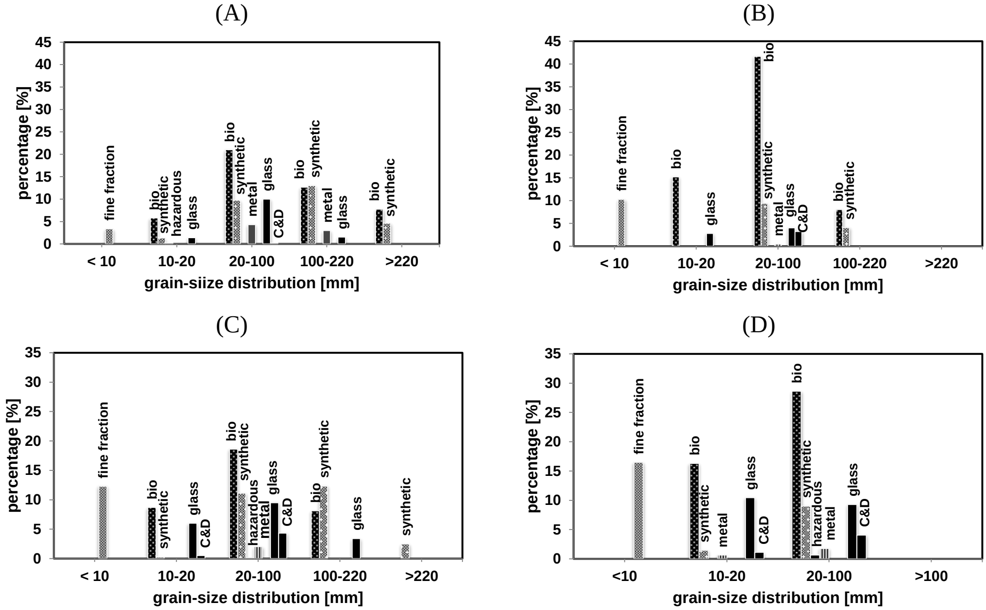

Fig. 6. Waste size distribution and composition of mMSW in 2012 (A) and 2015 (C) and in ofMSW 2012 (B) and 2015 (D)

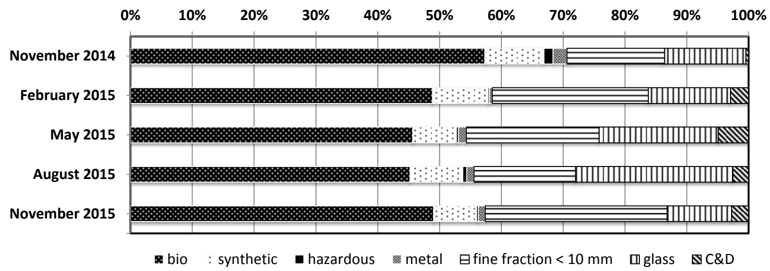

Fig. 7. Seasonal variation in the composition of ofMSW from the ZUT company

Physicochemical waste properties

Physical and chemical analyses confirmed higher content of organic matter in the ofMSW (VS = 54.0%, MC = 54.5%, Table 4) than in mixed MSW. The substantially lower calorific value (Q = 9.5 MJ/kg) of ofMSW than of mMSW results from greater moisture biomass and minerals fine "dirt" fraction content. Elevated mMSW calorific value results from synthetic waste fraction (see Table 4). A high content of minerals in the fine "dirt" fractions resulted in its low calorific value. Results of VS for -10 mm fraction confirm large percentage (61%) of organic matter.

Table 4. Physical and chemical properties of mMSW, ofMSW, fine "dirt" fraction (<10 mm) and MSW compost of municipal solid waste from ZUT company in November 2012. Symbol dm means dry matter

Sample	MSW properties					
	pH*	MC (% dm)	TS (% dm)	VS (% dm)	TOC (% dm)	Q (MJ/kg, dm)
mMSW	5.6±0.16	42.0±4	58.0±4	25.0±0.8	19.0±1.6	15.0±0.14
ofMSW	5.1±0.12	54.5±5	45.5±5	54.0±1,6	23.6±1.5	9.5±0.15
< 10 mm	-	32.6±2	67.4±2	61.0±0,4	19.2±2.4	6.4±0.1
MSW compost	-	39.6±6.4	60.4±6.4	27.3±0.6	-	5.9±0.15

