Analysis and Evaluation of the Waste Management in the Municipality

M. Mimra[*], M. Kavka and R. Renfus

Czech University of Life Sciences Prague, Faculty of Engineering, Department of Machinery Utilisation, Kamýcká 129, CZ 165 21 Prague 6–Suchdol, Czech Republic
*Correspondence: mimra@tf.czu.cz

Abstract. Objective of this paper was to analyse the waste management on an example of the municipality Nový Bor in the Czech Republic. The analysis is performed on comparison of Municipal Solid Waste (MSW) production in Nový Bor which systematically separates between mixed and sorted waste as commodities with a second life span. It was noted that the average amount of mixed MSW came to approximately 200 kg person^{-1} year^{-1} in Nový Bor in 2014 which was 24% below the Czech average value of 263 kg person^{-1} year^{-1} from the identical year. Comparison of the sorted waste production in 2014 showed that Nový Bor achieved better results than the Czech average of 39.7 kg person^{-1} year^{-1}; a common resident of Nový Bor separated 24.4% more waste via recycling containers (= 49.5 kg person^{-1} year^{-1}) and 11.6% more via Bag Collecting System (BCS) which means 54 kg person^{-1} year^{-1} in total. Unfortunately, approximately 80% of MSW from Nový Bor is landfilled so its energy producing utilisation is totally neglected. Generally, the decision how to dispose of waste depends more or less on price: disposal of MSW by landfill costs about 700 CZK t^{-1}, whereas in an incinerator about 2,000 CZK t^{-1}. The personalised, registered BCS clearly ensures a better, diligent waste separation (impurity only max. 10%) compared to the mixture found in 'anonymous' recycling containers placed all over the city where the impurity of sorted waste varies between 20–40%.

Key words: bag collecting system (BCS), municipal solid waste (MSW), mixed waste, sorted waste, waste collection system.

INTRODUCTION

Wilson et al. (2015) stated that the solid Waste Management (WM) belongs to the most important functions of a city government. Hoornweg & Bhada-Tata (2012) stated that poorly managed waste has essential impact on the health of the city residents, local and global environment. Equally, Sivakumar & Sugirtharan (2010) reported that solid waste generating depends on the economy of the population as well as the level of income of the respective family or individual.

According to the Czech Waste Act No. 185/2001 Coll. 'The Hierarchy of Waste Management', within the waste management framework, the following hierarchy has to be respected firstly: Waste prevention, preparation for re-use of waste, recycling of waste, another utilisation of waste (e.g. energy generating utilisation), and waste disposal – landfilling. Aleksic (2013) stated that around 70% of MSW generated in the Czech Republic is still being landfilled. As noted by Fisher (2013), the Czech Republic must fulfil recycling EU targets and enhance the WM by re-using of 50% of MSW by the

beginning of the year 2020. As a consequence, the Czech Ministry of Environment (2014) stated on 22 December 2014 that the Government of the Czech Republic approved a new Waste Management Plan for the period 2015–2024 with a special focus on the mentioned targets.

The Bag Collection System (BCS) proved to be one of the ways how to increase the yield and purity of the separated components of the municipal waste. Consequently, the aim of this research was to verify the potentially increased purity of sorted waste collected via BCS and to compare it with the results of the stable recycling containers. Increase in the proportion of separated components will reduce the overall amount of MSW.

The aim of this article is also to present the results of the utilisation of the BCS in the municipality and to outline its positive influence on increasing amount of collected, diligently separated waste, as well as to indicate the BCS as one of the effective tools supporting improvements in waste management. Change for the better was reached by the personalised registration of the collectors/contributors – anonymity can obviously mislead some citizens to some carelessness – and also by the financial reward offered to them. The impact of the BCS was documented on the data gained from the cities which implemented and kept using this system.

