LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
Environmental Technology
Double Degree Programme in Sustainable Development and Business

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**CURRENT ENVIRONMENT FOR DEVELOPMENT OF SOURCE SEPARATED WASTE MANAGEMENT SYSTEM IN SAINT PETERSBURG, RUSSIA, 2016**

Examiners: Professor Mika Horttanainen
Associate Professor Mika Luoranen

**ABSTRUCT**

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The focus of the work is the estimation of possibility to implement source separated municipal solid waste management in Saint Petersburg. Hence the overall Russian waste management system in operation is examined. The assessment was based on various sources of information.

At first, current legislative framework is studied on the basis of Russian National and Saint Petersburg regulations. Then, official researches of Saint Petersburg authorities regarding municipal solid waste management highlights the waste management infrastructure of the city. At last, websites of public organizations operating in source separated waste management promotion is critically examined to find out the level of community involvement.

Moreover, personal interviews were hold with main stakeholders in the field of local waste market in Saint Petersburg. In addition, public opinion poll was launched to estimate the social environmental consciousness of citizens.

Consequently, main challenges to source separation waste management is highlighted based on gathered information and opinions. The most suitable way towards source separated waste management is offered for Saint Petersburg conditions.

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**LIST OF ABBREVIATIONS**

AD – Anaerobic Digestion

C – Carbon

EC – European Commission

EEA – European Environment Agency

EPA – US Environmental Protection Agency

EU – European Union

FSSS - Federal State Statistics Service

FWCC – Federal Classificatory Catalogue of Wastes

GDP – Gross Domestic Product

GNI – Gross National Income

H – Hydrogen

HDI – Human Development Index

HMC – House Management Companies

JQ - OECD/Eurostat Joint Questionnaire

JSC – Joint-stock company

MBN – No More Waste [Musora Bolshe Net]

MRF – Material Recovery Facility

MSW – Municipal Solid Waste

N – Nitrogen

O – Oxygen

OCC – Old Corrugated Cardboard

OECD – Organisation for Economic Co-operation and Development

OJEC – Official Journal of the European Communities

RDS – Source Separate Collection [RazDelnui Sbor]

RSWO – Regional Solid Waste Operator

S – Sulfur

SPAR – Association of recyclers of Saint Petersburg [Sankt-Peterburgskaya Assochiachya rechiklinga]

UNDP –United Nations Development Programme

US – United States

WRAP – the Waste and Resources Action Programme

## INTRODUCTION

During the 21st century, humankind is going through a number of tremendous challenges. The degree of complexity is on the constant raise while we are moving towards 9 billion population, forecasted by a United Nations report to be reached by 2050. (UN Report "The 2015 Revision of World Population Prospects", 2015) Even though our planet has enough space to allocate this number of people, will it be able to resist the impacts of the crowd?

The current era is believed to cause significant changes in Earth's cycles due to the anthropogenic interference. Scientists have already proved the link between human activities and the fact that our planet's functions are in depletion. Uninterrupted consumption of earth's raw materials to support the needs of inhabitants in food, energy and heat led to natural resource exhaustion. However, constantly increasing intake is not the only process causing problems to the planet's welfare. Almost all extracted raw materials return to the natural environment modified by human intervention. As a result, these materials become wastes and environmental burden.

Ever increasing rates of population growth highlight the urgency of sustainable development in order to meet the needs of the present generation without compromising the ability of further generations to meet their own needs. To begin with, the consumption behavior should be restrained. As a result, humanity is setting forth the schemes and scenarios for development of renewable energy production. By doing this, limited natural resources will be substitute by inexhaustible power of wind, water, solar and geothermal energy. Moreover, this approach let wastes shift from environmental stress to a promising material for renewable energy as well.

Although, the idea of waste to energy is highly appealing, as it allows not only energy production but also reduces significantly the volumes of disposed waste, it has a number of thresholds. The major one is that when constructing a waste incineration plant a significant investments should be made not only to technological process but also to an emission treatment equipment. Otherwise, the environmental performance of this waste treatment method might be only slightly better than disposal, effecting drastically air quality and causing serious health hazards. Moreover, waste should undergo pretreatment process in order to become more effective as a fuel.

On the contrary, waste source separation enables waste treatment method which is higher on the waste hierarchy. (2008/98/EC) In addition, if waste is sorted, it becomes a better fuel for further incineration. In other words, waste should be separated by different sources in order to become a valuable, not dangerous material.

Source separation maximizes the advantage of waste in perspective of sustainable development. Firstly, it allows the recycling of certain materials. Secondly, recycled materials can be used in manufacturing processes. By doing this, the demand for natural resources will be lowered. Thirdly, energy recovery from precise waste fractions become possible. This leads to a conclusion, that closing the loop: refining and commercializing recycled material, making the profit from waste is the basis for the circular economy. It highlights the need in circumspect waste management system.

While European countries are succeeding in transition to source separated waste management schemes, Russia is lagging behind. Territorial aspects for far too long have postponed the necessity of proper waste regulation. However, in order to keep up to the times and develop sustainably, even as spacious country as Russian Federation, cannot omit the problem of waste management.

In the recent years, the idea and technologies for waste source separation have been extending in Russian megacities as Moscow and Saint Petersburg. However, even though this market sector is slowly developing, this movement is overall tend to be more ideological than practical. The average citizens are lacking any information about the need or methods of source separated waste

management. Similarly, the development of municipal waste treatment capacities is retarded. Currently, Russian government is elaborating the law, which imposes a different taxation on source separated and mixed municipal solid waste. The legislation will be passed by 1 January 2017 (Ministry of Construction of the Russian Federation). This information has heighten the interest in municipal solid waste management. Presently, it become a topic of interest for the governmental institution as well as social businesses.

Current waste management practices in Russia are resource-inefficient and result in negative environmental impacts. The major share of MSW, almost 90%, ends up at the landfill sites. (Minprirody Russia, 2012) While EU Members recover, on average, up to 60 percent of MSW, Russia's waste recovery rate is nearly zero.

The following thesis work pursues several objectives. Firstly, the target is to examine the current environment in Saint Petersburg as a basement for transition towards source separated municipal waste management system. The assessment is going to be based the number of conversations with main stakeholders of waste management in Saint Petersburg. Moreover, public official and non-official information will be considered based on public speeches and published interviews. Secondly, possible pathways for the changes, based on foreign experience, are going to be analyzed. As a result, the conclusion will be drawn about the most suitable for Russian conditions way towards MSW source separation system.

# 1. MUNICIPAL SOLID WASTE

Definition and composition of municipal solid waste (MSW) varies significantly depending on the country under consideration. OECD/Eurostat joint questionnaire (JQ) was the fundamental document for data and statistics collection about waste in the European Union. In 2004 after the adoption of the Regulation on waste statistics, the situation underwent slight changes towards webforms usage in data collection.

Taking JQ as a basis for MSW assessment as the most comprehensive one, household and similar wastes are regarded as municipal wastes. This explication includes bulky waste, like old furniture or mattresses, as well as garden waste, leaves, grass clippings, street sweepings and waste from street litter containers. (Eurostat, 2015)

EU's Landfill Directive describes municipal waste as a "waste from the households, as well as other waste which, because of its nature or composition, is similar to waste from household" (EU, 1999). The origin of municipal waste comparable by it's nature with household wastes varies significantly. It might be coming from commercial or industrial enterprises, business offices, schools, hospitals, prisons, different public spaces as streets, gardens, bus stops, markets, public toilets. Overall, there are four main sources of MSW (Tchobanoglous, Kreith, 2002):

1) Residential;
2) Commercial;
3) Institutional;
4) Industrial.

Food scrap, newspapers, clothing, disposable tableware, food packaging, cans and bottles are main components of residential discharges.

Office buildings or restaurants (commercial sources of MSW) are responsible for corrugated boxes, office paper, paper napkins disposable tableware and food waste flows in general waste stream.

Share of municipal waste from social institutions like schools, hospitals or prisons is covered by garbage from cafeteria and restroom rubbish bins, office paper, classroom and garden waste.

Industrial enterprises are commonly responsible for their own waste management systems. As a result, industrial process wastes are excluded from the general municipal waste volume. However, wastes such as various packaging (corrugated boxes, plastic film, wood pallets), office, lunchroom or restroom waste – waste of the similar to household waste nature, is treated as a part of general municipal solid waste management system. (EPA, 2000)

Moreover, although construction and demolition waste and municipal wastewater treatment sludges are commonly disposed at landfills along with MSW, they are not seen as municipal waste streams. (Eurostat, 2015)

To summarize the information for further waste assessment, the waste volumes collected by or on behalf of municipal authorities and disposed through the waste management system define municipal waste generation. (Eurostat, 2015)

According to Commission Decision on the European List of Waste (COM 2000/532/EC) Municipal solid waste (household waste and similar commercial, institutional and industrial wastes) subdivide to following list of fractions categories (EEA, 2000):

1) *separately collected fractions* with notable number of subcategories:

paper and cardboard, glass, biodegradable kitchen and canteen waste, clothes, textiles, solvents, acids, alkalines, photochemicals, pesticides, fluorescent tubes and other mercury-containing waste, discarded equipment containing chlorofluorocarbons, edible oil and fat, oil and fat (other than those mentioned in edible oil and fat category), paint, inks, adhesives and resins containing dangerous substances, paint, inks, adhesives and resins (other than those mentioned previously), detergents containing dangerous substances, detergents resins (other than those mentioned previously), cytotoxic and cytostatic medicines, medicines resins (other than those mentioned previously), batteries and accumulators (included in batteries and accumulators following subcategories: lead batteries, Ni-Cd batteries, mercury-containing batteries and unsorted batteries and accumulators containing these batteries), batteries and accumulators (other than those mentioned previously), discarded electrical and electronic equipment (other than those mentioned previously containing hazardous components), discarded electrical and electronic equipment (other than those mentioned previously), wood containing dangerous substances, wood (other than those mentioned previously), plastics, metals, wastes from chimney sweeping, other fractions not otherwise specified;

2) *garden and park wastes* (including cemetery waste) with subcategories:

biodegradable waste, soil and stones, other non-biodegradable wastes;

3) *other municipal wastes* with subcategories:

mixed municipal waste, waste from markets, street-cleaning residues, septic tank sludge, waste from sewage cleaning, bulky waste, municipal wastes not otherwise specified.

## 1.1 Methodologies for assessing municipal solid waste

There are two central approaches to conducting a research over waste generation to obtain waste characteristics for further assessment. Both of them were developed by EPA in the 70s years of twentieth century. First method supposes source-specific studies, when each waste component is estimated separately. It is appropriate for evaluation of local waste flows as it focuses on site-specific relations. The estimation consists of sampling, sorting and weighting waste samples of definite fraction. However, since the method is able to produce data only about precise source discards, which covers only limited area, it is not suitable for broad waste generation analyzes over the whole country. Extrapolation from these studies might lead to rude mistakes if the goal is to describe the actual situation on the broad scale. (Tchobanoglous, Kreith, 2002)

The second option, widely used presently for outlining waste characteristics is “material flow methodology”. In this case, the primary source of information about materials and products in waste traffic is production data (by weight). Waste generation rates is estimated from the stage of the product manufacturing process. The basis is the use of different materials during production stages. The method takes into account product lifetime as well as import and export rates. In contrast to sampling method, tracking down material flows allows to describe not only waste discards but also the generation patterns. Furthermore, while the acquired data might represent the nationwide situation, it reflects long-term trends and can be provided annually. It provide historical data for analyzes. As a result, time trends for waste generation can be defined, which in turn allow to track changes and make predictions about future patterns. (Tchobanoglous, Kreith, 2002)

While adjusted production data is fundamental for material flow analyzes, to gain the overall picture sampling method is essential. These site-oriented studies are crucial for assessing generation of food and garden wastes, some mixed inorganic waste. (Tchobanoglous, Kreith, 2002)

## 1.2 Main properties of MSW

Considering municipal solid wastes compounds, materials and products can be pointed out as the prime constituents. Following materials most commonly are out in MSW: paper and cardboard, garden (yard) trimmings, glass, metal, plastics, wood and food wastes. United States Environmental Protection Agency (EPA) reports a typical content of MSW in United States annually, which is given in Table 1.

**Table 1.** Typical MSW content, reported in the US (EPA, 2013)

| Waste component | Weight, % |
|---|---|
| Paper | 27 |
| Yard waste | 13.5 |
| Food waste | 14. |
| Plastics | 12.8 |
| Metals | 9.1 |
| Rubber, leather, textiles | 9.0 |
| Glass | 4.5 |
| Wood | 6.2 |
| Miscellaneous inorganic waste | 3.3 |

Every material group, with only food and garden wastes exception, consists of a several products variation. It might include such products as durable and nondurable goods, containers and packaging and other mixed inorganic and organic wastes from different sources. Pinpointed product kinds typically have each material category mentioned previously. There are several exceptions. Paper and cardboard are not seen as a part of the durable good group. Only small share of metals with no glass or wood is present in the nondurable product group. Relatively small shares of rubber, leather or textile are present in the containers and packaging product group.

There are several prime physical properties of waste as a material, which are analyzed for further decisions upon handling principals (Chandrappa, Brown, 2012):

1) waste density;
2) sizing of waste compounds;
3) moisture content.

Waste color, voids content, shape of components, optical, magnetic and electric properties might significantly influence municipal solid waste handling as well. These magnitudes are especially essential when the implementation of treatment methods to precise waste mass is settling. Optical characteristics helps in segregating glass and plastic fractions from garbage by separating opaque and transparent materials from each other. Waste magnetic property is the basis for engineering process of magnetic separators for metals extraction. Composting process parameters as well as leachate calculations are impossible without moisture magnitude of managed waste. Estimation of waste transportation and disposal facilities build upon waste density parameters.

There are a set of chemical characteristics of waste, fundamental for management systems design (Chandrappa, Brown, 2012):

1) moisture content;
2) volatile matter;
3) ash content;
4) fixed carbon;
5) fusing point of ash;
6) calorific value;
7) percentage share of main waste elements (carbon, hydrogen, oxygen, sulphur) and ash.

**Table 2.** Proximate and ultimate analyses of basic waste characteristics (Source: Chandrappa, Brown, 2012)

| Waste material | Waste density, kg/m$^3$ | Moisture content, % | Inert residue, % | Calorific value, kJ/kg | Carbon, % | Hydrogen, % | Oxygen, % | Nitrogen, % | Sulfur, % |
|---|---|---|---|---|---|---|---|---|---|
| Asphalt | 680 | 6-12 | - | 17100-18400 | 83-87 | 9,9-11 | 0,2-0,8 | 0,3-1,1 | 1,0-5,4 |
| Cardboard, corrugated paper box | 30-80 | 4-10 | 3-6 | 16300 | 44,0 | 5,9 | 44, | 0,3 | 0,2 |
| Brick/Concrete/Tile/Dirt | 800-1500 | 6-12 | 99 | - | - | - | - | - | - |
| Electronic equipments | 105 | - | 0-50,8 | 14100-45400 | 38,85-83,10 | 3,56-14,22 | 7,46-51,50 | 0,03-9,95 | - |
| Food waste | 120-480 | 50-80 | 2-8 | - | 48,0 | 6,4 | 37,6 | 2,6 | 0,4 |
| Garden trimmings | 60-225 | 30-80 | 2-6 | 4800-18500 | 47,8 | 6,0 | 38,0 | 3,4 | 0,3 |
| Glass | 90-260 | 1-4 | 99 | - | - | - | - | - | - |
| Leather | 90-450 | 8-12 | 8-20 | - | 60,0 | 8,0 | 11,0 | 10,0 | 0,4 |
| Metal(Ferrous) | 120-1200 | 2-6 | 99 | - | - | - | - | - | - |
| Metal (Non Ferrous) | 60-240 | 2-4 | 99 | - | - | - | - | - | - |
| Municipal solid waste biomedical material | 87-348 | 15-40 | - | - | - | - | - | - | - |
| Paper | 30-130 | 4-10 | 6-20 | 12000-18500 | 43,5 | 6,0 | 44,0 | 0,3 | 0,2 |
| Plastic | 30-156 | 1-4 | 6-20 | - | 60,0 | 7,2 | 22,8 | - | - |
| Rubber | 90-200 | 1-4 | 8-20 | - | 78,0 | 10,0 | - | 2,0 | - |
| Sawdust | 250-350 | - | - | 20500 | 49,0 | 6,0 | - | - | 0,10 |
| Textile | 30-100 | 6-15 | 2-4 | - | 55,0 | 6,6 | 31,2 | 4,6 | 0,15 |
| Wood | 156-900 | 15-40 | 1-2 | 14-17 | 49,5 | 6,0 | 42,7 | 0,2 | 0,1 |

Moisture, volatile matter, ash and fixed carbon content is defined during express analysis (elementary) of waste, whereas ultimate chemical analysis is needed for determination of prime elements and ash shares in total waste mass. (Tchobanoglous, Kreith, 2002) Presently, CHNS analysers is widely used for waste elementary analysis. However, even if there is no equipment available, waste elementary shares can be calculated from moisture content and general knowledge about waste fractions.

It is extremely complicated to pool the data about waste characteristics, as these values fluctuate vastly from different areas. Table 2 presents information about major physical and chemical properties of some waste materials, obligatory for successful development of management systems.

Biological waste properties are as important as chemical or physical, as waste is highly enabling environment for generation of bacteria. There five primary living organisms inhabiting municipal solid waste: fungus, protozoa, bacteria, insect, rodent. Protozoa is living in any aerobic environment, where bacteria exists, supporting their growth. Few protozoa species are parasitic and that is why these organisms pose a threat to animals and humans. For instance, such disease as amoebic dysentery proved to be caused by protozoa. And the list of illnesses originated from these living organisms is quite impressive. Moreover, fungi, the number of these species in MSW is considerable as well, are believed to be pathogenic to human and animal beings. Fungi results in hair, nail, skin or lung infections if a man got wounded in air contaminated by waste. Even liver cancer and fatty degeneration of liver can be traced down to asperigillus flavus organisms producing dangerous for human toxins. Furthermore, food or wound contamination by spores, produced by bacteria Clostridium, might lead to lethal outcomes, while C.Botulinum toxins cause food poisoning. Another example is gangrene, which might rapidly evolve from C.Persringens toxins getting into an open wound. (Chandrappa, Brown, 2012)

Along with these diseases caused by living in solid waste organisms, there is a wide range of insects, arthropod and annelids inhabiting waste. Depending on the climate zones, it might be cockroaches, dung beetles, ants, termites, mosquitos, houseflies or even spiders and scorpions. Centipede, millipede and earthworm are representatives of annelids in solid waste.

Degradation of MSW degradable fraction is significantly affected by biological properties, microorganisms' content, of the waste under study. For example, cellulose and lignin, contained in waste, can be easier broke down in fungi and actinomycetes presence. That is why, these organisms are commonly observed in compost, as they are responsible for decomposing complex organic matter. However, most commonly municipal solid waste have these species even before the beginning of composting treatment. (CPHEEO 2000)

## 1.3 Differences between developing and developed world MSW

The municipal solid waste components and volumes fundamentally depend on lifestyle, consumption habits of the population and living standards of the area under study. The level of technological development of examined country plays a significant role in this issue as well. Composition of solid waste in developed countries notably differs from the one in developing as well as the quantities of residues. For example, in contrast to the leading share of organic fraction in MSW stated in developing counties, packaging waste dominates among this waste type from industrialized ones. (Chandrappa, Brown, 2012) There are

several reasons for this disproportion. Firstly, the richer the country, the more money is spent on the packaging. Whereas food and other products in poor countries are distributed locally packed mainly in old newspapers, the weight of plastic package might significantly overcome the obtained product in rich urban communities. Secondly, level of living in developed world infers population with higher income, which in turn reduce the number of rag picking or scrap dealers. Rag picking is, on the contrary, an extremely widespread phenomena in the poor countries. As a results, the paper, plastic, glass and metal content in waste is quite low. People who earn their living though these activity can be seen do their best to exclude almost all the recyclable materials from the waste dumps not only in residential arias, but also commercial and industrial. Moreover, in India, for instance, where junk trade is highly common, houses and offices sell old paper instead of throwing it.

Summarizing, the MSW loads originated from town areas is in tight straight correlation with human development index (HDI). HDI in turn depends on three following aspects of country's population: life expectancy, gross national income (GNI) and educational indexes. (UNPD, 2015)

A number of studies over different countries' lead to drawing following conclusions regarding waste generation speed in large cities. In high-income countries municipal waste is generated at a rate of 1,1 – 5,0 kg/person/day, whereas these numbers more than twice lower for low-income – 0,4-0,6 kg/person/day and somewhere in between (0,52-1,0 kg/person/year) for middle-income rural areas. (Chandrappa, Brown, 2012)

There are a number of differences between waste properties, which are common for residues generated at non-industrialized sites of the world comparing with industrialized. First, waste in developing sites is marked to have 2-3 times higher densities. Moreover, organic fraction is a weighty part of waste which leads to a high moisture content in MSW. Compering with developed nations, these figures are 2-3 times higher. Another feature is that developing cities with sweeping along with open ground storages involves extensive rates of dust and dirt formation. (Chandrappa, Brown, 2012)

For example, while the avarage solid waste generated per person in East and South Asia is under 1 kg/capita/day (0,95 and 0,45 respectively), MSW generation in the USA more than 2 times higher (2,2kg/capita/day)(WorldBank, 2013).

## 1.4 Increasing growth trends in municipal waste generation

Studies upon waste generation need to be systematically refreshed in order to be up to date. As the living standards are increasing all over the world, industrialization is covering larger and larger areas, waste properties are constantly changing.

According to annual researches of US Environmental Protection Agency (EPA), total waste generation in the USA experienced substantial changes. Total volumes of produced MSW almost triple over the past 55 years. Waste formation in the United States was estimated to be 254,1 million tons in 2013(EPA,2016), whereas it was only 88,1 million tons in a far 1960 year (Tchobanoglous, Kreith, 2002).

Personal daily garbage generation patterns has almost doubled during the assessed period as well. The values has raised from 2,68 lbs (1,22 kg) in 1960 to 4,40 lbs (1,98 kg) in 2013 of

waste generated daily from one person. Figure 1 is the EPA material covering the whole dynamic of variations in MSW generation over the years 1960-2013 (EPA, 2016).

