FROM SOCIALISTIC CIRCULAR ECONOMY TO MARKET-ORIENTED WASTE MANAGEMENT: CASE STUDIES IN BELARUS AND UKRAINE

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SUMMARY: In the USSR quite efficient and robust centralistic waste management system was build up even earlier than in many developed European countries. It's operation was possible only under conditions of a planned economy, although some approaches were quite successful and might be adopted for the EU circular economy concept. After USSR collapse transition economies achieved different levels of success in waste management reforming. Project WaTra ("Waste Management in Transition Economies") is aimed to compare development of waste management in Belarus and Ukraine 25 years after USSR collapse, develop scenarios and roadmaps for future development of waste management systems in selected case study regions – Mogilev city (Belarus) and Derhachi district (Ukraine). Some first project outcomes are presented in this paper.

1. INTRODUCTION

The transition in ex-USSR and other socialistic countries from a centrally planned model towards a liberalized market has caused a fundamental change in all sectors of economy over the last 25 years, including waste management. In the USSR quite efficient and robust centralistic waste management (WM) system was build up. After USSR collapse in 1991, newly emerged post Soviet states faced the problem of decay of the state economy. Municipal services, including the waste management sector, were put in the circumstances of drastic underfinancing and fundamental changes of regulatory and institutional environment.

Despite similar starting situation 25 years ago, the post-socialistic states reached different levels of success in re-establishing the waste management sector - some have achieved significant results while others seem to be stuck in everlasting transition. The main influencing factors for these major differences seem to be not only the financial wellbeing of the particular country, but also the political situation. Interestingly, in countries tending towards "authoritarian" governance, with less political uncertainties and strong administrative mechanisms and controls that have prevailed over the economic turbulences, the situation in the waste management sector appears to be less dramatic.

Ukraine suffers badly under very poor waste management caused by lack of state funds, turbulences and untransparences of the emerging waste management market due to continuous change of political situation and stakeholders in state and local governments, and related absence of the long-term strategic planning. In more "authoritarian" Belarus the situation appears to be better due to stable political situation and continuing strategic planning and

enforcement efforts on the state level and available state funds. Some other post-socialistic states, e.g. Eastern Germany, have achieved much better and faster performance in reforming and improvement of WM system owing to large investment funds that were made available by Western Germany and EU.

Project WaTra ("Waste Management in Transition Economies"), financed from the Austrian IMPULSE program of the OeAD Fund, aims to compare situation in waste management sectors of Belarus and Ukraine before USSR collapse and after 25 years of the transition process, develop scenarios and roadmaps for future development of waste management systems in selected case study regions – Mogilev city (Belarus) and Derhachi district (Ukraine). First results of the project are presented in this paper.

2. WASTE MANAGEMENT SYSTEM IN THE SOVIET UNION

In the USSR quite efficient and robust centralistic waste management system was build up even earlier than in many developed European countries. The first national decree about measures on waste disposal was issued already in 1952. Although there was no special waste law, system of collection and utilization of recyclables was well-developed and had an extensive legislation. From mid-1970s resolutions were put into force establishing economic instruments and initiatives for enhancement of recovery of secondary raw materials, especially metals. The sanitary standard on collection and utilization of secondary raw materials was introduced in 1982. From 1986, the development of new materials or products had to include a concept for their re-use or recycling. Economic interests became main driver for enhancement of recycling much earlier than environmental protection, which has found recognition later. "Polluter pays" principle was introduced only in the end of 1980s, however, technical standards on design of MSW landfills were established in 1981-83 (for comparison: first technical standard for landfills in Austria was developed in 1988).

Due to the overall shortage of the consumer goods in the Soviet economy, the USSR did not experience an explosion of waste from surplus of goods and disposable products. In contrast, shortage of basic consumer products promoted tradition of goods conservation at the individual level, packaging was mainly reusable (mostly deposit glass bottles were used for all kinds of beverages and milf products) or degradable (paper). As a result, annual average waste generation was very modest - about 195 kg/cap. Due to strong state policy use of secondary raw materials was, in general, increasing much faster than waste generation (Skryhan et al., 2016; Stolberg et al., 2016).

Separately collected recyclables were accounted in the statistics not as "waste", but as secondary raw materials. Collection and processing of "municipal solid waste" (=residual mixed waste) and "secondary raw materials" (recyclables) were regulated by different sets of legal documents. Powerful centralised system "Gossnab" was in charge for collection and use of recyclables over the whole territory of the USSR, different departments were responsible for: a) industrial enterprises and farms, b) cities and c) rural areas. Collection of scrap metals and waste paper was organised through schools, universities, enterprises and organisations. Collection of recyclables from residents was organized through stationary and mobile collecting points, combination of collection points and shops (points-shops) and special civic amenity sites. Citizens earned money for bringing recyclables (glass, waste paper, textile, polymers) to collection points. In 1974 started experiment with collection points-shops, where collected recyclables were exchanged for scarce consumer goods and books. Such shops quickly became common and most effective form of collection. The level of waste paper collection by the end of 1978 was around 59 %, textile – 51%, bones (were used in animal feeding) – 43 %. About 90% of glass was collected through very efficient nationwide deposit system

(standardized bottles for milk and cold beverages were used across the country) (Skryhan et al., 2016). From 1974 food waste from households and commerce was separately collected and after heat-pretreatment used as food at the pig farms.

