Review paper

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Mixed municipal solid waste (MSW) treatment in Waste centre Spodnji Stari Grad, Krško

Ravnanje z mešanimi komunalnimi odpadki v Zbirnem centru Spodnji Stari Grad, Krško

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Abstract

The main task of mechanical recycling line is the secretion of useful fractions from mixed municipal waste and thereby reducing the quantities of waste landfilled on the municipal solid waste (MSW) landfills. The capacity of the mechanical recyclin line was 15 t/h of mixed municipal solid waste, which are collected mostly (80 %) in bags. They separate bio-waste (heavy fraction), foil, mixed paper, non-magnetic metal, magnetic metal, PET (polyethilene terephthalate) plastic, hard plastic, composite packaging and waste for substitute fuel. Remnants of sorted waste end up in the press container, secondary raw materials are compressed with horizontal channel baler. After six months of mechanical recycling line operation in a MSW landfill was landfilled only 24 % of the total collected quantities of MSW in Krško municipality or 48 % of the total MSW waste brought into the recycling line. In article will be presented in detail the mode of mechanical recycling line operation and the results of sorting for mixed municipal solid waste in Krško municipality.

Key words: mixed municipal solid waste (MSW), material recovery facility (MRF), waste sorting center, Dolenjska regional waste treatment center (CeROD)

Izvleček

Glavna naloga sortirne linije je izločanje koristnih frakcij iz mešanih komunalnih odpadkov, s tem pa zmanjševanje količin odpadkov, odloženih na komunalna odlagališča. Kapaciteta sortirne linije je 15 t/h mešanih komunalnih odpadkov, ki so v 80 % zbrani v vrečah. Separirajo se biološki odpadki (težka frakcija), folije, mešani papir, nemagnetne kovine, magnetne kovine, PET-(polietilentereftalat) plastika, trda plastika, sestavljena embalaža in odpadki za nadomestna goriva. Preostanki sortiranja končajo v stiskalnem zabojniku, sekundarne surovine pa se stisnejo s horizontalno (kanalno) balirko. Po polletnem obratovanju linije se na odlagališču odlaga še samo 24 % odpadkov od skupne zbrane količine odpadkov v občini Krško oziroma 48 % odpadkov, pripeljanih na sortirno linijo. V članku so podrobneje predstavljeni način in rezultati delovanja sortirne linije za mešane komunalne odpadke v Občini Krško.

Ključne besede: mešani komunalni odpadki, obrat za sortiranje/snovno izločanje, zbirni center za odpadke, Center za ravnanje z odpadki Dolenjske (CeROD)

Introduction

In accordance with the national operational programme of municipal solid waste treatment and taking into account the European guidelines have the greatest emphasis to waste prevention, re-use and recycling and reducing of waste quantities landfilled on the municipal solid waste landfill sites. At the restoration/establishment of the system of municipal solid waste management in the municipality Krško and Posavje region is necessary to take into account the operational waste management programme of Republic of Slovenia and the European Union (EU) and the national legislation in force in the field of waste management. In Slovenia it is necessary in accordance with the current legislation, to organize a separate waste collection at the source and treatment of residual waste prior to disposal, and thus put a small amount of waste as soon as possible.

Table 1 and 2 summarize the objectives of the EU directives related to the municipal solid waste treatment[2, 3, 4].

To achieve the objectives of the EU directives for re-use and recycling of municipal solid waste by 2020 it will be necessary to change the way of municipal waste treatment practices at Slovenia in accordance with good EU and world practices. According to the minimum (waste reduction) scenario, compared to the baseline year 2011 it will be required by 2020:

— reduce the rate of mixed municipal solid waste from 50 % to 36 %,
— increase the share of separately collected waste paper, metal, plastic and glass with 34 % to 47 % (including waste collected outside the operation of public services) and
— consider increasing the amount of separately collected kitchen waste (aprox. 6.5 %).