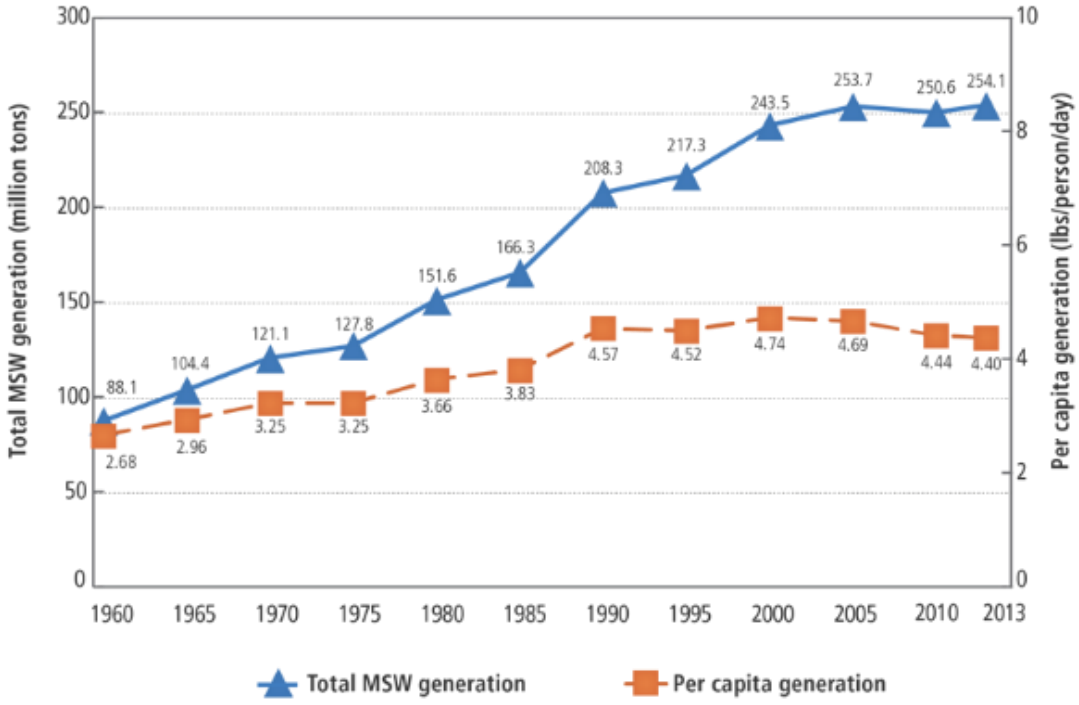


**Figure 1.** MSW generation rates in United States during 1960 - 2013 (Source: EPA website)

It is possible to emphasize several overall trends in relation to global waste generation patterns. Firstly, shares of paper and plastics content in waste flows are expected to continue growing. Glass and steel containers on the contrary, is predicted to become replaced by lighter materials (aluminum and plastic).

## 2 PRINCIPALS OF WASTE SOURCE SEPARATION

A holistic overview of a global waste management practices along with the ongoing increase in waste generation patterns, highlights an emerging necessity in circumspect and integrated solid waste management systems. One of the first steps towards such system is segregation of waste compounds with further separate treatment. By doing this, waste is switching from environmental and financial burden to a valuable material.

This chapter provides an overview of main pathways for municipal solid waste handling from source separation perspective. Basic principles of municipal solid waste source separation strategies described with several steps. At first, different waste collection and sorting approaches are reviewed. Secondly, there is a rundown of prime treatment facilities for major waste compounds when they are collected separately.

### 2.1 Methods of MSW collection and materials separation

The Waste Framework Directive 2008/98/EC (WFD) defines separate collection as follows: "'separate collection' means the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment".

Collection of any solid waste starts from the garbage bin containing refused material and ends with it's transportation to the treatment or disposal facility. Meanwhile, more than half of money spent on overall waste management by municipalities goes to financial support for waste collection operations. Since fuel prices are increasing as well as labor cost, efficient management system including well-judged logistic is required to cut the community expenses on waste handling. (Tchobanoglous, Kreith, 2002)

From source separated waste perspective the role of transportation unit in entire waste management system even more significant. The manner in which waste materials are sorted and collected determines the sequential treatment options and quality of the recycled products.

Feasibility of one or another treatment technology is estimated with regard to economic and environmental sustainability. Financial benefits from processing recyclable materials might decrease significantly depending on waste handling approaches. For example, mixed MSW treatment allows much lower quality of end products as against material separation at the source. In addition, waste materials containing toxic compounds due to insufficient separation or low level of social responsibility might pose a threat to environment as well as human health. For instance, if contaminated with toxic elements biowaste is processed to compost, it might lead to food poisoning with sequential human intoxication.

Furthermore, since quality of recovered material is concerned with waste collection schemes, transportation plays a leading role in market formation for recyclable materials. Thereby, in practical cases, either the possible collection technics precondition further waste processing scheme or already existing markets set requirement for waste handling approaches.

Segregation of recyclable materials from MSW seems to be highly appealing and cost-effective feedstock. However, in practice, problems related to efficient transportation logistic might occur.

The diversity of possible recycling programs leads to a vast range of processed materials, which require handling. These programs may imply separation of extensive number of recyclable materials or be limited to processing only one material. In any case, haulage system has an important role in overall waste management scheme, as weighty share of waste management expenditure is formed at this stage.

Moreover, recycling programs involve participation and commitments of a large number of people in society. There are multiple approaches to provide collection of materials from waste, which demand different levels of individual contribution. At the outsets, inculcate of recycling habits in community may be in form of recursion of beverage containers through vending machines at supermarkets. The next step is organization of drop boxes and drop-off centers or even centers providing payback for broader range of recyclable materials.

Furthermore, if material recovery initiated by conscious households and supported with separate curbside collection (or additional separation if required), recyclable materials might be obtained via one step. Another pathway is joint transportation of separated but commingled recyclable materials and further treatment at the Materials recovery facilities (MRF).

The least appealing option is processing of mixed MSW volumes in order to separate valuable materials. This method requires hand separation of these materials from the total waste streams with little mechanical assistance. It is called front-end processing or mixed-waste processing.

Thus, the role of collection and transportation of recyclable materials from generated waste streams cannot be overestimated. It is the major tool to cut the expenses if the waste management scheme is rational enough. Inversely, poor logistic of transportation operations of waste recyclable materials will draw to high expenses and will put overall feasibility of recycling business at risk.

Summarizing, with relation to waste source separation, there are three primary approaches towards waste collection. All of these strategies allows recovery of recyclable materials from generated municipal waste stream with different degrees of efficiency:

1. Collection of source separated recyclable materials

Recyclable materials are gathered separately at the source by generator or collector and do not require any subsequent processing before further treatment;

2. Collection of commingled recyclable materials

All recyclable materials are mixed and collected together with further separation at centralized material recovery facilities:

3. Collection of mixed municipal solid waste

Collection of mixed MSW from the source, which requires further processing to enable material recovery at mixed-waste or front-end processing facilities.

(Tchobanoglous, Kreith, 2002)

Technology development for source separation municipal waste management has various grounds. In Europe, for example, one of the central factors enabled development in this industrial field was elaboration on environmental legislation came into effect in the dawn of XXI century. Thus, even though it was not remunerative, treatment approach to waste materials such as packaging or electronic waste shifted towards recycling. This operational environment had strong securement – two main principles “polluter pays” and “extended producer responsibility”. Under this regulation, recycling of unprofitable waste materials (in free market circumstances) was secured. (Cimpan et al., 2015)

On the contrary, waste management system of the United States leaned towards material recycling under the driving force of public opinion instead of environmental legislation development. As the social awareness about environmental risks was rising, waste recovery and recycling rates were slowly increasing as well.

### 2.1.1 Waste source separation

As it was discussed previously, collection operations are tightly linked to sorting methods applied to generated waste streams. This subchapter focuses on waste sorting and collection

approaches used when waste management scheme involves initial fraction separation of recyclable materials from the collecting point (households).

Even though mixed waste collection without any separation seems to be the most convenient to average household, sorting recyclable materials straightaway at the source of waste generation allows obtaining the highest quality of recovered materials. Thus, a number of waste management schemes imply home sorting with further separate waste fractions.

The system imply two different principales of waste materials segragation. On the one hand, there is a possibility of drop-off system (bring system) arrangement in municipality for recyclable compounds separated from waste. In this case, there is a sufficient infrastructure for collection of recyclables from centralized stated points such as central collection sites, material banks or street-side containers. Waste producer has individual responsibility for separation of waste materials from his/her waste stream and delivery to these public collection points. (McDougall, White, 2008)

On another hand, kerbside collection is applicable to manage recyclables materials. This option is more convenient to households as it enable picking up recyclables almost from their houses in the similar manner mixed MSW is taken. On the contrary to bring systems kerbside might require higher financial support, as it involves wide range of collection points and hence more transportation operations. However, it allows participation of more people since it is similar to conventional mixed waste management system.

There are several junctures to be assessed and taken into consideration if waste management scheme implies home sorting in any form.

One of the concerns during home sorting is working out sound transportation logistic and schedule to provide sufficient volumes of collected material for further processing and minimize transportation costs.

Material contamination is another area for consideration when home sorting is under consideration. In general, contamination refers to the share of non-targeted materials collected with specific method. This might be reflected in mixing different types of recyclables in one containers, designed for a unique material (e.g., plastic in a glass bin). Another example of material impurity is presence of dirty material containing some previous product leftovers. Also, non-recyclable materials spoil the overall separated material stream.

As main responsibilities for proper waste separation are on households. It is important to provide clear guidance for home sorting techniques and define basic rules.

Summarizing, sorting recyclable material from waste streams at the source of their generation has both advantages and disadvantages. It is one of the most beneficial approach for manufacture of recovered materials since the high quality obtaining. Furthermore, it reduces the expenses on pretreatment before further handling. It is easier to process source separated streams from the collection site.

On the other side, home sorting is the least appealing method from households' perspective. First of all, it requires additional space in apartments to keep waste components separately. Moreover, if there is no kerbside collection provided for recyclables, people have to transport their waste to drop-off point. To make the matters worse, it is not always possible to leave

all materials at the same central point. This in turn, requires time and money for transportation as well as a strong personal motivation and commitment. Consequently, if there is not enough motivation among society, the material recovery rates are tend to decrease while contamination of already separated recyclable materials is increasing.

Another issue related to primary source separation occurs in waste management systems which involve separate material collection at the source (from households). The generation rates for different waste materials fluctuate significantly between compound's types as well as within one type depending on external circumstances. Thus, required collection frequencies for different waste materials vary. As a result, it is a complex task to design a strong schedule for transportation operations with minimum financial expenses.

### 2.1.2 Centralized sorting at MRF

Material recovery facility is a generic term for facilities specialized on mixed waste stream segregation. The process implies various processing methods as well as a wide range of processes. However, manual waste separation might be utilized to some degree, the preference is given to mechanization of operations. Hence, sophisticate combination of mechanical, pneumatic and optic waste material sorting methods are in use. (Cimpan et al., 2015)

When waste management system involves material recovery facilities (MRF), the role of households is limited to separation of general stream of recyclable material in their waste from non-recyclable. Afterwards, commingled recyclables are collected and then processed at central service.

The amount of separated recyclable fractions as well as applied technologies vary between facilities as there is different demands from further processors of recovered material. For instance, MRF may be restricted to manual sorting of waste or, on the contrary, utilize fully automated sorting systems. As a result, there is a notable fluctuation in required investments and operational costs, which are relatively low during hand sorting and increase jointly with level of mechanization. (Tchobanoglous, Kreith, 2002)

In general, manual sorting from a raised picking belt is a widely applied technic at MRFs as it is one of the simplest one. It might be placed at the outset of separation process or after a number of pre-treatment steps. Hand sorting is the first step process at MRF when the target is to exclude materials that can damage equipment ulteriorly used for mechanical treatment. Thus, bulky waste compounds such as large plastic or rubber blocks, truck tires are detached at this point. (Tchobanoglous, Kreith, 2002)

Another approach, requiring manual sorting, is when the man's power of observation is needed. Human eye is estimated to be capable of separating some precise materials, such as colored glass, types of plastic or paper and cardboard, more effectively than any machine. As a result, hand sorting is integrated at MRF after major mechanic treatment units (magnetic separation, screens, air knifes, trommels) when the general waste stream is already divided to the single compound flow (glass, paper, plastic bottles). By doing this, PET and HDPE plastic material can be separately recovered from the total stream of plastic bottles. Another widely spread examples of hand sorting is separation of brown, green and clear glass from each other, as well as newspapers, cardboard and office paper segregation from common paper flow. (Tchobanoglous, Kreith, 2002)

Infrared sensors are used for segregation of clear, translucent and opaque materials. Near infrared (NIR) sensors are applied in separation of plastic materials to different plastic types.

Consequently, manual sorting might provide waste stream separation to such fractions as paper, cardboard, glass, PET containers, film plastics, textiles, depending on the required material. Although, one consider hand sorting as a labor intensive method of waste separation, it might be used for job creation and reduction of unemployment rates as long as working conditions are acceptable.

Mechanical sorting utilize three prime types of technologies. One of them is built on mechanical separation mechanisms, which have physical properties of the waste stream as a basis (roll crushing, shredding, baling). Secondly, particle properties such as density, shape and size can be used as a key parameter for stream separation (e.g. screening, air classification/knife, flotation). The third class of technologies is focused on the specific material property and utilize it's unicity as a key factor to its segregation (magnetic/ electrostatic/electromagnetic separation). (McDougall, White, 2008)

*Dual-stream commingled collection*

This model supposes the division of recyclable waste materials into two streams: one flow is packaging waste (containers' material such as plastic, metal and glass), another flow is paper and cardboard (so called "fibers").

This approach is mainly secured by extended producer responsibility principle as it is targeted to involve packaging waste in recovery processes.

Separate collection of mixed packaging waste emerged in Europe in the last decade of 20$^{th}$ century. Germany was a pioneer at this MSW collection method in early 90s when trade and industry founded Duales System Deutschland GmbH (DSD GmbH) to meet the Packaging Ordinance of 1990s. Since ordinance highlighted the need to avoid and recover packaging waste, the proper waste management system was developed. This model with few modifications is in operation over all EU states and several non-EU countries.

**Programs for collection of co-mingled recyclables**

At the dawn of recycling schemes development, there was a widely spread "Blue Box" programs around Europe and United Stated. The approach consisted in placing container, colored in blue, at the kerbside next to MSW containers. Households were supposed to separate recyclable materials from their general waste streams and leave them in this box. Then trained workers divided recyclables on targeted compounds and collected them by specialized vehicles along with overall garbage collection. The main detached fractions were glass, paper and cardboard, plastic and metals. If there was any non-recyclable materials or inappropriate compounds for established recycling program, it was returned to the Blue Box. As a result, households were aware of what waste compound were suitable for recycling. Moreover, the level of contamination of precise material flow was notably low, as professionals were separating materials at the source. That fact, in turn, reduced the operations required at MRF before following treatment. In general, Blue Box programs appeared as a successful bridge to further recycling strategies extension, since it involved social education of basic waste source separation principals. (McDougall, White, 2008)

However, the Blue Box method is more suitable for houses rather than urban high-rise buildings, which are prevalent in huge cities. Another approach similar and easier than Blue Box is placing all the recyclable materials in a blue bag and then throw it away with the general mixed waste stream. Even thought, it is more demanding for further separation operations as involves labor force at MRF, it is most convenient for average households since their habits stay almost unchanged. (Tchobanoglous, Kreith, 2002)

Both of mentioned above strategies is a positive first step for development of recycling programs in communities where the lack of knowledge about recycling patterns is evident. Even though, it enables reaching high participation rates among households, it demands energy for subsequent processing as well as financial backing. (Hester, Harrison, 2013)

On the other hand, a study over source separated municipal waste collection hold in Helsinki region by Tanskanen and Kaila in 2001 pointed out that commingled collection of recyclables is more favorable among small properties. The conclusion holds true as generation rates of different waste fractions are rather low at these sites. As a result, transportations cost increases since volumes of recovered material are nor corresponding with fuel consumption and pick-up operational costs.

Summarizing all of the above, processing of co-mingled recyclable stream at MRF might be a satisfactory to reaching EU's targets goals option for waste management scheme. It has both benefits and shortcomings. While it provide significant yields of recyclable materials collected from citizens, recycled end product quality might safer. On the one hand, Tanskanen and Kaila (2001) argues that commingled waste collection is the best available option from economical perspective. On the contrary, waste source separation is considered to be the best treatment option for some compounds. For instance, Hester and Harrison (2013) argue that plastic fraction require preliminary subdivision to different types of collected plastic. Only by doing this, the value of this secondary raw material can be maximized.

**MRF exploitation experience and recovered material outcomes**

Local authorities in England have been evolving their recycling programmes from initial separation of waste materials by households to co-mingled kerbside collection of these materials for the several past decades. Presently, as it is stated at WRAP's survey, England possesses 61 MRF in operation around the country and planning to increase this number. The facilities' production capacities are fluctuating from lower than 10000 to over 100000 tonnes annually.

Most of waste management schemes in England significantly rely on co-mingled collection of recyclable household waste materials from the kerbside. This system mostly imply initial segregation of newsprints, magazines, mixed paper, Old Corrugated Cardboard (OCC), steel and aluminum cans/containers as well as plastic bottles (PET, HDPE) into a separate stream, which goes to MRF for further treatment. Glass material is organized into a separate stream and comes only to several MRFs for bulking.

From the operation process of MRFs visited during WRAP research, it can be concluded that the materials coming to centralized facilities are mostly sorted to five categories: Mixed paper, OCC, Mixed plastic, Aluminum and Ferrous metals.

However, this system has notable disadvantages.

Most plastics preprocessors are unable to use mixed plastics bottles and most of the higher value paper mills can only accept a small percentage of mixed paper. Therefore, these material streams are often shipped to other facilities to be sorted by resin and by fibre grade prior to use by the preprocessor.

### 2.1.3 Centralized sorting of mixed MSW

If waste management scheme applies no source separation nor any central segregation of recyclable materials, another sustainable option to utilize generated MSW is to produce electricity or steam out of it. This approach has been in practice since first decades of 20$^{th}$ century. (McDougall, White, 2008)

Even though solid waste does not demand any auxiliary fuel to be burned, the calorific value of moist unprocessed MSW as received can reach only half magnitude coal can produce, commonly even lower. Moreover, combustion of generated volumes of municipal waste without any pretreatment might result in severe environmental contamination (with heavy metals or toxic elements, formed during incineration). To tackle these issues, add economic benefit and improve fuel quality, production of Refuse-Derived Fuel (RDF) was enhanced. Thus, waste is altered to a valuable feedstock for energy production. (McDougall, White, 2008)

Production of RDF require central sorting of total MSW stream. The key approach to RDF manufacture is to separate combustible materials in solid waste, such as plastics,paper and cardboard from non-combustible fraction. By doing this, the moisture and ash content of waste fuel is significantly reduced. The segregated combustible part is then shredded (coarse RDF) and might be further pelletized (densified RDF). Depending on type of refused-derived fuel produced it can become a market product (densified) or require on site burning at short notice (coarse). (McDougall, White, 2008)

From the sorting unit perspective, RDF production can be subdivided to three or five basic stages depending on targeted type of fuel. Liberation and screening of waste stream has a purpose of oversize and fine materials exclusion. Generally, this is the main step for separation combustible materials. At this stage, crude coarse RDF (cRDF) can be obtained, even though this fuel contains metals and some other non-combustible fractions.

The following step is fuel refining and consists in size reduction of separated maretial, classification and magnetic separation. Classification subdivide waste stream by density. As a result, heavy and light fractions are split for subsequent treatment. Light compounds, such as paper and plastic film, are feedstock for densified RDF (dRDF) production, while heavy ones (metals, dense plastics) undergo magnetic separation to secure ferrous metals and aluminum removal.

The last stage of fuel preparation is optional: as long as it is last step of dRDF production, it is omitted at cRDF manufacturing process. Unit involves drying and shaping of the produced previously fuel rich fraction. As a result, energy content is densified and waste transit to a valuable fuel comparable to conventional ones.

Consequently, along with solid fuel production RDF plants contribute to segregation of recyclable materials, such as glass, aluminum, ferrous or compostable fractions, from the total MSW stream. Hence, launching waste management scheme involving waste incineration might not only have high energy recovery rates but also contribute notably to material recovery.

However, waste incineration gives rise to environmental concerns. While retreated plastic content of waste fuel contribute significantly to it's heating value (energy content), it might cause air pollution. Combustion of PVC plastics is one of the most broadly known source of as dioxins. Dioxins are one of the most toxic elements known in science. (EPA,2016) However, it is not plastic incineration itself, that causes dioxin emissions but the outcome of any incomplete combustion process. Despite this fact, there is a firm popular misunderstanding that causes the public treat of waste incineration treatment method.

In addition, waste incineration has a bad history of effecting overall air quality. The problem hides beneath poorly managed emission treatment. Since it requires notable investments, many industries tend to cut these expenses by neglacting emission treatment equipment and massage figures. Moreover, since any waste cannot be fully burned, certain amount of residues (ash) require utilization. After waste incineration ash may be contaminated with heavy metals.

These facts result in hard social criticism towards waste incineration plants in some countries.

By and large, there is a wide range of researches, leading to various conclusions regarding which waste collection scheme is more profitable. Depending on the certain case, each of them have strong sides, as well as weak ones. Krivtsov (2004) pointed out that while there is a lack in promotion methods for sustainable waste management in communities, any progress in this field is limited. Presently, the major concern regarding shifting to source separated waste collection is whether benefits obtained during recycling may overweigh the excessive energy consumption of renewed MSWM schemes.

## 2.2 Main reasons to recycle materials

Municipal solid waste management schemes are rarely based on full source segregation of household waste. Decision making may depend on feasibility of waste collection site reconstruction, changes in transportation cost, subsequent increase in waste collection services and overall social willingness to participate.

However, EU Waste Directive sets a strict target that "by 2015 separate collection shall be set up for at least the following: paper, metal, plastic and glass". Hence, the development of infrastructure for segregation of these materials from the generated waste stream is secured in Europe.