MATERIALS AND METHODS

Even two adjoining cities in one district may decide to engage different companies for their WM services – a good example is Nový Bor and Česká Lípa (only 10 km distance) in the Czech Republic. Nový Bor utilises BCS, whereas Česká Lípa does not and also, they are engaging different waste disposal companies.

13,144 habitants lived in Nový Bor in 2014. 58.6% thereof lived in family houses. In year 2008, municipality Nový Bor adopted the BCS for recyclable waste. The personalised stickers serve for identification of each registered person and of the selected commodity. BCS has been used for three types of waste commodities so far: plastic, paper and since 2012 also for small electrical appliances (e.g. broken radio, electric razor, mobile phone). All the volunteers who are participating in BCS get rewarded at the end of the year, nevertheless they do not receive any banknotes handed out physically to them but the corresponding counter-value is deducted from their obligatory fee for MSW services in the next year.

In this article, we will compare the amount of generated waste for the period 2008–2014 in both of the above mentioned cities. For each kind of waste in the respective year, the average amount of waste per person in kilos and percentage changes; it was calculated by using the following equations:
Calculation of the specific amount of the waste

$$SPA = \frac{TAW \cdot 1000}{NH} \qquad (1)$$

where: SPA – specific amount of waste (kg person^{-1} year^{-1}); TAW – amount of waste (t), NP – number of habitants.

Calculation comparing the amount of the waste between the single years

$$YYCH = \frac{SPA - \left(SPA^{n-1}\right)}{SPA^{n-1}} \cdot 100, \%, \qquad (2)$$

where: YYCH – year-on-year change in production of the waste (%);, SPA – specific amount of the waste (kg person^{-1} year^{-1}); SPA^{n-1} – specific amount of the waste in previous year (kg person^{-1} year^{-1}).

Calculation of the comparison with the referential year

$$CHRY = \frac{SPA - (SPA^r)}{SPA^r} \cdot 100 [\%]. \qquad (3)$$

where: CHRY – change of the waste production from the referential year; SPA – specific amount of the waste (kg person^{-1} year^{-1}); SPA^r – specific amount of the waste in the referential year (kg person^{-1} year^{-1}).

RESULTS AND DISCUSSION

All MSW generated from Nový Bor is only disposed in a landfill which does not seem to be really eco-sensitive, let alone that the incinerator in Liberec is only 10 km farther than the landfill. The price for the disposal in a landfill is around 700 CZK t^{-1} and about 2,000 CZK t^{-1} in an incinerator. Since the WM is a business as any other, its managers search for the cheapest option of how to handle the garbage disposal. That is the reason why some firms and plants rather opt for the landfilling than for the incineration of the waste.

From 2000 to 2003, the production of mixed municipal waste increased by 40% in the Czech Republic. Unavailable support of an energy generating utilisation as well as the higher price of waste incinerating causes that the waste ends buried in the landfilling. According to the data obtained in 2003, alarming 87% of the municipal waste were landfilled and only 13% were recycled or re-used. In 2014, the share of the separated waste soared on 20% and the production of MSW dropped to 80%. Habid et al. (2013) stated that incineration of MSW may be used for the heating in the city as well as for generating of electricity. MSW has a great heating potential which varies from Low Heating Value (LHV) between 8–12 GJ tone^{-1} to Upper Heating Value (UHV) of 18–20 GJ tone^{-1} where the LHV corresponds with approximately 42% of the fuel value of bituminous coal (23.9 GJ tonne^{-1}). This demonstrates that even if a material recovery is not economically feasible, its energy recovery can still bring us some environmental and economical benefits.
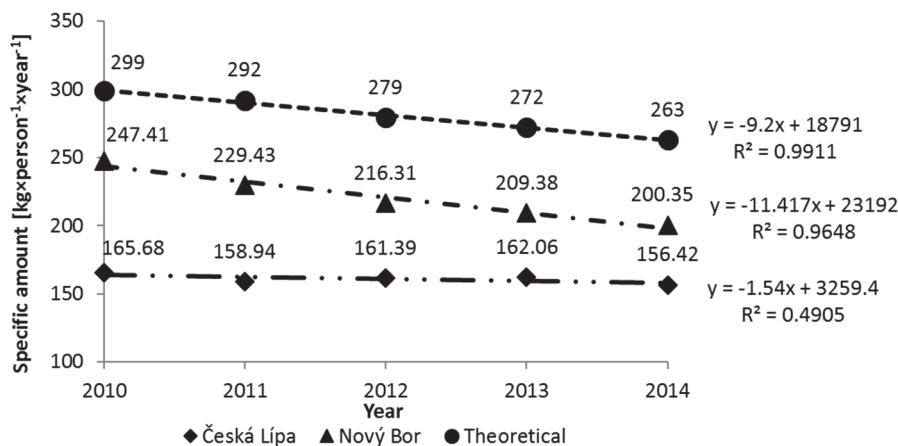
Comparison of the collected mixed MSW in cities Nový Bor, Česká Lípa and the Czech Republic overall
In the graph below (Fig. 1), data of mixed MSW production are presented. These data were obtained from the Department of Management of Technical Services from the City Administrative Office of Česká Lípa, and the City Administrative Office of Nový Bor; also, the average amount of waste in the Czech Republic published by ISWM in

