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**OPTIMISING OF HANDLING OF SORTED MUNICIPAL WASTE
ON AN EXAMPLE OF THE TOWN OF TŘEBÍČ**

**OPTIMALIZACJA POSTĘPOWANIA Z ODPADAMI KOMUNALNYMI
NA PRZYKŁADZIE MIASTA TŘEBÍČ**

Słowa kluczowe: odpady komunalne, segregacja odpadów, optymalizacja zbiórki odpadów.
Key words: municipal refuse, waste sorting, collection optimising.

W ocenie sytuacji sortowanych odpadów w mieście Třebíč, przede wszystkim oceniono kilka wskaźników wpływających na sortowanie odpadów, takich jak: liczba kontenerów i ich wypełnienie. Stwierdzono, że w latach 2005–2006 wzrosła liczba kontenerów, co spełniało postawiony cel. Wymaganiem celem był wzrost ilości i jakości sortowanych surowców oraz wzrost wykorzystania kontenerów. Założone cele zostały osiągnięte. Zaobserwowano, że jeśli nawet kontenery nie były w pełni wypełnione, to w tym wypadku nie jest istotny wzrost ich liczby, ale jakość odzyskiwanych surowców. Jeżeli by dodano kolejne kontenery, prawdopodobnie nie byłyby one zapelnione i jednocześnie istniałoby prawdopodobieństwo, że do tych kontenerów będą wrzucane odpady innego rodzaju aniżeli zalecone.

Stwierdzono, że na badanym terenie mieszkańcy do pojemników na odpady komunalne wyrzucają znaczną ilość odpadów, które można odzyskać. Dzieje się tak, bez względu na to, że wystawiona jest wystarczająca liczba kontenerów na poszczególne rodzaje odpadów i umiejscowione są w dogodnej lokalizacji. Staje się to wyzwaniem dla pracowników firm sortujących, którzy powinni zwrócić uwagę mieszkańców na lepsze sortowanie odpadów w gospodarstwach domowych.

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1. INTRODUCTION

For optimising of sorted collection of usable components of municipal refuse, it is necessary to have sufficient facilities, mainly containers and other means for waste disposal. The town of Třebíč is quite large and with almost 39 thousand of inhabitants it has a big potential as regards sorting of waste. In this town and also in the territory of the whole region, the amount of sorted components of municipal refuse is influenced significantly by a waste sorting plant. Construction of the waste sorting plant increased the standard of facilities of the whole town and the whole region.

Sorting in the region of Třebíč happens in households by placing of the individual components to the corresponding containers and their gathering at an outside place (collection area) which is used by more households. Sorted waste is then discharged by individual collection vehicles. In the region of Třebíč only dry fraction is collected (paper, cardboard, glass, metal, plastic). For future, collection of wet fraction (bio-waste) is being planned.

Paper and mixed plastic is then sorted additionally on a sorting line. Union of municipalities decided to build their own sorting plant, as the nearest sorting plant is situated in Žďár nad Sázavou, i.e. the collection distance is 50 km, and another one is in Brno, which is 60 km. Both these places are situated in a big transport distance, which is unsuitable from the economic point of view.

2. MATERIAL AND METHODS

2.1. Technologies used in waste sorting plant

Collection of municipal refuse and sorted waste is regular. It is ensured by collection vehicles of ESKO-T company which also runs TKO Petrůvky waste dump and uses the same vehicles for collection of the municipal refuse and sorted waste. In the town of Třebíč, glass, paper and plastic is collected once in every 2 weeks, the same as the municipal refuse. In the morning collection vehicles transport waste to TKO Petrůvky waste dump and in the afternoon they transport the sorted waste from colour-coded containers and collection centres to the sorting line. The sorting line is also used by collecting companies from the Znojmo and Jihlava districts and the collection area covers approx. 320,000 inhabitants.

In the region, mixed plastic (PET bottles, foils, PEHD packaging, cartons and other packaging), paper and glass are collected. Every commodity has a container of different colour.