This chapter will discuss basic recovery and recycling approaches applied to most commonly separated waste compounds both at the source or at MRF, such as paper and cardboard, glass, metals and plastic. In addition, the feasibility of biowaste segregation from the household waste stream will be considered. Moreover, since hazardous waste, such as waste electrical and electronic equipment (WEEE), is notable share of household waste stream and

requires separate collection and treatment, opportunities for it's further utilization will be highlighted.

### 2.2.1 Paper and cardboard

There are two fundamental raw materials for paper manufacturing process: wood and recovered paper or board. (Worrell, Reuter, 2014) As commercial and industrial life is continuously developing on a global scale, the paper production is increasing. However, wood feedstock is not matching the same pace. On the contrary, wood demand is high in other industrial fields, such as energy production. Moreover, some countries lack sufficient forest resources to cover their growing needed. As a result, paper and board recovering from generated waste volumes is becoming remunerative business. For example, Germany and France limited to internal wood feedstock are inclined to increase recovered material share in paper production. (Worrell, Reuter, 2014)

Worrell (2014) claims that increase in the share of recovered paper and board as a raw material at paper mills has clear benefits. Firstly, it is rather profitable since recovered material is notably cheaper than virgin wood. Moreover, processing recovered paper into pulp used in paper production requires less energy than wood treatment. Hence, recycling paper and board material is highly viable not only from economical perspective, but also as it contributes to natural resource conservation as well as improves energy-efficiency of paper production.

However, feasibility of secondary raw material utilization on the large scale in paper industry significantly relies on production cycle, specifically on the targeted end product. On general, paper industry contributes products of four main categories to a global market: 1) packaging paper; 2) graphic paper; 3) tissue paper; 4) paper for technical and other purposes. The shares of recovered paper used in different paper types' production vary notable. The highest utilization rates are observed in packaging and graphic paper manufacturing process. For instance, production cycle of newsprints allows almost 90 percent of paper recycling, in corrugated case materials these numbers may be even higher. (CEPI, 2012)

To be able to meet specific industrial standards recovered paper and board in Europe is classified to five different classes and has 67 grades according to the European List of Standard Grades of Recovered Paper and Board (EN 643). The highest recovery yields are in following three classes: mixed papers and boards (sorted)), supermarket corrugated paper and board and sorted graphic paper for deinking. (Worrell, Reuter, 2014)

On general, the key target of recovered paper or board treatment is to gain a specific material without any unwanted impurities that provides fibers for a stable continuous paper manufacture. As a result, converting recovered paper or cardboard into a recycled pulp suitable for further utilization in paper production imply a wide complex range of technological steps. Since the most exacting step, determining the following treatment, is purification of recovered material, the secondary material's quality plays significant role. From the quality perspective, separate collection of waste paper and cardboard allows the lowest possible level of secondary material contamination.

Confederation of European Paper Industries (CEPI) supports source separated paper collection rather than commingled recyclables collection. To promote this approach it launched the IMPACTPapeRec project in February 2016. The key aim of this campaign is

to contribute to development of paper separate collection schemes for countries, which are falling behind average European paper recovery rates such as Poland or Bulgaria. Moreover, countries such as the UK and France, which were pioneers of recycling programs' implementation, are under consideration as well. Since applied collection schemes implies mainly commingled recyclables collection, the CEPI's target to shift this approach towards initial source separation of paper and cardboard. (CEPI, 2016)

Summarizing, paper and board recovery from MSW volumes is a profitable business as there is a high demand for this material in pulp and paper industry. Source separation of paper and cardboard fraction at the source of waste generation allows obtaining recoverable resources of a good quality, that requires little subsequent processing. As a result, substantial remunerative business relations might occur between waste generators and material processors as long as material quality matches required production standards.

### 2.2.2 Plastics

Remarkably, even though plastic packaging is extremely widespread in modern world, plastic has rather new history as a recycling material. Against paper, glass or metal, which have been recycling for ages, plastic material has low recovery rates. Even countries with advanced waste management system and high recycling rates (for example Finland), does not apply plastic segregation for material recovery.

One of the reasons is a wide variety of types of plastic. Even among 7 officially marked types, there is a various additives and compounds that makes hard for processors to manufacture in one process. Hence, either an expensive technological treatment is needed or initial separation not only by different materials but also by plastic type. That puts a pressure to households, since they need to differentiate storage for even more materials, which takes space and time. This, in turn, reduces the community participation level into plastic sorting. As a result, an overall feasibility of plastic recycling is ambiguous. (Worrell, Reuter, 2014)

### 2.2.3 Glass

Glass manufacture, as any large-scale industrial process, involves extensive consumption of different raw materials. Three fundamental materials are following: silica sand, soda ash (sodium carbonate) and calcium carbonate. The further fluctuations in mixture composition related to wanted color of final product. There are three prime glass classes based on color: clear, brown and green. To obtain a certain color of a final product precise chemical compositions are added. For example, while brown glass production requires chromium and iron, green color attained only with insignificant additive of chromium. (Krivtsov, et al., 2004)

To manufacture glass a certain share of recovered glass material (cullet) is required as a feedstock as well. The basic steps of recovered glass material production suitable for further utilization in glass industry involves glass crushing with subsequent color separation. In this case sorting process is automatized and commonly applies laser-separation equipment.

In general, glass recovery form waste stream implies initial hand sorting to remove obvious contamination. Then it is crushed to obtain cullet. Next step is targeted for metals and plastics removal and involves cullet sieving. Magnetic separation is needed to remove ferrous metals.

The purification is accomplished by eddy current and vacuum sorting. (Worrell, Reuter, 2014)

Salvaging recovered glass in the glass manufacture processes preserve natural resources by lowering demand for raw materials. Moreover, similarly to recovered paper usage, improves energy-efficiency of the entire glass production by reducing energy consumption during glass melting. (Krivtsov, et al., 2004)

Since every glass product requires precise feedstock quality, final product determines whether glass recycling is feasible in considered manufacturing process. Thus, the most common glass recycling option is container glass production. On the contrary, as flat glass manufacture sets extremely high standards for raw materials, recovered glass treatment impossible in this process.

Along with obvious options of glass reprocessing at glass production, there are other recycling technologies. Construction industry may use cullet as substitution for sand, gravel or rock material, for example in concrete production or as additive in brick production. Moreover, recovered glass might be melted to obtain completely different products, such as glass wool used for insulation. (Eisted et al., 2009) Hence, it is important to research the existing market for secondary glass material while planning MSWM schemes.

Summarizing, increased glass recycling during glass manufacture contribute significantly to energy-efficiency of an overall industry. Thus, any detriments related to increased fuel or energy consumption during glass recovery from waste (collection, transportation and processing) are easily overweighed by improved production process.

### 2.2.4 Biowaste

The vast part of municipal solid waste is a biodegradable fraction. Hence, it is important to manage this notable content effectively.

Moreover, waste organic content has a notable influence on waste further treatment. The prevailing of organic fraction in MSW poses a major harm to any recycling of waste materials. As it spoils the quality of potentially recoverable materials such as paper, cardboard and plastics.

The most common and long-used method for organic waste treatment is anaerobic digestion technology (AD). Target waste materials is the biodegradable waste content such as food waste, grass, yard trimmings. Another method for organic waste treatment, becoming widespread recently, is combustion. Such organic waste materials as wood, paper, cardboard is estimated as combustible waste fractions. (Verma 2002)

Prior to digestion or combustion process it is important to remove such waste components as glass, stones, metal, sand (inert materials). Otherwise, it increases the material volume. Moreover, it increases the risks of equipment wear. (Subov 2013)
The end-product of AD is compost. One the one hand, the quality depends significantly on the initial waste composition. Some specialists declare compost made from waste to be a good fertilizer. (Verma, 2002) However, the risk of contamination with heavy metal is increased if compost is made from municipal solid waste. (Hargreaves et al. 2008)

On the other hand, EU has notably tightened the legislation regarding management of biodegradable waste content for a good reason. Directive (2008/98/EC) appeal to reduce biowaste volumes landfilled, as being landfilled organic matter poses a threat to environment. It emits methane, a green house gas, which influences global warming process. (EC, 2015)

# 3 EXPERIENCE OF EU COUNTRIES IN TRANSITION TO SOURCE SEPARATED MSWM SYSTEMS

European Union has quite a long history with solving waste management issue. It was 1975 when the Council Directive 75/442/EEC on waste was adopted prompting a transition towards sustainable MWM. The member countries were obliged to manage their waste giving preference to waste prevention and recycling strategies over widespread waste incineration and disposal (landfilling). Thus, the waste hierarchy, which is still in use, was formulated.

The amendment to waste Landfill Directive 1999/31/EC straitened biodegradable waste handling, setting precise reduction targets for landfilled organic waste in long-term period. The latest Waste Framework Directive (WFD) put in force in 2008, required separate collection systems for at least four waste materials (paper, metal, plastic, glass) by 2015. Thus, legislation development sustained source separation practices among EU countries. This chapter refers to several case studies of MSWM transition towards source separated waste management systems.

Finland was chosen as the closest neighbor and a trailblazer of source-sorting waste management systems. This country managed to change conventional paradigms shortly. Moreover, it succeeded not only in sustainable waste treatment but also cost-efficient.

Another case study covers municipal waste management practices in one of the post-soviet EU country – Estonia. It was chosen as an example of transiting waste handling system with resembling to Russia case initial circumstances and social pattern.

The leadership of Nordic countries (Sweden, Finland, Norway) in successful implementation of source-sorted waste management schemes is notable. Being EU members for more than two past decades, countries managed to put in operation strong waste separation systems, providing high energy and material recovery yields. Even though their experience is educational, the best practices which worked in their case might not be successful in Russian case. That is why, the focus of case studies were offset to former Union Republics of Soviet Union – Estonia and Latvia.

According to recent EU studies on waste management performance, Estonia, side by side with Finland, was one of the three countries setting the pace in separate waste collection. (EC, 2015)

## 3.1 Developed source separated system aimed on energy recovery on example of Finland

The development of municipal solid waste management system in Finland was held with a strong incline to energy recovery from a waste content. Over the last ten years, Finland managed to quadruple the share of MSW treated with incineration technologies.

Statistics Finland pointed out that while municipal solid waste generation reached 2.6 million tonnes in 2014, half of this amount was treated at energy recovery facilities. Recycling and material recovery is estimated to be treatment option to one third of generated MSW in Finland. (Statistics Finland, 2015) The overall state of art in municipal solid waste treatment technologies are presented in Figure 2.

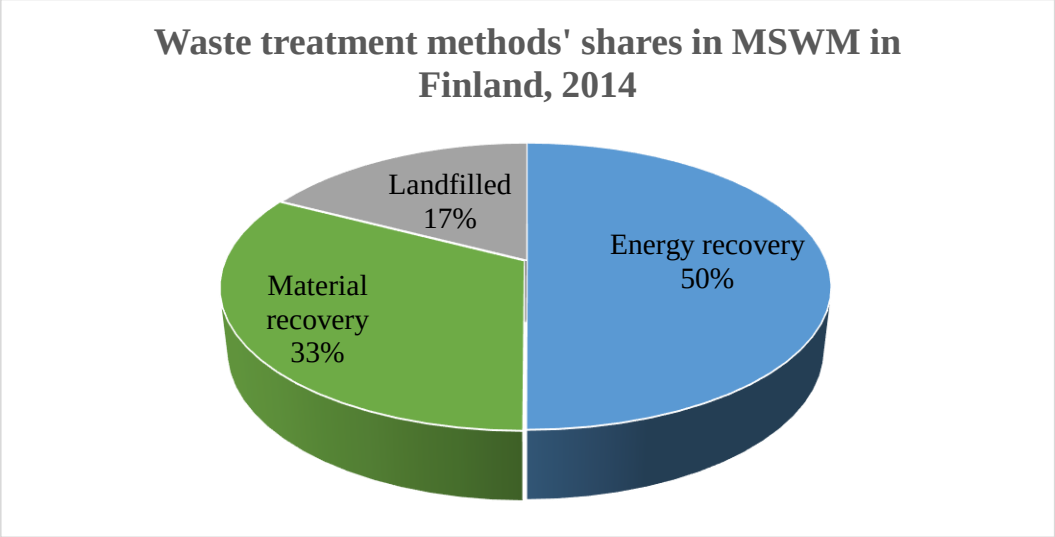


**Figure 2.** Treatment methods in use in MSWM in Finland, 2014 (Source: Statistics Finland, 2015)

The major separately collected waste materials in 2014 were paper and board, organic waste, glass, metal, wood, plastic and electrical equipment scrap. The mass fractions of these materials in the general separately collected waste statistics are in Figure 3. The overall amounts of separately collected waste accounted to be 1,14 million tonnes, which is 43% of total waste generated in 2014. (Statistics Finland, 2015)

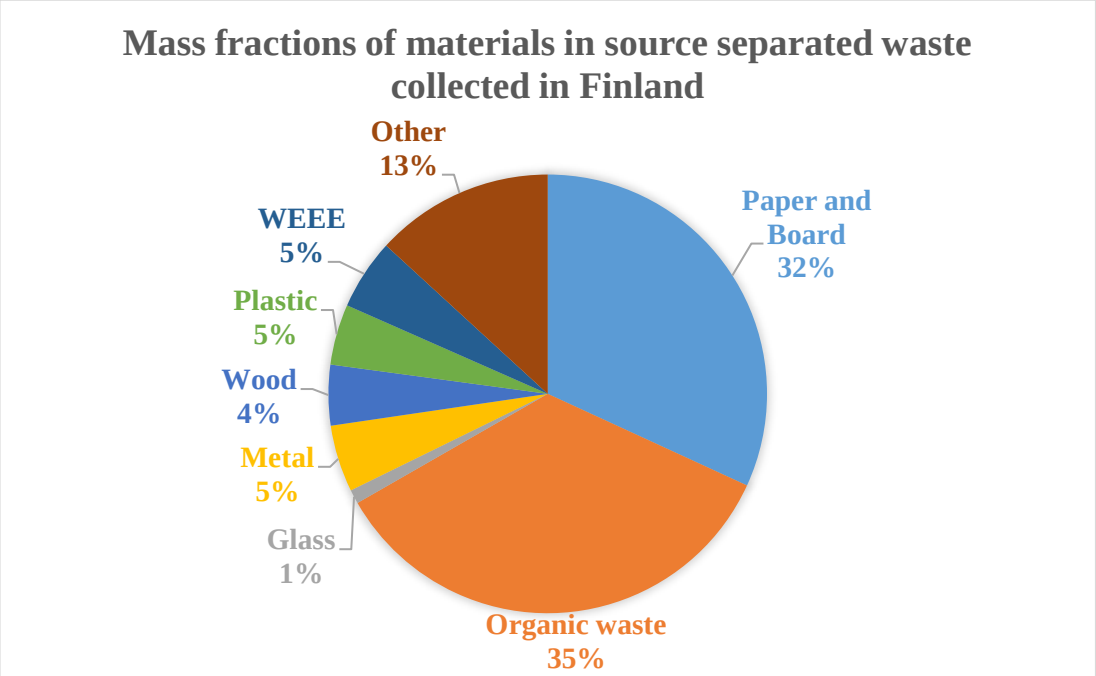


**Figure 3**. Mass shares of different materials in separately collected waste in Finland, 2014 (Source: Statistics Finland, 2015)

Thus, organic waste as well as paper and board waste are notably the largest material flows among separately collected waste in Finland. Each of them were amounted to one third of general materials formation in 2014.

Although the share of mixed waste in MSW management system in Finland is still more than half, initial source separation enables incineration treatment technologies with lower environmental risks. Presently, unsorted waste volumes are even increasing since combustion treatment is becoming widespread. (Statistics Finland, 2015) Hence, the conclusion may be drawn that even with notable share of separated from waste materials, MSWM strategies in Finland rely significantly on recovery of energy content from waste.

A case study of Finland was examined further in order to find the key factors which launch and secure successful transition towards source separated municipal waste management in Finland.

## 3.2 Case study Estonia

As it was already mentioned, Estonia is an outstanding example of rapid success in changing conventional MSWM system. After becoming a member state of European Union in 2004, it managed to rearrange waste management in accordance to EU requirements. Thus, over a decade the capital of Estonia, Tallinn, was marked as one of the three European capitals leading in source separation of municipal wastes. Above half of MSW generated in municipality was treated via recycling in 2014. (EC, 2015)

Estonia has a history of being a part of USSR for half of the XX century. Fostering on the same values and traditions, public spirit has common grounds over all member countries. Even though, after the collapse of the Soviet Union, Russia and Estonia have chosen different paths for development, the communities still have similarities in both countries. As

a result, Estonian waste management transition case is of particular interest when the tools for modernizations in the same area in Russia are assessed.

This chapter is aimed to trace the Estonian success story in order to find the key drivers facilitated transition towards waste sorting. Hence, at first, the main modifications in National legislation since early 2000s were pointed out. Secondly, the implementation strategies along with factors influencing the process are weighted on the example of the capital – Tallinn.

### 3.2.1 The impact of changes in legislative system

National legislative system is the major initiator of any local or countrywide development. The area of waste management is not an exception. Legislative policy has significantly toughened on the waste handling issue in Estonia during last decades. As a result, it enabled and secured the development of sound infrastructure for innovative waste management systems.

From the outset, Environmental charges in Estonia was partly backed with a Landfill tax. The tax was introduced in 1991. Fees differentiated for different waste streams disposed. However, levied tax on municipal waste landfilling remained extremely low (0,3euro/tonne in 2004). The improvements begun with enforcement of Environmental Charges Act in 2005. There was a steady growth in fees over the ten years to reach the level of 29,84 euro per tonne of MSW disposed in 2015. (Justice and Environment, 2011) (Figure 4)

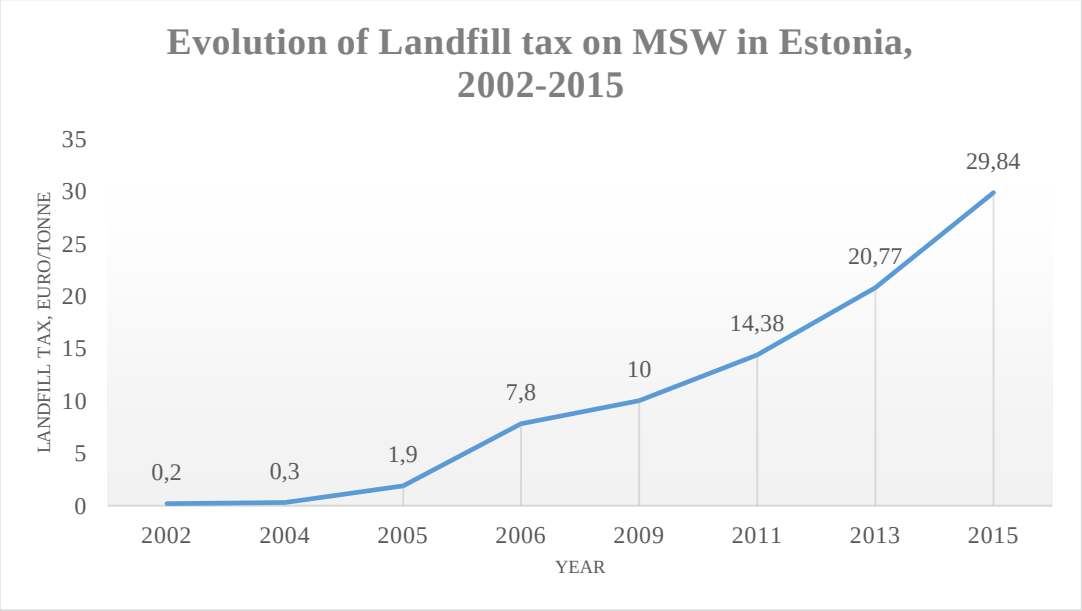


**Figure 4**. Evolution of Landfill tax on municipal wastes during 2002-2015 (Source: Eurostat 2015)

Municipalities received 75 % from the Landfill tax back to the local budget. This revenue was to invest into new landfills or development of alternative infrastructure for waste treatment. (EEA, 2015)

The enforcement of Environmental Charge Act came along with the Waste Act of 2004. Waste Act banned the disposal of any untreated waste at landfills. Thus, over time, landfilling of municipal solid waste became highly unprofitable option. Consequently, as

waste landfilling was decreasing (Figure 5), demand for alternative treatment methods increased.

Moreover, Waste Act regulated the First Waste Management Plan, prepared for the years 2002-2007. The main objective of the Plan was to obtain the system of national standard in compliance with EU waste management requirements. The Ministry of Environment with six regional Environmental Board offices were responsible for the Plan's implementation. Thus, management of municipal waste collection, transportation and disposal became the duty of each municipality. Overall, first Estonian Waste Management Plan was aimed to allocate the duties between main players involved in countrywide municipal waste management. Thus, basic routines to establish sound waste management infrastructure were stated. (Justice and Environment, 2011)

The second Estonian Waste Management Plan was focused on handling biodegradable waste fraction in compliance with EU Waste Directive of 2008. It covered years from 2008 to 2013. The main target was to separate biodegradable waste from mixed MSW flow and, consequently, reduce the share of biodegradable municipal waste sent to landfill.

In pursuance of Waste Act of 2007 requirements majority of waste treatment companies have waste sorting facility. By doing this, they are able separate all possible waste recoverable materials. Otherwise, their operations would interfere with the ban on untreated waste disposal.