The system "Soyuzvtorglavresursy" of Gossnab in the 1980s included 5677 collecting points for recyclables from the population and 527 enterprises for treatment of recyclable materials (waste paper, textile, polymers). Precious metals used in the electronic industry were also controlled and accounted. The special state programme envisaged double increase of recyclables' use from 1986 until 2000, by the 2000 the level of treatment had to reach 100 % for some types of waste (ferrous and non-ferrous scrap metal, waste paper, textile, polymers, leather and wood). The government introduced a number of technological lines for processing of paper, textile, polymeric and wooden waste, used tyres, glass, oils etc. The special institute of materials recycling was founded to provide scientific-engineering know-how. Eastern Germany had a very similar system for management of recyclable materials and achieved following recycling rates already in 1989: paper - 55%, glass – 65%; textiles – 70%; thermoplastics – 80% (Maletz, 2016). In order to promote re-use of goods, an extensive network of second-hand shops was operating throughout the country.

Most of residual mixed waste was transported to landfills, and only insignificant part was treated in "composting" or incineration plants installed in some large cities. In 1967 the order was issued about construction of waste treatment plants with production of compost or fuel (analogue to MBT plants) from mixed waste and development of the quality standards for the compost produced. From 1971 to 1987 nine aerobic treatment facilities were launched in the large cities, they produced low-quality "compost" from mixed waste. Another 20 facilities were under construction by 1990.

Operation of this optimized system was to a great extent subsidized from the state budget and was unfortunately possible only under the conditions of a planned economy. Cross-subsidization was widely spread approach in municipal services. Tariffs for the population were much lower than for legal entities. Tariffs for the population did not cover all costs of municipal services, the difference was subsidized from the state budget or at the expenses of legal entities. The high level of the cost for collection and treatment of "unprofitable" waste was compensated by including these costs in the cost of production of relevant industries.

State policy supported enhancement of the motivation and broad involvement of the population in the collection of recyclable materials in order to form cultural behavioral patterns and to promote the importance of the recycling. Each school, university or the institution had the plan of activities aiming at collection of paper, metal and other recyclables. Presenting these activities in form of cooperation or contests the government successfully implemented the plans and achieved the state indicators, active participants and winners of the competitions received bonus payments. One of successful awareness campaign examples with important educational value: since 1974 all-Union competition for schoolchildren and students on collection of paper was held with a motto "Million to Motherland!", which resulted in doubling of waste paper collection.

Among advantages of the Soviet system were unified all-union strategies and approaches, effective enforcement of governmental decisions, large centralised administrative, production, institutional and research capacities, powerful information support and propaganda. By 1990 USSR already reached quite developed and sustainable resource management system. It can be considered an example of "socialistic circular economy" and some of its approaches might be adopted for the future circular economy in EU.

3. EXISTING WASTE MANAGEMENT IN UKRAINE AND BELARUS

3.1 Waste management in Ukraine

During the transition period to the market economy, the Ukraine lost the old Soviet instruments in waste management that widely stimulated efficient waste collection, separate collection of recyclables. After USSR collapse, by the end of 1990s separate waste collection and recycling in Ukraine decreased by 70-80% accompanied by the drastic increase of waste amounts by 40-50% due to increase of the products assortment and packaging, changing of the consumption behaviour towards overconsumption. Current standard of MSW management services and facilities in the country is very poor. Due to the economic recession and lack of financing, around 70% of Ukraine's current waste collection contrainers and transport vehicles are obsolete. The waste management sphere lost its significant financing from the state, many specialized waste management companies changed their main field of operation.

MSW collected by organised collection services in Ukraine is estimated at 48 million cubic meters or about 9.2 million tonnes in 2015 (excluding data from the temporarily occupied territory and Crimea), approximately 270–300 kilograms per capita per year. This is significantly lower than the EU's generation rate of 510 kilograms, but much higher than Ukraine's own generation rate in 2000 (about 170 kg/cap). As only 77.46% of the population in Ukraine is serviced by organised MSW collection services and large share of waste is now circulating outside the official waste management system (illegally disposed/burned or informally collected), the total amount of MSW generated is considerably larger. Due to the low level of coverage of organised MSW collection services especially in rural areas significant quantities of waste are illegally dumped or burned on backyards and in open areas (i.e. 'wild' dumpsites). While EU Member States recover, on average, up to 60 % of MSW, the overall level of recovery of MSW is low as only 5.93% in 2015 of MSW generated was recovered. This includes 2.73% (1.3 million m^3) of incinerated municipal waste, 3.2% (1.55 million m3) of waste directed to recycling plants and about 17,000 m3 (0.003%) of waste composted (EBRD, 2017). The rest (i.e. about 94%) was directed to landfills.

In Ukraine there are more than 6000 registered landfills and dumpsites which typically do not meet environmental standards (inventarisation of disposal sites is ongoing, so the number is not final). Very large number of landfills/dumpsites (i.e. in almost every settlement), as well as the proliferation of unauthorized dumpsites in Ukraine makes the landfilling situation practically uncontrolled. The quality of data on MSW is poor, there are no systematic studies with official data on MSW composition and available data is spread across different sources and reports, often contradictory in nature. Waste recycling is usually done by private small enterprises focused on plastic, paper or rubber recycling. Informal sector is largely involved in extracting recyclables (metals, paper, glass and plastic) from the household waste stream – either from street waste bins or at the landfills. The unreasonably low fees and tariffs (environment tax on disposal of waste - €0.14/ton; average annual MSW management consumer tariff per resident – € 6-10; average waste management fee – 2 €/m^3 or ~€10/t) do not incorporate an investment component, do not stimulate separate collection and sorting and create distorted incentive for cheap landfilling. Gaps in legislation, implementation and enforcement, low tariffs for waste services and political and regulatory uncertainty undermine investor confidence.