For purposes of monitoring the environmental objectives of the EU Directives relating to the

Table 1: *The objectives of the EU Directives related to the municipal solid waste treatment*[11]

Targets from EU Directives	Year	Colection targets (in mass fractions, *w*/%)
storage of biodegradable waste on landfill	2006*	reduction of up to 75 % with respect to 1995
	2009*	reduction of up to 50 % with respect to 1995
	2016*	reduction of up to 35 % with respect to 1995
Municipal solid waste (at least for waste paper, metal, plastic and glass) – EU Directive 2008/98/ES	2015	implementation of separate collection
Municipal solid waste (at least for waste paper, metal, plastic and glass) – EU Directive 2008/98/ES	2020	re-use and recycling increased up to 50 % of total municipal solid waste quantity

*Slovenija is in accordance with 5th article of Directive 1999/31/ES postpone the implementation of the objectives for 4 years.

Table 2: *Indicators for assessing achievement of environmental objectives in Slovenia*[11]

	2011	2020	
		Minimum scenario	Feasible scenario
The share of mixed municipal solid waste (%)	50	36	33
The share of separately collected waste fraction (%)	50	64	67
The share of separately collected biowaste (%)	12	12	15
The share of recycled municipal solid waste (%)	45	61	64
The share of landfilled municipal solid waste (%)	47	15	11
The amount of municipal solid wastes (kg per habitant)	428	447	447
The amount of recycling wastes (kg per habitant)	193	271	285
The amount of landfilled municipal solid wastes (kg per habitant)	202	66	49

treatment of municipal solid waste in Slovenia (collected within and outside the public service) were constructed indicators, the values for 2011 and 2020 for the target are shown in the Table 2.

In accordance with the novel ZVO-1B Ur. l. RS, št. 70/2008[5, 10] the waste management must deal with three separate services namely the service for the collection and transportation, service for the waste treatment and service for the waste disposal. In the case of municipal solid waste of Krško the first two jobs, the collection, transportation and the waste treatment with the concession contract is carried out by the company Kostak. Disposal of residual waste by Decree is carried out by a regional community service CeROD on the regional landfill Leskovec at Novo mesto.

Waste treatment in municipality Krško and Kostanjevica

In the municipality Krško and municipality Kostanjevica na Krki (total 15 local communities) in accordance with the Act of waste management in the municipality Krško[1], the company Kostak carried out the collection and disposal of municipal solid waste. In both municipality areas operates 225 public collection points for separate collection of waste.

The quantities of waste fractions collected separately on public collection points and the quantities of waste collected with public services in the municipality Krško and municipality Kostanjevica na Krki in the period 2003 to 2011 are summarized in the following Tables 3 and 4.

Company Kostak transport all mixed and separately collected municipal solid waste into own Waste collection center Spodnji Stari Grad. Waste collection center, which is located near a closed waste landfill Stari Grad, began with operating in 2003. In Table 3 and 4 shows the quantities by public services collected waste and the quantities and shares in both municipalities separately collected fractions of wastes. We can see that the share of separately collected fractions gradually growing and today reaches about 40 % (cf. Figure 1), which approaching the 50 % objective target for Slovenia (cf. Table 2).

From the Table 4 we can see that the amount of waste collected in the municipality of plant growing. The main reason is the active involvement of all citizens in the county held a public waste removal, replacement of bulk tank to the individual, the opening of new businesses, increased purchasing power, clean dumps and operation of the collection center. The increased separate collection of waste also contributes intensive raising awareness through public media by company Kostak.