The sorting plant is a simple steel hall. The technology used comprises of a conveyor, sorting belt and continuous press. Sorting is performed manually. Two workers stand opposite each other and they sort waste from the sorting belt. They can stop the belt as required.

The number of employees in the sorting plant is twelve. There is one head employee, two people operate the press and they can handle a lift truck, the other employees operate the belt. The employees work in shifts. The other part of employees performs additional sorting of glass before it is taken for processing. In the sorting plant there is a continuous press – BOA type, this press enables sorting of up to 6,000 t/year. At the moment the line sorts about 2,000 t/year. This press makes bundles with the dimensions 1,200×800×800 (h×w×l). The press output differs according to the type of material. It can range from 2 to 10 t/h. The pressing force is 400 kN. Bundles prepared in this way are loaded by means of lift trucks to lorries.

Table 1. Quantity of sorted commodities [t] from the collection area

Tabela 1. Ilość wysegregowanych surowców [t] z badanego obszaru

Type	year 2004	year 2005	year 2006
Glass	252	269	754.30
White glass	0	0	56.44
Plastic	205.54	282.98	421.04
Paper	577.26	740.95	1,158.98
Carton	5	5	7.03
Total	1,035	1,298	2,397.79

The amount of sorted commodities is increasing, which is positive, but the amount of waste placed on TKO Petrůvky waste dump is also increasing, which is undesirable. This trend is given by fast growing standard of living and connected higher amount of produced waste.

2.2. Purchasers of sorted raw materials

Waste recycling is understood as repeated use of production processing and consumer waste, substances and energies as sources of secondary raw materials in original or modified form. Recycling is one of the ways leading to solution of problems connected with raw materials. Due to the necessary recycling and sale of these materials in the market, ESKO–T company concluded contracts with certain purchasers. Choice of companies was made on the basis of current prices. During the sale, a simple motto applies: „The cleaner (better sorted) product, the better price”. Before the bundles of material are transported to the determined companies, the bundles are tested. For paper we determine its dampness which is subsequently deducted from the weight. We also monitor the proportion of components of the individual types of paper. Even though fixed price is determined for plastic, the purchaser can change it. Discounts are made for excessively dirty bottles. For foils we also monitor their cleanness.

2.3. Location of containers

For correct functioning of the system of collection of sorted commodities, it is necessary to optimise location of containers for this collection. The number of containers is determined

according to the tabulated values. If we already know the theoretical number of containers, it is necessary to locate these containers correctly. Location depends on situation in each region which is always different. The area of location of containers is the crucial factor. Various results are achieved in towns and villages, for example due to various degree of anonymity of inhabitants or distance from the containers.

Table 2. Recommended density of location of containers

Tabela 2. Zalecana gęstość lokalizacji kontenerów

Type of development	Delivery collection				Disposal collection				Bagged collection			
	paper	plastic	glass	bio-waste	paper	plastic	Glass	bio-waste	paper	plastic	glass	bio-waste
Number of inhabitants per one container												
Blocks of flats	400*	400	400	–	200	200	200	200	–	–	–	–
Houses	60	60	60	–	20	20	20	20	4	4	–	4
Village	400	400	400	–	–	–	–	–	4	4	–	4