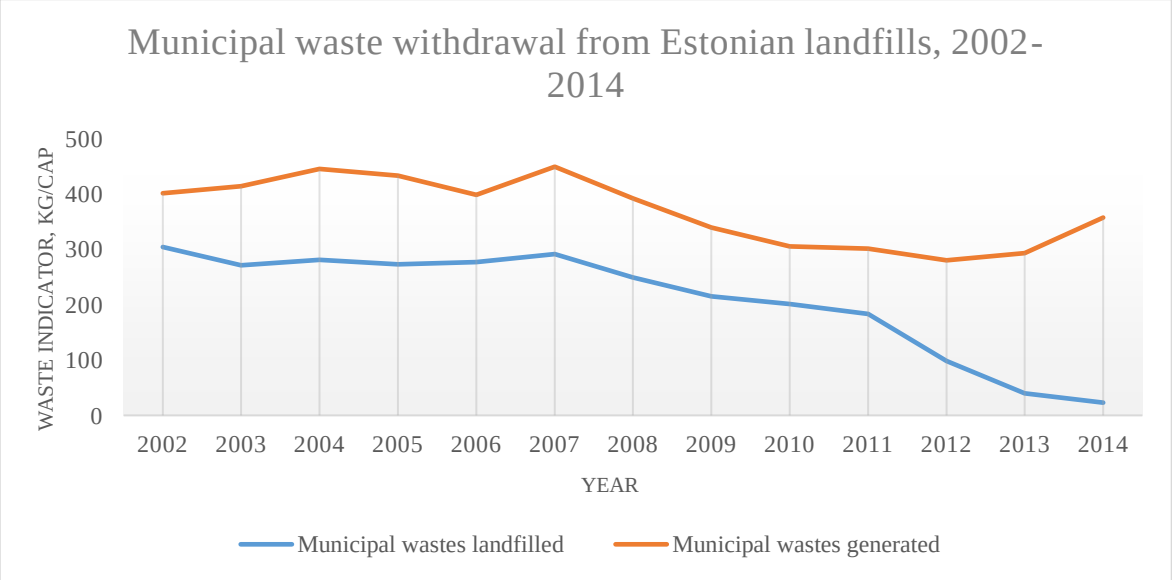


**Figure 5.** The time span process of taking away municipal wastes from landfills in Estonia. (Source Statistics Estonia, 2015)

To conclude, Figure 5 represents how much time it took to withdraw municipal waste from the landfills in Estonia. European waste indicators – total municipal waste generated and landfilled wastes, took into consideration. As it was mentioned, a complex set of factors was influencing this time-consuming process. One the one hand, the moderation in national regulative system clearly played the role. The decrease in landfilled waste after 2007 arose from the Waste Act ban on landfilling untreated wastes. However, the Figure 4 clearly illustrates that the most significant changes were obtained only in 10 years from the start of

the transition. One of the reasons might be the construction of WtE plant at Iru in 2012, that treats currently up to 90 percent of mixed municipal waste generated in Estonia.

### 3.2.2 The role of local authorities

One of the key instruments in bringing Estonian waste management infrastructure to another quality level was organised waste collection schemes (OWCS) introduced in the Waste Act. The explanation for these schemes was as follow "collection and transportation of the municipal waste from the predetermined waste collection district to the predetermined waste treatment facility by a waste company selected by the local authority". In other words, it was a legally initiated reorganization of existing in a country waste market according to the new rules. Even though this transition process was controlled by local authorities, the major players was waste market stakeholders themselves. (Breme, 2011)

The fundamental innovative idea of OWCS was to unify all municipal waste market stakeholders: households, waste holders, as well as waste collectors and processors. To meet this purpose, the waste holders register was created. This system is an interactive network database. It comprises information about all sites generating municipal waste (with division by areas and city districts) with waste classes and containers in use. Waste collection companies are in charge of refreshing and adding information with accordance to services they provide. As a result, every household (waste holder) was tracked and obliged to be covered by waste collection services. Consequently, the administrative control over waste services, fees and quality became transparent.

Another factor influencing the transition process was reduction of Estonian waste management system to two tiered – National and Municipal in 2007 (instead of three tiered National, Country, Municipal). (Justice and Environment, 2011) As a result, in addition to National Plans Local waste management plans was required. By doing this, municipalities became solely responsible for fulfilling waste management obligation. As a result, along with OWCS, it was a strong incitement for local authorities to invest more in the municipal waste management system. Moreover, they were stimulated to cooperate to form regional structures to increase waste handling efficiency.

Overall, it is hard to overestimate the role of municipalities in successful rearrangement of waste management system in Estonia. First of all, after national regulations development, their duty became to ensure a sound waste collection system from every resident under their responsibilities. This system had to provide environment for separate collection and transportation services from households as well as civil bring in points for packaging and hazardous wastes. Moreover, municipalities were in charge of raising the level of social environmental consciousness and promotion of waste reduction among their civilians. Along with furnishing residents with information about current waste-related requirements and opportunities. Consequently, even though government stayed aside from the direct provision of services on the waste market, it had a major influence on securing the development of infrastructure. As a result, households got a secure waste management system with sorting facilities. (Justice and Environment, 2011)

### 3.2.3 Extended Producer responsibility outcomes

In addition to efficient administrative involvement into waste management locally, Estonia was good in addressing the EU Packaging Directive requirements. Beverage packaging

became obligatory to deposit through the special return system for glass, metal and plastic cans/bottles in 2005. Every consumer of drink in a glass or plastic bottle or can prepaid the certain deposit when bought a drink. The money amount to be returned is indicated on the label. The system has more than 1000 collection points all over the country. (EC, 2014) (EEA,2015)

Moreover, important fact that packaging return system in Estonia draw people attention not only to environmental problems but social as well. Hence, since 2011 many collection machines offer a choice of returning the paid deposit for packaging or donate this money to help children. The donated money then spend on cultural education for indigent children. For instance, charity funds buy books for children in hospital or organize theater visits. The amount of donated through this system money is around EUR 200 000 over three first years. (EEA, 2015)

Thus, organisation of reachable deposit system for this packaging was a strong measure to implement extended Producer Responsibility Principle. As a result, recovery of beverage packaging waste was ensured. In 2014 packaging returning rates were notably high, reaching 80% for plastics and even more for glass. (EEA, 2015)

### 3.2.4 The capital case example

Consider Estonian waste management system in more details on the example of one city – Tallinn. Estonian population reached 1 315 944 in January 2016. More than one third, 423 420 inhabitants, lives in the capital. The city's area is 159,3 square km with population density of 2657,8 people per square kilometer. (Statistics Estonia, 2015)

In 2003, before entering EU Tallinn had a long way to go towards municipal waste source separation. Modernization started when an old landfill site Pääsküla was closed in 2003 and a new one – Tallinn landfill was put into operation in Jõelähtme rural municipality. Even though new landfill had a Waste Sorting Facility in operation, it was unique for the country.

Tallinn Waste Sorting Facility pretreated municipal waste before final disposal at Joelahtme landfill. The following waste compounds were segregated during treatment: paper, metal, glass and plastics for further reselling and profit earning. In addition to these returns, the facility charged fee equal to landfill's one. Hence, it barely stayed in business looking forward to upcoming changes with EU affiliation.

In addition to sorting facility, Tallinn landfill had capabilities for composting and production of alternative energy. However, still only 5-7 percent of household waste was recycled in Estonia before the entry in EU. (EEA, 2015)

The embedding of the organised waste collection schemes, required by Waste Act began in Tallinn in 2005. The City of Tallinn had gradually develop the waste market with the help of waste holders register. It enabled a separate collections of household waste at the spot of generation. That shift towards OWCS assigned responsibilities to each waste producer to pay for the further treatment services for their waste. As a result, a strong waste management market, which comprised both municipal and private structures, was established. (Kivimägi, Loigu, 2013a)

Over time, waste management infrastructure developed according to the national plans. As a result, currently there is quite strong infrastructure for source separated waste management in Estonia. There is a system of separate collection from the households for biodegradable, paper and cardboard waste. Moreover, there is a good collection network for hazardous wastes. Electronic wastes can be brought in to the public points centers.

It is stated in Final Report of European Commission on "Assessment of separate collection schemes in the 28 capitals of the EU" that door-to-door separate collection network almost fully covers households all over Tallinn. The services provide separate collection of paper and cardboard and biowaste at the sport of their generation. In addition, there is a separate bin for co-mingled collection of packaging materials under the Extended Producer Responsibility. Furthermore, the advanced infrastructure of Bring-in civil site allow citizens to drop off paper, cardboard, glass and metal materials. (EC, 2015)

### 3.2.5 Community involvement

Being a member state of European Union, Estonia actively engaged in the EU project European Week of Waste Reduction. It pursue several objectives. From one perspective, it was drawing public attention to the threats that might pose inefficient waste management. But more prior aim was to raise social awareness about available waste reduction methods. Estonian Ministry of Environment coordinated this program three years in a row 2009, 2010, 2011. (TED, 2014)

On behalf of separate municipality, Tallinn involved main waste market stakeholders to take part in this awareness campaign. Thus, regional waste recyclers, for example Paikre Landfill, Vaatsa Landfill, Rang-Sells, ETO, Pandipakend, sponsored waste reduction promotional actions for precise waste fraction. Moreover, NGOs engaged in the program highlighted the topics of sustainable consumption and reduction of packaging. For instance, non-profit association JCI Estonia launched "Killerkott kampaania" promoting plastic bag reduction.

One environmental campaign initiated by Municipality of Tallinn in 2003 even had it's own mascot called Prugihunt or Waste Wolf. In general, the Waste Wolf campaign was an environmental program for children. It included environmental lessons about waste sorting and minimization for children of different age, workshops on waste reuse and recycling practices. During different years this campaign had various focus in the waste management areas from just rising social awareness to separate collection of hazardous wastes. It proved to be highly successful and in a few years spread among other rural areas in Estonia. For instance, Figure 6 is from the environmental lesson in Rukkilille kindergarten held in 2015. The notable success of Waste Wolf campaign was marked with Estonian national award for the best environmental campaign in 2012. (TED, 2014)


**Figure 6.** Environmental lesson "Separate waste to save nature" held with Waste Wolf at Rukkilille kindergarten, Estonia, 2015 (source: TED, 2014)

However, the fact that the Waste Wolf campaign had a constant financial support from EU funds, makes it a little bit challengeable to be regarded as 100 percent feasible pathway for other cases with no external funding. (TED,2014)

### 3.2.6 Threats for further development of waste recycling

Even though outstanding success of Estonian educational programs regarding waste sorting was highlighted in official reports (EEA, 2015), Harri Moora imparted his apprehensions in 2011 (Morra, 2011). Currently, he is a director of the Environmental Management Programme at Stockholm Environmental Institution (SEI) in Tallinn. Moora noted that there was still a number of serious thresholds for successful development of source separate collection system for MSW in Baltic State countries. Low level of public awareness from one side and high contamination level of separated material from another obstructed the extension of source separate collection infrastructure. Along with high operational costs for separate collection feasibility of this area's further development was ambiguous.

Consequently, the interests in development process for municipal waste handling was turned towards managing mixed MSW. Hence, investments became more focused on projects of low-cost Mechanical biological treatment (MBT) and mass-burn waste incineration plants. As a result, in 2012, Estonia launched energy recovery from municipal solid waste. (EEA, 2015)

Eesti Energia invested into waste-to energy unit for mixed municipal waste incineration at the Iru power plant near Tallinn. The facility's capacity is around 220000 tonnes of mixed MSW annually. Thus, almost 90 percent of mixed municipal wastes generated across Estonia is treated at the Iru. The power plant sets half price for waste treatment comparing to landfill price. As a result, the price for waste collecting services had decreased all over the country. The similar pattern is noticed regarding landfilled mixed MSW.

However, there is a popular believe that waste incineration has extremely negative impact on the environment. Along with posing a serious threat to human health. Due to this facts, to eliminate a possibility of any hazards, a prior assessment was conducted. It indicated only

1% change in the overall environmental impact of the power plant after putting WtE unit in operation. Moreover, it is a legal requirement to set a real-time emission monitoring system at this new unit. Thus, the environmental and human health are secured from any negative side affects of the waste incineration. (Eesti Energia, 2016)

In 2013 European Environmental Agency assessed the Estonian transition in waste management. Even though Estonia effectively implemented organised waste management schemes, the recycling rates remained rather low in 2010. On the one hand, OWCS enabled qualified separate collection of household wastes. That, in turn, should lead to increase in material and organic recycling (composting). However, while the volumes of landfilled mixed waste was reducing, the funding of local budgets was depleting as well. Hence, the motivation to invest in recycling facilities remained low.

EU Cohesion Fund was ambition for developing recycling in Estonia. However, according to the Estonian Ministry of Environment report of 2013, there was no projects fitting for purpose feasible to develop.

On the contrary, that prevailing conditions served as a good grounds for development of mixed MSW treatment facilities: mechanical biological treatment and waste-to-energy incineration plants. (JPC, 2014)

## 3.3 What Saint Petersburg can learn from the Baltic country's case

Russia and Estonia have GDP per capita (PPP) of the same order of magnitude (TradingEconomics, 2016). However, Saint Petersburg has almost four times more inhabitants than the whole Estonia. (RFFSSS, 2016) Moreover, the population density in Saint Petersburg is 3631,47 inhabitants per square kilometer. That is one thousand higher than in Estonian capital.

The real obstacle is that Estonian waste management transition process to a great extent supported by EU funding, for instance European Structural and Cohesion Funds. That makes any EU cases hardly fully applicable in Russian environment. However, there are doubts that external funding might be inefficient in a long run since it distort local waste management market. By doing this, it empowers a lock-in to one technology of a large scale investment. (Morra, 2013)

Anyway, irrespective of differences, Russia might learn a lot from Estonian transition process towards integrated waste management.

From the perspective of waste management system modernization, there were several factors, that secured this transition. First of all, it was an increase in a landfill tax. By making waste disposal expensive, a possibilities for alternative methods occurred. Moreover, the prohibition of unsorted municipal waste disposal switched focus to the new processing facilities development. As a result, the projects of new MSW recovery facilities in Estonia emerged in 2011, such as Mass-burn treatmnet and Waste-to-Energy plant in Tallinn.

To put together all the outcomes of the changes took place in Estonian legislation system Figure 6 was developed.

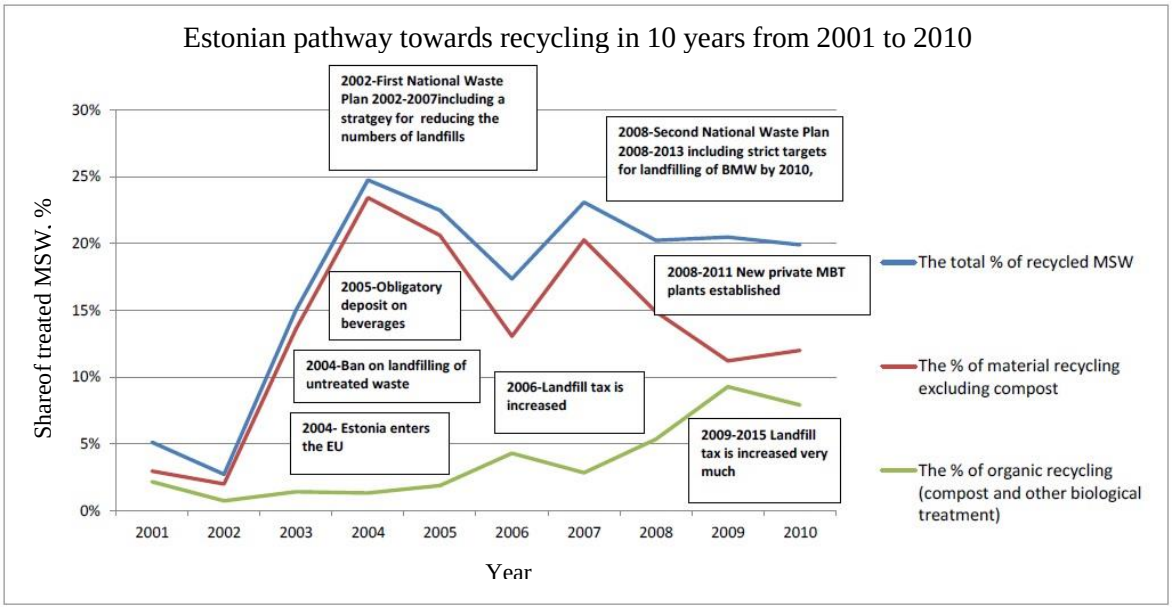


**Figure 7.** Estonia roadmap of the first years towards increase in MSW recycling rates (Source: Estonia country profile, EEA, 2015)

Briefly, as Peeter Eek (2013), the head of the waste department at the Ministry of Environment of Estonia, argued that waste sorting is an essential prerequisite process for entire waste generated in municipalities before it's final disposal. (Kivimägi, Loigu, 2013b) As a result, to be able to meet EU waste legislation and preset targets, Estonian Ministry of Environmental in 2003 developed the National Waste Management Plan for a five year period. It was the first public document about waste handling paradigms. (EEA, 2015) Moreover, country continued development of waste legislation after becoming EU Member State in 2004. Thus, in 2007 Estonian waste management system was dwindled to a two level hierarchy divided to National and Local accountabilities. By doing this, municipal authorities became directly responsible for implementing best waste management practices available. For instance, local authorities became in charge of waste management plan preparation in accordance with national standards.

Thereby, local waste management plan is an efficient tool to provide patterns for development of waste transportation schemes in targeted area. As it obliges local authorities to design waste collection programs, keep a record on waste management activities under their responsibilities and search for better options in this field. Summarizing, figure 6 illustrates the first decade of transition process in Estonian waste management systems.

In consequence, the key drivers for development of municipal waste sorting infrastructure in Estonian was:

1. National ban on landfilling of non-pretreated MSW;
2. Increased landfill tax;
3. Strong national and local waste management planning.

However, when we trace back the changes in Estonian legislation, it is obvious that the implementation of any policy significantly depends on the facilitating mechanisms.

Thereby, local governments have a great influence on waste management environment. Local authorities are either the key initiator of development or a prime obstacle. It was a high level of municipality involvement that enabled a pathway for successful changes in Estonian waste management system.

However, if we compere Estonian transition to another Baltic country case – Lithuanian, an interesting pattern can be highlighted. The development of waste management system is the more efficient the less direct control over this process local authorities have. Most municipalities in Estonia stayed aside waste management cooperations. As a result, the waste management market, controlled greatly by private sector had much more competition and opportunities for development. In Lithuanian case, on the contrary, municipalities engaged into waste management. By doing this, there was a lock-in to a single technologies and the development of alternatives was hindered.

Another significant difference between these Baltic countries is the rate of Landfill tax. (Breme, 2011) Since Russian government as well as Lithuanian still avoids taxation of municipal waste landfilling, it is important to point out this difference.

Lithuania still doesn't levy any tax on municipal waste disposal. Average gate fee for landfilling is 15 euro per tonne of waste, while Estonian average price is 45euro/tonne (with a tax of 12euro/tonne and a ban for unsorted MSW disposal). Thus, Lithuanian case is a clear example that if the landfill fee remains low, any development of new infrastructure for recycling is impeded. (JPC, 2014)

One more critical distinguishing feature in Estonian and Lithuanian waste management transition is level of producers' involvement. Lithuanian producers and importers didn't take charge of packaging producer responsibility. As a result, the infrastructure for beverage waste deposit system is poorly developed over the country. Whereas, in Estonia collection points for beverage packaging have a great influence on the overall material recycling rates. (JPC, 2014)

To conclude, even though Lithuania is the EU state as long as Estonia, it has a long way to go towards integrated municipal waste system. Source separation system is still at a low development level in the country, as it has no legal support from the government.

The similarity in Russian and Lithuanian cases are rather notable. Thus, it might be a good idea to take Estonian case as a model for Russian waste management development.

# 4 CURRENT STATE OF ART OF MSWM IN SAINT PETERSBURG

According to government standard 30772-2001 «Resource-conservation. Waste treatment. Terms and definitions» municipal solid waste stream in Russia is generated by two separate flows. One is consumer wastes from residential areas of the city – household wastes. Another is waste from non-residential buildings: offices, commercial facilities, schools, hospitals – commercial waste. These waste streams have different composition and characteristics. Altogether, they form MSW volumes estimated by statistics and considered further in this study. Average ratio of residential to nonresidential waste streams in general municipal waste is 4:1.

There is a five-level classification depending on level of hazardous for all the waste generated during production and consumption processes in Russian Federation. The hazard level is increasing correspondingly from I to V, with V related to unhazardous. (FL 89-FZ)

General stream of unsorted municipal solid waste is marked with IV hazard level, while bulky waste (collected separately from the residential areas) is V level. However, there is a high share of hazard waste in Russian MSW stream as there is no tuned system for separate collection of electric batteries, accumulator cells, broken electronic equipment, various fertilizer and toxic chemical, medical drugs or energy-saving lamp.

The main challenge in Russian municipal waste assessment is the lack of reliable statistical data available. Presently, there is a volume based approach to household waste record keeping. As municipal solid waste is collected from residential areas in containers, it comes into statistical account in cubic meters unit. However, all treatment plants capacities are stated in tonnes of waste it is able to process. Presently, conversion of waste units in Saint Petersburg is hold with conversion factor from cubic meters to tonnes equal to 0.173. (Rospotrebnadzor, 2012)

However, this estimation method is highly unreliable. The share of light bulky packaging materials in MSW, such as various plastics or film packaging material, are gradually increasing every year. While waste volumes are growing, estimated waste unit weight does not increase with the same pace. The conversion factors applied are usually unable to take ongoing changes into account. As a result, waste generation might be inflated. This significantly complicates accurate material or energy recovery estimation process, as the volumes of generated waste are rather imprecise. (Rospotrebnadzor, 2013)

Lack of general information is another area for consideration, when Russian MSW management system is under assessment. There is few official statistics on municipal waste available. Aside from that, there was not any scientific researches on waste composition and structure for the past decades. Although the waste composition change is pointed out in late reports on MSW programs (Rospotrebnadzor, 2012), there is no validation by practical consideration. This work used several governmental sources for drawing conclusions on municipal waste characteristics in Saint Petersburg.