Table 3: *The quantities of separately collected fractions of wastes (in tonnes) in the municipality Krško[9]*

Year	Bulky waste	Hazardous waste	Paper	Plastic	Glass	Biowaste	Other separated waste fractions*	Total
2003	323	3	61	27	83	1	–	498
2004	349	12	102	64	94	472	–	1 093
2005	623	7	311	98	110	1 067	–	2 216
2006	620	6	315	170	120	1 282	273	2 786
2007	816	11	331	147	136	1 797	457	3 694
2008	576	6	273	175	164	2 048	1 120	4 362
2009	–	12	540	244	181	1 935	1 767	4 698
2010	–	16	603	248	188	2 738	1 962	5 755
2011	–	12	731	299	251	3 208	845	5 346

*Bulky waste from 2009 onwards shown under other separate fractions. Under other separate fractions are listed tin cans, composite packaging, styrofoam, waste grave candles, wood, tires, organic kitchen waste, electric and electronic equipment waste.

Table 4: *The quantities of waste (in tonnes) collected with public services in the municipality Krško, Kostanjevica na Krki*[15]

Year	Krško	Kostanjevica na Krki	Total (t)	Separate collected waste fractions (t)	Share of separate collected waste fractions (mass fractions, *w*/%)
2003	10 494	–	10 494	498	4.75
2004	10 016	–	10 016	1 093	10.91
2005	12 871	–	12 871	2 216	17.22
2006	14 370	–	14 370	2 786	19.39
2007	15 822	638	16 460	3 694	22.44
2008	11 792	737	12 529	4 362	34.82
2009	12 854	773	13 627	4 698	34.48
2010	12 461	1 102	13 563	5 755	42.43
2011	13 218	796	14 014	5 346	38.15
2012	10 024	752	10 776	–	–

Waste collection center Spodnji Stari Grad collect and sort waste plastic, paper, glass, sheet metal, packaging (carton) and biological, bulky and hazardous waste. Glass does not specially handled and mostly disposed of on an old landfill area. Plastics and sheet metal is sorted, pressed and prepared for further processing. Paper and cardboard they separate on the mechanical recycling line. Biological treatment of waste composting plant in the compost, which is mostly used for the rehabilitation of the collection center areas. The remaining bulky waste are collected in two annual campaigns, hazardous waste in one annual campaign[13]. Since 2007 (closure of local landfill Spodnji Stari Grad), all remainings after municipal waste recycling are unloaded on the ramp into roller tipping containers, waste compress and prepare for transportation on the landfill CeROD in Leskovac at Novo mesto (from the place about 39 km).

The company Kostak in 2011 has carried out waste sorting analysis, although it has been determined the average structure of the waste. Table 5 shows the structure of treated mixed municipal solid waste from municipality Krško and Kostanjevica na Krki, on which data has been estimated revenue that can be achieved from the sale of processed waste fractions[7].