The regulations of the former Soviet Union have remained in force and have been slowly replaced or amended by new laws and regulations. The development of waste management strategies and regulations have been slow, however in many cases the problem is not the absence of legislation (i.e. environmental norms and standards for collection and landfilling operations exist), but rather the lack of monitoring and enforcement of such legislation. The

most significant step was adoption of the new Law on Wastes in 1998, however it is of rather generic and declarative nature. No state strategy for waste management was approved so far. Ongoing economic recession, political turbulences and social crisis require more urgent actions leaving waste management far behind on the agenda.

Signing of the EU Accession Agreement in 2014 requires substantial reform of Ukraine's environmental and waste management legislation, setting of quantitative targets and indicators, introduction of Waste Directive and Landfill Directive. Draft waste management strategy for the years 2017-2030 has been recently developed by international donors (EBRD, 2017) with the aim to set out a series of measures that will bring Ukraine closer to adopting an integrated MSW management system in line with the EU-Ukraine Accession Agreement. Strategy foresees:

- coverage of population by separate collection of dry recyclables - 48% by 2030;
- construction of collection centres with composting plants and 90 sorting lines
- reduction of disposal sites and construction of sanitary regional landfills
- introduction of EPR schemes for packaging waste and WEEE from 2017
- deposit/refund system for post-consumer beverage packaging (glass bottles)
- centres for “second hand” goods and clothes as well as products in need of repair (WEEE)
- pilot bio-stabilisation MBT plants with production of RDF for the residual MSW by 2024
- establishment of controlled home composting (6 % or urban, 12% of rural population)
- achievement of overall recycling rate of 7% of collected waste in 2022 and 15% in 2030.

3.2 Waste management in the case study Derhachi district, Ukraine

The Derhachi district is one of the 27 districts of the industrial Kharkiv region in the eastern part of Ukraine. District has 95 ths. inhabitants, includes 15 communes with 63 settlements and administrative centre Derhachi town (20 ths inhabitants).

Waste generation. There are no reliable data on the amounts of MSW due to the lack of official monitoring and absence of data on streams beyond the official collection system (dumping, littering, yard composting/burning, informal collection). Therefore, the household waste generation rate from different sources (population and entities) was calculated based on municipal wastes generation norms. “Norms” are to be established by local authorities or waste services providers based on the measurements of waste amounts, however, they are generally obtained by calculation and define the upper level of the amount of generated waste. If no local norms are established, waste generation can be calculated according to minimum national waste generation index. Norms take into account waste generation in improved and un-improved housing areas based on seasonal fluctuations. The waste amounts calculated based on norms is used to obtain a landfilling permit for a certain amount of waste for the calculation of the environmental tax.

Norms established for seven towns/villages of the Derhachi district range between 280-580kg/cap depending on type of housing (with or without improvements), they were used for calculation of the generated waste amounts. In 2014 studies on analysis of the waste composition in Kharkiv region were carried out, averaged results are presented in Table 1.

Collection. The current MSW management system is characterized by low level of collection coverage. Although according to official data, 90% of population is covered with the services (42 settlements of 63), in reality in many small settlements waste collection is carried out on very irregular basis, many households and horticultural associations do not have agreements on waste collection. Data on waste collection in official statistics is contradictory. Preliminary estimations and informal discussions reveal that only about 30-45% of generated waste is formally collected (10.8 ths t/a), while the rest is dumped at the illegal dumpsites, composted or burned at backyards etc.

The main problem is the lack of containers and proper vehicles and their high moral and physical obsolence. Currently the district is served by 17 vehicles with depreciation rate of 85 %, there are no vehicles in 6 communes. Collection system comprises container use at multi-story housing area; bring sites and bags collection at private households and rural settlements.

Separate collection, sorting and recycling. Pilot separate collection of recyclables (glass and polymers) has been implemented since 2014 in two communes, covering 7% of the total population of the district, separate collection rate is ~0,3% of the waste collected in the district. Waste sorting is also carried out on the informal basis. The amount of collected recyclables and processing activities is not monitored. Processing and recycling of MSW is carried out mostly by small private enterprises. There is data from local authorities about sorting of 7% of the collected waste, however no further details are available. Separate collection of bulky, construction and demolition waste and hazardous municipal waste is not carried out.

Disposal. Collected waste is landfilled at 4 disposal sites located at the district territory. Largest semi-sanitary Derhachi landfill (13.2 ha) is located in the Derhachi town and serves regional capital Kharkiv city (1,7 mln. inhabitants) and Derhachi town, three smaller dumps (5.5 ha, 2.8 ha, 0.06 ha) receive waste from the the rest of the Derhachi district. Illegal dumping is wide-spread, annually about 300 illegal small dumps are eliminated. The loan-financed project on construction of the sanitary landfill and sorting line at Derhachi landfill has been recently launched.

Table 1 summarizes main facts about waste management in Derhachi district and Figure 1 shows simplified waste flow diagram of the existing waste management system in Derhachi district. Data on collected waste was received from local authorities and statistics, Illegal disposal rate was estimated based on official figures on annual waste amounts from elimination of illegal dumps, rate of informal collection of recyclables and home composting were estimated and cross-checked based on average literature data (Ramusch and Lange, 2013, Mihai and Ingrao, 2016).