Saint Petersburg Committee for Nature Use, Environmental Protection and Ecological Safety keeps the record of MSW generation rates. In 2014 it was 10 million cubic meters and increase in the waste volumes was forecasted for the following years. The Figure 8 shows the forecast in more details and in thousand tonnes unit. (Rospotrebnadzor, 2012)

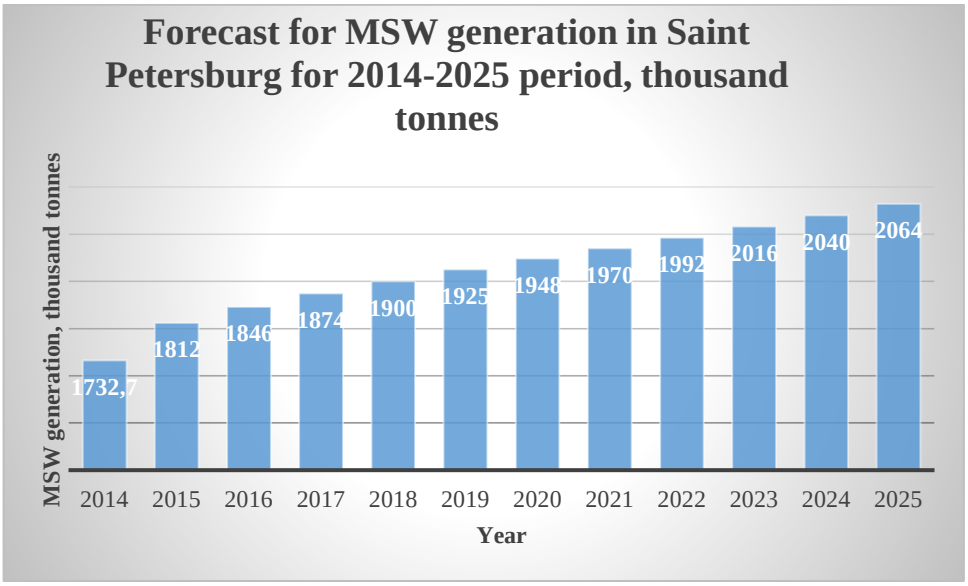


**Figure 8.** Estimation on MSW generation rates in Saint Petersburg, tonnes, 2014-2025 (Rospotrebnadzor, 2012)

According to the facts in "Regional Municipal Waste management program in Saint Petersburg for 2012-2020" standard of household waste (without bulky waste) generation per one Saint Petersburg resident is 1,64 cubic meters annually. MSW density is considered as 159 kg/m$^3$. By evidence of landfill "Novyy Svet-ECO", which has a gravity control of arriving MSW, average municipal waste density was 153,6 kg/m$^3$ in 2010. (Rospotrebnadzor, 2012) For the forecast, represented at Figure X, waste density was considered to be 173,27 kg/m$^3$, as not only household waste but also bulky waste was taken into account.

According to the instructions №30-p of Saint Petersburg Tariff Committee for year 2015, waste generation in Saint Petersburg is 362 kg per citizen per year. Considering this waste generation rates and population of the city this year (FSSS, 2016) waste generation would be amounted to 1880 thousand tonnes. Hence, the correspondence in official data can be followed.

The latest national research about waste management suggests typical MSW composition for big Russian cities as it is in Table 3. It is mass fractions of main municipal waste stream fractions.

**Table 3.** Morphologic composition of MSW stream in Russian mega cities (Sources: Rospotrebnadzor, 2012; Koluchev, 2013)

| **Waste fraction** | **Mass shares of fraction, %** | | **Annual accumulation, thousand tonnes (calculations for Saint Petersburg case 2012)** |
|---|---|---|---|
| | **Research data, Koluchev, 2013** | **Official data (Saint Petersburg), Rospotrebnadzor, 2012** | |
| Organic waste | 36,4 | 27 | 515,12 |
| Paper&cardboard | 29,7 | 22 | 404,2 |

| Waste fraction | Mass shares of fraction, % | | Annual accumulation, thousand tonnes (calculations for Saint Petersburg case 2012) |
|---|---|---|---|
| | Research data, Koluchev, 2013 | Official data (Saint Petersburg), Rospotrebnadzor, 2012 | |
| Plastics | 5,8 | 15,2 | 285,76 |
| Metals | 3,5 | 5 | 86,48 |
| Glass | 6,3 | 9 | 167,32 |
| Textile | 6,6 | 4 | 80,84 |
| Residual waste | 11,7 | 17,8 | 340,28 |
| **Total** | **100** | **100** | **1880** |

Saint Petersburg's governmental center of scientific research assessed main municipal waste streams went to landfills. As a result, educed mass shares of main materials in MSW composition in Saint Petersburg are given at Figure 9 and Table 3. (Rospotrebnadzor, 2012)

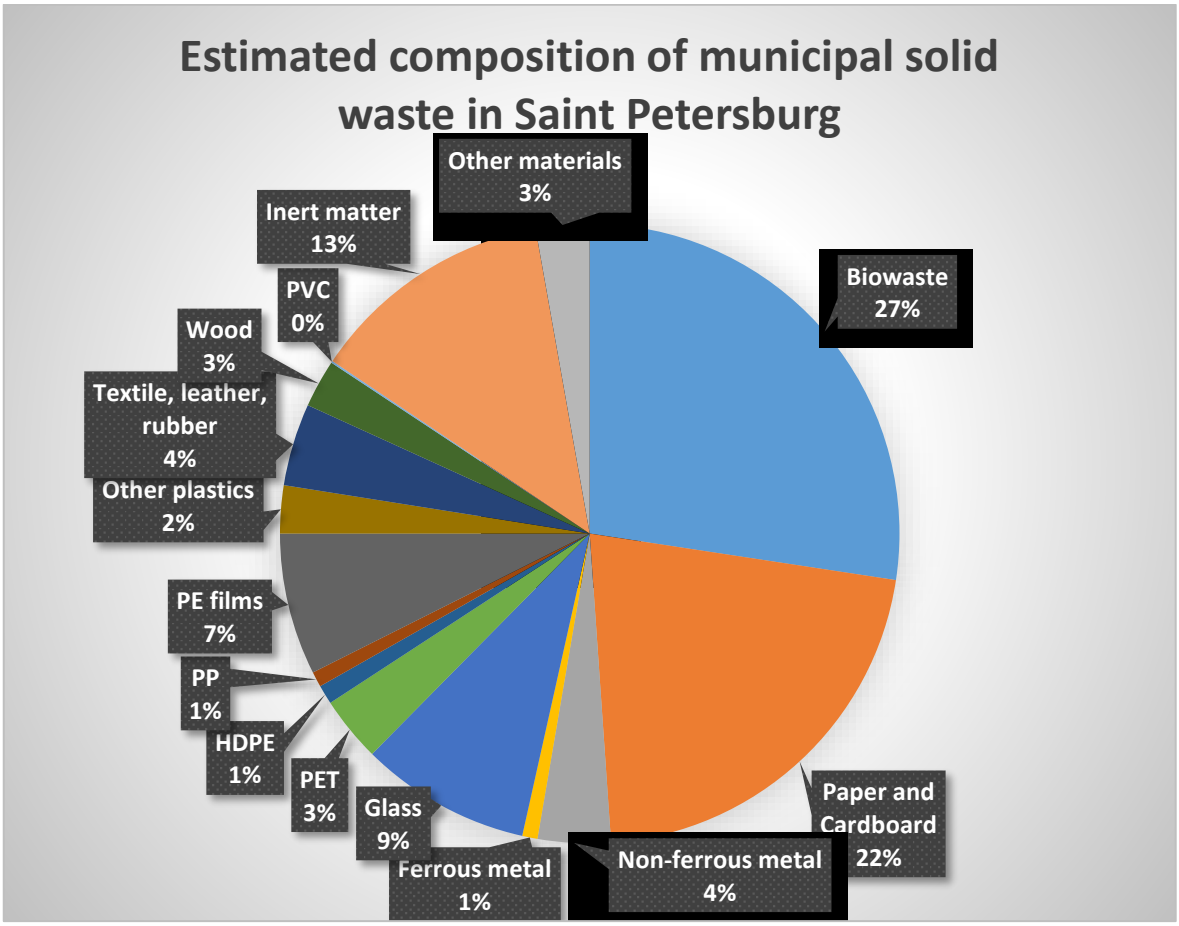


**Figure 9.** The mass shares of waste fractions in average MSW stream in Saint Petersburg, 2012 (Source: Rospotrebnadzor, 2012)

It ought to be remarked, that composition of assessed waste stream coming to municipal landfills varied significantly depending on waste generation origin, transportation organisation and occurrence of any sorting pretreatment. For instance, plastic packaging share in MSW stream from high-rise building with garbage chute tend to be higher than in street containers. Additionally, such streams have a high level of contamination with organic fraction. (Subov, 2005)

Moreover, there is a different level of material separation at transfer stations. Although mainly there is no waste compounds segregation at transfer stations, some large government transportation companies, such as Spechtrans №1 utilize several sorting facilities around the city.

In 2015 based on data from municipalities 8,85 million cubic meters of municipal solid wastes were generated in Saint Petersburg. Take waste density of 153,6 kg/m$^3$, based on practical Novyy Svet Eco results. Then we will have waste generation rate of 1,35 million tonnes of MSW annually in Saint Petersburg. (St.Petersburg Administration, 2016e)

Waste materials' outcomes that may be obtained if the full recovery is possible was assessed. The results are combined at the Table 3 when morphologic waste stream composition is regarded on the national research basis (Koluchev, 2013). Hence, there is two main fractions in Russian MSW stream – organic waste and paper&cardboard.

Take precise look at one of state landfill – Novyi Svet Eco in order to assess the deviation level of generalized official data from the practical case. This landfill is a unique facility for the city as it has a weight reception control. Thus, the waste composition data record is kept in mass unit straight away, which favors avoidance of mistakes during unit transfer process. Moreover, there is a data record of it's waste sorting facility. Thus, the following data on waste fractions ratio was obtained during year 2015 (Figure 10).

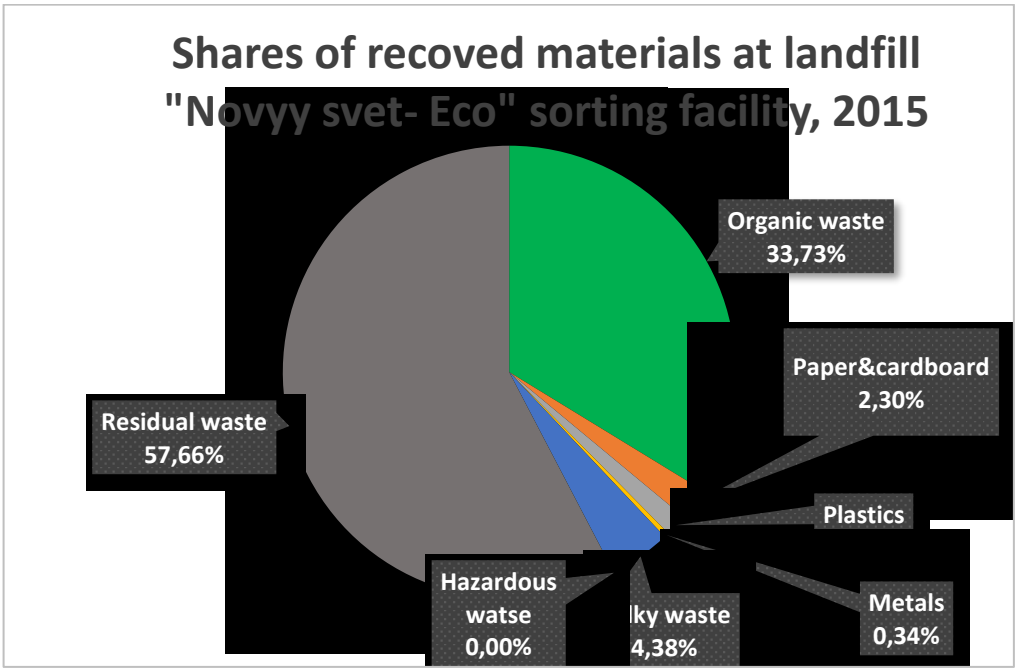


**Figure 10.** The mass fraction of waste materials after separation at landfill "Novyy svet-Eco" sorting facility, 2015 (Source: Novyy svet-Eco data)

Thus, assessment of "Novyy svet eco" data reveals the large share of residual waste left after mixed MSW sorting. The second large segregated waste compound is organic waste, which is one third of total stream. It is used as a material for partial filling during landfill reclamation works. The material recovery rate is extremely low. Consequently, these outcomes supports the idea that significant content of organic waste in general stream prevents recovery of valuable materials such as paper, glass or plastics.

Previously, there was a growing trend in the share of hazardous wastes in MSW in Saint Petersburg. Since there was nor system for separate collection of hazardous materials, nor educational program, citizens had no idea that these materials cannot be thrown with a mixed waste. The most dangerous hazardous waste compounds to be pointed out: batteries and accumulators, equipment containing mercury (luminescent lamp), outdated medical drugs, waste oils. The situation had improved when "Ecocar" program was launched by local government in 2010. (St.Petersburg Administration, 2016a)

## 4.1 Legislative basis

Legal framework for operations in waste management area in Russia is stated in Federal Law № 89 from 24.06.1998 with latest improvements in 2014. Currently, there are a new amendments coming into force in January 2017 that will bring significant changes in Russian municipal solid waste management system. This chapter will provide an overview of

changes took place in Russian legal system for the past decades from MSWM perspective. (№458-ФZ)

According to Article 23 of Russian Federal Law 89 (with latest improvements), there are a number of fundamental principals in economic regulations with regard to waste management:

Reduction of waste;
Waste inclusion into national economic turnover;
Payment for waste disposal;
Economic incentives for waste management activities. (Article 23 FL 89)

As provided by amendments to National Law № 89 from 2014 authorities on waste management are divided between two control levels: subjects of the Russian Federation (national level) and municipal formation (local level) (FL 89).

The following issues are addressed at the national level:

Organisation of waste collection process (including source separate collection);
Development and implementation of regional programs on waste management;
Adoption of Areal schemes for municipal waste management;
Regional waste controller selection.

Local authorities are responsible for following commitments:

Participation in organisation of waste collection and transportation processes on municipal level;
Participation in organisation of MSW treatment, utilization and disposal activities on municipal areas' level;

The primary target of Federal Law № 458 enacted in 2014 is to enable a development of strong environment for waste management in order to comply national legislation with OECD standards.

With relation to municipal solid waste management the Law create following guidelines:

a) maximal possible utilization of feedstock;
b) waste prevention at the source of generation;
c) waste volumes reduction and hazardous level lowering at the source;
d) waste treatment;
e) waste recycling;
f) waste neutralization;
g) waste disposal in environmentally sound manner;
h) adoption of economic regulatory tools for waste management;
i) stepwise restriction on disposal of precise waste compounds:
   - biodegradable waste fraction;
   - waste without mechanical/chemical pretreatment and secondary materials segregation.

The main changes induced by the legislative amendments and affecting creation of strong environment for implementation of new guidelines on waste management strategies are pointed out.

First of all, it is introduction of ecological dues from Russian producers. This due system has similar to European extended producer responsibility (EPR) principal targets. The money collected from manufactures are to be formed in special governmental fund. Thus, the financial reserve will be founded to cover the incentive demand of stakeholders of waste treatment businesses. As a result, it will establish a back up fund for development of enterprises targeted for waste material recycling. (Bulaeva 2009)

Another significant innovation is obligatory licensing for companies operating in field of waste collection, transportation, processing, recycling and disposal. Since the requirement relates to wastes of I to IV level of hazard, organizations engaged in MSW management must obtain a license to continue working. Consequently, companies only with transparent and legal waste management practices will stay in the waste management market. While planning MSW handling schemes, it will be possible to estimate all existing options to choose the best possible technology, since they are registered.

Based on this information, each municipality should fill in Territorial scheme of waste management.

Territorial scheme is an official record, which contains information about all activities in field of waste management. It is developed separately for each subdivision of the Russian Federation. Executive authority of subdivision is in charge of this document. The accession order should be free for every interested person. Thus, it will be published at the administrative web-page. The Territorial scheme of waste management should be developed by the end of autumn 2016. (St.Petersburg Administration, 2016e)

In more details, this record should include regional specific data on three major areas regarding waste management planning. Firstly, all waste generation sources with volumes of waste and waste accumulation sites should be fixed. Secondly, it should contain detailed information about all waste treatment/disposal facilities, operating in the subdivision. This data is to be represented also in flow diagram of MSW streams.

Thirdly, Territorial scheme should set strict annual targets for waste recycling, utilization, disposal rates.

Territorial schemes should be agreed within local authorities for every region in the end of autumn 2016. Thus, municipalities will be able to plan further development based on this schemes.

Farther, each subdivision of Russian Federation is required to organize waste management development plan in a regional specific Program of actions. This program is based on elaborated Territorial scheme. To control waste management as well as overall areal development process new legal entity Regional Waste Operator will be introduced in January 2017. (89FZ)

Regional Operator is chosen under competitive selection held by empower legal body. There is a strict zonal distribution of authority between different regional waste operators. The

election period is 10 years. However, the executive branch of government may sever relations with chosen operator in case of it's inefficiency.

On the one hand, regional operator enters into agreement with waste holders (housing organizations, private sector) regarding collection of their waste. By doing this, it is obliged to provide proper waste collection, transportation and treatment services. So, on the other hand, it enters into agreements with waste operators. Thus, it becomes responsible for the overall municipal waste life cycle under his area of responsibility.

Consequently, this innovative stakeholder is going to take a leading role in modified waste market. It will have command authority in decision making process regarding changes in regional waste management. Territorial scheme of waste management is planned to become a useful tools for assessing the best possible development options. Moreover, it will have monetary funds and right to invest in development of precise waste management infrastructure under his supervision.

From householders perspective there is a reformation of municipal waste fee system. Presently applied household waste costing system is rather controversial. Waste fee is included in accommodation payment. Thus, the amount of waste generated in one apartment is calculated on the housing floorspace basis. Scale of charges for sanitation was 3,56 rubles for square meter per month in 2015. (StP Rates Committee, 2015) As a result, households have established amount of waste generated per month and constant waste fee. However, this figures are not transparent in the housing bills, as they do not represent the actual waste generation. Moreover, this method does not take into account number of people living in the apartment, which confuse actual waste generation values.

Amendments to the Federal Law №89 on waste management that are coming in force since 2017 year, relocate residential waste fee to household utility rates bills. The foundation for waste generation rates is going to be the amount of people living in a precise apartment. Waste fee will be charged due to standards for waste generation per person multiplied by people registered in the apartment. By doing this, waste record keeping will shift from cubic meters units to tonnes. Even though, this method has gaps as well, since the figures obtained are still not true-life waste generation, it is a step forward in Russian waste management system.

### 4.1.1 Local laws and regulations in Saint Petersburg

Saint Petersburg is one of the three Russian cities of Federal importance – the Federal subject of Russian Federation. (The Constitution of the Russian Federation, Chapter 3, Article 65) Being one of the Federal Subject of Russian Federation, Saint Petersburg government is responsible for own laws and regulations development in accordance to Federal laws. (The Constitution, Article 5)

Presently, major document setting the approach to ecological regulation development is Saint Petersburg Governmental Regulation from 2013 "About Ecological policy of Saint Petersburg in time period to the year 2030". Hence, within the frame of Prevention and mitigation of negative environmental impact programme there are several targets set concerning municipal waste management:

1. Development of favorable economic conditions for waste generation reduction; waste inclusion into secondary economical turnover, including business support;
2. Encouragement of adaptation and implementation of low-waste and resource-saving technologies and equipment in compliance with legislation in force;
3. Establishment and further development of infrastructure for environmentally sound waste management, including waste processing and disposal applying best available technologies;
4. Step by step introduction, in compliance with existing legislation, banning on landfill for unsorted waste as well as waste that might be used as secondary raw materials;
5. Development of source separate collection system for household waste, including adoption of motivation of household waste sorting activity among citizens.

With relation to legislation changes, there will emerge two Regional Waste Operators, whose work will be tightly connected. On the one hand, there will be Regional waste operator of Saint Petersburg, having the city waste management under control. On the other hand, there will be Regional waste operator of Leningrad region. Any decisions of these two head legal entities should be coherent in order to obtain a strong waste management environment.

Territorial scheme of waste management in Saint Petersburg is already developed. For this work the leading experts of local waste market was attracted: waste collectors, transporters, academic institutes as well as leaders of related voluntary body. Currently, it is under assessment by the local authorities. ((St.Petersburg Administration, 2016e)

Moreover, to establish a sound control base for waste handling and increase the efficiency of waste management system in Saint Petersburg, there is Regional Waste Inventory in operation since 2013. The main target of this inventory is to supplement existing municipal waste management strategies with systematic information on major waste handling operations. Moreover, it provide a platform for communication for main waste processors as they can post advertisements on different type of waste operations. In addition, it enables communication process with community concerning waste management objectives and achievements. (FinNode,2012)

Tariff Committee of Saint Petersburg sets certain fees for apartment maintenance every year. Thus, waste collection and treatment (disposal) price is changing every year. In 2016 it amounted to 3,71 ruble per square meter of one's apartment per month. The costs originate from the MSW generation rates and collection fee with regard to service provider.

The generation rate is equal to 1,88 cubic meters per person per year. This figure is stable during last years, since it is estimated not measured value. The increase in waste management fees arises from collection and treatment services. MSW collection costs 459,35 ruble/$m^3$ and 589,22 ruble/$m^3$ for collection with further disposal in 2016. In 2015, for instance, both of these services were 100 rubles cheaper.

However, this upward movement is insignificant in terms of waste management treatment facilities development. Moreover, price differentiation for sole collection and collection with landfill disposal is extremely small. As a result, even though there is a room for households to contract with alternative waste treatment services, it would be economically unfeasible.

## 4.2 Saint Petersburg waste management system in operation

Sanitation process of residential sector of Saint Petersburg currently is hold in bulk, utilizing 6 or 0,75 cubic meters containers. Centralized waste management scheme does not imply any waste separation at the source. The important aggravating factor in Russian MSW collection system is that there is no segregation of hazardous wastes, such as batteries, from the general municipal waste stream. As a result, highly dangerous components might render difficult and environmental hazards of the following waste treatment. (Subov 2009)

### 4.1.1 Municipal waste collection and transportation system

MSW collection and transportation in Saint Petersburg is realized through wide range of privately own companies. On average, based on different statistical researches, the number is around 53 transportation organizations. Until recently, there was no obligation for having license on waste handling activity. As a result, a number of unfair business practices in the field of waste management is common issue. (Rosprirodnadzor 2012)

Market share dominance on waste transportation market hold two major haulers public JSC "Autopark Spechtrans №1" (south-east districts of Saint Petersburg) and "Autopark Spechtrans №6". Operational area of one company is usually restricted to one riverbank (Neva river). This is in order to minimize transportation load on the bridges construction.

In average, house management companies of high-rising buildings pays between 130 – 175 euros per month for municipal waste removal. (St.Petersburg Rates Committee, 2015a) The rate depends on waste volumes (container size) and removal frequency. Mainly, waste management scheme imply transportation to final disposal at municipal landfills. If wastes are transported to waste treatment facilities, price for removal services will be higher.