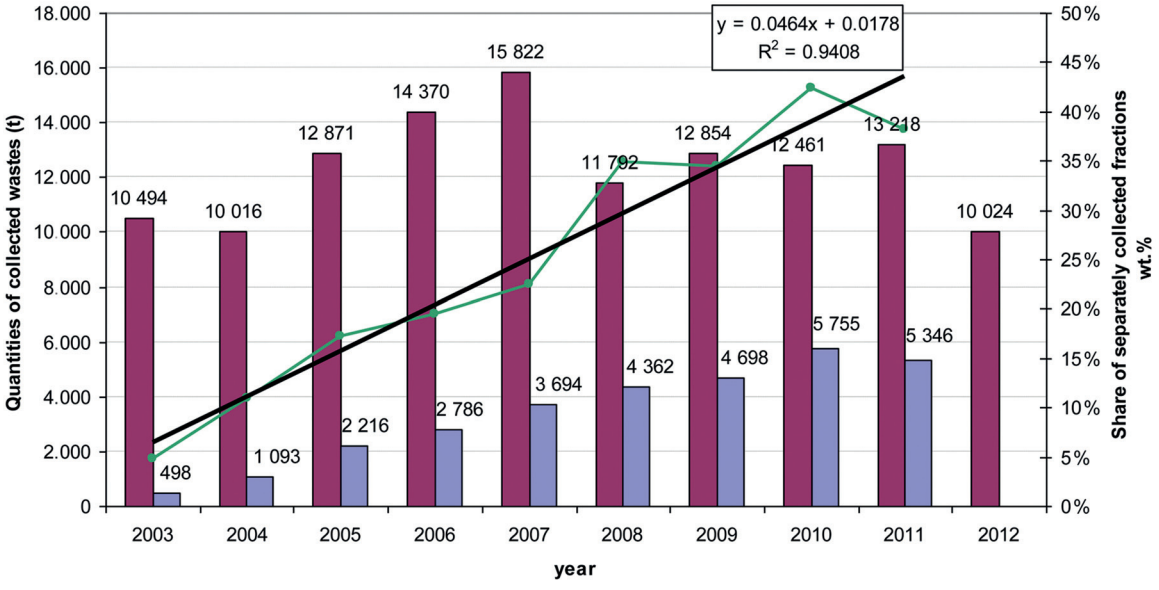

Figure 1: *The quantities and shares of separately collected fractions in both municipalities between 2003/2011.*

Table 5: *Estimated revenue and operating costs from the mechanical treatment of mixed municipal solid waste fractions in Waste collection center Spodnji Stari Grad*[7]

Type of waste	Share after sorting analysis in mass fractions, *w*/%	Quantity in mass fractions, *w*/% sorting analysis (t)	Estimated revenue from the sale		
			Estimated quantities (t)	Av. price (EUR/t)	Total (EUR)
Paper and cardboard	9	867	433.5	85	36 847.5
Plastics	23	2 098	1 049.0	60	62 940.0
Metals	5	456	228.0	150	34 200.0
Tetrapac	3	274	137.0		
Tekstil	6	547			
Wood	6	502	251.0	3	753.0
Styrofoam	1	91			
Bio waste	29	2 600			
Glass	9	867	433.5		
Other waste	9	821			
Total	**100**	**9 122**	**2 532.0**		**134 740.5**

The expected total annual cost of waste management in municipality Krško have been estimated to 74.14 EUR/t of waste and 59.37 EUR/t, taking into account the reduction in costs from revenues from the sale of fractions after mechanical recycling. The share of the cost of the mechanical treatment of waste in the total cost of treatment after the investment will amount to approximately 72.75 % or 43.62 EUR/t of waste[7].

In Figures 2 and 3 show the difference in the final composition before (2011) and after mechanical treatment/sorting (2012) of mixed municipal solid waste. We can see that the share of sorted fractions separated after the introduction of mechanical processing/sorting increased by about 1 % (we get new separated fractions like aluminium (ALU) cans, composite packaging (carton), various types of plastics and glass) for 15 % the proportion of organic waste for composting and about 26 % decrease in the proportion of waste for landfilling in CeROD.

In 2012, Waste collection center Spodnji Stari Grad was upgraded with a single stream (binary) mechanical recycling line (opening 17. 8. 2012), is currently one of the most modern recycling facility in Slovenia, which is capable of processing up to 15 t/h (50 000 t per year) of mixed municipal solid waste. Waste recycling will be upgraded in the near future also with a closed biological waste treatment facility.

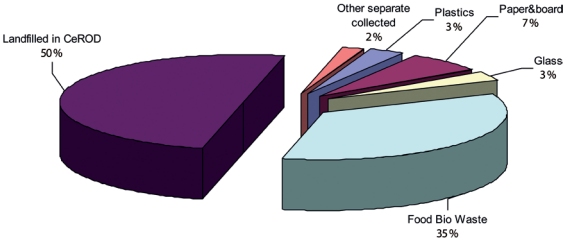

Figure 2: *Average composition of collected MSW before introduction of mechanical treatment (2011) of mixed municipal solid waste.*

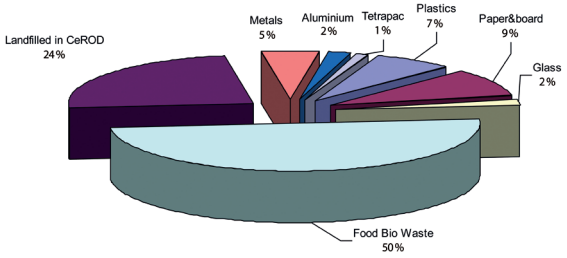

Figure 3: *Average composition of waste residues after introduction of mechanical treatment of MSW*[8].