*pH of aqueous faze after leaching (wt part of waste with 4 wt parts of water)

MSW compost impurities size distribution

In mature compost, the content of undesirable glass and other inorganic impurities differed significantly between the two years analyzed, 48% in 2012 and 22% in 2014. Thus, in 2014, 225 kg glass was landfilled with each megagram of compost. Identified impurities in mature compost were mainly glass with a small amount (0.6%) of thermoplastics. According to the granulometric analysis of the glass fraction of the MSW compost, about 80% of the glass particles were greater than 8 mm (Fig. 8).

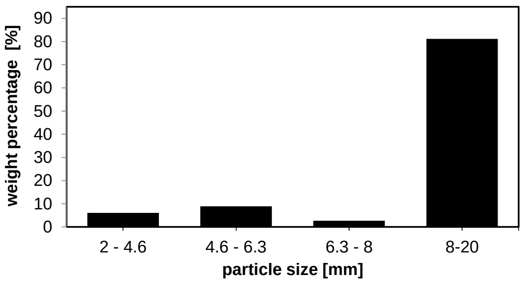

Fig. 8. Particle size distribution (% of total mass) of glass fraction separated from mature MSW compost in the ZUT company

Discussion

Mechanical sorting at the ZUT company is configured for the recovery of secondary raw materials such as plastic waste, packaging waste, waste paper and cardboard as well as removal of impurities to arrive at a biodegradable fractions that can be processed to useable compost or feed for methane fermentation. In the oversize

100/80 mm fraction the glass stream occurs most frequently in form of unbroken bottles or jars allowing their separation at the beginning of the sorting line. At later stages (Fig. 2) the glass matter undergoes disintegration and the particle size distribution (fractions <10, 10–20, 20–100, 100–220, >220 mm) depending on mechanical processing scheme in the treatment plant. In process fragmentation of fragile and brittle components makes separation increasingly becomes more challenging. The waste size distribution analyses gave information about the size and content of the waste in different processing stages, which is a necessary knowledge to be able to discuss the end-use potential. These fine mineral particles can adhere to, or be entrapped in, wet/adhesive surfaces of some MSW fractions during MBT, especially bio-waste, and became increasingly difficult to remove (Zhu et al., 2015). Together with fine "dirt" and C&DW particles, those finer mineral particles exert an adverse effect on waste treatment technologies and equipment, i.e. grinding effect (faster wear of the conveyor belt and damaging of the joint between the belt sections, and mechanical damage of the transportation line (in the case of bulky waste) (Mazurkiewicz, 2008). Though the mechanico-biological treatment processing offers possibilities to recover mineral matter from mixed municipal waste.

As the largest inorganic contaminants in the form of mineral waste such as concrete, gypsum panels, stones, gravel, broken glass passed the sieves (0-100 mm and 0-80 mm size fractions; see Fig. 6) and the mechanical processing chain, they ended up as impurities in the ofMSW (as much as 45-50%). Further sieving of the compost (20 mm) resulted in a low amount of other inorganic impurities, but the amount of glass pieces was remarkably high (22-48% of the total weight). This is substantially higher than other published studies with comparable waste treatment techniques (Table 5). Though the amount of impurities can also depend on different composition of the mixed waste (Iran, France, Spain, and Poland). The results indicate that there is a potential for improvement in the glass removal procedures at the waste treatment plant. This should preferably be done in the early stages of the mechanical process, before the glass pieces become crushed.