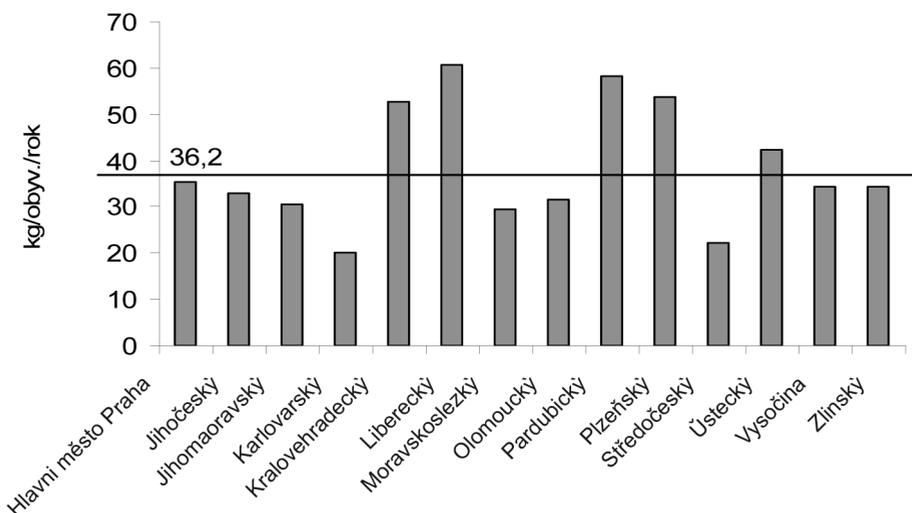
* The values are for orientation only – they must be adapted to a particular situation in the given locality and to the type (volume) of containers used.

3. RESULTS AND DISCUSSIONS

3.1. Comparison of regions

The town of Třebíč is situated in the heart of the Vysočina region, in the region with clean air, water and beautiful countryside. It is thus a region which should be protected and not polluted with various emissions and wastes. People should be aware of this “paradise”. But if we look in detail in the statistic figures of the Czech Republic, we will find out that the Vysočina region is not one of the regions with the biggest amount of sorted commodities, as it is reflected in the following graph showing the data from the year 2005.

In the Vysočina region there are 5 big towns which used to be district towns. These are the following towns – Havlíčkův Brod, Jihlava, Pelhřimov, Třebíč and Žďár nad Sázavou. When production of the total quantity of the sorted waste components was compared (see table No 3), it was found out that the smallest amount of the sorted commodities is in the territory of the town of Třebíč. On the contrary, the best results are achieved in the town of Žďár nad Sázavou. And the difference is quite high – 11.09 kg/inhabitant/year. This difference can be caused by different size of towns, when Žďár nad Sázavou is half of the size of the town of Třebíč. The smaller number of inhabitants increases the quantity of sorted commodities, as there is not such anonymity as in bigger towns.



Graph 1. Comparison of regions

Wykres 1. Porównanie regionów

On the contrary, the town of Jihlava, which is the biggest of these towns and at the same time it is also the regional capital, is in the middle of the compared towns. It is surprising that a town of this size is on better position as regards the amount of the sorted commodities than a town of a size of Třebíč.

Table 3. Average quantity of sorted waste in the Vysočina region

Tabela 3. Średnia ilość wysegregowanych odpadów w regionie Vysočina

Town	Quantity of sorted waste [kg/inhabitant/year]			
	Year 2003	Year 2004	Year 2005	Year 2006
Žďár nad Sázavou	25.55	28.08	29.85	34.69
Havlíčkův Brod	25.35	25.63	26.59	30.65
Jihlava	18.34	23.29	24.88	28.83
Pelhřimov	15.01	17.37	22.11	28.43
Třebíč	13.28	16.08	18.76	25.76
Vysočina region Average	19.80	22.43	24.63	29.85

In all the towns there has been a significant increase of the quantity of sorted waste in recent years, as it is shown in table No 3. As regards the average of the whole Vysočina region, the increase between 2005 and 2006 is 5.22 kg/inhabitants/year.

The average amount of sorted waste in the whole Vysočina region in 2005 is thus 24.63 kg/inhabitants/year. Compared to the national average, this figure is very low. The val-

ue of the national average in amount f sorted commodities is 36.20 kg/inhabitant/year. The difference is 11.57 kg/inhabitants/year. Such a high difference in sorted commodities can be caused by various ways of life, mainly by difference between the town and village way of life. Another important factor is also awareness of inhabitants.

3.2. Production of waste in the town of Třebíč

If we want to assess the situation of handling of the sorted commodities, we have to know quantity of these sorted components. The obtained values were written in a table and assessed (table No 4). In 2006, the whole town of Třebíč produced 7,942 tons of home waste, which is by 681 tons/year more than in 2005. The amount of the produced waste was divided into several items, according to the separately collected commodities and amount of the municipal refuse. By means of these values, we determined quantity of the home waste and its individual components per one inhabitant per year and then also production per week.