Binary model of waste material recovery

In Waste collection center Spodnji Stari Grad using a single stream mechanical recycling line for mixed municipal solid waste separation. The separation of one material from a mixture of materials is termed as binary process, as two outputs from the operation[16]. A binary separator receiving a mixed feed of x_0 and y_0. The goal of the unit operation is to separate the x fractions in as pure form as possible and with the greatest total recovery possible.

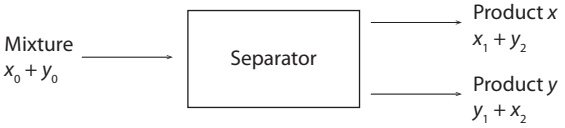

Figure 4: *A binary separator receiving a mixed feed of x_0 and y_0*

One exit stream will contain the x components or product, the desired material. Separation will not be perfect, there will inevitably be contamination as y_1. A second exit stream, containing mostly the y component or reject (cf. Figure 4.). Note that this stream will also contain some of the component x_1. The recovery of x can be expresed as:[6]

$$R(x_1) = \frac{x_1}{x_0} \cdot 100 \tag{1}$$

where
$R(x_1)$ ... recovery of x in the first output stream
Equation does not take into account purity of the product. If the separation device is not operational, then all the input will pass through. In other words, $x_0 = x_1$ with the result that $R(x_1) = 100$ %. The purity of the product in the extract stream x is defined as:

$$P(x_1) = \frac{x_1}{x_1 + y_1} \cdot 100 \tag{2}$$

There are also difficulties with using purity alone as a descriptor of separator performance. For example, it might be possible to extract a small amount of x in a pure state, but the recovery ($R(x_1)$) will be very small. It is therefore necessary to describe the operation of a materials separation device by incorporating both the recovery and purity. Binary separator efficiency can be determinated as:[14]

$$E(x,y) = \left(\frac{x_1}{x_0}\right) \cdot \left(\frac{y_1}{y_0}\right) \cdot 100 \tag{3}$$

Example for binary separator can be eddy current separator. An eddy current separator is to separate aluminium product from an input stream of material. The feed rate to the separator is 1 500 kg/h. The feed is known to contain 55 kg of aluminium and 1 445 kg of reject. After 1 h of separation a total of 65 kg of material is collected in the product stream. On close inspection it is found that 46 kg of product is aluminium.
Recovery of aluminium product:

$$R(x_1) = \frac{x_1}{x_0} \cdot 100 = \frac{46}{55} \cdot 100 = 83.6\ \% \tag{4}$$

Purity of aluminium product:

$$P(x_1) = \frac{x_1}{x_1 + y_1} \cdot 100$$

$$= \frac{46}{46 + 19} \cdot 100 = 70.8\ \% \tag{5}$$

Efficiency of separator:

$$E(x,y) = \left(\frac{x_1}{x_0}\right) \cdot \left(\frac{y_1}{y_0}\right) \cdot 100$$

$$= \left(\frac{46}{55}\right) \cdot \left(\frac{(1500 - 65) - (55 - 46)}{1445}\right) \cdot 100$$

$$= 82.5\ \% \tag{6}$$

Mechanical treatment of MWS in Krško

Capacity and technology of mechanical recycling line in Waste collection center Spodnji Stari Grad was coordinated on the basis of the average composition of the MSW waste in Krško municipality (cf. Table 5). Mechanical recycling line is designed to have one hour of 15 t mixed municipal waste (50 000 t per year), which are mostly (80 %) collected in plastic bags.
Mechanical recycling line is designed for the separating mixed MSW, bio-waste (heavy fraction), mixed paper, non-magnetic metals, magnetic metals, PET (polyethilene terephthalate) plastic, hard plastics, composite packaging, glass and alternative fuels fractions, etc.