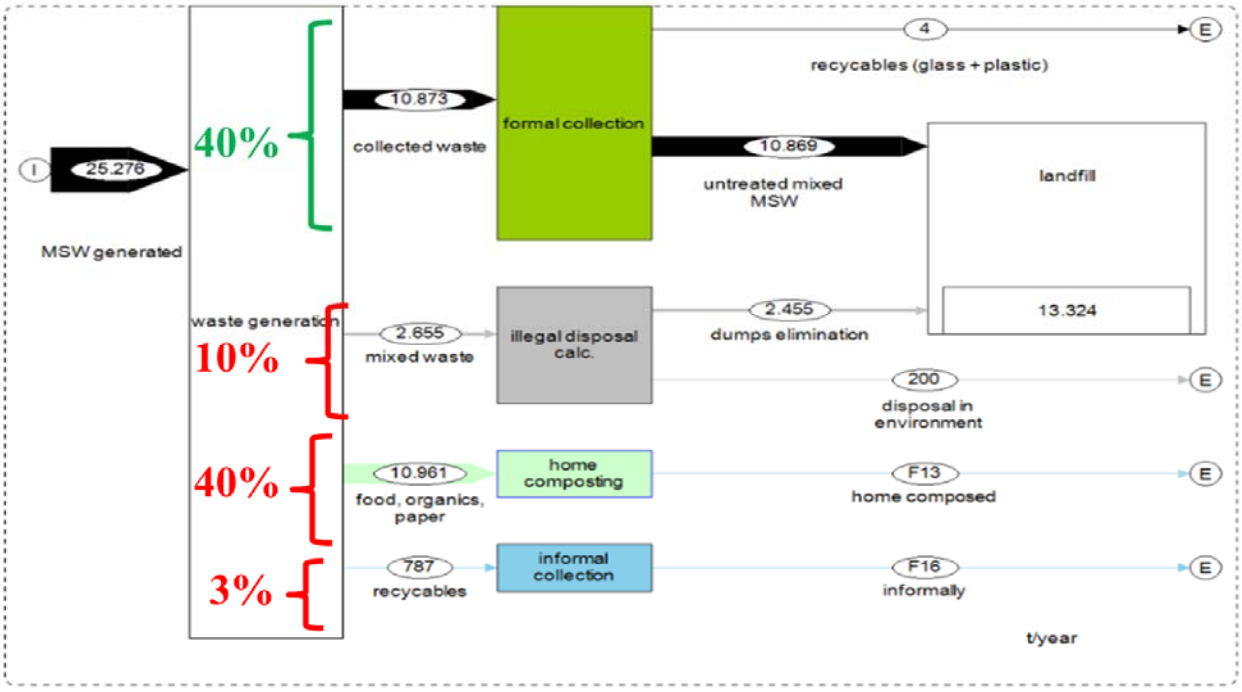

Figure 1. Flow diagram of the existing waste management system in Derhachi district, Ukraine

3.3 Waste management in Belarus

Similarly as in Ukraine, higher incomes and rising consumption have lead to steady increase of MSW generation in Belarus since 1995 by almost 3 times: from 143,5 kg per cap per year in 1995 to 421,7 kg per cap per year in 2014 (4000 ths t in 2014).

After collapse of USSR Belarus has succeeded in development of quite strong own environmental and waste management legislation. The Law on Waste management was adopted in 1993, various standards and regulations for coordination of activities related to collection and processing of recyclables and packaging materials were developed in the last decade. Belarus was the first post-Soviet country which adopted the ban for landfilling of recyclable materials in 2003 as well as the established the EPR principle in 2014 managed by the designated centralised responsible institution – Operator of Recyclables. However, relevant EPR regulations are still under development and implementation of ban for landfilling of recyclables is also pending due to absence of monitoring procedure. Governance system in waste sector is quite complicated, e.g. collecting points for recyclables belong to different organizations subordinated to 5 different ministries, two ministries deal with legal framework in the waste management. Similarly as in USSR, separately collected recyclables are accounted in the statistics not as “waste”, but as secondary raw materials.

Waste management targets and indicators are defined by the state programs and regional 5-years waste management plans. During last 25 years 8 state waste management programs were adopted, setting quite ambitious quantitative targets for improvement of landfilling standards, increase of collection coverage, separate collection and recovery of recyclables. The last program foresees: by 2016 - organization of collection of hazardous and electronic waste by 2016; by 2025 - 100% coverage by separate collection (with 70% separate collection efficiency), construction of plants for waste recycling, composting and incineration in the cities with population of more than 70 ths.persons by 2025. Implementation of these plans is hampered by the economic recession in the last several years and lack of money in the state budget.

Since introduction of new waste regulations in 2003, more than 70% of urban population has been covered by separate collection, in the large and medium-size settlements several transfer stations, 90 sorting and 5 waste treatment facilities were constructed. Producer responsibility principles and goals for waste recycling have been largely introduced into regulations. Pilot waste treatment plants (e.g. mechanical-biological treatment) were constructed. In the new concept for communal waste and material resources utilisation for 2014-2020 substantial increase in material recovery is foreseen in line with best EU practices.

Separate collection of recyclables is organized through waste containers and system of stationary collection points remained since USSR time, majority of them is operated by three state organizations. People get money for bringing recyclables to collection points bringing container collection into unfavourable competition with collection points. Dominant type of collected recyclables through the container system is plastic, through collection points – paper. According to different sources, in 2013 the collection of recyclable materials (paper, glass, plastic, textile, used tires) was about 12 to 20% from total amount of collected MSW, the amount increased 5 times from 2008. Belarus government and Operator of Recyclables finaced construction of 90 sorting stations for sorting of mixed waste and after-sorting of source separated waste. The extraction of recycled materials is about 19 % of the MSW received for sorting. The rest amount of MSW is transported to landfills. Recycling facilities are usually built for environmental reasons using governmental subsidies. At the moment, there are enough recycling facilities for recycling of glass, plastic, textile and metals, their capacities are underused due to lack of supply of high-quality materials.

