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Municipal Solid Waste Management in Kazakhstan: Astana and Almaty Case Studies

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The present paper provides an overview of the Municipal Solid Waste (MSW) management in Kazakhstan and focuses in more detail on two major cities, Astana, the new capital and Almaty, the former capital of the country. Legislation, current management policy, facilities and infrastructure, as well as typical solid waste quantity and composition are presented and analysed in detail in the light of the recently approved long-term waste management plan. The analysis is supported by the implementation of a Decision Support Tool (DSS), which provides insights in waste management needs and supports comparison and ranking of Integrated Waste Management (IWMP) alternatives. Finally, a certain IWMP plan is proposed, which could be used as a basis for further detailed feasibility studies.

1. Introduction

The quantity of municipal solid waste (MSW) in developing countries has been consistently rising over the years and its composition is similar but varies from country to country depending on the average standard of living, climate and cultural, industrial, infrastructural and legal factors. MSW disposal in most developing countries around the world poses major environmental problems. Several environmental and public health problems arise from insufficient collection and disposal systems. With only some exceptions, waste management in Kazakhstan is in the very first steps and municipal solid waste is disposed in open dumps and a small portion in engineered landfills (Inglezakis et al., 2014; Ministry of Environment and Water Resources, 2014). Outside of the big cities, typically only about one quarter of the population has access to MSW collection services and 97 % of MSW is taken to uncontrolled dumps and substandard authorized landfills without processing or recycling. Technology and infrastructure do not meet current standards due to a lack of economic incentives and although some standards/requirements are in place, enforcement is weak due to insufficient state control. More than 93 % of the 4,530 municipal waste disposal landfills are illegal and from the 307 authorized waste disposal facilities, only this of the city of Astana is designed in accordance with international standards (Government of the Republic of Kazakhstan, 2013). Moreover, there has been little incentive for local authorities and business in the waste disposal sector to increase added value recovery through recycling, composting, or energy recovery from urban waste, with recycled volumes reported to be less than 5 % of total MSW volume (Government of the Republic of Kazakhstan, 2013). The country currently has no waste-to-energy plants, as centralized incineration or biological plants, thus producing "green" energy from MSW is not established. It was projected that the first pilot project equipped with mechanical-biological treatment waste plant with waste-to-energy capabilities will be built in Aktau. According to the plan, this plant will be the first organization that can produce "green" energy from MSW by using the technology of anaerobic decomposition of organic waste fractions (Ministry of Environment and Water Resources, 2014). Thus, is evident that Kazakhstan needs to build a new integrated waste

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management system, taking into account reforms in the institutional and legal framework. To face the future problems a sufficient waste management system should be developed and Decision Support Tools is one of the available means to achieve this goal.

A waste management plan has to be developed according to the needs of the respective region where it will be applied. However, there are some common elements that do not depend on the region. Such elements include the characteristics of the waste treatment technologies that will be integrated into the management system. Competent authorities and stakeholders have to be able to identify how those technologies can be applied within technical and financially feasible terms always respecting and satisfying the legislative restrictions and prerequisites. In addition, they have to examine them as standalone units in order to comprehend their environmental impacts, advantages and disadvantages. In that context the Decision Support Software (DSS) tool, developed by members of the research team in collaboration with partners from Europe, is applied in Astana, capital city of Kazakhstan in order to examine and compare the application of different waste treatment options (Panagiotidou et al., 2012). The DSS tool for waste management is a computer integrated tool, aiming at supporting the decision maker throughout the various steps of waste management planning and allows a thorough understanding of the complex interplay between the numerous factors involved in integrated waste management. It is true that most existing tools developed for assessing waste management practices are incorporating large number variables and result in complex solutions, inadequate for practical use. On the other hand, DSS tool is a user-friendly software equipped with multiple functions, as described elsewhere. As any decision support tool, DSS provides solutions that can be considered neither optimal nor absolute, as the solution includes the perceptions of decision-makers. PROMETHEE multi-criteria decision making method and MATLAB graphical user interface environment were used. After developing the Graphical User Interface (GUI), a standalone distributable application (exe) for Windows Operational System is created, using MATLAB Compiler, allowing executions on computers with no MATLAB installed. As far as the application of PROMETHEE method in the present case study, it seems that its major advantage towards other multicriteria methods lies in its simplicity and very clear information that is easily obtained and understood by both decision-makers and analysts.

