1. Introduction

The following years will bring the most intense changes in the field of municipal waste management in Poland. This is mainly due to the requirements posed by EU directives which have already been implemented in the Polish law, but also to an act which will become effective on 1 January 2012 under which gminy (municipalities) will have to assume the obligations of estate holders within the scope of municipal waste management. All these changes are supposed to lead to the creation of a system which will guarantee considerable limitation of the amount of landfilled municipal waste. The reduction of municipal waste stream ought to be quickly increasing and should significantly exceed 50%. In view of the anticipated amount of produced waste this reduction may constitute even more than 7 – 8 million Mg in 2020. This limitation should take effect mainly as a result of recovering, preparing for re-use and recycling particular fractions of materials (paper, plastics, glass and metals) and due to the treatment and reduction of biodegradable waste. When we analyse the present state, i.e. the capacity of the existing installations for sorting, recovery and for
biological treatment and incineration of waste as well as the pace of realising investment processes in this area, we may already say that achieving such a level of reduction will not be possible or it will be extremely difficult. On the other hand, however, particular examples of modernising some technological installations carried out in the years 2010 – 2011 or the construction of several new waste management establishments which are to start operation in 2012 or 2013 prove that even in the Polish conditions it is possible to build installations which provide high level of recovering material fractions and in effect to achieve reduction of waste to be landfilled, while retaining high efficiency. Big challenges require undertaking well-considered and well planned actions. The new system is going to be based on regional waste treatment installations. Even if all the currently planned incineration installations are actually built, their capacity will only allow the treatment of not more than 20 % of the produced municipal waste. The remaining waste stream will be treated in other types of installations. The construction of a network of sorting and recovery installations, of mechanical and biological treatment and waste incineration installations is being planned. It is crucial that the constructed installations and applied technological processes are those which have already been verified on other markets and have been adjusted to Polish – in particular local – conditions and needs. High process efficiency and good performance ought to become the crucial among basic criteria of their assessment and selection.

In the following part of this article we will present the practical aspects of sorting and recovery processes as well as some technological innovations in the context of ambitious goals assumed in the National Waste Management Plan Poland 2014 (Krajowy Plan Gospodarki Odpadami 2014).

2. Municipal waste in numbers and the objectives of the National Waste Management Plan Poland 2014

According to data included in the National Waste Management Plan Poland 2014 the amount of municipal waste produced in Poland in 2011 is estimated to reach about 12.5 million Mg and in 2020 – about 14.2 million Mg. In autumn 2010 the Central Statistical Office of Poland (GUS) published new data concerning, among other things, municipal waste management in Poland. In 2009 over 94 % of gminy (municipalities) carried out separate waste collection. This undertaking resulted in the recovery of e.g. almost 500 thousand Mg of waste in the form of plastics, paper, metals and glass. Paper and plastics constituted about 250 thousand Mg of the stream of recovered waste. As compared to 10 million Mg of municipal waste collected in 2009, the amount of waste collected separately and directed for recycling was about 5 % [3].

Figure 1:
Municipal waste collected from private households in Poland
In Poland mixed municipal waste from households – dependent on where it derives from (whether from urban or rural areas) – contains considerable amounts of particular fractions of materials. The share of the four basic material fractions in the total municipal waste stream is the following [2]:

- paper: \(~5\) to \(~20\) \%,
- plastics: \(~10\) to \(~16\) \%,
- glass: \(~8\) to \(~10\) \%,
- metals: \(~1\) to \(~3\) \%.

Figure 2 and 3 show the anticipated amounts of produced waste in the following years and they allow a simple calculation of the required levels of recovery and reduction.

Figure 2:

Anticipated amount of produced municipal waste in Poland, including produced biodegradable waste which can be landfilled

Source: The author’s own elaboration based on data included in the National Waste Management Plan Poland 2014

Two years after the new framework directive 2008/98/EC on waste came into force, the whole range of requirements and objectives that arise from it was reflected in the National Waste Management Plan Poland 2014 which became effective on 1 January 2011, in which the following goals concerning municipal waste management were assumed:

- including all the inhabitants in an organised system of collecting municipal waste until no later than 2015,
- including all the inhabitants in a system of separate collection of waste until no later than 2015,
• decreasing the amount of biodegradable municipal waste which is sent to landfills, so that no more than:
  * 50 % in 2013,
  * 35 % in 2020
  of the mass of this waste produced in 1995 is landfilled,

• decreasing the mass of landfilled municipal waste up to no more than 60 % of the produced waste by the end of 2014,

• preparing waste materials, at least such as paper, metal, plastics and glass from private households (and, if possible, of other types of waste similar to that collected from private households) for re-use and recycling in the amount of at least 50 % of their mass by 2020.