Residual of wastes after recycling process are pressed in a pressing container, secondary raw materials are pressed by the horizontal (channel) baler.

Mechanical recycling line is located in a conditioned enclosed facility for purpose of its minimal impact on the environment. Workspaces, where they are adequately lighted, heated and ventilated properly. The main components of recycling line are tipping floor with filling shaft and bag opener/breaker, feeding and picking conveyor belts, Trommel drum screen, magnetic and Eddy-current separators, ballistics separator, NIR (near infra red) optical identification system, PET (polyethilene terephthalate) perforators, baller press, sorting cabins and pens with containers for the separated waste fractions.

Technological flow diagram of mechanical recycling line of Waste collection centre Spodnji Stari Grad can be seen in Figure 5. Main technological processes of mechanical recycling lines are:

— delivery of waste in a tipping floor into closed facility,
— filling of waste with wheel loader into vertical shaft and bag opener/breaker,
— conveyor of waste in a Trommel drum sieve and waste separating into light and heavy fractions,
— waste separation in the ballistic separator depending on the specific weight; waste fractions after separation traveling on separate belt conveyors into different technological units on additional manual or optical NIR (near infra red) sorting,

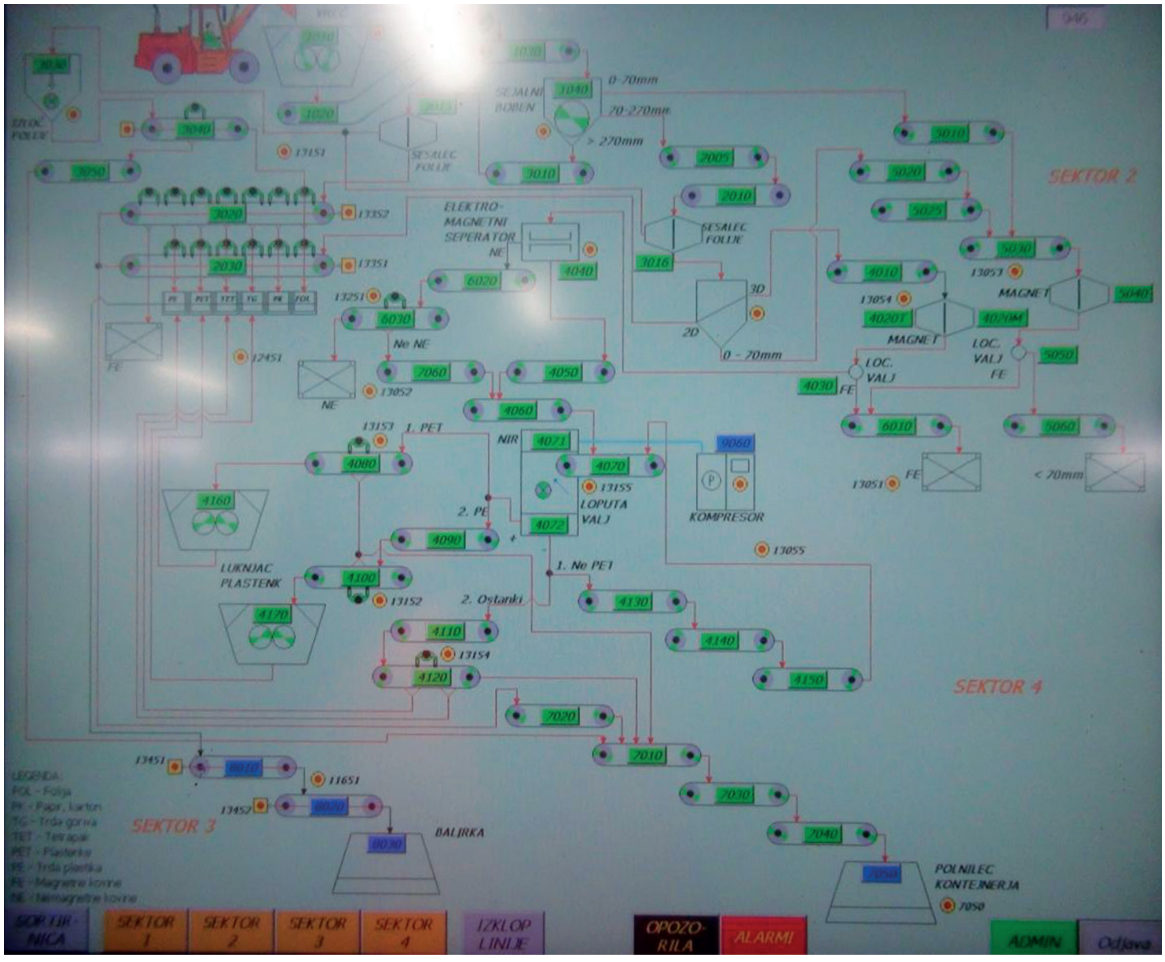

Figure 5: *Technological diagram of mechanical recycling line in Waste collection centre Spodnji Stari Grad.*

— NIR is a electronic device that allows sorting on 52 different types of waste; with optical sensor waste is determined by the type of material at the same time; for waste separate is using a nozzle under high pressure air,
— metal waste sorting is carried out on belt conveyors with magnetic and Eddy-current separators, whose job it is to separate iron from other non-ferrous metals,