2. Assessment of the current situation of municipal waste management

Waste management in Kazakhstan is regulated by the Environmental Code of the Republic of Kazakhstan and relevant amendments as of 17.07.2009 and a number of other orders and resolutions relevant to Sanitary Rules, as the Order of the Ministry of Health of the Republic of Kazakhstan № 555 dated 28.07.2010 on the approval of Sanitary Rules and the Resolution of the Government of the Republic of Kazakhstan dated March 6, 2012 № 291 on the approval of the Sanitary Rules. Recently, the Program of Modernization of Municipal Solid Waste Management for the years 2014-2050 was issued by the Ministry of Environment and Water Resources (2014). The program is based on the act № 577 of 30/05/2013 entitled “Concept of transition of Kazakhstan to a Green Economy”, and the act № 750 of 06/08/2013, which is the action plan of the Government of Republic of Kazakhstan to implement this concept. The Program of Modernization of Municipal Solid Waste Management for the years 2014-2050 is considered as one of the priority areas for implementation of Green Economy program. This program aims to increase efficiency, reliability, environmental and social acceptability of MSW collection, transportation, processing and disposal services. According to the plan the target for MSW recycling is up to 40 % by 2030 and 50 % by 2050 and storage of residual MSW volumes at environmentally friendly and sanitary landfills to increase to 100 % by 2050. Also, the plan is to introduce a household waste separation program for consumers, implement the principles of a manufacturer’s extended liability to develop a mechanism to attract investments, and update MSW recycling and storage standards using new technologies, such as anaerobic digestion, composting and biogas.

Astana is the capital city of the Republic of Kazakhstan with a population of 872,619 (NSC, 2016). Waste management problems in Astana can be well understood in the light of rapid urbanization in many cities along Kazakhstan. As the economic situation improves, with Astana constituting approximately 8.5 % of the total GDP of 151.67 billion USD in 2011 the concerns for waste management rises since a stronger economy often leads to an increased waste production due to a higher purchasing capacity. According to the latest data at 2013 about 1,118 t of MSW are generated per day in Astana and the collection capacity is approximately 600-800 t (Inglezakis et al., 2015). Based on these data, waste generation rates are 507 kg/y per capita or 1.39 kg/d per capita, while waste collection rates are 365 kg/y per capita or 1 kg/d per capita (72 %). As analyzed in more detail elsewhere (Inglezakis et al., 2014), there are differences between the statistical data (based on waste collected) and actual data (normative, based on waste generated, experimentally measured) due to several factors as lack of weighing equipment in landfills, low collection rates by organized systems, disposal at illegal dumps and booming construction activity in the city which produces large amounts of construction and demolition waste and brings in an increasing number of commuting workers who generate waste but are not officially registered as citizens of Astana. Almaty is the former capital of Kazakhstan until 1998 and continues as the major commercial and cultural centre of Kazakhstan, as well as its biggest population center. The current population is 1,703,482. and according to data provided by the waste operators, municipality statistics (2014) and other reports the municipal solid wastes collected in Almaty is 612,300-672,693 t/y, which gives an average of 1,760 t/d, which corresponds to 1.03 kg/d per capita (ASD, 2013; MHI, 2014). The official norm for Almaty is higher than Astana at 2.55 m^3/person/year for people living in apartment houses and 2.9 m^3 /y per person for people living in private houses resulting in a generation rate of 1.17 kg/d per capita.

Concerning the annual waste rate growth, according to the latest projections, production of municipal solid waste in the period 2011-2025 in urban areas is likely to grow by more than 50 % along with growth in prosperity (Government of the Republic of Kazakhstan, 2013). This means that the annual waste growth rate is expected to be 3.33 %, higher than other developing countries in Asia, as for example Malaysia where the rate is at 2 % (Moh and Manaf, 2014). Due to the absence of reliable data, the annual waste generation growth in this study is set equal to the annual population growth, under the assumption of constant waste generation rate per capita for the following years. According to National Statistic Committee, NSC (2016) population data for the decade 2005-2015 the average annual population growth in Astana is 4.72 % and Almaty 3.14 %. These rates are high, indicating an urbanization trend however, taking into account that Astana is the new capital this rate is expected to be higher the following years. Thus, for projection purposes the values of 5 % and 3.14 % for the annual waste growth will be used for Astana and Almaty, respectively. MSW composition varies depending on weather conditions and season. In the fall amount of food waste increases markedly that is associated with the use of a population of more fruits and vegetables, but in the summer and spring the number of small dropouts (street debris) grows. The composition of MSW also has changed significantly over the time. So, the proportion of plastic materials and paper has increased recently, whereas coal and slag has almost disappeared (after the transition to centralized heating). The average composition of municipal waste in Astana and Almaty is presented in Table 1 and is derived from several sources. In order to calculate the prognosis of packing waste generated the proportion and composition of packaging waste in municipal waste is required. As expected the composition of packaging waste differs by region and in absence of local data an average value is used, based on published data for other regions in the world (Inglezakis et al., 2016).