2015 is used. The volumes are expressed as a specific amount of waste by using equation 1. The total average amount of waste in the Czech Republic is recalculated per person and is marked as 'theoretical'. The data show the course of the last 5 years and give an overview about the production of waste in Nový Bor and Česká Lípa on a district scale as well as on a nationwide scale.

This shows that the waste production in Nový Bor is almost at the midpoint between the highest and the lowest value of the MSW production. The generation of the waste has constantly decreased in the entire analysed period. Also, it can be expected that this decreasing trend will continue in the following period. Nový Bor has had a higher MSW production than Česká Lípa – apparently due to the character of the city and the prevailing number of family houses, which gives the city the character between 'Mixed development of cities' and 'Rural development' according to the criteria mentioned in ISWM (2015). The specific amount of the MSW comes from a certain housing developments but it does not include the commercial waste which is similar to the household waste by its nature; the amount of that household waste is estimated by 50–60% of the entire production of MSW (households and other waste similar to that) in 'Urban development' and by 20–30% in 'Rural development'.

The changes in the generated amount of the mixed MSW from 2010 to 2014 can be seen from the values in Fig. 1. In Česká Lípa, a reduction of the collected mixed MSW by 1.54 kg person^{-1} year^{-1} occurred in these years, whilst the index of determination was quite weak. In the analysed period of time, a certain interannual decrease occurred only during two years (drop-off by 4.07 and 3.47%); the other years have shown a slight increase (by 1.54% and 0.42%). In the Czech Republic, this interannual decrease in the production of the mixed MSW leveled off at 9.2 kg person^{-1} year^{-1} whilst in Nový Bor, it was 11.42 kg person^{-1} year^{-1}. In both cases the index of determination is quite strong. In Nový Bor, the slight decrease moved between 0.32% in 2013 and 7.27% in 2011.

Figure 1. Comparison of specific amount of mixed MSW.

Collection of the sorted waste in Nový Bor

In the following part of this article, data collected from Nový Bor (which were used for the extended calculations presented in the methodology) are shown. Approximately 50% of the residents do actively collect recyclable waste.