In 2013 there were 164 semi-sanitary and non-sanitary landfills and 2755 mini-dumps in

Belarus, the trend of the recent years is to close small disposal facilities.

Current waste management tariff for population (e.g. 3 Euro/m^3 or ~15 Euro/t in Mogilev city) is to significant extent still subsidized from the state and cross-subsidized from tariff for legal entities. However, share of costs carried by population has been increasing gradually as part of state policy on elimination of cross-subsidies: from 25% in 2008 to 60-80% in 2015.

While implementing new market approaches (e.g. EPR scheme), Belarus retained also many valuable components of waste management system from USSR time: centralised management and infrastructure for collection of recyclables, recycling capacities, voluntary-obligatory public awareness initiatives (e.g. plans and competitions for collection of recyclables at institutions, schools, state-wide cleaning activities), as well as many elements of institutional framework and responsibilities, including waste registration system, where separately collected recyclables are considered not “waste” but secondary resources. Disadvantage of the existing centralised approach are: cross-subsidies, dependence on (limited) state financing, lack of competitive business environment and investments, technological concepts for the MSW management are often approved on the state level without connection to the regional realities; licensing procedures limit private business initiatives.

3.4 Waste management in the case study city Mogilev, Belarus

Mogilev city is a regional center of eastern Belarus, 3rd largest city of Belarus with a population of 380 ths. inhabitants.

Collection. MSW collection in Mogilev is carried out in several ways: “container use” at multi-story housing area; “yard detour” – weekly collection of bags from private households and rural settlements; “self-pickup” – residents or entities transport waste to the landfill on their own; “collection points” – people bring recyclables getting some money; collection of recyclables at legal entities.

The coverage by waste collection services is 100%. However according to estimates, waste that is catched by official waste collection system (108 ths. tons/year) makes only about 60% of the generated waste (estimated by waste generation norms as for Derhachi district), the rest is littered/illegally dumped, collected by informal sector, composted or burned at backyards.

Separate collection, sorting and recycling. Separate waste collection system covered on average 45,8 % of urban and 14,4 % of rural population in Mogilev region in 2008. In Mogilev city, separate waste collection in containers is organised throughout the city, however, number of fractions collected can vary. Paper, glass and plastic are collected separately, however collection rate in containers is very low (~0,6% of the collected waste). Major part of recyclables (6,7% of collected waste) is collected through system of collection points and at legal entities. There are 46 collection points for collection of recyclables (paper, glass, polymers – PET and films, WEEE, textile). Separate collection points for scrap metals are operated by two state companies. From 2016 there is special state organization responsible for collection of WEEE and batteries directly from households and enterprises.

In the Mogilev city 100% of collected MSW is delivered to manual sorting plant “ZUBR”. The plant with the capacitiy of 90 ths t/a started in 2009. Efficiency of mixed waste sorting is very low – about 5%, but overall plant’s efficiency reaches about 15% by after-sorting of waste from containers for separate collection and collection points. The sorted fractions are sold to recycling plants, residues after sorting are landfilled. Despite demonstrative punitive measures, Illegal waste collection takes place, recyclables are transported to Russia, where selling prices are higher.

Treatment and disposal. Mogilev city waste is disposed of at semi-sanitary landfill located outside of the city. Old small-scale composting plant (current throughput of 550 t/yr) is operating since 1980s, processing mixed waste and using worms for composting process. Due to low

quality of output material it is mixed with soil after processing.

Main facts about waste management in Mogilev city are summarized in the Table 1, waste streams in Mogilev city in baseline scenario are depicted on the Fig.2. Composition of waste (Table 1) is derived and adapted from information from waste operator, however, it is to be noted that figures represent composition of residual waste (deducting separately collected recyclables), while composition of waste in Derhachi district is “at source” and not influenced by separately collected waste.

Table 1. Main waste management facts for Derhachi district (Ukraine) & Mogilev city (Belarus)

Parameter	Mogilev city	Derhachi district
Area	119 km^2	895 km^2
Population	380 440	95 144
Waste collection	108 301 t	10 873 t
Waste generation (estimated)	181 426 t/a 477 kg/cap/a	25 276 t/a 257 kg/cap/a
Collection coverage (official data vs. estimated capture rate by formal system as % of generated waste)	100 / 60%	90 / 40%

Waste composition:	City Mogilev	Derhachi district	
		Derhachi town	Rural area
Food waste	30%	24%	17-19%
Paper and cardboard	8%	6%	1-6%
Polymers, combined packaging	8%	18%	8-11%
Glass	7%	20%	18-24%
Metals	2%	1%	2-3%
Textile, wood, leather, rubber	8%	6%	6-12%
Hazardous waste	1%	<1%	<1%
Other	36%		35-37%