Table 1: Input data regarding waste composition (%)

Type	Astana	Almaty
Organics	27.6	28.8
Garden	2.8	5
Paper/cardboard (packaging)	6.8	6.8
Paper/cardboard (other)	4.4	15.2
Wood (packaging)	0.6	0.6
Wood (other)	0.0	0.0
Glass (packaging)	4.5	4.5
Glass (other)	10.4	2.3
Metal (packaging)	0.0	2.2
Metal (other)	1.0	0.9
Plastic (packaging)	6.8	6.8
Plastic (other)	8.7	4.3
Other	26.4	22.6

The waste in Astana that is collected is processed in the Mechanical-Biological Treatment Plant (MBT) or is directed to the landfill (Inglezakis et al., 2014). The projected capacity of the MBT complex is 600-800 t/d. The complex was projected to recover 20 % of incoming waste, so the remaining 80 % of waste is briquetted (compacted) and disposed to the landfill. The facility accepts mixed (not separated) solid waste and proceeds to separate out the recyclable materials. In March 2013 the waste acceptance capacity of the plant was about 300-380 t/day. However, in reality only about 6 % of the incoming waste is recycled (paper, plastic, glass and metal), while the rest is briquetted and disposed in the landfill. The recycling rate is much lower than the potential of the waste (46.9 %) due to low market demand and the potential of recycling is indeed higher. The recovered materials are about 0.3 % by volume metal, 2 % plastic, 3.1 % paper and cardboard and 0.6 % other material. The feasibility of implementation of the biogas plant (anaerobic digestion) for organic waste treatment to the currently operating facility is under consideration. It also is important to mention that the plan is to implement separation at source (at home) system in the country in the near future. Finally, concerning final disposal, the operating section of solid waste landfill is 12 ha and has a capacity of of 2.8 Mt of MSW it is already almost completely filled and is closing with the subsequent expansion is planned for the second half of 2016. The new

landfill is built using modern technologies, including collection and utilization of generated methane system, rainwater collection and wastewater treatment and drainage systems. The area of the new landfill is 50.4 ha and it will consist of 4 cells. The projected capacity of first cell is 2 Mt of MSW with the projected life of 6 y. In Almaty, the waste is collected by 73 private companies with the company "Tartyp" covering 70 % of population. The first municipal waste processing plant in Kazakhstan was opened in December 2007 in Almaty with support of local municipality. Vtorma-Ecology Plant covered 90 % of the city's utilization of MSW. Due to the economic crisis the price of recyclables has fallen in 1.5-3 times, and the plant was not able to cover its costs and pay the loans and as a consequence in October 2010 the plant was closed. Today there is no waste recycling facilities in the city and all waste is disposed in landfills. There were six landfills near Almaty in 2009 but now there is only one active landfill with an area of 44 ha, where the most of waste is disposed. Today in Almaty, 3 Mt of solid waste is disposed at the landfill. Valuables are salvaged, recycled, and then sold to Russia, China, etc. in an estimated rate of 1.5 t/d (MHI, 2014).
Based on the preceding analysis, the data in Table 2 are used in the DSS tool. The details on the DSS tool are provided by Inglezakis et al. (2016) and Panagiotidou et al. (2012).