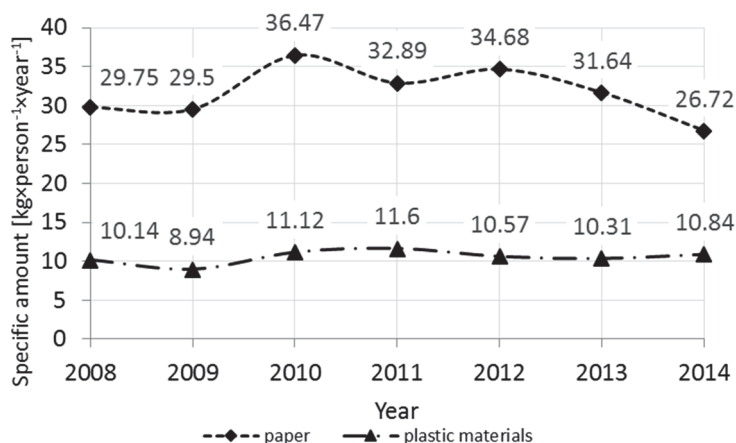**Paper waste collected via stable recycling containers**

In Fig. 2 and Table 1 placed below, data concerning paper waste collection within seven years are displayed; also data about the number of habitants, etc. are displayed. At first view, it can be registered that 2010 was the strongest year; a significant increase of paper production was observed nationwide. In 2010, prices of the collected commodities soared up because companies needed to stimulate and motivate people's willingness to bring more paper to the waste collection. In this year, the repurchasing price of paper was about 2 CZK per kg which has been the highest in the past dozen of years. Consequently, it can be noticed that the production of paper rose by 25.53% as opposed to the beginning of 2008. Further development slightly went down. For calculation in the below tables , equations 1, 2 and 3 were used.

Table 1. Collection of paper via stable recycling containers in Nový Bor

Year	Number of habitants	Amount (t)	Specific amount (kg person^{-1} year^{-1})	Year-on-year (%)	From 2008 (%)
2008	11,380	338.60	29.75	0.00	0.00
2009	11,383	330.70	29.05	-2.36	-2.36
2010	11,434	417.00	36.47	25.53	22.57
2011	12,329	405.50	32.89	-9.82	10.54
2012	12,831	444.98	34.68	5.44	16.56
2013	12,892	407.90	31.64	-8.77	6.34
2014	13,144	351.15	26.72	-15.56	-10.21

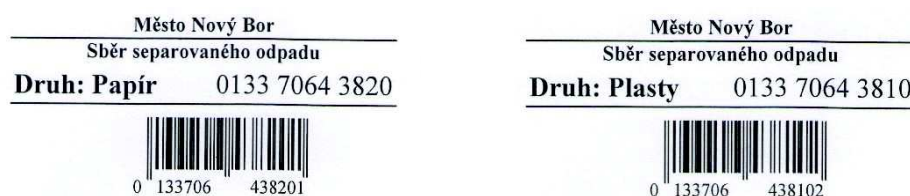**Plastic waste collected via stable recycling containers**

In Fig. 2, we present data concerning plastic waste collected via stable recycling containers; the course is fluctuating within the whole range: there was the strongest year 2011 with almost twelve kilos per person. Opposite to the peak from 2011 is the year 2009 which was the weakest one within observed period with the collected amount of 9 kg per person. Nevertheless, it can be stated that the production of Nový Bor is more or less stable and varies around 10 kilos per person per year.
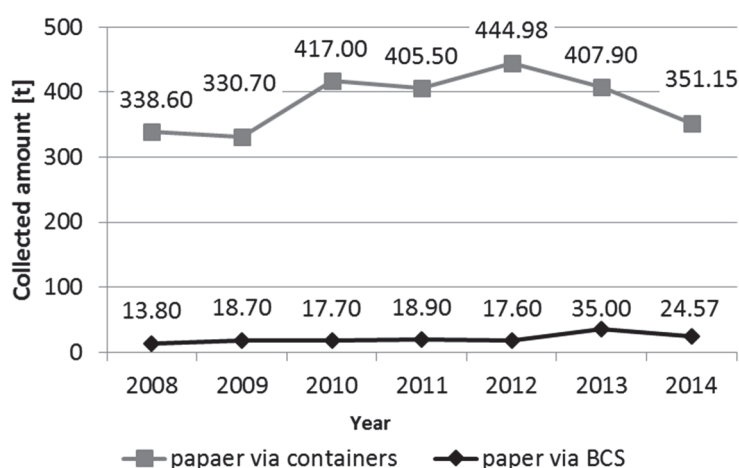

Figure 2. Collection of paper and plastic materials via stable recycling containers in Nový Bor.