Transport enterprises mainly apply two-step waste collection from Saint Petersburg's residential areas. First, municipal waste from high-rise buildings is picked mainly in small 8 cubic meters containers. Then at transfer stations it is reloaded to bigger containers accompanied with additional compression. By doing this, transportation expenditures of haulaging little waste volumes are decreased. (Rosprirodnadzor, 2013)

The necessity of low volume containers is conditioned to compact planning of some Saint Petersburg districts. For example, historical part of the city, which fully include three districts Tsentralny, Admiralteysky and Petrogradsky, has mainly small yards with arch entrance. This constructional decision makes services of any waste containers larger than 1,1 $m^3$ impossible. Part of Kronshtadtsky, easten part of Vasileostrovsky and south-west part of Vyborgsky are also specified with this site development. (Rosprirodnadzor, 2013)

Another building type indicative for Saint Petersburg is areas of new site development. (Rosprirodnadzor, 2013) This includes following districts: Kalininsky, Krasnogvardeysky, Krasnoselsky, Kolpinsky, Primorsky, Moskovsky, Nevsky, Vyborgsky and Frunzensky and partly Vasileostrovsky Kronshtadtsky, Petrodvortsovy and Pushkinsky. These districts have sporadic building.

The main features regarding waste management in above districts is existence of garbage chutes in high-rise buildings. In addition, almost every yard in these districts has organised

waste ground with access way. As a result, waste collectors apply $6m^3$ containers for waste removal in these areas.

These constructions are required by Russian sanitary regulations. It induces certain rules on the way MSW collection is organised. For instance, garbage chucks are obligatory in apartment buildings of 5 floors and higher. Along special waste container yard with convenient transportation roads should be provided for this house type. (SanPin 42-128-4690-88)

Collection schedule planning is another important point at waste transportation scheme. It is regulated by Russian legislation as well. According to national sanitary regulation, MSW removal frequency differentiates with regard to the temperature (season). If it is more than 5°C, MSW should be removed daily; otherwise waste can be collected during three days (but not longer). (SanPin 42-128-4690-88)

Moreover, in order to comply with sanitary rules, waste collectors may operate only in certain time period. The target is to keep a comfortable noise voltage. As a result, MSW can be collected between 7 am and 11pm, any earlier or later activities are forbidden. (SanPin 42-128-4690-88)

In addition to national standards, Saint Petersburg has a local governmental regulation regarding cargo transport. (St.Petersburg Governmental regulation from № 272, 2012)

There are certain limitations on vehicle navigation around regional roads with regard to car tonnage. However, vehicle fleet applied for municipal waste collection may use city roads with license approved by Development Committee of Saint Petersburg.(Saint Petersburg Development Committee, 2015b) Hence, waste collectors traffic should be agreed not only on collection frequency needed, but also with local authorities.

Overall, two-phase municipal waste transportation method is a strong ground for waste material recovery operations. However, only major waste transportation companies may afford this activities. In general, there is no facilitated waste separation at these units. Waste transfer stations are used just to put MSW from one container to another.

It is largely due to the fact that number of transportation organizations operating in the city is high, collection of sufficient amounts of waste for profitable material recovery by one of them is rather hard task.

### 4.1.2 Municipal waste sorting facilities

*Hazardous wastes*

State unitary enterprise “Ecostroy” is unique provider of hazardous waste collection from households in Saint Petersburg. “Ecocar” project, mentioned previously, is part of their services. Also, they have “Ecoterminal” bring in points in operation around the city. (Saint Petersburg Administration, 2016a)

From the outset, while handling the hazardous waste challenge Saint Petersburg local authorities launched pilot projects on separate collection of luminescent and energy-saving lamps in 2008-2009. Based on this experience, in 2010 the chain “Ecocar” for systematic

household hazardous waste collection was established. (Saint Petersburg Administration, 2016a)

“Ecocar” program is a truck fleet of specially equipped vehicles for hazardous wastes receiving from citizens. They are spread all around the city, as they have an official schedule of parking places. Ecocars are certified to collect and treat following range of widely spread hazardous household waste from society: used mercury lamps, mercury thermometers, old batteries, accumulators, office equipment, car tyres, household chemistry, outdated medical drugs. This waste collection method is free of charge. Collected wastes are to be treated for secondary material recovery at specialized factory Saint Petersburg state unitary enterprise “Ecostroy”. Waste residues of production process are planned to be disposed at landfill for hazardous wastes “Krasnyy Bor”. (Saint Petersburg Administration, 2016a)

However, participation rates remained quite low as mobile receiving centers with constantly changing locations turned out to be inconvenient for citizens. Thus, to promote hazardous waste segregation by households “Ecoterminal” and “Ecobox” programs were set up.

Ecoterminals (for batteries and mercury lamps, termometers) as well as Ecoboxes (mainly for batteries) are provided by municipality on request and free of charge to any involved community. For example, representative of homeowners association, management company, educational institution might apply for arrangement of Ecobox on their responsibility. Lately, stationary “Ecoboxes” are put in operation in some chain food stores – Prisma, Karusel, Laim and gas station - PTK. As a result, collection rates increased almost one and a half time in one year (2015 compared to 2014), leading to 188 tonnes of hazardous wastes collected separately. Overall, taking year 2010 as a reference point there was a tremendous progress in a five year period. As at the outsets of Ecocar program hazardous waste collection rates hardly reached 2,5 tonnes in 2010. (Saint Petersburg Administration, 2016a)

*Sorting stations of mixed municipal solid waste*

According to General Scheme of Saint Petersburg cleaning of 2013, there are two main waste sorting facilities in the city: “Kvantum” JSC and “Resursosbereshenie” JSC. Both of them are privately owned enterprises.

“Kvantum” sorting process relies primary on manual separation method. Thus, recovery and efficiency rates remain rather low. The facility capacity is 90 thousand tonnes of MSW annually. Even though there is a project for increase up to 180 thousand, even current capacities are not fully loaded. Since there is no demand in the city.

On the contrary, “Resursosbereshenie” JSC invests in leading European equipment to obtain mechanized sorting process. As a result, it has two sorting facilities in the south districts of the city and one in Leningrad region (at subsidiary production unit Landfill “Novyi Svet Eco”).

“Autopark Spechtrans №1” is an associated company of “Resursosbereshenie”. Since it provides services only for south part of the city, waste sorting facilities are in the south part of Saint Petersburg.

“Staroobryadcheskaya” waste treatment plant was put into operation in 2011. The production capacity is 100 000 tonnes of MSW annually. Facility is capable of recovery

more than two-thirds income waste materials, leaving only 25 % headed to landfills. The end products are recoverable materials such as paper, plastics, metal, glass and RDF. (JSC "Autpark №1 Spechtrans" 2016a)

In addition, "Resursosbereshenie" JSC runs another waste sorting facility – "Predportovaya".

Moreover, there are three official transfer stations in Saint Petersburg in Petrogradsky, Kolpinsky and Primorsky districts with joint capacity of 600 tonnes per year. However, these sites provide only reloading with no waste sorting. In addition, any information about transfer station in Saint Petersburg is not transparent. There is a number of transfer stations which provides some waste separation but operates illegally. (GSh) Hence, it is hard to estimate the actual overall capacities city possesses in the area of waste sorting. (JSC "Autpark №1 Spechtrans" 2016a)

Summarizing, in practice, only two municipal waste sorting facilities are in operation in Saint Petersburg. They owned by one of the largest waste hauler – "Autopark №1".

Being part of holding company "Resursosbereshenie" JSC, Autopark №1 has motivation and funds to develop the field that is yet unprofitable in the country. (Drun personal interview 14 August 2016) However, even successful development of "Resursosbereshenie" JSC sorting facilities has insignificant contribution to overall town waste management system development.

Being one of the few municipal waste management stakeholders with integrated MSW treatment strategies, enterprises profitability is ambiguous, as there is no strong environment for further large-scale marketing of segregated waste materials. In addition, considerable share of hazardous waste compounds in MSW stream impair quality of recovered secondary materials that can be further treated and utilized. (Yazev, 2007) For example, segregated organic waste fraction, which might be processed to fertilizer, is inappropriate if contaminated with even one battery.

Among all the diversity of private and municipal waste collection services in Saint Petersburg, only few has waste sorting facilities. There number slightly increased during past years. The overall layout of officially registered MSW sorting facilities in Saint Petersburg are in Figure 11. (Rospotrebnadzor, 2012) This fact might be explained by low level of motivation for segregation of waste materials. First, rather high capital investments for sorting line construction. Moreover, while there is low price for secondary material and unstable market demand, payback period might be ages. Thus, until there is no legal incentive, there is no reason to engage to such unprofitable business.

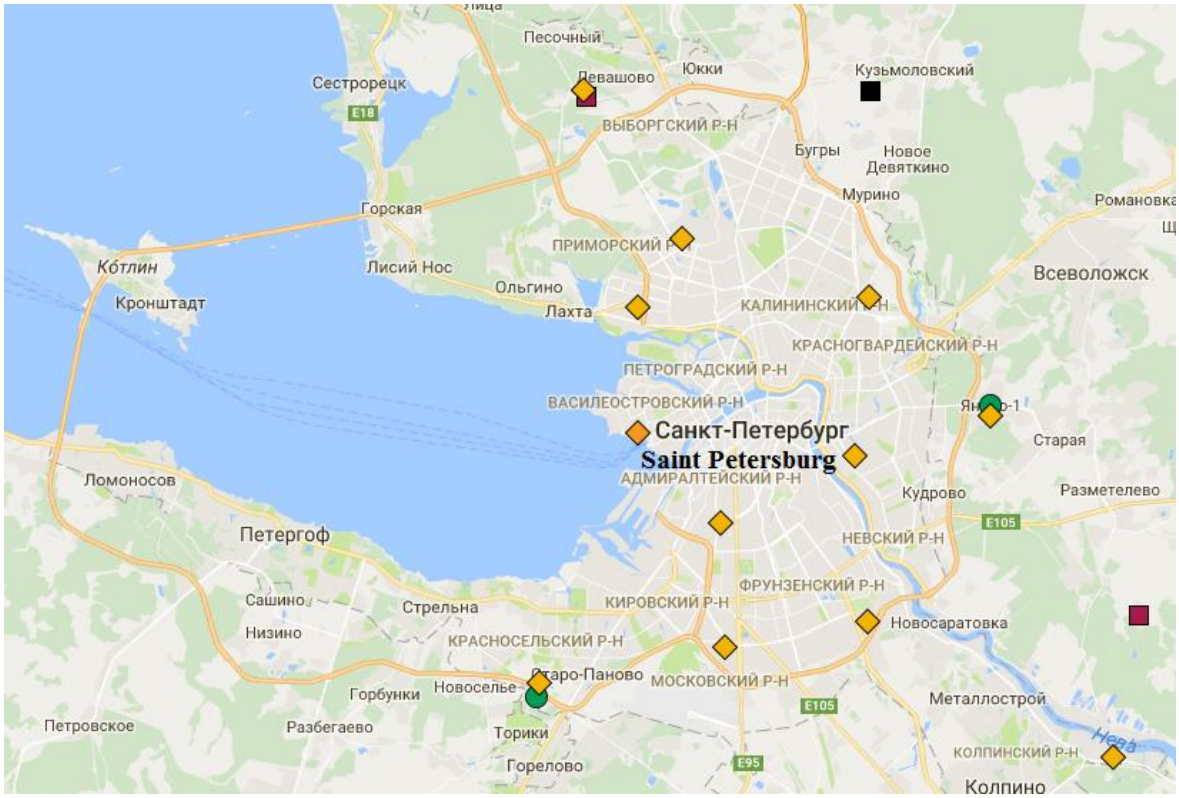


Figure 11. MSW sorting facilities (marked yellow rhombs), Saint Petersburg, 2016 (Source:Saint Petersburg Administration, 2016e)

To conclude, waste sorting business, as well as waste management field in general, is a shady area in Russia. Since currently there are some blanks in legislation leading to lack of controlling and preventative tools, it is seen as possibility to make cheap money. As a result, many uncertainties come out when this field is under assessment. The current waste management environment can be estimated only based on official reports. Thus, a wide range of waste processors stays unrecorded.

Currently operating MSW sorting facilities are designed for mixed waste stream. As a result, even existing capacities will require modernization if waste management schemes shift to, for example, commingled collection of recyclables. Anyway, investments for rearrangement will be needed. Hence, city's ability to treat sorted household wastes cannot be build upon existing waste sorting capacities.

*Source separation*

Besides, "Autopark Spechtrans №1" put up the capital in pilot development of household waste separation at source. Hence, it provides several containers for sorted waste fractions. The pilot project covers only limited areas of the city. (JSC "Autpark №1 Spechtrans" 2016b)

The design of separation scheme is based on the experimental cases. Hence, there is special container type colored in yellow or blue and yellow (Figure 12). It is for collection of dry recyclables: paper, glass, metals, plastic bottles and oilcans. The households are asked to compact delivering materials. Separated recyclables then taken by a special vehicle to

Predportovaya sorting center. Then commingled materials are separated, compressed and sold.


**Figure 12.** Special containers of "Autopark Spechtrans №1" for household waste separate collection, Saint Petersburg, 2016

*Public bring-in center*

Unique bring in center "EcoTochka" for separated waste is operating in Saint Petersburg in Frunzensky district. It is located at the parking lot of "Auchan" supermarket. The enterprise was established after successful Greenpeace public action in 2006. (Babanin I.,2008)

Wide range of materials are collected separately from the citizens: hazardous wastes, paper and cardboard, glass, metals, textile, plastics (7 types separately), tetra pack (Figure 13). All materials are then sold to recycling companies. No monetary relations are set between citizens and spot operators.


**Figure 13.** Public source separated waste bring in point "EcoTochka" in Saint Petersbrg, 2016

The site is working 24 hours 7 days a week. Moreover, it has maintenance man, who assist citizens in waste separation process according to announced schedule.

The disposition near supermarket is a win-win case for both Auchan and EcoTochka. The neighborhood of supermarket provide a constant flow of people coming by cars. Thus, they are able to bring and hand in waste materials before buying new one. Since the level of environmental consciousness is rising in Russian community, people find supermarkets providing such facilities to be more preferable. Hence, Auchan is benefiting from such ecofriendly neighbor putting no monetary stimulus to it's development. (Babanin I.,2009)

Summarizing, one public centralized separated waste collection point is not enough for such mega city as Saint Petersburg. Many citizens from distant districts are unable to participate, even if they would like to engage in waste sorting practices. However, Ecotochka case shows that it is possible to operate in Russian waste market not in the red even with no external support. It would be beneficial to the city if more centralized bring in point in operation.

Currently, there is a network of drop-off points for recyclables represented at a targeted map and reachable at a web-page *Recyclemap.ru*. Thus, every interested citizen may choose the most convenient place to bring picked waste material.

### 4.1.3 Voluntary body

There are several social active organizations operating in Saint Petersburg that advocate all-round transition to municipal waste separation at the source. The most broadly known are "Musora.Bol'she.Net" (or MBN, translation is No more waste) and "RazDel'nyi Sbor" (or RDS, transl. Separate Collection).

The MBN was founded as private enterprise in 2004. Nowadays it is spread in 90 Russian cities and 5 CIS countries, having tens of thousand followers. From the outset, main area of activities is organisation of public large-scale litter collection in order to clean polluted territory. Moreover, currently, they actively contribute to outreach activities. For instance, they develop Eco-classes program for kindergartens and elementary schools, organize

various special ecological workshops and lectures. Furthermore, number of their programs, such as “Ecoblock” and “Mortgage value of packaging materials” carry the torch for introducing waste source separate collection. (M.B.N. 2016a)

First one, Ecoblock, is aimed at improving waste management strategies in apartment houses. MBN act as waste sorting agent between house management companies and waste collection providers. Hence, they interpose presorting process at the place of waste generation before transportation. As a result, interested households might conveniently engage in waste sorting. (M.B.N. 2016b)

Second project see public events, such as football matches or music festivals, as a target place for introducing waste sorting. At first, certain little value is added to the cost of each beverage sold under this MBN’s program. Then, packaging waste, such as can, plastic or glass bottle, can be returned during this event with the same pay-back. As a result, this activity acculturate attitude to waste as a secondary material resource not a trough away garbage. Statistics proves that two third of beverage packaging is returned. Even though some end ups at garbage bins anyway, no packaging is left on the territory (public waste collectors). (M.B.N. 2016c)

Overall, “Musora.Bol’she.Net” actions increases the level of social environmental consciousness. Organisation expands involving more motivated proponents and fruitful projects all around the country. It gives hope for further approaching development of integrated waste managements in Saint Petersburg, since the share of concerned citizens growth each year.

Another voluntary body advocating separate collection of MSW in Saint Petersburg is RazDel’nyi Sbor. The fundamental idea of this group is to make waste sorting handy for every household. To fulfill this target volunteers organize public event once per month, where everyone may bring their separated waste materials. The event is held in every district of Saint Petersburg and even suburbs. Overall, once a month there is 22 bring in point operating locally in districts of Saint Petersburg and 3 points in Leningrad region. (Figure 14)

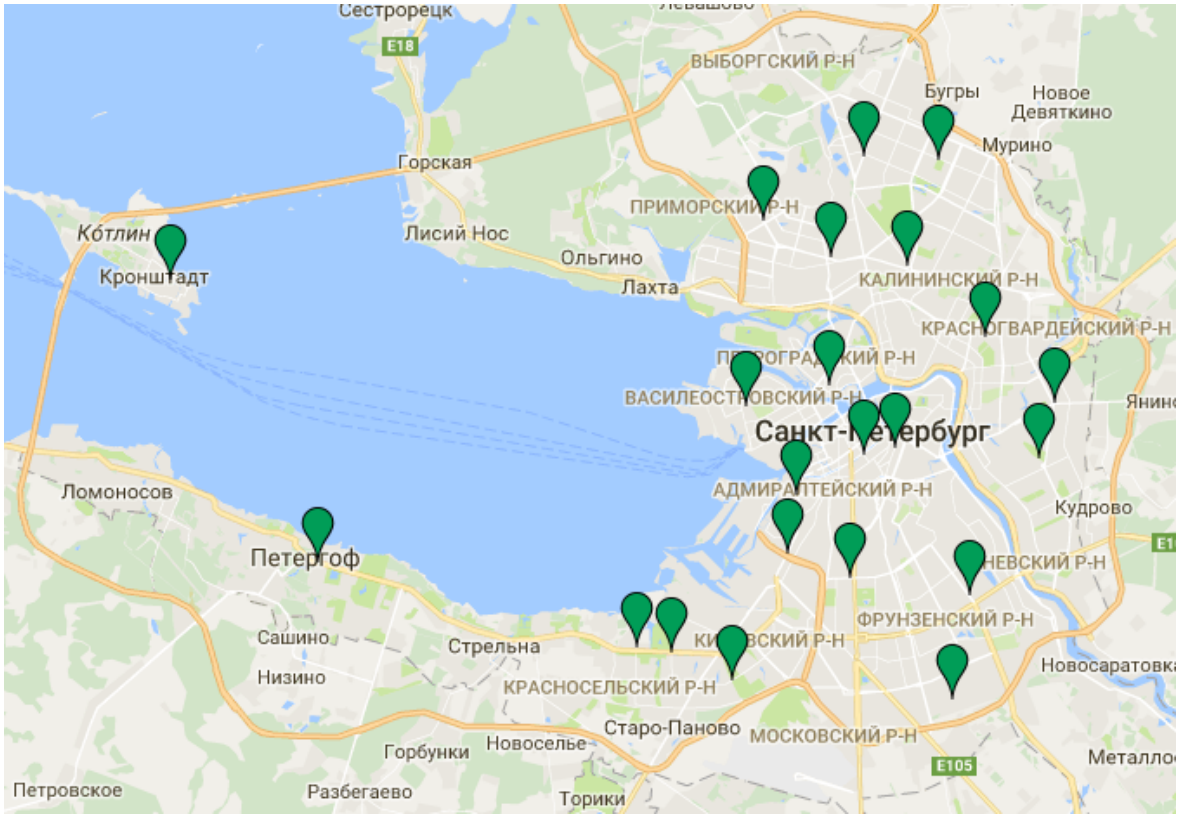


**Figure 14.** Location of RDS's bring in points on the map of Saint Petersburg, 2015

Experience shows that the number of average citizens involved in MSW sorting activities is growing every year. For instance, in 2015 the number of participants was more than 40 thousands, which almost doubled previous year's figures. Hence, it can be concluded that overall, the levels of environmental concern and community involvement are raising. People are ready to separate waste once comfortable infrastructure is provided.

However, taking into account the scale of the city, it is still less than 1% of Saint Petersburg total citizens participating in these events.

Taking RDS experience as an example, consider what outcomes might be expected from waste separation on a small scale in the current city's environment. The boundaries of this analyze is that only data provided by internet social community is available. Even though, the amount of collected waste materials were tracked, the initial value was quantity of collected bags. Hence, since accurate interpretation to mass shares of the waste is hard, only volume based analyze was carried.

From the outset, there is a list of waste materials proceeded at these voluntary running bring in points. Participating households might separately hand in following waste fractions: paper and cardboard, metals, glass, plastics, tetra pack. Plastic is asked to be separated to 5 different types as well. The separation is based on the demand of processors taking the gathered waste materials.