The above mentioned objectives are definitely important and if we manage to achieve them it will prove a big advance in organising our waste management system, even if we have to revise the deadlines for achieving them.

The possibility of achieving the objectives mentioned in paragraphs 3, 4 and 5 is strictly connected with the type of applied waste recovery and treatment technologies.
3. The results of achieving the objectives of the National Waste Management Plan Poland 2014

One of the objectives of the National Waste Management Plan Poland 2014 is to recover at least 50% of the weight of paper, plastics, glass and metals from private household waste and to prepare it for re-use and recycling by 2020 [3]. In other words, we may say that in order to meet the requirements of the new waste directive it is necessary to separate/recover over 20% of waste from municipal waste stream collected from private households in the form of material fractions every year. When we consider the anticipated amounts of produced waste and the share of particular material fractions – namely paper, plastics, glass and metals – we are talking about the recovery of over 2.7 million Mg of these material fractions per year. This recovery is directly reflected in the reduction of the amount of landfilled waste and in the limitation of the amount of landfilled biodegradable waste (paper) and it depends to a large extent on the efficiency and performance of the technological sorting and recovery installation.

In order for the objectives of the National Waste Management Plan Poland 2014 and of the new framework directive 2008/98/EC to be achieved, many investment processes will have to be carried out in the following years in the area of waste sorting, recovery and treatment installations. A lot of attention is paid to creating a system of separate waste collection. Some positive changes can already be seen in this field. They are mainly related with the analysis of the economics of the process and with efforts to optimise the systems of waste collection, making allowance for the needs of its receivers, for management possibilities and for the development of techniques and technologies of sorting and recovery processes. However, it may at times seem that the main goal is only to implement separate waste collection and not to recover particular material fractions of appropriate quality as expected by receivers (recyclers) at the minimum specific costs. On the other hand, regardless great experience, gained also in Poland in the last few years, there are still some municipalities where there is an ongoing discussion on the validity of sorting mixed municipal waste from private households. What is questioned is the recovery of recyclable materials, in particular in the context of technical possibilities of separating those fractions in an efficient way and, what is more important, the quality of the recovered material fractions and the supposed problems with managing them. If, however, we analyse the market of particular material fractions management it will turn out that apart from the last period of economic crisis, materials separated in mixed municipal waste sorting installations have been an object of trading in Poland. Moreover, it seems that entities that deal with recovering recyclable materials, both - mixed municipal waste and separately collected waste – reach various price levels which depend on quality only in the case of paper. For other fractions of materials – Polyethylene-Terephthalate (PET), Polyethylene-/propylene (PE/PP), film, cardboard packaging – the offered prices are on the same level (with only a few exceptions).

Bearing the aforementioned in mind it is worth to remember that without recovering material fractions from mixed municipal waste we irretrievably lose materials which might be re-used. Under directive 2008/98/EC, there is no obligation of achieving appropriate levels of recovery and of preparing waste for re-use and recycling only through the development of separate collection of waste. The directive mentions e.g. the creation of an appropriate network of installations for the disposal and recovery of mixed municipal waste. It also points out economical, technical and environmental aspects of the issue [3].

Implementing separate collection ought to make allowance, in particular, for the needs and expectations of the receivers (recyclers) of particular material fractions as well as for the available technical and technological means.
4. Technological sorting and recovery installations

4.1. The present state

The number of municipal waste sorting installations at the end of 2009 was 173, with a total capacity of 2.2 million Mg per annum\(^2\). This means that the capacity of the existing installations allows the treatment of less than 20% of the produced municipal waste. A great majority of sorting installations which have been used until today were put into operation in years 2000 – 2010. These installations are characterised by a rather small hourly capacity and low level of recovery of recyclable materials, since the recovery, apart from metals, depends on the number of employees working in sorting cabins, their productivity and the economics of the process carried out in this way. There are numerous reasons for this state of things. The most important of them include: easy access to still cheap labour force, low costs of landfilling waste and the lack of actual motivation to search for effective and highly efficient solutions.

However, these conditions have been changing considerably in the last few years. The plans of introducing further changes also lead to a situation where more and more attention is given to efficiency, performance, availability and effectiveness of the sorting and recovery processes.

Even though there are still some waste management establishments being designed and constructed which, due to the applied technical and technological solutions, do not allow either the required level of reduction of biodegradable waste or the recovery of particular material fractions for further recycling on the level as indicated in the National Waste Management Plan Poland 2014, we observe a still growing number of positive examples of investors’ activity. Maximisation of recovering materials and reduction of waste stream to be landfilled become priorities.