The Bag Collection System (BCS) for separated waste in Nový Bor

The following part deals with the data regarding a relatively new collection system called BCS, which is used in the households. With this system, the waste is separated into bags marked with personalised barcodes (see Fig. 3). Although this system is not widespread yet and is currently used in only a few municipalities, it can be considered a unique tool. This tool supports diligent separation and collection of municipal waste generated by households. The BCS system was implemented in Nový Bor in 2008, and the following Fig. 4 displays the entire course of the system from the beginning until 2014.

Město Nový Bor		Město Nový Bor	
Sběr separovaného odpadu		Sběr separovaného odpadu	
Druh: Papír	0133 7064 3820	**Druh: Plasty**	0133 7064 3810
0 133706 438201		0 133706 438102	

Figure 3. Example of the stickers with printed barcode for paper and plastic separation.
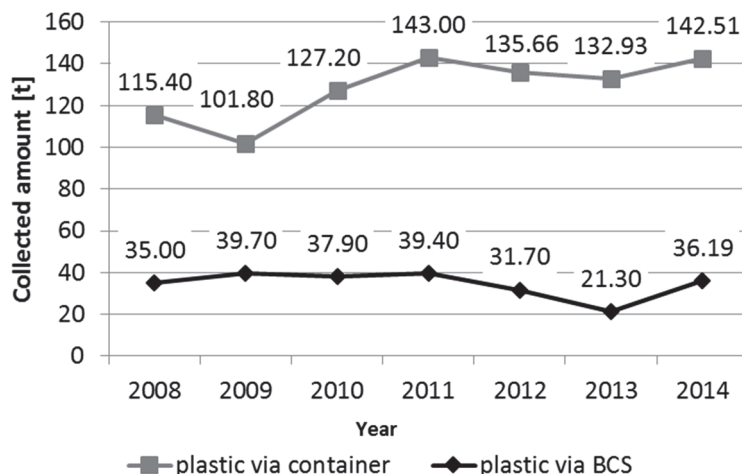

Figure 4. Comparison of the total collected amount of paper via recycling container and via BCS.

'Subjects' here apply to either individuals or a representative of a family. The number of subjects is multiplied by 3.8 for practical calculation to discover how many people actually are involved in the system. It is not really likely that one person would be able to produce and collect for instance about 50 kilos of plastic waste in one year's time. A further issue which has to be taken into account is that the number of subjects is registered as a total number of all subjects. The City Administrative Office has not registered single numbers of subjects for each commodity as it did not consider it economically feasible. Furthermore, the current situation does not make it desirable.

Paper waste collected via BCS

Fig. 5 shows the total amount of the commodity collected in each year, but more important is the specific amount of this commodity per year. In terms of percentage, the highest production per person was in 2013. Although the percentage rate tends to decrease, the number of the participants collecting paper increases dramatically: compared with the referential year 2008, in 2013 the number was more than double.

Figure 5. Comparison of the total collected amount of plastic via recycling containers and via BCS.

As we can see from Fig. 4, the amount of paper collected via stable containers increased gradually till 2012. From this point, it started decreasing. However, the growth did not really correspond to the increased number of inhabitants as it is obvious from the decreased amount of collected paper per person with the maximum of 36.47 kg person^{-1} year^{-1} in 2010. After 2010, it fell. The paper collected via BCS reached its peak in 2013 at the maximum of 35 kg person^{-1} year^{-1}. In the entire analysed time, by means of the stable containers the amount of 31.6 kg person^{-1} year^{-1} was collected. By means of the BCS, it was 36.8 kg person^{-1} year^{-1}. According to Fig. 4, BCS contributed to the improvement concerning the collected amount of paper from 3.9% in 2012 to 7.9% in 2013. The share of participants in the BCS increased from 2.86% (from the total number of inhabitants of Nový Bor) in 2008 to 6.7% in 2014. Therefore, it is obvious that the amount collected per participant via BCS was higher than the amount collected via stable containers.