Table 2: DSS input data

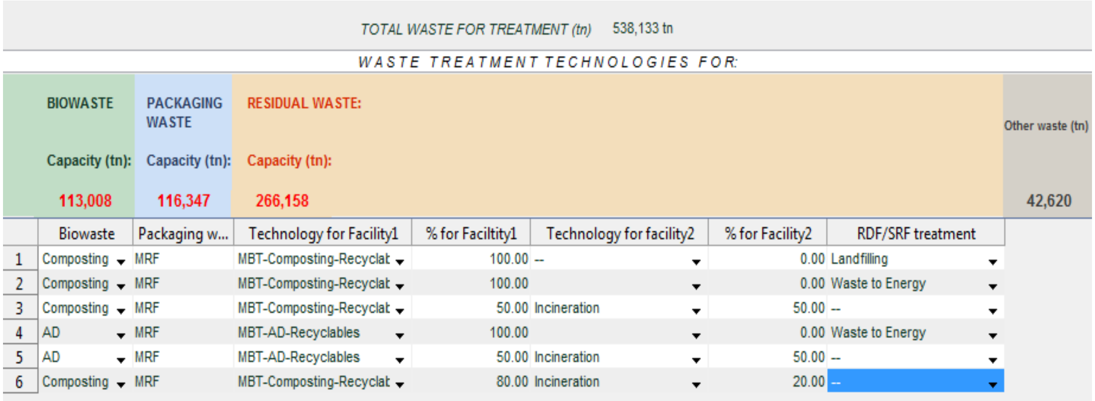
Parameter	Astana	Almaty
Waste generation per capita (kg/day)	1.39	1.17
Annual waste generation growth (%)	5.00 %	3.14 %
Equivalent population[1]	872,619	1,703,482
Population reference year	2016	2016
Planning period (years)	20	20
Plastics price[2] (€/t)	300	300
Ferrous metals price[2] (€/t)	40	40
Aluminum[2] (€/t)	833	833
Glass[2] (€/t)	23	23
Paper[2] (€/t)	21	21
Electricity[3] (€/MWh)	85 (biogas)	85 (biogas)
	0 (incineration)	0 (incineration)
MBT capacity (t/y)	124,100	0

[1]NSC data (2016)
[2] Average market data fluctuate and the values reported in the table are averages subject to large deviation.
[3]Three different green feed-in tariffs are set in Kazakhstan: solar, wind and biogas. The price in the table is for biogas (2014) while there is no incineration waste-to-energy feed-in tariff.

Finally, it should be noted that the government's policy is in principle in line with European Union policies although, as expected, the targets timeline is much different. Taking into account that MSW legislation is undeveloped, the targets set in DSS tool are derived from the European Union legislation, which is a solid and successful regulatory framework and can be a pilot for legislation development in Kazakhstan. It should be noted that EU legislation is explicitly mentioned as good example and is analyzed in some detail in the Program of Modernization of Municipal Solid Waste Management for the years 2014-2050 (Ministry of Environment and Water Resources, 2014).

3. DSS tool results and discussion

After the basic data are defined for the case studies of Astana and Almaty, formulation of alternative scenarios can be performed (Figure 1). Scenario 1 is MBT-Composting-Recyclables (100 %) and Landfilling of the residual waste and is used as baseline due to its simplicity. Furthermore, taking into account the governmental policy for separation at source, it can be assumed that this base scenario will be soon accompanied by Materials Recovery Facility (MRF) and composting or anaerobic digestion facilities for treatment of the separated recyclables and biowaste.



TOTAL WASTE FOR TREATMENT (tn) 538,133 tn

WASTE TREATMENT TECHNOLOGIES FOR:

BIOWASTE	PACKAGING WASTE	RESIDUAL WASTE:	Other waste (tn)
Capacity (tn):	Capacity (tn):	Capacity (tn):	
113,008	116,347	266,158	42,620

	Biowaste	Packaging w...	Technology for Facility1	% for Faciltity1	Technology for facility2	% for Facility2	RDF/SRF treatment
1	Composting	MRF	MBT-Composting-Recyclat	100.00	--	0.00	Landfilling
2	Composting	MRF	MBT-Composting-Recyclat	100.00		0.00	Waste to Energy
3	Composting	MRF	MBT-Composting-Recyclat	50.00	Incineration	50.00	--
4	AD	MRF	MBT-AD-Recyclables	100.00		0.00	Waste to Energy
5	AD	MRF	MBT-AD-Recyclables	50.00	Incineration	50.00	--
6	Composting	MRF	MBT-Composting-Recyclat	80.00	Incineration	20.00	--

Figure 1: Screenshot of the DSS tool – Alternative scenarios formulation

The results of the application of the DSS Tool are presented in Figures 2 and 3. Based on the weights assigned to the tool the proposed scenario for the residual waste in Astana is number 2: MBT-Composting-Recyclables and Waste-to-Energy for the Refuse-derive fuel(RDF) produced at the MBT and for Almaty is number 6: MBT-Composting-Recyclables for 80 % of the waste and Incineration for the rest 20 % of the waste and the RDF produced at the MBT.