4.2. Evolution of the sorting and recovery processes

In order to achieve the above mentioned ambitious objectives a different approach towards technological processes from the one presented so far is needed. It mainly concerns the sorting and recovery processes. Simple methods which have been used until now are not sufficient any more. There is a need to apply more effective, productive and more efficient technological solutions.
What is important is to get to know and take into account the potential of the produced municipal waste, changes that may take place in a several year perspective, the needs of receivers and tendencies concerning price levels of particular materials as well as management possibilities. Once we know the potential of the available technical solutions we may create appropriate configurations of technological installations which are actually adjusted to individual needs.

2008 was the year when the new waste framework directive 2008/98/EC came into force and when a company, being part of the TITECH group was established in Poland. The time convergence is accidental. However, the activities are also intertwined with the priorities of the directive. As soon as in 2009 a technological concept of sorting and recovering material fractions from mixed municipal waste and from separately collected waste was presented – it was adjusted to the specificity of the Polish market. The basic objective was to create a concept of a technological installation providing maximum recovery of particular material fractions used mainly for recycling. The focus was on providing the recovery of the basic material fractions, such as:

- paper,
- PET packaging,
- PE/PP packaging,
- PE film,
- beverage carton,
- ferrous and non-ferrous metals and
- fractions (obtained from the remaining part of the stream) to be used for the production of high-quality alternative fuel (RDF),

providing, at the same time, high recovery efficiency and effectiveness as well as the lowest possible specific costs for one Mg of the recovered recyclable material. These concepts are based on automation of the sorting processes with the use of optical separators which provide very high quality of separating particular material fractions – at the level exceeding 80 – 90%.

Figure 5: A sample composition of municipal waste from private households and prices of raw materials
Figure 6: A simplified flowchart of the municipal waste sorting and recovery processes

At present some installations are being constructed which, apply those technological concepts. In 2010 a modernisation of sorting installations for mixed and separately collected municipal waste, which had been used for several years, was carried out. The scope was to integrate optical separators into existing technological systems in such a way that it is possible to achieve the maximum level of recovery of plastic and paper fractions. The result of these modernisations is the recovery of over 80 – 90 % of plastics and over 85 – 90 % of paper from the waste stream directed to the separators. At present plastics recovered in this way are mainly used for the production of alternative fuel. The only materials which are separated manually are PET, some of PE/PP and film. Further automation of the plastics sorting process is planned for the future, so that PE film, PET bottles and PE/PP packaging can be recovered and directed towards recycling. As a result of advancing changes in sorting processes, recovery is carried out by separators and the work of people in sorting cabins is limited to supervising the process – and occasionally removing some objects from automatically separated material fractions.

4.3. Technological innovations in the sorting and recovery processes

It was in the year 1993 when the Norwegian government stipulated that a special packaging must be recovered after its use out of the remainders of the Norwegian households – the beverage carton. This act set off the development of a technology revolutionizing the whole waste management market.

TITECH has initiated automation of waste sorting processes only 16 years ago, by constructing the first optical separators which use near-infrared spectroscopy to identify materials. However, the most dynamic development and expansion on international markets has taken place in the last decade. Today, the firm is developing a range of technologies the scope of which is to identify the greatest number of materials with the highest accuracy possible and to separate them efficiently. All this is combined with the highest possible capacity and high level of purity. In sorting municipal waste, the optical separators that are used are based, in particular, on near-infrared (NIR) sensors and on visible light (VIS) sensors, and in specific applications also on electromagnetic (EM) sensors and X-ray (XRT) sensors.

The material stream is spread on a highly accelerated conveyor belt (up to 4.0 m/s) above which the detection unit is located. This unit includes lamps to light up the conveyed material and a near-infrared sensor and visible light sensor measure the reflection from the material. When lighting up material the light is to a certain amount absorbed and to another amount reflected. This reflected light bares the information about the colour and type of the material from which it has been reflected.
The operator just has to decide on a very simple interface which material is to be sorted. The desired material is ejected by the means of compressed air into a chamber separating the refused material from the desired one.

In short:
- High speed processing of information: material, shape, size, colour and location of objects;
- Precise sorting by air jets.