Plastic waste collected via BCS

In Fig. 5, data regarding amounts of collected plastic waste via BCS are displayed. At first view, the increasing number of subjects (in 2008, 325 subjects; in 2015, 900 subjects) can be noticed. We can conclude from these numbers that the installation of such a system is successful. The incentive which motivates people to collect a substantial amount of plastic waste is apparently the 1.50 CZK per kilo payment they receive.

As we can see from Fig. 5, the development of plastic material collection via stable recycling containers does not show a distinct trend. In 2009, there was a slight decrease

of the collected amount to 101.8 t. In 2010 and 2011, the amount slightly increased and reached its peak for all the analysed period with 143 t. The pace of growth of collected plastic material neither reflected the increase of inhabitants nor the better economic situation. The average yield of plastic waste collected via stable containers during the analysed period of time was only 10.5 kg person^{-1} year^{-1}. In contrast to that, the average yield of the same material collected via BCD was 66.5 kg person^{-1} year^{-1}. From this comparison, we can clearly state that the BCS for plastic materials is much more efficient than the stable containers. However, we also noticed that BCS was even more efficient at the beginning of its implementation in 2008 with the yield of 107.69 kg person^{-1} year^{-1}. Then it started decreasing to 41.13 kg person^{-1} year^{-1} in 2014. From Fig. 5, it is clear that the share of waste collected via the BCS changed with regard to the overall collected amount from 14% in 2013 to 28% in 2009.

Scrap metal from small electrical appliances collected via BCS

This recyclable segment was implemented four years ago so there is not much representative information about it yet. In Table 2, data regarding the number of small electrical appliances collected via BCS are displayed. In 2012, people were apparently informed about the new sorting of these goods. In the following year 2013, the number of the active participants increased and the collected amount peaked at 0.81 kg per person per year. The latest monitored year 2014 was even lower than the year 2008 because people had already disposed of all the unnecessary or broken electrical devices gathered at home. The development of the collection of scrap metal depends on people's behaviour – concerning whether they decide to keep or replace old electric appliances. It is necessary to understand that people do not really like throwing away expensive devices; hence, the process of disposal of old electronic appliances can take some time.

Table 2. Scrap metal from small electrical appliances collected via BCS in Nový Bor

Year	Number of subjects	Amount (t)	Specific amount (kg person^{-1} year^{-1})	Year-on-year (%)	From 2008 (%)
2012	635	0.33	0.52	0.00	0.00
2013	750	0.61	0.81	54.64	54.64
2014	880	0.35	0.40	-50.84	-23.98

Collection of such appliances for recycling purposes does not have a long history in our country. The available results are too fluctuating so as to be able to determine a representative outcome. However, it is certainly a very good approach to collect all the broken or obsolete appliances. Volume of this waste is not so high; thus, there are not so many recycling containers designed especially for these devices. In addition, people often dispose of their outdated electronic devices in the mixed waste. By contrast, the BCS motivates people to separate their electronic appliances at home and put them in the appropriate bags for recycling.