Table 4. Production of waste in the town of Třebíč for the year 2006

Tabela 4. Produkcja odpadów w miejscowości Třebíč za rok 2006

Number of inhabitants	Commodity [t/year]				
	Paper	Plastic	Glass	Municipal waste	Total home waste
38,299	647	170	329	6,796	7,942
	Commodity [kg/inhabitant/year]				
	Paper	Plastic	Glass	Municipal waste	Total home waste
	16.89	4.44	8.59	177.44	207.36
	Commodity [kg/inhabitant/week]				
	Paper	Plastic	Glass	Municipal waste	Total home waste
0.32	0.08	0.16	3.41	3.98	

The waste production per one inhabitant per week will help us to compare the production of the specific quantity of home waste produced by the inhabitants of the town of Třebíč with tabulated values. The tabulated values are shown in table No 5.

Table 5. Indicators of specific quantity of home waste

Tabela 5. Wskaźniki określania ilości odpadów domowych

Type of development	Specific waste quantity			
	kg/inhabitant/week			kg/inhab./year
	Average	Max. value	Min. value	Average
Housing estates in large towns	3.0	3.9	1.4	156
Housing estates in smaller towns	2.5	3.2	2.3	130
Mixed development of towns	3.0	3.4	2.5	156
Village development	3.8	4.7	3.0	198

Table No 5 is divided according to the type of development. In the assessment Třebíč was included in the mixed development of towns, due to the reason that it is a smaller town which is by nature partially of housing estate type and partially of type with houses. Part of the town comprises of block of flats which are supplied with heat from the local heating plant. The second part comprises of development of houses which are supplied with heat individually. For this development category, the tabulated average value is 3.0 kg/inhabitant/week and the maximum value is 3.40 kg/inhabitant/week. Compared to that, the amount produced by inhabitants of Třebíč is 3.98 kg/inhabitant/week. The difference of the production of waste produced by the town of Třebíč and tabulated maximum value is 0.58 kg/inhabitant/week. If the value of the difference is recalculated to production for the whole year, we will come to the figure of 30.16 kg/inhabitant/year. In the whole production of waste, the town of Třebíč does not differ too much from the tabulated values, unlike the separated components, there it is rather opposite.

3.3. Number of containers

As we have already mentioned, in the town of Třebíč waste is sorted by means of containers with a volume of 1.100 l, with an exception of clear glass containers which have a volume of 1.300 l. Subsequently there is additional sorting at the waste sorting plant (delivery collection). The collected commodities are paper, plastic and glass, which is collected as mixed or white (clear). Separation of clear glass was introduced only a short time ago due to the reason of better use of this raw material during recycling. All the commodities have their own containers which are colour coded:

- Blue – paper
- Yellow – plastic
- White – clear glass
- Green – coloured glass

The necessary amount of containers is determined and derived from the recommended tabulated values (see table No 2). To find out whether the current situation is sufficient, it is necessary to compare the tabulated values with the number of containers situated in the town. Together with the knowledge concerning the frequency of collection we can come to certain conclusions and propose necessary changes.

As it has already been mentioned in previous chapter, the town of Třebíč cannot be simply divided according to the type of development. It is a town with both block of flats and houses. When comparing the number of the necessary containers (according to table No 2), it is necessary to include the town into the group of housing estate development or development comprising of houses. In the housing estate development it is necessary to have one container per 400 inhabitants to achieve the necessary filling of the containers. In the development comprising of houses, it is necessary to have 60 inhabitants per one container to ensure the sufficient filling. From the data from ESKO – T company, the following tables No 6 and No 7 were pre-

pared. They show the numbers of containers for the individual collected commodities, number of collections and also the quantity of the sorted waste for two years (2005 and 2006).