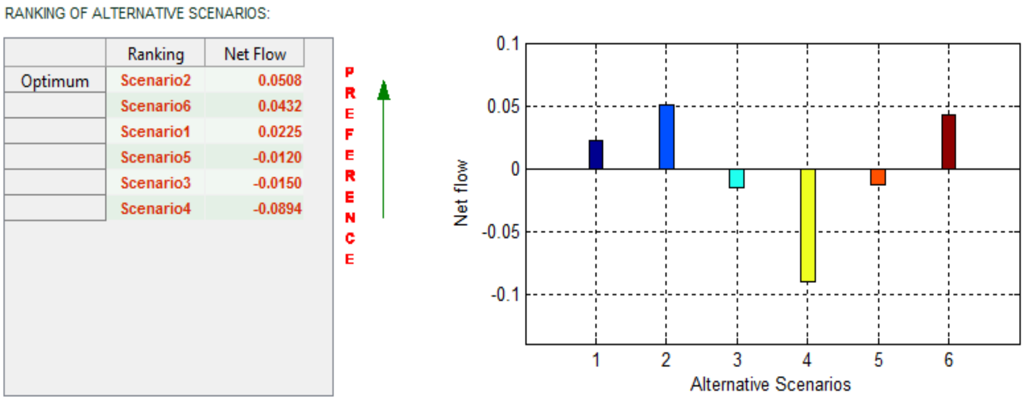
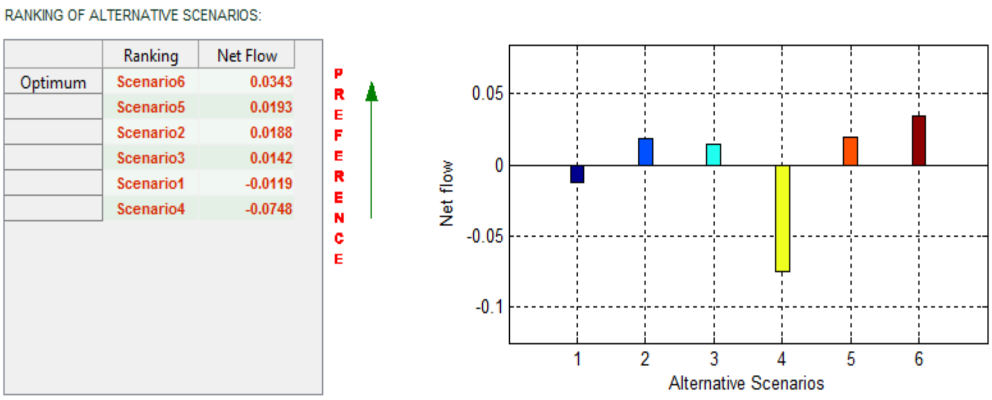


Figure 2: Results of the application of the DSS Tool for Astana case study



4. Conclusions

One of the major advantages of the DSS tool is its simplicity so that non-specialists in the field of waste management can participate in designing and assessing various waste management schemes. Although minimal, the degree of involvement of decision-maker is important, as he is responsible for the setting of qualitative criteria and weighing. Moreover, the design of graphical user interface of DSS tool was given a great importance, taking into account that the user must be attracted to use the DSS tool by its user-friendliness. The application of DSS tool provides the valuable possibility to test the tool, by changing various preference parameters and visualize the influence of these parameters on final ranking. However, it must be underlined that the objective of DSS tool is not to provide absolute solutions, but assist the decision-makers to evaluate alternatives. The application of the DSS tool on Astana and Almaty case studies demonstrated that the proposed scenario is separation at source for both biowaste, which is then composted and packaging waste, which is processed in MRF installations and for the residual waste in Astana is number 2: MBT-Composting-Recyclables and Waste-to-Energy for the RDF produced at the MBT and for Almaty is number 6: MBT-Composting-Recyclables for 80% of the waste and Incineration for the rest 20 % of the waste and the RDF produced at the MBT. It can be concluded that the DSS Tool can offer support for decision makers not only for planning process, but also for the assessment of adopted solutions.

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