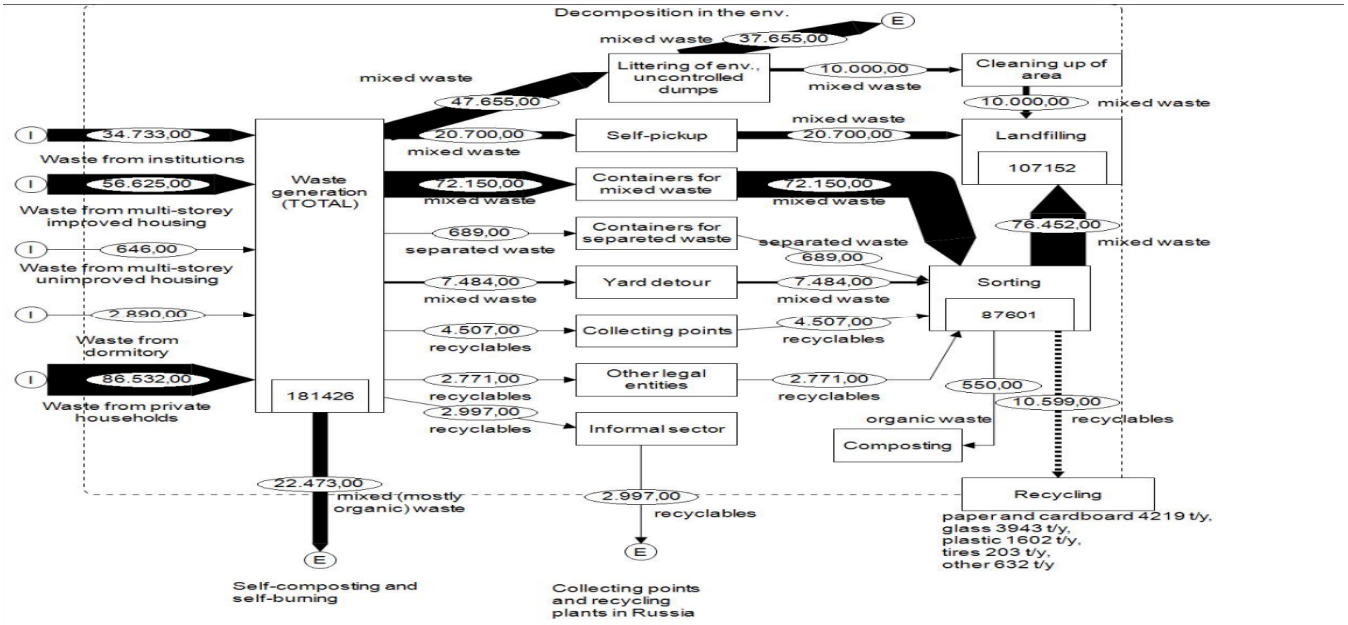

Figure 2. Flow diagram of existing waste management in Mogilev city, Belarus (Skryhan et al., 2016)

4. FUTURE SCENARIOS

Scenarios for future organisation of waste management system in 2025 were developed and later estimated and compared using set of environmental, economic, social and technical indicators. Main aim by selection of scenarios was to provide basic sound WM components at a 1st step (Scenario 00) - full waste collection coverage, sanitary landfilling and pre-treatment before landfilling. Other scenarios are oriented either a) towards increase of recycling or b) towards enhancement of energy recovery or c) combination of both. Due to small waste amounts expensive high-tech treatment technologies (incineration, anaerobic digestion) were excluded from consideration for in Derhachi district. Separate collection efficiencies are taken from the studies of Boer et al. (2005) and Pöttschacher (2016).

4.1 Future waste management scenarios for Derhachi district, Ukraine

Table 2. Overview of baseline and future waste management scenarios in Derhachi district

Scenario name	Scenario description	Separate collection efficiency	MSW infrastructure
Baseline	~40% collection coverage, no sanitary landfilling. Negligible amounts of separately collected glass and plastic	negligible amounts of glass and plastic (<0,2%)	• 4 dumpsites • small waste sorting facility
00 No recycling, san. LF & MBT	100% collection coverage, elimination of dumps. Separate collection of hazardous & WEEE waste. Construction of new sanitary landfill and pre-treatment before disposal. These components are pre-requisite in all other scenarios.	as in baseline	• MBT • Sanitary landfill
1a $Recycling_{low}$ [pl, gl]	Separate collection of 2 recyclable fractions (low collection efficiency)	plastic 33%; glass 50%	• MBT • Sanitary landfill • 3 collection/sorting points for recyclables
1b Recycling [dry-wet bin]	Separate collection of residual waste and dry recyclables in a two-bin (dry-wet) system	plastic 70%; metals 81%; glass 71%; paper 85%	• MBT (including a module for sorting of dry-wet bin) • Sanitary landfill
2a $Recycling_{high}$ [pl, gl, me, pa]	Separate collection of recyclables in different bins	plastic 65%; glass 69%; metal 60%; paper 74%	• MBT • Sanitary landfill • 3 collection/sorting points for recyclables
2b $Recycling_{high}$ [pl, gl, me, pa, org]	Separate collection of recyclables in different bins. Separate collection of organic waste	plastic 65%; glass 69%; metal 60%; paper 74%; organics 51%	• MBT • Sanitary landfill • 3 collection/sorting points for recyclables • Open windrow composting
3a RDF + $Recycling_{low}$ [me, gl]	Separate collection of metal and glass to maximize the quality of the produced RDF	metal 60%; glass 50%	• MBT • Sanitary landfill • 3 collection/sorting points for recyclables
3b RDF + $Recycling_{low}$ [me, gl, org]	Separate collection of metal and glass to maximize the quality of the produced RDF. Separate collection of organics to reduce moisture of residual waste and increase RDF quality.	metal 60%; glass 50%; organics 22%	• MBT • Sanitary landfill • 3 collection/sorting points for recyclables • Open windrow composting

4.2 Future waste management scenarios for Mogilev city, Belarus

Table 3. Overview of baseline and future waste management scenarios in Mogilev city