Table 6. Number of containers in the town of Třebíč as of December 31, 2005

Tabela 6. Liczba kontenerów w miejscowości Třebíč z 31 grudnia 2005

Commodity	Number of containers	Frequency of collection *	Sorted quantity [t/year]	Sorted quantity [kg/week/container]
Paper	141	52	442	60.30
Plastic	147	52	104	14.20
Mixed glass	127	13	–	–
Clear glass	22	13	–	–
Total glass	149	–	221.9	28.64

* Number of collections per year.

Table 7. Number of containers in the town of Třebíč as of December 31, 2006

Tabela 7. Liczba kontenerów w miejscowości Třebíč z 31 grudnia 2006

Commodity	Number of containers	Frequency of collection*	Sorted quantity [t/year]	Sorted quantity [kg/week/container]
Paper	164	52	647	75.86
Plastic	172	52	170	19.00
Mixed glass	145	26	–	–
Clear glass	68	12	–	–
Total glass	213	–	329	29.70

* Number of collections per year.

In the years 2005 and 2006, the number of containers for sorted waste increased. Together with the increase of the number of containers, also the quantity of sorted commodities increased, as follows:

- **paper** – number of containers increased by 23, the quantity of the sorted collected paper increased by 15.56 kg/week/container;
- **plastic** – the number of containers increased by 28, the quantity of sorted collected plastic increased by 4.80 kg/week/container;
- **glass (total)** – the number of containers increased by 64, the quantity of the sorted mixed glass increased by 1.06 kg/week/container.

If we take in consideration that the town of Třebíč is all in the type of housing estate development, we thus assume that to fill one container sufficiently we need 400 inhabitants. We then come to the following conclusions (counted for the year 2006):

- **paper** – The number of inhabitants is divided by number of inhabitants necessary per one container, i.e.: $38,299 / 400 = 95.7$, i.e. approx. 96 containers. The total number of containers for collected paper in the town of Třebíč is 164. After these values are deducted, we have **68** extra containers;

- **plastic** – The minimum number of containers is 96 containers (the value is obtained in the same way as for paper). The total number of containers for plastic is 172 containers, which is **76** extra containers;
- **glass (total)** – The minimum number of containers is again 96 (the value is obtained in the same way as for the previous commodities). The number of containers for glass is 213, if we count together the containers for clear glass and coloured glass. The number of extra containers is **117**.

These numbers of excess containers seem to be quite high. If we count also the quarters with houses, we will come to a conclusion that the total numbers of containers are sufficient. The containers which are excess according to the theoretical calculation are situated in the areas of the town with development comprising of houses. To be able to assess conclusions, first it is necessary to determine the value of filling of containers. The assessment of filling of containers is specified in the following chapter.

3.4. Filling of containers

For determination of filling of containers, we need to recalculate the sorted quantity specified in weight units (tab. No 7) to the volume quantity. For this calculation, we will use table No 5 which shows the volume density of waste:

- **Paper** – The production of sorted paper is 674 tons/year, i.e. 75.86 kg/week/container. The volume of paper in one container is 0.95 m³; for determination of the filled space we used a formula for calculation of volume by means of volume density.

$$\rho = \frac{m}{V} [kg \cdot m^{-3}] \quad \text{i.e.} \quad V = \frac{m}{\rho} [m^3]$$

The containers to which the waste is collected have a volume of 1,100 l, i.e. 1.1 m³. The empty volume is difference of both values, i.e. 1.1 – 0.95 = 0.15 m³. If we recalculate it to percentage, we will come to a result that the empty space in the container is 13.6%. When calculating filling of container for paper, we found out filling of the container of **86.4%**.

- **Plastic** – The filled volume of the container for plastic is 0.63 m³, after it is deducted from the whole container volume we get 0.47 m³ of free space. By recalculation, we get 42.7 % of free space in the container. The filling of containers for plastic is only **57.3 %**.
- **Glass** – For determination of filling of containers for glass, we do not differentiate whether they are containers for clear or coloured glass. The total amount of collected glass is 29.7 kg/week/container, i.e. the container has 0.12 m³ of filled space. The free space is 0.98 m³, which is 89.1 %. The filling of container is **10.9 %**.