— Individual waste fraction is eliminated and conducted with separate belt conveyor; finally storage is taking in separate pens with containers/bunkers.

Middle fractions with waste sizes from 80–320 mm; In this fraction of waste is expected to be present mainly plastics and metals. In order to increase efficiency of sorting ballistic separator is used. Ballistic separator separates middle fraction in three fractions 2D/3D/0–70 mm. Small fractions is combined with waste fractions from Trommel drum screen. Flat 2D fraction passes directly into the sorting facility. According to sorting analysis data in this fraction is expected mainly medium size plastic, paper, cardboard and textiles. As with a large fraction is also here possible carried out by manually sorting. At the sorting belt is space for 10 workers. Remain of wastes from the sorting belt is transported directly into press container. 3D-fraction is further separated, first via the overband magnet removes the magnetic metals and the Eddy-current separator eliminates non-magnetic metals.

The rest of the waste materiala separated in the NIR (near infra red) separator, at the first stage as a larger in waste presented portion separate only PET (polyethilene terephthalate) packaging and in the second phase separating all types of hard plastic. At the end of this sorting line, there are three fractions of PET (polyethilene terephthalate) plastic, hard plastic and scrap, who go to the final quality control in the sorting facility. According to the sorting analysis data in the sorting rest of the waste material are expected to have a composite packaging and fractions for substitute fuel preparations. It is also possible carried out by manually sorting, so as to reduce the amount of waste destined for dis-

Figure 6: *Details from mechanical recycling line of mixed municipal solid waste.*