Scenario name	Scenario description	Separate collection efficiency	MSW infrastructure
Baseline	100% official collection coverage. Separate collection. Manual sorting plant for sorting of mixed waste and after-sorting of recyclables, small amount of residual waste is aerobically treated. Landfilling at non-sanitary landfill and Ilegal dumping.	system of bins and collection points for paper; glass; plastic; metals. separate collection rate ~7%.	• Sorting plant • Semi-sanitary landfill • Old small-scale "composting" plant for residual waste
00 No recycling, san. LF & MBT	Elimination of illegal dumping. Collection of WEEE & hazardous waste. Recyclables are after-sorted at the existing sorting plant ZUBR and residual waste is treated in the aerobic MBT plant. Construction of a new sanitary landfill.	as in baseline	• Sorting plant • Aerobic MBT for residual waste • Sanitary landfill
Sc 1 Partly recycling (dry/wet bin)	Separate collection of recyclables in wet and dry bins, after-sorting at the existing sorting plant. Residual waste treated in the aerobic MBT.	plastic 70%; glass 71%; metal 81%; paper 85%	• Sorting plant • Aerobic MBT for wet bin • Landfill
Sc 2 Full recycling (separate collection + composting)	Maximizing recycling. All recyclables are collected separately, incl. organic waste which is sent to the composting plant. Residual waste is treated in the MBT plant.	plastic - 65%; paper - 74%; glass - 69%; organics - 51%	• Sorting Plant • Aerobic MBT • Composting • Landfill
Sc 3 Full recycling + energy recovery	Maximizing recycling as 1st priority, and energy recovery (as 2nd priority). All recyclables are collected separately as in scenario 2. Residual waste is combusted in the waste incineration plant.	collection rates same as in scenario 2.	• Sorting plant • Incineration • Composting • Landfill
Sc 4 Full energy recovery	Maximizing energy recovery. Only inert fractions and wet biowaste are collected separately to increase calorific value of incinerated waste. Biowaste is processed for energy recovery in the anaerobic digestion plant.	glass - 69%; metal packaging - 60%; organics - 51%.	• Incineration • Anaerobic digestion • Landfill

5. METHODOLOGY FOR ASSESSMENT OF SCENARIOS

Based on extensive review of various methods and methodologies used for planning and assessment of waste management scenarios (e.g. Allesch and Brunner (2014)) most appropriate environmental, economic, social and technical indicators were selected to be used in the study (Milutinovic et al (2013); Rigamonti et al. (2015); Vucijak et al. (2015); Arikan et al. (2015); Den Boer et al. (2005)). Among main criteria for selection of indicators were plausibility for local conditions, practicability and easy understanding by local stakeholders.

Indicator	Description	Unit
Economic assessment (7 quantitative indicators)		
1. Investment costs	Investment costs of WM scenario	[€]
2. Annual operation costs	Annual operational costs (labour, energy, fuel etc.)	[€/a]
3. Total annualised costs	Total yearly discounted costs of WM for municipality incorporating both capital and operating costs over lifetime (in €/a and €/t waste collected)	[€/a,€/t]
4. Revenues generated	Revenues from selling the recovered materials and energy	[€/a]
5. Ratio of fees & revenues and total annual WM costs	Diversion between income from MSW fees and generated revenues and total annualised costs of WM system	[%]
6. Costs as % of regional budget	Costs of waste management as % of city/district budget	[%]
7. Costs as % of salary	Costs of WM per person as % of minimum and average wage	[%]
Environmental assessment (6 quantitative indicators)		
1. Separate collection rate	Ratio of the amount of source separate collected waste and the amount of collected MSW	[%]
2. Recycling rate	Ratio of the amount of materials actually recycled (incl. compost and materials recovery from combustion residues) and the amount of collected MSW	[%]
3. Energy recovery rate	All energy recovery achieved in the MSW management system (from combustion, RDF use, biogas from landfills or biogas plants etc.) as % of energy content in the collected waste	[%]
4. Landfilling rate	Waste left for disposal at landfills (mixed waste, treatment residues etc)	[%]
5. Biodegradable waste diversion rate	Amount of biodegradable waste diverted from landfilling (pre-treated, composted etc)	[%]
6. Greenhouse gas emissions	Emissions of greenhouse gases in waste management scenario generated in waste management activities (emissions from collection and composting not included)	[t CO2eq.]
Social Assessment (7 qualitative + 1 quantitative indicator)		
1. Odour	Increase of the odour caused by waste management activities (composting, separate collection of biowaste)	- *
2. Visual impact	Intensity of odours increases in scenarios with separate collection of bio waste.	- *
3. User convenience & complexity	Related to the number of waste fractions to be collected separately.	- *
4. Distance to container	Distance to waste collection containers	- *
5. Private space	Space occupied by the waste temporary storage inside the city inhabitants' private properties	- *
6. Noise	Increase of the mean sound level caused by additional waste management activities (filling of containers, increased traffic etc)	- *

7. Traffic	Additional traffic pressure from waste colelction and transport vehicles	- *
8. Job Creation	Number of new jobs created as a results of introduction of scenario (based on lit.data)	Nr.
Technical assessment (4 qualitative indicators)		
1. Technical reliability	Ability of technology to perform desired function within a specified period of time, robustness and reliability, prevalence of its use in the practice	- *
2. Qualified personnel and maintenance	Requirement of qualified personnel and maintenance requirements (spare parts, qualified operators etc.)	- *
3. Sensitivity to quantity of input material	Flexibility of technology to change of waste flows quantity and technical and economic expences for adjustment of the technical infrastructure.	- *
4. Sensitivity to quality of input material	Flexibility of technology to change of waste quality and technical and economic expences for adjustment of the technical infrastructure.	- *

*Scoring (expert-based survey)

The list of indicators was discussed at stakeholder meetings in both case study regions, where ranking of importance of indicators was conducted by local stakeholders (mainly local authorities, but also representatives of waste management companies, NGOs and scientific community). Economic indicators (costs, especially investment costs) were ranked as the most important, followed by environmental indicators “separate collection rate“ and “landfilling rate”, social indicator “user convenience” and technical indicator “technical reliability”.