The calculation of filling of containers can also be made for the year 2005. By comparison of the years 2005 and 2006 we can determine development tendencies of waste sorting and filling of containers.

Table 8. Filling of containers

Tabela 8. Zapelnienie kontenerów

Commodity	Filling of containers year 2005 [%]	Filling of containers year 2006 [%]
Paper	68.0	86.4
Plastic	42.7	57.3
Glass (total)	10.0	10.9

4. CONCLUSION

When determining the number of containers it was found out that if the town of Třebíč was all of the housing estate development type, the numbers of containers would be in excess. However, the town of Třebíč comprises partly of quarters with houses and thus the numbers of containers are sufficient. The containers are situated evenly in both the housing estate development and development comprising of houses.

In the years 2005 and 2006, in the town of Třebíč there was a significant increase of number of containers for separated collection for all the sorted commodities. Simultaneously with this increase of number of containers, also the quantity of collected commodities increased. Also the use of the containers and thus also the filling of the containers increased, for all the commodities. For collected paper, it was an increase of the use of containers by 18.4%. For collection of mixed plastic it was an increase of the use of containers by the value of 14.6%. Collected glass also achieved an increase in the use of containers but compared to the other commodities only by 0.9%.

It was thus found out that the containers for separated waste are filled from 80% to 40%. It shows that the total number of containers is sufficient. This result was achieved by finding that none of the containers was filled 100% permanently, regardless the type of separated commodity. If the containers were overfilled regularly, it would be necessary to reassess the numbers and layout of containers.

Despite this satisfactory situation in the number of containers, the town of Třebíč is on the last place in the region as regards the quantity of the sorted commodities. It could be caused by the following:

- size of towns,
- standard of living of inhabitants,
- awareness of inhabitants,
- willingness of the inhabitants to sort waste,
- interest of inhabitants in the environment.

Some of these influencing factors can be influenced by the collecting company and some not. The size of the town and standard of living of the inhabitants cannot be influenced. On the other hand, awareness of the inhabitants and interest of the inhabitants in

standard of living could be increased. It shows that the most important factor is people and their willingness to sort waste. Even though it seems simple, on the contrary it is usually most difficult to try to change thinking of people.

REFERENCES

- ALTMAN V. Odpadové hospodářství, 1991. Vyd. 1. Phare sv. 30. Ostrava. Vysoká škola báňská – Tu Ostrava.
- BOŽEK F., URBAN R., ZEMÁNEK Z. 2002. Recyklace, vlastním nákladem, Vyškov.
- Firemní materiály společnosti ESKO–T.**
- Internetový portál Českého – statistického úřadu.**
- Internetový portál: Jak třídít – www.jaktridit.cz**
- Internetový portál krajského města vysočiny Jihlavy – Plán odpadového hospodářství kraje Vysočiny. www.kr-vysocina.cz**
- JELÍNEK A. a kol. 2001. Hospodaření a manipulace s odpady ze zemědělství a venkovských sídel, vyd. Obchodní tiskárny Hořovice, Praha.
- JEŽKOVÁ R., SITA CZ a.s. 2006. Odpady 3/2006: 7.
- Obecný vzdělávací systém pro úředníky místních samosprávných orgánů PHARE CZ 0209-02-01-005.**
- Vládní nařízení č. 197/2003 Sb., o plánu odpadového hospodářství ČR.**
- Vrbová M., AOS EKO – KOM, a.s. 2005. Odpady 6/2005: 10, ISSN 1210-4922 MK ČR 6330.**
- Vyhláška č. 381/2001 Sb., kterou se stanoví Katalog odpadů. Seznam nebezpečných odpadů a seznamy odpadů pro účely vývozu, dovozu a tranzitu odpadů a postup při udělování souhlasu k vývozu, dovozu a tranzitu odpadů, ve znění pozdějších předpisů.**
- Zákon č. 185/2001 o odpadech a o změně některých dalších zákonů.**