This technology is successfully applied nowadays in any kind of waste stream:
- Packaging Waste and Paper,
- Commercial and Industrial Waste,
- Construction and Demolition Waste,
- Municipal Solid Waste and many more.
4.4. Optical sorting in municipal waste sorting processes

Near-infrared (NIR) sensors and visible light (VIS) sensors applied within the autosort optical separators allow the identification of the whole range of different materials. Then, they can be separated by use of compressed air. What is of greatest importance in the case of municipal waste is the detection and separation of the most valuable fractions of materials, i.e.: paper, PE film, PET bottles, PE/PP packaging and beverage cartons. Moreover, it is possible to separate a group of defined material fractions from the municipal waste stream – this includes e.g. Polystyrene (PS), PE/PP, wood and possibly paper and textiles, so that they can be used in the production of alternative fuel of required quality as expected by its receivers. The type of separated fractions may be adjusted to the current needs and the type of treated waste. It is particularly important if a sorting installation is also used for sorting other waste streams, e.g. industrial waste, bulky waste or construction waste. In the case of construction waste it is possible – obviously, apart from separating paper and plastics – to recover wood and obtain an inertial fraction of high purity.

Figure 9: TITECH sensors with DUOLINE technology

Figure 10: Material identification with VIS/NIR – the principle of operation of an optical separator
4.5. Limitations of using optical separators in sorting processes

Optical separators do not permit separation of glass, stones, metals and black materials from the municipal waste stream. Another limitation is objects which can be identified but due to their properties or shape are difficult to be separated by the use of compressed air. This includes e.g. very long and heavy objects. That is why it is important to take this fact into account when preparing a concept of a technological process and when designing the installation.

After all, even the most advanced and efficient machine will not compensate for conceptual and design errors of a technological installation. Thus, in order for separators to achieve optimum results it is necessary to form appropriate concepts of the sorting, recovery or treatment processes.

4.6. Innovations in municipal waste treatment special applications

Separating metals in the alternative fuel production process

The production of high-quality alternative fuels has been growing in importance in the recent years – also in Poland. The quality of alternative fuel produced only by shredding...
municipal waste becomes insufficient. In this area installation users also observe more and more profits from using optic separators. Apart from the already mentioned possibilities of separating particular types of materials, if we also apply an electromagnetic (EM) sensor it will be possible to create programmes allowing the elimination of waste containing metals (combined with metals) from the waste stream directed to post-shredders. Separating metals results in the reduction of wear and tear of shredder parts and in operational downtime of the installation which decreases operating costs and increases efficiency.

**Online analysis of alternative fuel parameters**

The cement industry is the only receiver of alternative fuel in Poland and it requires appropriate quality of alternative fuel parameters. It is anticipated that the demand for alternative fuels will keep increasing in the upcoming years. In order to provide expected quality it is necessary to apply appropriate production processes and to be able to supervise the quality of the end product.

Therefore, a system has been created that allows for continuous supervision of alternative fuel parameters. Such parameters as: moisture, chlorine content and calorific value may be visualised during the production process or during proportioning the material right before putting it into cement mill installations, so immediate reaction is possible, if needed.

![Figure 12: Refuse Derived Fuel from waste](image)

![Figure 13: A simplified flowchart of RDF online analysis with using of optical sensor](image)
Preparing organic fractions for further waste treatment processes

One of the biggest challenges in waste management in Poland is the reduction of biodegradable waste landfilling. One of the possible ways of reducing this waste stream is to subject it to mechanical and biological treatment. Biological treatment technology also applies anaerobic processes the scope of which is to recover biogas and to convert it into electric power. Unfortunately it very often happens that the composition of such fractions poses problems with carrying out the process appropriately. An organic fraction – usually within the range of 0/15 – 50/70 mm – which is separated mechanically from mixed municipal
Figure 16: Highspeed XRT processing used in TITECH x-tract

Figure 17: Organic fraction from MSW

Figure 18: A simplified flowchart of Organic cleaning process
Innovations in Sorting Processes for Mixed Household Waste

waste contains large amounts of glass, stones and plastics. These materials have a negative impact on the biological process. Plastics are separated in the way that has already been described – by using an optical separator. Highly efficient separation of inertial fractions becomes possible due to the application of a separator which uses X-rays to identify materials. The method of separating stones, glass, metals, batteries, bones etc. is analogous with that based on optical separators, i.e. by use of compressed air. If we incorporate the autosort optical separator and x-tract into the technological process of preparing fractions for biological treatment processes, we can eliminate undesired materials. The objective of such a solution is not to recover material fraction which is to be recycled with high accuracy, but to improve the properties of an organic fraction (containing biodegradable waste) which is to be further treated.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Organic input &gt; 20 mm</th>
<th>Output after Autosort and x-tract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic material, bones and wood</td>
<td>%</td>
<td>69.3</td>
</tr>
<tr>
<td>Organic material</td>
<td>%</td>
<td>61.9</td>
</tr>
<tr>
<td>Bones</td>
<td>%</td>
<td>3.4</td>
</tr>
<tr>
<td>Wood</td>
<td>%</td>
<td>3.9</td>
</tr>
<tr>
<td>Plastic</td>
<td>%</td>
<td>7.6</td>
</tr>
<tr>
<td>Inert material</td>
<td>%</td>
<td>18.1</td>
</tr>
<tr>
<td>Metals</td>
<td>%</td>
<td>5.0</td>
</tr>
<tr>
<td>Discharge</td>
<td>t/h</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Figure 19: Separated inert fraction from organic from MSW