Table 5. Comparison of impurities in the final compost product

Impurities	Compost (Sharifi and Renella, 2015)	MSW compost (Coppin, 2008)	MSW compost (Lopez et al., 2002)
	(% dm)		
Stones	18.2	-	*ns*
Glass	11.1	1.25	13.3
Plastics	0.3	0.34	*ns*
Sum of impurities	29.6	1.44	20.7

ns – not specified, dm – dry matter

According to the waste management guidelines (Act on Waste, from July 1, 2013), households-derived compost is usually of good quality. Although the MBT technology is a two-step procedure that potentially could lead to recycling of nutrients in the form of compost, it does not currently offer good possibilities to recover mineral materials in a form suitable for recycling. Broken glass (> 8 mm) could be a factor limiting the use of the compost, as physical contaminants (metal, plastic and glass particles) set limits according to the European Standards (ECN, 2008) along with the content of heavy metals and pathogenic indicator organisms. If the compost does not meet those limits, there are very limited uses, such as for coverage of landfills. Additional screening, 8 mm for instance, would allow for a reduction of significant amount of mineral impurities. This would increase the quality of the compost and increase the recovery of glass. A factor complicating this may be that some larger organic particles would be removed.

Veeken and Hamelers (2002) proved that organic waste collected in villages contains more than 50% of soil minerals. Minerals in the form of gravel or sand are a natural component of the environment, whose presence in the compost is not harmful and the granulation less than 2 mm is acceptable by Polish compost quality regulations. There are, however, contradictory opinions regarding the presence of dirt particles in compost. Jones et al. (2009) and Sikora (2004) showed that mineral fraction in waste had a low nutrient content, and therefore reduced the value of the MSW compost, and did not significantly influence the microbial activity in the composting process.

In contrary, other authors proved that adding minerals to the organic material could be beneficiary as it stimulated the degradation of organic contaminants in the compost (Van Gestel et al., 2003). On the other hand, it has been confirmed that microorganisms have an impact on the composition of the waste mineral matter. They release organic acids which can cause disaggregation and dissolution, and also contribute to secondary mineral formation (Banfield et al., 1999; Grinsted et al., 1982).

Large quantities of mineral waste are usually landfilled as a cover layer. Presence of sand and C&DW on the landfill site as a cover layer reduces odor and gas diffusion through the cover layer (Plaza et al., 2007; Solan et al., 2010; Kaartinen et al., 2013). Cullet removed from the compost and sent to landfills could be a feasible alternative as it has similar properties to sand (Reddy, 1999).

Final comments

Apart from fractions separated in an early stage of waste collection and processing, the "3Rs" (reduce, reuse, recycle) of the waste disposal hierarchy is seldom applied to mineral matter. Hence, selective collection where the waste is generated seems to be the proper solution to for a potential increased recovery of mineral matter. This gives the possibility to separate pure fractions suitable for reuse, in accordance with the principles of 3R the Pomeranian Region collection of both separated and mixed waste fractions, implemented in 2013, enhanced awareness and public support for the new waste management system. Most of MSW mineral matter compounds, for example glass, sand and gravel, ash, crushed concrete could be reused to substitute a percentage of the sand, gravel, cullet used in construction and packaging.

Collecting municipal household waste for central sorting and treating in a mechanical-biological treatment process may pose problems to achieve such material reuse. The presented results of the current study indicate the following conclusions. 1. The mineral fraction constituted a significant part of the mixed MSW stream (about 20 wt.%). 2.Since mineral particles constitute such a large part of the mMSW, they can have a rather negative impact on the technical equipment used in the sorting line, and on the quality of the final products e.g. compost. 3.Separation of a larger part of minerals from the MSW stream could be possible at the beginning of the sorting line, but the mechanical treatment chain results in fragmentation of the particles into smaller that are increasingly difficult to separate in a pure fraction for reuse, i.e. in a form that it not contaminated with other waste. 4. A considerable amount of minerals is separated out when sieving the compost, but this fraction is currently landfilled with limited possibilities for reuse. 5. This analysis indicated a hampered possibility to separate inorganic matter in a form available for reuse (some of them together with the ballast goes to the landfill and is irretrievably lost) in the mechanical-biological waste treatment system. Hence, a more effective system should be based on improved segregation at the source where the waste is generated.

Acknowledgements

The research was funded by the Polish-Norwegian Research Programme operated by the National Centre for Research and Development under the Norwegian Financial Mechanism 2009-2014 (Project Contract No. Pol-Nor/202919/57/2013). The authors wish to acknowledge the outstanding support from the Waste Treatment Plant in Gdansk (Zaklad Utylizacyjny Sp. z o.o.). Additional thanks goes to the master student Aleksandra Glogowska.

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