posal on CeROD landfill. In the sorting shafts of PET (polyethilene terephthalate) plastic and hard plastic fractions are two perforators who perforating bottles and thus improve the efficiency of the (channel) baler.
Fine fractions with waste sizes from 0–70 mm; Fine fractions of the waste is composed mainly from organic and inorganic materials that go into the composting facility (heavy fraction). Magnetic metals from the fine fraction of waste are eliminated by overband magnet above the belt conveyor. Fine fraction of the waste is transported by a system of conveyor belts to the composting container, and will be further processed in the composting plant.
Energy usage in Material Recovery Facilities includes mainly electricity used for the operation of motors (belt conveyors, balers, optical separators, etc.) and diesel fuel used for heating and vehicle operations (front loaders and forklifts). Electricity consumptions ranging from 15 kW h/t to 20 kW h/t of feedstock depending on the degree of mechanization and diesel fuel consumption is estimated at 7.7 kW h/t of feedstock[12, 17]. According to data from Material recovery facilities in Greece, specific electricity consumption is 15–19 kW h/t of feedstock, while fuel consumption is up to 10,5 kW h/t.
Total instaled power of mechanical recycling line in Waste collection center Spodnji Stari Grad is 164.2 kW (conveyors 106.3 kW or 64.7 % and sorting devices 57.9 kW or 35.3 %)[7]. Average estimated electricy energy consumptions of mechanical recycling line Stari Spodnji Grad is 164.2 kW h/(15 t/h) = 10.9 kW h/(t/h), which ranks it as very energy efficient.

Conclusions and future objectives and tasks regarding waste management in municipality Krško and region Posavje

First results of mechanical recycling line operation in Waste collection center Spodnji Stari Grad indicate on increase of waste separated fractions and higher purity of useful raw materials, about 26 % reduction of waste quantities for disposal on the landfill CeROD (deposition only about 25 % the origin of the waste) and

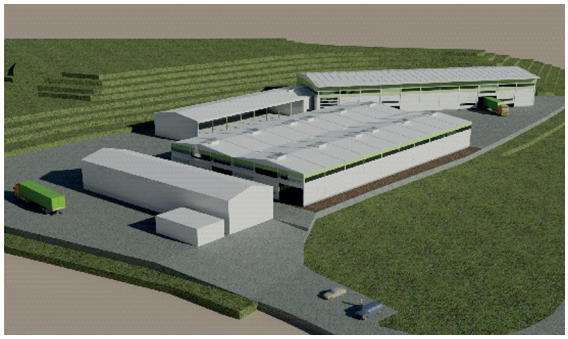

Figure 7: *Future view on Waste collection center Spodnji Stari Grad with facilities for mechanical and biological treatment of mixed municipal solid waste.*

the possibility of acceptance waste fractions for preparartion of alternate fuels from waste.
The advantages of mixed municipal waste treatment from municipality Krško, municipality Kostanjevica na Krki and in all Posavje region in Waste collection centre Spodnji Stari Grad can be divide into:

- economical; economic benefits are primarily in lower transport costs of mixed municipal wastes in CeROD, which have over the years amounted up to 50 000 EUR per year and lower the cost of waste treatment as in the case of processing waste in the mechanical biological treatment (MBO) facility in CeROD,
- ecological; ecological advantages are in reducing emissions of exhaust gases due to fewer waste transport services, a smaller quantity of wastes deposited in the landfill CeROD (Leskovec), and lesser impact on the environment due the indoors sorting and treatment of waste in halls,
- social; social benefits are primarily in new jobs and a lower cost of waste management in municipality Krško or Posavje region.

Future waste management objectives and tasks in the municipality of Krško and Posavje region aimed at upgrading the biological treatment facility, IPPC (Integrated Pollution Prevention and Control) permit authorization for 15 t/h or 50 000 t per year mixed municipal solid waste treatment, unification of separate waste collection in Posavje region, rank of Waste collection centre Spodnji Stari Grad into a new national waste management operational program, the promotion of efficient waste separation and collection system, the selection of contractor for mixed municipal waste treatment in the

entire Posavje region, matching and confirmation rates of mixed municipal waste treatment, part of the environmental benefits paid to the development of separate waste collection system and to ensure adequate quantities of waste from Posavje region for CeROD or redefine of mass waste streams and the construction of relevant facilities. The annual quantity of mixed municipal solid waste from Posavje region into landfill CeROD was around 12 500 t.

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