5. Conclusions

- Mixed municipal waste constitutes to over 90% of municipal waste collected in Poland and contains over 40% of recyclable fractions (paper, plastics, glass, metals, wood).
- Recovery of recyclable fractions from municipal waste rich in particular types of such fractions is possible and may be efficient, effective and economically justified if we conceive good technological concepts and apply available technical solutions.
- It will be extremely difficult to reach the objectives assumed under the National Waste Management Plan Poland 2014 in the range of waste management without subjecting mixed municipal waste from private households to treatment.
- Achieving the goals stipulated in the new framework directive 2008/98/EC on waste of 19 November 2008 and those assumed under the National Waste Management Plan Poland 2014 ought to be the basic requirement and assessment criterion for the currently carried out projects related to waste management, technological sorting, recovery or treatment installations (designed and constructed waste treatment establishments) and currently created systems of collecting waste.
The specificity of the Polish market also requires that technological installations for mechanical and biological treatment ought to be equipped with some solutions – in the area of mechanical treatment – allowing efficient recovery of material fractions both from mixed municipal waste and from separately collected waste.

The sole separate collection and its development do not guarantee achieving the objectives indicated in the National Waste Management Plan Poland 2014 and in the directive. They do not guarantee high level of recovery nor efficiency either. It is indispensable to optimise separate waste collection systems as well as the existing technological infrastructure (treatment, sorting and recovery installations).

When choosing appropriate solutions in the area of separate waste collection and technological installations it is necessary to analyse and assess all the stages - from collection to recycled materials' management.

Constructing a multifunctional installation for sorting mixed municipal waste and separately collected waste from private households should be preceded by a detailed analysis of available technical and technological solutions, of the waste stream composition and of the economic aspects of conducting such an activity. High level of recovery is only possible if efficient solutions related to the automation of the sorting and recovery processes are applied and only if the waste has appropriate potential in terms of contained materials. The only criteria used in deciding whether automation of sorting should be applied ought to be: a) economics, b) the quality of recovered material fractions.

In 2012 – 2013 in Poland the first multifunctional installations for sorting mixed municipal waste and separately collected waste from private households will be put into operation. They will be based on the technological concepts. These installations, apart from a range of functional and innovative solutions, will also be equipped with autosort optical separators to allow the recovery of: PE film; PET (including colour division); PP/PE; beverage cartons; paper mix and cardboard; fractions used for the production of alternative fuel. These installations will be examples of a technological breakthrough in constructing municipal waste sorting installations in Poland.

The present situation in waste management in Poland is not quite favourable for entities that actually deal with reducing the amount of landfilled waste – e.g. by recovering material fractions – no matter if they deal with separate collection and sorting of waste or if they recover recyclable material from mixed municipal waste stream by use of installations. The construction of an efficient system requires the introduction of mechanisms which would provide economic justification for the recovery of material fractions and passing them for recycling as well as justification for recycling itself.

Deep morphologic analysis of the waste stream, being aware of changes in quality and quantity, knowing the expectations of material fraction or waste stream receivers, knowing price levels of materials and of disposing of the remaining part of the waste stream, critical approach to the offered black box solutions, visiting reference facilities which use particular possible solutions, the analysis of operating costs, dialogue and exchanging experience between investors and users of already existing installations and installation or equipment providers – all of these ought to constitute the foundations for the creation of optimum installations and waste management establishments where efficiency and economics should be the key criteria of assessing waste management systems which are currently being formed and of the selection of technical and technological solutions applied in technological installations.
The level of recovery, preparation for re-use and recycling and reduction in the amount of biodegradable waste as required for the year 2020 can only be achieved if we consistently keep creating and actually manage to create a good, effective and efficient waste management system in the upcoming years, an integral part of which will be installations with adequate capacity to be able to treat all the waste produced in Poland. A rational and efficient system on every stage of operation: from collecting waste, through transportation, recovery and recycling, up to treatment and disposal. If it so happens then there will be a chance of getting close to the assumed goals concerning the level of recovery or reduction of landfilled waste in the next 10 years.

6. Bibliography


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