The amount of the respective materials collected via BCS can be seen in Fig. 6. As the graph shows, there is not a definite trend in the development of the amount of collected waste. The yield of the waste production is affected by several factors. One of them is the economic development of the country. The interesting fact is that with economic progress, the purchase increases: people can afford to buy more and consequently produce more waste. Unfortunately, more wealth does not insure a better

separation of waste. Therefore, it is highly recommendable to motivate people (already starting at a very young age with this 'education' whenever possible) to adopt some positive recycling habits and to care about the environment.
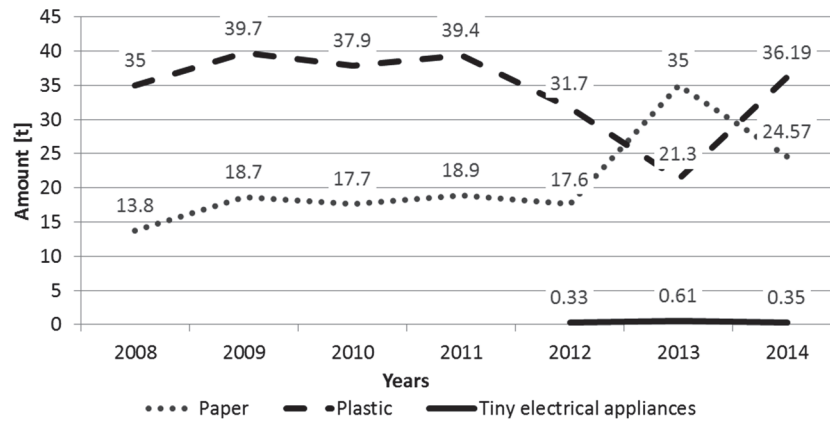
Figure 6. Graph displays the development of collected amount of separated waste by BCS.

CONCLUSIONS

Mixed MSW generation in Nový Bor has tended to decrease; this decline is constant and it is apparently still going to continue. However, the MWS production in Česká Lípa is even lower – seemingly due to a different character of the city. And the overall results of Nový Bor are still remarkably good.

Bing at al. (2014) found out that the success of the separated waste collection system results from the optimised reverse logistics network. This makes the overall recycling system more efficient and sustainable while taking into account the interests of various stakeholders (municipalities, households, etc.). According to a research paper published by EKO-KOM (2014), if you ask people to bring their waste to a container which is located more than 400 m away from their house, only 5% of the population will be willing to walk there. The collection network can also be supplied via BCS, collection yards, etc. Rousta et al. (2015) stated that the statistical analyses of the research results indicated a significant decrease (-28%) of packaging and newsprint found in the residual waste after establishing a collection system close to the people's residences. Hence, a shorter distance to the drop-off points definitely contributes to a better waste recycling.

According to the results of the analysis of Nový Bor and the related experiences from other Czech municipalities, the BCS can be recommended as a fully functional system worth adopting. As stated by EKO-KOM (2013), every Czech citizen sorted on average 39.7 kg of recyclable waste, that is paper, plastic, glass and carton. According to the conducted analyses, every inhabitant of Nový Bor sorted on average 49.4 kg of the waste via stable recycling containers (not including the BCS) and 54 kg altogether via both systems (containers + BCS) in 2014. In fact, the BCS in Nový Bor is still a relatively new idea so people are getting used to it, but the participation in this system has progressively increased from about 300 subjects at the beginning to the current almost 900 active subjects. As stated by Rousta & Ekstrom (2013), the results of their

research showed that in a medium sized Swedish city, approximately 68 wt% of the combustible fraction and 29 wt% of the food waste were not sorted correctly. Therefore, it would be a very good idea to change some factors such as the inhabitants' anonymity (by using personalised barcode stickers for a quick and easy identification) and to offer a financial motivation (financial reward or at least a discount for MSW services or other) in order to enhance the inhabitants' involvement in the waste management system.

In view of the recorded findings and shared experience about the execution of the BCS, it is obvious that this system is strongly recommendable in order to obtain a higher yield and to maintain a cleaner separation of the respective recyclable materials. The quality and accuracy of waste separation definitely improve as soon as the respective collectors are no longer anonymous. This can be achieved by using the personalised stickers with barcodes on the bags. In general, this system is advisable for the parts of the cities with family houses. It is not so recommendable for multistory buildings, where the participation has been considerably lower so far. Moreover, this system works well in small and medium-sized cities, where people tend to know one another.

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