7. CONCLUSIONS

1. In the USSR quite efficient and robust centralistic waste management system was build up even earlier than in many developed European countries. By 1990 USSR already reached quite developed and sustainable resource management system. It can be considered an example of “socialistic circular economy”. Operation of this optimized system was to a great extent subsidized from the state budget and was unfortunately possible only under the conditions of a planned economy, however some of its approaches might be adopted for the future EU circular economy.

2. The main success factors for reforming of waste management system in transient countries seem to be not only the financial wellbeing, but also the stability of the political situation. In countries tending towards “authoritarian” governance, with less political uncertainties and strong administrative mechanisms and controls that have prevailed over the economic turbulences, the situation in the waste management sector appears to be less dramatic. In Belarus, many elements of the Soviet WM system have been preserved, at the same time continuous efforts on further development and enforcement of national waste management strategies and relevant legal framework during the last 25 years have lead to better performance of the waste management system. In contrast, in Ukraine, the old system of waste management was to a large extent destroyed, country suffers badly under very poor waste management caused by lack of state funds, turbulences and untransparences of the emerging waste management market due to continuous change of political situation,

governments and related absence of the long-term strategic planning. The situation with state financing in waste sector is much worse than in Belarus and investment climate is very unfavourable due to political uncertainty. Comparison of situations in Belarus and Ukraine reflects the fact that waste management is not only the problem of technological solutions, but is by far more influenced by a combination of the political, societal, economic, as well as cultural and behavioural challenges.

3. Challenges faced in planning and assessment of waste management scenarios:

- Lack of data about waste quantities, as well as significant waste streams circulating beyond the formal collection system (littering, illegal dumping, backyard composting and burning, informal collection) was a big challenge. For quantification of waste streams and planning of facilities, assumptions about waste composition and estimates of waste amounts were necessary. Current and future waste amounts were estimated based on waste generation norms, officially reported collected amounts and estimates of "inofficial" waste streams making up difference between norms and official statistics.
- Using of Life Cycle based indicators as was intended at the project beginning in line with stater-of-the-art assessment approaches (e.g. Boer, 2005) was considered as not plausible due to: a) lack of knoweldge and understanding among stakeholders in the case study regions and low practicability of results; b) absence of databases on local technologies, emissions etc. Only one (meanwhile well-known) indicator - greenhouse gas emissions - was used from the list of LCA indicators (some data assumptions from EU were used for calculations). Instead more common and understandable indicators were applied.
- Following drawbacks were observed while using qualitative social and technical indicators:
  - The scoring of social indicators is highly subjective, making the final justified decision hardly possible.
  - Depending on the social indicator it happens that „doing nothing" (remaining in the status-quo situation) can bring „better" results (e.g. separate collection worsen "user convenience").
  - Opinion from experts vary, increasing number of experts or asking specialists from other fields of knowledge or different stakeholder groups would have significant influence on results.
  - It is not evident how to integrate the social/technical assessment results in an overall result.

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REFERENCES

Allesch A., Brunner P. (2014): Assessment methods for solid waste management: A literature review. Waste Manag Res. 2014 Jun; 32(6):461-73.

Arikan, E. et al. (2015): Solid waste disposal methodology selection using multi-criteria decision making methods and an application in Turkey

Den Boer E., Den Boer J., Jager J. (2005): Waste Management Planning and Optimisation. Handbook for Municipal Waste Prognosis and Sustainability Assessment of Waste Management Systems, pp.193-212; ibidem-Verlag, Stuttgart.; ISBN ISBN 3-89821-519-9

European Bank for Reconstruction and Development (2017). Draft MSW strategy. Supporting investments in sustainable municipal management and recycling in Ukraine.

Maletz R. (2016): Presentation at WaTra project workshop, Kharkiv, 23.06.2017, Ukraine *(unpublished)*: Secondary Raw Material System in Eastern Germany before 1990.

Mihai F-C., Ingrao C. Assessment of biowaste losses through unsound waste management practices in rural areas and the role of home composting. Journal of Cleaner Production, Elsevier, 2016.

Milutinovic, B. et al (2013): Multi-criteria analysis as a tool for sustainability assessment of a waste management model

Pöttschacher S. (2016): Die Wertstofftonne im Vergleich zur getrennten Sammlung. Diplomarbeit / Masterarbeit - Institut für Abfallwirtschaft (ABF-BOKU), BOKU-Universität für Bodenkultur, pp 113

Ramusch R., Lange U. (2013): Role and size of informal sector in waste management – a review. Proceedings of the ICE - Waste and Resource Management. 166. 69-83.

Skryhan H., Melnikova I., Shilova I., Karpenko Y., Arlouski P., Shashanka S. (2016, unpublished): WaTra project report: “Overview of waste management in post-soviet states: Belarus, Russia and Kazakhstan. Waste management in case study region: Mogilev city and district”.

Stolberg F., Abashyna K., Chernikova O., Khandogina O., Pavlova M. (2016, unpublished): WaTra project report “Overview of waste management in transition economies (post-socialistic countries): Georgia, Moldova, Ukraine“

Rigamonti, L. et al. (2015): Integrated municipal waste management systems: An indicator to assess their environmental and economic sustainability

Vucijak, B. et al. (2015): Multicriteria decision making in selecting best solid waste management scenario: a municipal case study from Bosnia and Herzegovina