Turning to figures: volunteers managed to collect 27853 bags (of 240 liters) of separated MSW in 2015. It was estimated as approximately 86 tonnes of paper and cardboard, up to 84 tonnes of glass, 29,3 tonnes of plastic and 8,8 tonnes of metals. All of these values are

doubled compered to previous year. Volume composition of waste materials hand in during RDS's events represented at Figure 15. (RDS, 2016)

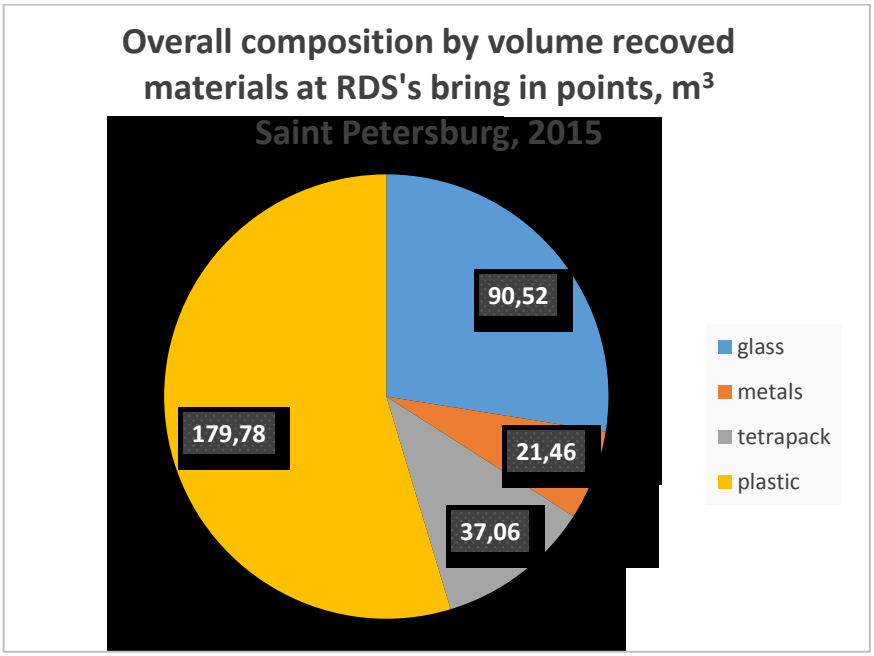


**Figure 15.** Volume composition of recovered materials during RDS's activities in 2015

Since amounts of monthly recovered materials were increasing, transportation costs increased as well. It was up to 3,5 thousand euros in 2015, which is quiet a price for voluntary running body. Moreover, money went to warehouse rental, waste bags purchase, promotion materials and other.

However, waste material deposit returned up to 6,8 thousand euros in 2015. That covers the transportation expenditures. RDS cooperates with 15 private enterprises in the field of waste recycling. Mainly it is single waste fraction processors and two jointly paper and plastic. (RDS 2016)

In addition, since RDS has a year history, they have a sponsorship help amounted to 3,3 thousands euros in 2015. (RDS 2016) Also, people make donations to support the idea.

To conclude, analyzing overall income and expenditures, RDS was able to earn almost 2,1 euros profit in 2015. Hence, even though transportation costs is a massive expenditure, sorted waste materials disposition to treatment shows a profit even in current city's environment. Need to be noted that all the waste separation work was done without any compensation to people, which is significant difference to any official waste collection.

It is worthy of note that "Razdel'nyi sbor" has no governmental support. They are able to hold these activities backed by volunteers' enthusiasm and belief in necessity of reachable waste sorting. That is to say, that once waste management is enough circumspect the positive outcome is certain. (Nagorskaya T., 2016)

### 4.1.4 Municipal waste treatment facilities

However, the Regional Program on waste management in Saint Petersburg was launched in 2012, still more than 80% of municipal solid waste generated is landfilled with no pretreatment. (RosStat, 2016)

*Disposal facilities*

In 2016 Saint Petersburg waste management system keeps 2 state licensed landfill for MSW (Novoselky and Novyy Svet Eco) and 2 landfills for hazardous wastes in operation. Moreover, there are 4 official private landfills. (Rospotrebnadzor, 2012)

Novoselky landfill is the oldest disposal facility in the city, being in operation since 1973. The landfill capacity is 32 Mt. It is located in north industrial estate of Saint Petersburg that is currently a part of the city. Since there is a restriction for disposition of waste treatment facilities within the city, there was a number of cases to close this facility.

Furthermore, since Novoselky is the oldest landfill city has, it is reaching the limits. It is in operation for 43 years at the present time. There is an estimation that it should be closed by the year 2017. (Saint Petersburg Administration, 2012)

Due to the long operational period, there is an environmental problem of odor nuisance in Primorsky district. Hence, with reference of unacceptable health conditions, citizens actively try to force the landfill shutdown during past years.

Up to date, site reclamation planning work is done. As consisted with project, the process will take 7 years. The monetary investments are estimated to 26 million euros. However, Saint Petersburg state budget makes no provision for this expense for the year 2016.(Kirillov V., 2013)

Moreover, Nikolay Bondarenko, vice-governor of Saint Petersburg, insists on incapability of landfill Novoselky shutdown at an early date. He argues that while there is no industrial capacities for alternative waste treatment, there is no other choice for waste disposal. (Amirhanov A. 2016)

The statement is fare enough, as one state owned alternative of “Novyy svet Eco” landfill is insufficient to cover the megapolis’s demand in waste disposal.

Novyy svet Eco is the second large landfill currently operating in Saint Petersburg. It is located in Leningrad region 30 km to the south from the city. The overall capacity is 18 million tonnes of waste with 900 kt annually.

The site was designed for Leningrad region needs in 2001. However, since one of the state landfill, operating in the south of the city, was closed in 2013, Novyy Svet Eco accepts major Saint Petersburg municipal waste stream on reserve capacities. As a result, if it continues working to capacity, the operational period will end by 2021.

Figure 16 represents the lay-out of main MSW processing facilities around the city at the moment.

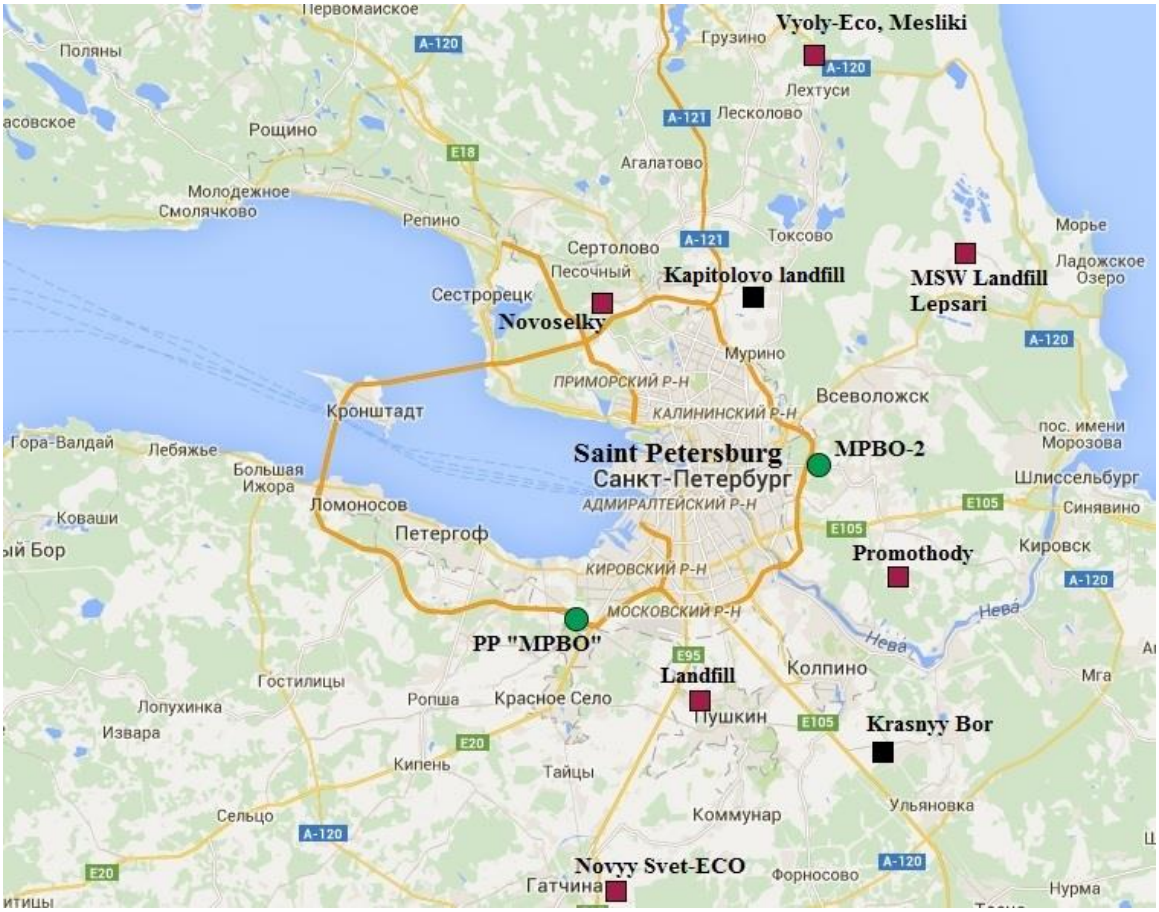


**Figure 16.** Lay-out of Saint Petersburg waste management system facilities, 2016 (green dots-waste treatment plants; black squares-hazardous waste landfills; red squares-MSW landfills)

In addition to state owned or officially recorded landfills there is a wide range of private businesses as well as illegal waste dump around the city. Along with official public landfills that are reaching their limits, illegal waste disposal pose a real treat to safe natural environment in Saint Petersburg's suburbs and Leningrad region.

According to governmental regulations, landfill disposal fees in Saint Petersburg and Leningrad region are fluctuating from 1,2 to 9,6 euros per tonne of MSW. (Saint Petersburg Rates Committee 2015, Leningrad region Rates Committee, 2016).

In comparison to European price tag for municipal waste landfilling, it is inadequate. While the largest landfill gate fee is in Luxemburg (149 euros/tonne), it is 50 euros at the average in Europe. Hence, waste disposal price is more than 5 times higher in Europe than in Russian. Besides higher price, there is a landfill tax, amounted on average to 26 euros. (EEA, 2016)

*Mechanical Biological Treatment (MBT) facility*

Megalopolis used to have two municipal waste treatment facilities in possession: St. Petersburg State Unitary Enterprise "The waste treatment plant" (MPBO-2) in settlement Yanino and Pilot waste treatment plant (PP MPBO) in Levashevo settlement. Presently, in terms of Regional program on waste management in Saint Petersburg for 2012-2020 these plants were united into governmental industrial complex on waste treatment – MPBO-2 with three facilities around the city.

Thus, there are two production sites for waste treatment in the south areas of the city and one waste disposal facility (landfill) in the north. Figure 16 represents lay-out of industrial facilities at the city map. Moreover, since the complex keeps a fleet with leading municipal equipment, it can provide waste collection from various residential areas and container types without any intermediate transportation party.

MPBO-2 became the head facility of this complex with MPBO pilot plant used as a secondary production site. Both are mechanical waste treatment plants. Industrial process of these facilities includes several steps. At first, received waste flow undergo manual separation process. The segregated compounds are then packed and further distributed on request to end processor. Magnetic separator is applied for iron scrap segregation. PET bottles are sorted by optical methods. Separated waste compounds and their prices are presented in the Table 4.

**Table 4.** Separated waste materials on MPBO-2 (with prices of further material realization 1euro=74,3 rubles)

| Recovered waste material | Packaging Unit | Price, Euro/unit |
|---|---|---|
| Corrugated board and paper | Bale of 190 kg | 0,08 |
| Newsprint paper | Bale of 220 kg | 0,04 |
| Cullet (mixture of differently colored glass) | Bulk | 20,2 |
| PET mixture | Bale of 62 kg | 0,34 |
| Various film materials mixture | Bales | 0,12 |
| HDPE | Bale of 95 kg | 0,27 |
| Scrap iron (cannery cans) | Bale of 30 kg | 0,07 |
| Aluminium scrap (beverage cans) | Bale of 30 kg | 0,78 |
| Aluminium (household scrap: kitchenware, sports equipment) | Bag | 0,74 |
| Brass scrap (machines and equipment details: screw, bolt, springs) | Bag | 1,82 |
| Copper scrap | Bag | 3,19 |
| Chromium steel scrap | Bag | 0,08 |

All waste left after sorting processes proceeds further to industrial complex facilities. MPBO-2 utilizes aerobic composting in biocylinders as the key treatment process. After biocylinders obtained compost product need to spend around six months at afterripening fields. This is a final production unit, aimed at reduction of methane share in the compost during systematic stirring. Finally, organic waste fraction turns into product used as fertilizer.

Originally, when MPBO-2 was designed in 1970, compost obtained during biodegradable waste treatment was planned to be utilized in agricultural sector. However, as there is no initial household waste source separation (even basic segregation of hazardous wastes), compost quality is quite low. For instance, end product of MSW treatment has high contamination levels of heavy metals.

Moreover, capacity of two plants are insufficient to process the waste in right production conditions. While industrial complex receives 200 000 tonnes annually, it is able to afford grounds for proper treatment of only 60 000 tonnes. That is why, conditions required for production of high-quality fertilizer from biodegradable waste fraction is severely troubled. Time periods that organic waste spend at biocylinders as well as at after-ripening fields are

significantly shorten in order to be able to treat more waste volumes. (Rospotrebnadzor, 2012)

As a result, compost product is not suitable for use in agriculture, as it does not comply with existing standards. Consequently, more than half of produced compost is disposed at landfill. Even though, MPBO-2 might partly utilize their compost product for reclamation of landfill edges, it turned out to be inefficient on practice. Moreover, due to production process infringements utilizing end product might be even dangerous owing to increased methane concentrations.

Noncompostable part left after MSW treatment is transported to landfill owned by the complex as well. Thus, MPBO-2 accomplish only partial waste decontamination without perceptible reduction of waste volumes headed to disposal. (Rospotrebnadzor, 2012)

Established industrial complex MPBO-2 possesses licensed landfill "Novoselky" in Leningrad region as a subsidiary for storage of municipal and industrial wastes. However, this landfill had been in operation since 1973 and was estimated to reach it's limits by year 2016. Even though it requires reclamation, Saint Petersburg's administration is lacking funds to facilitate this activity.

Under Regional Waste Management Program, the production capacity of MBPO-2 second facility Pilot plant is planned to be increased in 2012-2020. Thus, joint industrial complex capacity will be measured up to 600 000 tonnes of MSW annually. This will cover the urban demand for organic waste treatment in Saint Petersburg. However, since currently pilot plant is lacking financial support for development, the facility is mainly in use as another MSW landfill in MPBO-2 system.

Currently, cost of waste treatment at MPBO-2 is higher than disposal. MBPO-2 treatment complex charges 16,7 euros per tonne of MSW. While waste disposal fee at "Novoselky" landfill is around 8,5 euros per tonne. Moreover, the complex provide waste removal from households services at price of 1,6 euros per tonne. (St.Petersburg Rates Committee, 2016)

*Recycling facilities*

According to interviews with people actively involved in waste management in Saint Petersburg, there is a wide range of waste processors in the city or at its suburbs. These enterprises are commonly a private business oriented at recycling of one or two waste fractions. Their capacities are small but commonly still not covered with material supply.

Waste market environment is so that capital investments to open recycling business has a long payback period. Since the market price of waste disposal in Russia is low, there is low demand for alternative services.

Besides, there is a lack of public information about alternative waste treatment facilities. As a result, community see no point to engage in waste sorting, as anyway it would end up at landfills. Thus, since public participation rates in separate delivery of waste materials are low, it is hard to get a sufficient feedstock for enterprises. Consequently, currently, it is extremely hard to run business solely in Russian waste management market.

Section-shaped web-portal "Waste inventory" for waste management in Saint Petersburg and Leningrad region was launched in 2013. It was the main outcome of FinNode project

targeted for development of cross-boarder cooperation in this field. The major goal was to obtain a database of waste processors operating in the region.

However, the outcomes are insufficient for three years. Private enterprises are reluctant to register in this system. Russian legislation require any enterprise, operating in municipal waste management obtain a license. It is forbidden to provide any services regarding municipal waste treatment without this permit. Get one's business in full compliance with regulations requires time and money, many private industry do not have or want to spend. That is why, they stay away from the official record keeping in this field.

In turn, "Waste inventory" database's objective was connection of different waste processors existing in the city to minimize their risks and expenditures. Moreover, it was an informational campaign for citizens about alternative waste treatment methods and facilities city already has. In light of coming legislative change, there is a hope for further effective development and implementation of this project as a planning tool for Regional Waste operator.

Currently, the most reliable source of information regarding recycling alternatives city has might be found from Saint Petersburg Recycling Association. This is a nongovernmental cooperation of waste collectors, transporters, processors and developers of waste recycling technologies. Thus, it can be concluded that city has a number of processors for separated types of plastic (mainly PET and film), paper and cardboard, metals, some hazardous wastes, wood waste, rubber.

*Summary*

In figures, according to official data, Saint Petersburg has two waste treatment plants and 6 landfills. Landfill capacities are reaching their limits. It is estimated to last at latest until early 2020s.

Hence, there is an obvious demand for development of alternative industrial capacities for waste treatment and/or disposal.

However, detect locations for new landfills is highly problematic. Since there is legislative restriction on waste disposal facilities in the city boarders (89-FZ), Saint Petersburg is required to request Leningrad region municipality to allocate the territory. Regional authorities, in turn, is reluctant to provide space for Saint Petersburg municipal waste dumps. Hence, there is a serious bottleneck for new landfills arising

Summarizing, the city's waste disposal capacities are scarce. It is estimated to become fully terminate in 5 years. As a result, inevitably significant investments are required to waste management field in Saint Petersburg. Otherwise, the city will be buried under it's wastes. Hence, it is a high time for development of alternative methods of waste treatment.

With regard to municipal waste treatment, there is some industrial capacity in Saint Petersburg. Even though only one municipal complex is under official accounting, there is a network of private unrecorded processors of various separated waste materials. Hence, initial environment for municipal waste separate collection exists.

However, absence of official list of private businesses is obviously a complicating factor for further market development. Waste processors are scattered around the city and Leningrad

region. Since it is privately owned business, they have no external support. Thus, since municipal waste separation is poorly developed in Russian, processors run short of materials to cover their production capacities. As a result, a payback period is so long, that only one of five new enterprisers in waste management field manage to stay in business. Generally, they go bankrupt in half a year.

To conclude, Saint Petersburg has industrial rudiments to enhance a strong waste management environment. Even though existing capacities are insufficient to fulfill whole city's need, it is good grounds for modernization and development. When companies involved in waste management are fully listed in waste inventory, waste market will have a strong tool for cooperation and mutual development.

## 4.3 Waste management development perspectives from different stakeholders

Transition towards source separation was assessed considering positions of different involved waste market players. Thus, a number of interviews were held during summer and autumn 2016. The objective was to gain a better perception of the problem based on the qualitative judgments of experts of Russian waste management field.

The target was to interview representatives from all steps of municipal waste management system. Hence, there was an effort to form contacts with following stakeholders of waste management market: collection and transportation service providers, waste processors, recycling business owners, administrative body and voluntary body activists.

At first, the production manager of "Novyy Svet Eco", Alexey Myasnikov, offered an opinion on waste market development of waste disposal operators. Then, waste haulers' opinion was considered during discussion with "Autopark Spechtrans №1" representatives. Igor Drun is a manager of "Staroobryadcheskaya" sorting facility. He shared his outlook on waste separation having an impressive experience in municipal waste sorting directly in Saint Petersburg. Thus, Mr. Myasnikov and Mr.Drun drafted the main bottlenecks for transition towards source separated MSW management in Russia from leading industrial stakeholders' perspective.

Thirdly, Anna Garkusha express the public activists' opinion on the current challenge of waste market transformation. Moreover, she is actively involved as an external consultant during discussions on the governmental level regarding most possible pathway for waste management system development in Saint Petersburg. Thus, she highlighted not only the level of community involvement but also local authority's views on the issue.

Mindset of local government administration was also assessed from various public speeches and interviews, information provided on the official webpage. Moreover, a chairman of environmental panel attached to Legislative assembly of St. Petersburg, Victor Loshechko, appeared at a student forum in Saint Petersburg. Besides, Ivan Serebrichky, vice-chairman committee of St.Petersburg Committee on environmental management, shared his outlook on waste separation issue from municipal perspective. Overall, they outlined the main features of MSWM system from municipality's perspective as well as forecasted the most feasible development actions.

Moreover, to eliminate the risks of wrongly interpreted community mindset, a public survey was held. The outcomes enable judgments on average public attitude towards Russian waste management system as well as prospects of successful transition towards source separation.

Summarizing, the feedback was enthusiastic almost from all waste management stakeholders, except private sector of waste recycling entrepreneurship. Having conversation with several representatives, a conclusion upon general picture can be made though. Overall Russian recycling business is generally a small private enterprises trying to survive in waste market environment. This sector see support neither from authorities nor community. Upcoming legislative changes are, by and large, perceived as authorities putting a spoke in their wheels.

In general, even though not all target groups of waste market stakeholders was directly interviewed, the gathered feedback is estimated to be sufficient for further judgments. Since the resemblance in different parties' opinions is traced. Besides, major features of Russian waste management were highlighted. As a result, conclusions about most possible pathway for MSWM development can be drawn.

### 4.3.4 Viewpoint on MSW source separation of voluntary body leader

Anna Garkusha is the leader of social activity group "Razdel'nyy Sbor". This voluntary body organize public bring-in points for waste materials every month since 2011. During these years, they manage to make a significant contribution to increase in the level of public environmental consciousness. According to the record keeping, the share of citizens getting involved in waste separation locally at their houses is steadily increasing. Moreover, Anna actively involved in governmental projects as an external consultant on waste management issue. Hence, her expectations regarding actual possibilities of shift in MSWM for Saint Petersburg was of interest. (Garkusha, telephone interview, 16 October 2016)

*Lisiy Nos successful case*

Anna mentioned a good example of waste management transition happened recently at a small Saint Petersburg's suburb Lisiy Nos. The case provides a vision of a possible pathway for development on the larger scale.

Lisiy Nos is a residential settlement in the north of Saint Petersburg. It has 4854 inhabitants. (Rosstat, 2016) This municipal formation is rather detached, located in Kurortnyy district between Saint Petersburg and Sestrorezk. Hence, it has low impact of any external factors. As a result, any transitions are easier to introduce and trace the implementation process and outcomes straightaway.

The town has a dominant private sector. It used to have MSW management services provided by municipality. However, two years ago local authorities decided to cut the expenses. Thereby, private sector was switched from common municipal waste container sites to a privately owned. Owners of private houses were required to organize private waste collection site and contract collector. Thus, vast share of households in the town got responsibility to find service providers for their waste removal. Moreover, since this expense was divided to a separate fee, it was easy to assess. (Garkusha, telephone interview, 16 October 2016)

As a result, Lisiy Nos residents became aware of the price tag of their own waste management. The expenses were based on the waste generation rates straightforwardly. The more householder produced waste, the more frequently it ordered a truck to collect those wastes. Hence, the more money he paid for waste management services. Collection of one mixed waste container is approximately 1,8 euros. Consequently, the motivation to reduce one's wastes appeared. (Grudnikov V. 2015)

At that time, the activists of RDS voluntary body negotiated with administration on enabling waste source separation. (Garkusha, telephone interview, 16 October 2016) Eventually, addressing the occurred demand, municipality of Lisiy Nos organised bring in points for recyclable waste materials. Thus, people could bring in separated paper and cardboard, plastic bottles, glass and metals. The volunteers contracted different waste recycling companies to gather these materials for further treatment.

After a while, many residents became involved into source separation as it allowed to cut their waste management expenses. Currently, there is even negotiations to launch a collection of commingled recyclable materials straight from the households. Since the level of community involvement is high enough. However, there is a problem to define the suitable materials. As on the one hand, there is no industrial facilities to separate mixed recyclable fractions. On the other hand, facilitating separation to many fractions on the sport will increase transportation expenses.

Concluding, the main motive empowering local transition to source separated waste management at Lisiy Nos was an order from the top. If local authorities change the system in the way, when waste sorting becomes slightly remunerative for every person involved. Hence, the demand for source separation emerge, once there is an individual responsibility to pay for each mixed waste removal services. The main factor enabled MSW source separation at the sport was that households became obliged to pay for the waste they produce.

*Main factors preventing transition in MSWM system*

Anna highlighted several vulnerable points that retard transition towards source separated waste management in Saint Petersburg.

The main area of concern is indifference of House management companies (HMC) to source separation practices. The fundamental reasons for this is no official differentiated tariffs for recyclable materials removal. As a result, HMC see no point in shifting public utilities to separated waste collection.

Another factor is that any reorganizations demands investments. For example, to introduce separate collection, container sites require reconstruction and new containers. While containers for separated waste materials might be provided on the free basis by waste collection companies, reconstruction needs money input. House management companies are reluctant to pay for this as well as local authorities.

Hence, when going deeper in the details, the main obstacle is undeveloped legislative and regulation system. Presently, municipalities appropriate budgetary funds for development of waste management infrastructure. However, currently, it is unable to motivate nor industries nor community to engage in modifications of waste management system. So public is

looking forward to the amendments to national law on waste management coming in force since January 2017.

Ecological dues from Russian producers along with environmental taxation are introduced to form budget accounts. Regional solid waste operator (RSWO) is new independent body in charge of waste management in the area of responsibility. So, in turn, RSWO is believed to distribute budgetary money properly between main waste market player. Thus, it will bring to rights overall waste management industry.

Anna found it strange that currently local authorities has such low interest in developing MSWM. The prevalence of illegal dumping, along with state landfills reaching their limits are facts.

As an example of governmental indifference, Anna brought sore case of Krasnyy Bor landfill. This is hazardous landfill site in Leningrad region, which reached the limits 4 years ago. Hence, it should be closed and reclamation launched several years ago. However, as there was no alternatives for hazardous waste disposal, it continued receiving wastes until recently. (Garkusha, telephone interview, 16 October 2016)

Volunteers of Russian Greenpeace periodically brought the problem back to light of discussions. Nevertheless, this issue was by and large ignored by the local authorities. Only in summer 2016 the administrative decision was made, which finally restrict landfill operations. So, it took four years to take action to solve the challenge of hazardous waste disposal at the precise site. (Garkusha, telephone interview, 16 October 2016)

However, at this moment Saint Petersburg has an enormous problem of hazardous waste disposal. There are no alternatives for hazardous waste treatment that might cover the demand, other than Krasnyy Bor landfill.

Even though municipal wastes are less dangerous, there is a same pattern in the disposal area. The official landfill capacities are reaching their limits. There is no new sites under construction, as no new lands are detached. Along, there is hardly developed waste recycling industry. While waste generation in increasing parallel to city's population, waste disposal capacity is rapidly reducing. Thus, experts foresee unavoidable system collapse in MSWM sphere in Russia.

To summarize, community leaders see the fundamental obstacle to system transition in undeveloped legislation and control system.

*Most possible development pathway*

Anna expressed a strong believe that system transition in waste management should be built upon strong legislative basis.

As an external consultant, Anna is in opinion of developing waste management in the city through initial segregation of biodegradable waste fraction. She reasoned it by the fact that city already has two state MBT plants (MPBO-2). Their capacities are able to process the total estimated organic fraction generating in Saint Petersburg. Although modernization is still required, the process will take less time. Moreover, the capital investments in launching the transition will be much lower. (Garkusha, telephone interview, 16 October 2016)

Furthermore, due to Anna's work connected with organisation of RDS actions, she has an opportunity to communicate with waste recyclers. Thus, she claims that there is an industrial capacity for waste processing in Saint Petersburg and region. The scale is mostly small private enterprises. However, even these small capacities are not fully loaded.

Hence, some districts might straightforwardly switch to source separated waste management schemes. It only requires wise logistic planning (districts close to recycling industrial sites) in order to cut transportation expenses. Over the time, when public got used to waste sorting, new recycling businesses will be easier to set up. So, separation practices might be expanded over the whole city.

Community participating rates might be an area of concern. Mostly, society still demands educational programs on recycling and waste management. However, the progress of last four five years support the idea that citizens of Saint Petersburg are quickly learning and ready to engage into waste separation. (Garkusha, telephone interview, 16 October 2016)

The level of environmental consciousness is high enough to ensure positive outcomes ones source separated MSWM system is convenient to use. Even currently, material recovery rates at the central bring-in point are gradually increasing. This means that more people got involved in waste separation.

Summarizing, on behalf of independent expert in Saint Petersburg waste management, Anna sees biodegradable waste separation to be the first step in system transition. Further, the increase in sorted fractions will be parallel to recycling industry development. The community participation rates are believed to be sufficient almost from the outset, even without significant pecuniary advantage. The level of environmental concern in society is high enough to secure citizens engagement to source separated waste management once there is a reliable and convenient infrastructure.

### 4.3.2 Viewpoint on MSW source separation of industrial stakeholders

"Resursosbereshenie" JSC owns the leading waste sorting facility (Staroobryadcheskaya) as well as disposal site (landfill Novyy Svet-Eco) in Saint Petersburg. In addition, major waste collector Autopark Spechtrans №1 is a member of this structure. Thus, to assess transportation, sorting and disposal areas of MSWM in the city several conversations were held with manager of sorting facility – Drun Igor (Drun, personal interview, 14 August 2016) and technical manager of landfill site Myasnikov Alexey (Myasnikov, personal interview, 23 June 2016).

"Staroobryadcheskaya" is one of three official sorting facility for mixed MSW in Saint Petersburg. It utilize the most sophisticated sorting process in town, that enables segregation of metals, different types of plastic, paper and cardboard. Moreover, biodegradable fraction is screened and passed to MPBO-2. Moreover, sorting facility produces RDF. The company distribute this fuel to cement factories. However, this industry is no very interested in such fuels yet. Only European cement plants operating in Russia buy RDF as an additive to production process. (Drun, personal interview, 14 August 2016)

Overall site is a project of Autopark Spechtrans №1, so it is fully operated by this waste collector. Hence, Mr.Drun has a broad view on waste management system from both

transportation and sorting perspectives. As a result, he was more focused on challenges for improvements in waste sorting technologies.

Novyy Svet Eco is an advanced landfill facility in Leningrad region. Being part of "Resursosbereshenie" holding, it is engaged in adoption of the best European practices. Hence, this site gradually develops process flow for mixed MSW treatment. Currently, recovery of plastics (PET-bottles), metals, glass and biodegradable fraction is possible. Since, manual waste sorting is utilized the recovery rates are only 10-12 percent. Management team plans to modify the facility in order to increase recovery rates. Moreover, there is a landfill gas collection and treatment system on stream this winter. This is the first project on utilizing landfill gas as energy source in Russia. (Myasnikov, personal interview, 23 June 2016)

According to landfill's roadmap, management team of "Novyy Svet Eco" is sound both in European practices and Russian reality. As a result, Alexey opinion regarding their experience and possibilities of MSWM transition was of precise interest.

*Main factors preventing transition in MSWM system*

Main Saint Petersburg waste market stakeholders declare that removal of municipal refuse is an area of considerable concern in Russia. Even more challenges come into sight when waste recycling is assessed.

Even the leading waste market players experience the lack of external support. Both speakers confessed that any modernizations targeted to sustain environment has currently no economic benefits. On the contrary, they are detrimental. For example, construction of mixed waste separation line demands investments, while it is hardly profitable even in a long run. Thus, only a high level of environment consciousness of individuals in management teams empowers such modifications.

Thus, since it is unprofitable to introduce environmentally-oriented changes even to leading stakeholders, then there is no possibility for broader expansion. Small private transportation, recycling or sorting enterprises are hardly making both ends meet in present waste market environment. To sum up, currently only the awareness of responsibility for future generations, facilitate individual-driven changes locally. However, these incentives are insufficient to stay in waste management business.

To support this point, Drun (2016) referred to illegal waste dumping business as one of the main deterrent for MSWM development. He consider dumps to hinder expansion of centralized material recovery facilities (MRF) in the city.

Waste dumping is quite common in Saint Petersburg and Leningrad region. Since it is the easiest and fastest way to make waste management profitable. While waste disposal at state landfill site is around 45 euros per one waste truck, illegal site is less than half-priced. So dishonest waste collector earns about 25 euros pure profit. It is only for one truck. If there is approximately 10 hauls per day, the gains are really significant. Furthermore, these operators might reduce price for their services to provide a competitive offer. (Drun, personal interview, 14 August 2016)

There is no commercial benefit for waste haulers to contract with more expensive waste acceptors. Because it will lead to increase in prices for their own services. This, in turn, will decrease the company's competitive ability on the waste market, as there is a wide variety of cheaper service providers. As a result, honest waste transporters who cannot alter prices due to treatment service providers, often go bankrupt.

Igor Drun see two reasons behind this expansion: absence of any regulative tools and low level of environmental conscience in society. It was 2012 when municipal waste transportation became free from obtaining a license. As a result, almost anybody could get a suitable truck and operate as a waste collector. Hence, running such business required rather low initial investments. Moreover, if handing over wastes to unofficial companies (or dumping it somewhere), business became profitable straightaway. This area of entrepreneurship grew rapidly, while control system were poorly developed. Thus, waste transportation services become highly unreliable in terms of end point for municipal wastes.

Another bottleneck for MRF implementation, pointed out by manager of sorting facility, is lack of financial support in this industry. (Drun, personal interview, 14 August 2016) Any modifications towards sorting process demands initial investments in equipment. External investments are required either from municipality or private funds. Most commonly local authorities are experience lack of budget funds. So waste industry forced to find private funding for development by itself. However, Mr. Drun explained that, presently, it is a hard task.

Private investors consider putting money in MSWM system modernization to be not profitable. On the one hand, the payback period is quite long due to low market price of recovered waste materials. In addition, companies cannot increase prices for services to speed it up, as they won't be competitive on the market. As a result, private enterprises are disinterested in implementation of new sorting technologies. (Drun, personal interview, 14 August 2016)

On the other hand, generally speaking, any investments in development of MSWM system capacities is extremely unreliable in the country. As the market is full with various offers, the demand in one's services is hardly predictable. Moreover, waste sorting treatment facilities might be out of demand due to slightly higher prices.

Summarizing conversation with Mr.Drun, fundamental idea is that modernization of MSWM system requires reasonable investments. However, money inflow in waste management is blocked by current waste market environment. Sound monitor system, set by national and local legislation, is prerequisite to get Russian waste management under control.

In other words, only a total system change will secure cash inflow into MSWM transition process. For example, if all waste market player are obliged to implement sorting technologies, they become under the same pricing conditions. Hence, there will be a fair competition and opportunities for development.

Myasnikov (2016) highlighted another negative consequence of illegal waste dumping for MSWM development. For the MSW disposal business, crucial point is that waste collection companies fully control the price for MSW removal. This fact has several drawbacks, that influence overall development of MSWM industry.

Firstly, waste collection services include price for further waste treatment services. This is part of MSW removal fee (additionally to transportation costs). Waste collectors are responsible for contracting with further waste processors and choose whether sorting, recycling or disposal methods are applied. The situation on the market is such that while only few waste treatment facilities offers services with highest gate prices, there are numerous low-cost illegal landfills. (Myasnikov, personal interview, 23 June 2016)

In other words, the present system is such that waste holders pays for disposal services indirectly via transportation companies. Hence, it is waste haulers choice whether wastes end up at state facility or illegally dumped. The share of privately owned companies in transportation is rather notable. Hence, the competition is intense. For that matter, tempting possibility of cutting one's expenses occurs. There is no motivation for waste collector to pay higher price at municipal landfills or treatment facilities when there is a choice of cheaper ones. As a result, municipal wastes partly tend to be illegally landfilled.

However, this pattern of present municipal waste management system has one considerable outcome. Currently taxation system in Russian operates as follows. State waste treatment or disposal facilities set their gate price in relation with national taxation system. By doing this, certain amount of money is placed at local administrative funds. Subsequently, this money is supposed to be spent for modernization of these facilities in order to minimize their environmental impact. Put the other way round, this money might be a governmental source for funding transition towards IWMS. (Myasnikov, personal interview, 23 June 2016)

As consequence, illegal dumping not only pollutes environment, but also drive away money from the administrative funds. These funds, in turn, are supposed to be spent on development of MSWM system. Hence, any improvements of waste management system are delayed.

As a remark, Myasnikov (2016) also mentioned that the area of illegal dumping is broadly developed in Russia. This business area is seen as an easy money. Thus, it is extremely criminal. As a result, overall patterns of MSW management system in Russia are hardly changeable. Only stiffening of legislation and administrative control along with increase in deviation penalties might secure the environment for changes.

Moreover, to facilitate systematic transition to Integrated waste management system, the sufficient monetary funds are required. Inflow of money to waste industry might be achieved from two major sources. One is allocations coming from extended producer responsibility principle or ecological tax. It will oblige all producers to pay for recycling of their products in the end of it's life cycle. Another source is environmental fees with regard to waste treatment process. Within this framework, significant increase in a landfill tax is needed.

However, to secure this money transferring process from industries to environmental funds sound legislation and control systems is prerequisite. Otherwise, for instance, increase in a landfill tax might lead to increase in illegal dumping or waste incineration. That is definitely unwanted outcome.

To sum up, the basic idea of Mr. Myasnikov was that there is no administrative or legislative tools to control waste collection companies. While administration sets the certain tariffs for waste disposal at state landfills, there is nothing on waste transportation. In this case, it is impossible to control the process of money transfer from waste producers (households) to

state disposal sites. Even the small landfill tax there is, does not reach the administrative funds. As a result, administrative budgets lack funds to secure waste management transition.

Generalizing the main findings from both conversation, can be noted that all changes towards IWMS that "Resursosbereshenie" implemented is a goodwill of its management team. While there are involved leaders who see the urgent necessity of MSWM system modernization, the industrial capacities are developing. However, the certain tools for development are required as well.

The major obstacle is lack of governmental regulative tools that results in illegal waste dumping. (Nikitchenko E., 2013) Moreover, there is absolutely no monetary incentives for development from the governmental level. (Kuznezova N. 2015) On the contrary, the legislation system only prevent some good projects from implementation at this moment.

*Most possible development pathway*

While private waste processors and social activists insist on MSW separation at the source (at least to 5 fractions), leading waste sorting business argue that it is unnecessary. Moreover, such deep separation is unwanted from technological perspective.

Drun (2016) claims that MSW source separation to many fractions at the sport is useless. Even though activists are firm on cleaner material and higher recovery rates, the initial community education requires time. Transition to source separated waste management on the large scale won't happen during one night in Russian conditions. For instance, it took Sweden around two decades to shift to IWMS.

From outset, source separated waste streams would anyway had a high level of contamination. Thus, it will require pre-sorting before targeted material recycling. The city has no industrial capacities for that. In turn, Staroobryadcheskaya sorting facility is able to proceed mixed waste with material recovery and RDF production.

Hence, Mr. Drun (2016) claimed that the best option in Russian environment is to implement waste sorting at the landfill sites and transfer stations. Along with that, good idea is to parallel launch educational campaigns for citizens. The fundamental objective is to habituate community to separate their waste at least to two compounds: biodegradable and non-biodegradable. This change is expected to go smoothly the more especially as waste management system operated like this in Soviet Union time.

Another objective is to accustom wide public with necessity of material recovery during MSWM. Introduction of main sorting principals and recycling programs are needed. By doing this, the grounds for introducing collection of commingled recyclables from household waste will be secured.

After these steps only, Mr. Drun sees implementation of commingled recyclables collection to be argumentative. Since by this time new industrial capacities along with society will be ready for these changes.

As businessman involved in transportation services, Igor Drun believes that full source separation is feasible to introduce in Saint Petersburg. However, the scale should be limited. The large-scale transition towards initial separation by households is unfavorable, since the

city is large and number of recycling enterprises is insufficient. Thus, it will result in sophisticated transportation logistics and high expenses.

Alexey Myasnikov (2016) likewise favors the preference of commingled MSW collection over initially source separated. On the one hand, he marked the high level of environmental consciousness in society. That will lead to quite high participating rates once convenient source separated system is introduced. However, on the other hand, industrial waste treatment capacities needs proper assessment. Otherwise, citizens will produce separated materials, but these volumes will be impossible to process due to lack of recycling facilities. Consequently, commercial outcomes of several options require detailed estimation before final decision making.

To handle this problem, Myasnikov lays hopes on Regional solid waste operator (RSWO) coming in force next year. Having limited area in focus, generalized information about all waste management capacities in this area, this new stakeholder will be able to take a weighted decision on the best available technologies. Moreover, RSWO will have funds (from environmental fees and taxes) to invest in most rational development pathways.

Leading waste management market in the region for the past decades, Novyy Svet Eco is a good candidate to handle these responsibilities. As RSWO they will be able to assess if expenses for transition to source separated waste management pays off or not. If not, then centralized mixed waste sorting might be a better option than forced introduction of innovative waste management schemes. In this case, commingled MSW collection might become the best option.

Moreover, there was one more fact favoring commingled household waste collection over at the sport separation. Alexey mentioned that presently EU states conduct research on alternatives to source separated waste management. Having well operating MSWM system for the past decades, they tend to look for alternatives that are more effective. Hence, Russian undeveloped system might consider this experience and lean to alternative methods to waste separation at the spot. (Myasnikov, personal interview, 23 June 2016)

Summarizing, the feedback from leading MSW industrial stakeholders, there is an urgent necessity in MSWM system modification. The most preferable pathway for the industrial party is step-by-step transition towards system based on commingled collection. Such shift presents several strong points. By doing this, the operating industrial capacities will be used most rationally. Moreover, it will require the lowest investments to renew existing sites. Furthermore, in this case the least habitual adjustments from society is needed. Hence, short term overall positive outcomes are expected.

The main impulse enabling improvements in MSWM is expected from the governmental party. The amendments to operating legislation system is prerequisite to secure the transition process. Presently, the regulation system is changing in the right direction: waste minimization priority, innovative stakeholder. As a result, positive outcomes are seen be forthcoming next year.

However, needs to be noted that in general even leading stakeholders have indistinct notion on the changes that law revision is going to bring next year. Even though the core of new legislation system regarding waste management is strong and comply with best European

experience, nobody is too optimistic. Since there were a number of illustrative examples in Russian history when the laws are good but their implementation leaves much to be desired.

### 4.3.3 Viewpoint on MSW source separation of local authorities

It was hard to arrange personal meetings with representatives of local authorities. Thus, the basis for the assessment were official web pages of Administration of Saint Petersburg and Committees in particular. Moreover, there was a number of interviews with city's administrative body on the TV broadcast. The following participants shared their views: Victor Loshechko the head of ecological department of legislative assembly of Saint Petersburg governor, Denis Zavyalov chairman and Leonid Shimarek the head manager of Committee for development of Saint Petersburg, Valeriy Saposhnikov head of Petrogradskyy district . The focus of these programs was current waste management patterns and the development pathways. (Television channel "St.Petersburg", 2016) As result, a complete idea of an administrative position on waste management system in Saint Petersburg

The city has a local TV channel – "Saint Petersburg". It broadcasts a weekly program with detailed discussion of main problematic areas of the city. Since MSWM is a serious problem of the city, there were a number of programs at this channel during the past years with main administrative and social experts involved.

The main areas of these discussions are the major weaknesses of the current MSWM system as well as the possibility for improvements. There are two subjects actively brought to light by mass media.

One is the pilot project of source separated waste management introduced of 2006. It was a partial transition to MSW source separation in some city's districts. Even thought there was no special educational programs, the community got involved in the new rules of waste collection. However, the project outcomes were dissatisfactory. Since there was no infrastructure to enable further treatment of source separated wastes, the streams were collected by one truck and ended up disposed at landfills. By doing this, the feasibility of such system transition was broadly questioned. Since citizens fell into deep disenchantment with separation of wastes noticing their effort neglected. (Television channel "St.Petersburg", 2015)

Another case is an example of ongoing voluntary project in Petrogradskyy district. There are 12 bring in points for separated waste materials in this district operating since spring 2016. Volunteers have constructed these sites by with support of local administration and small private business. After six months of work, volunteers notes the progress in social attitude and increase in participation rates. (Television channel "St.Petersburg", 2015)

However, the overall feasibility of this method of household waste separation is still questioned by many factors. First of all, the current capacities of these bring-in points are estimated to be insufficient to cover the whole district demands. Once all district population is engaged in source separation, they won't be able to process such volumes. Moreover, the construction of these sites is improper for winter conditions. (Television channel "St.Petersburg",2016) Despite these facts, this example is a good foundation for discussion on various pathways of waste management transition in Saint Petersburg.

*Main factors preventing transition in MSWM system*

The assessment of both of these cases highlights one common bottleneck for development of current waste management system. There is no infrastructure to enable any efficiency in source separated waste treatment. Even if citizens follow rules of source separation, there is neither transportation offer nor industrial capacity to process separately collected materials.

The development of infrastructure is determinant by financial support. Administrative body leave this to the private business, while private investors see no profit in investing in waste management industry since it is extremely unstable. As a result, the development process is blocked.

Furthermore, so far, all changes towards source separated waste management were initiated and held by voluntary body. Thus, only local changes were obtained. Taking into account the large scale of the city, it is impossible to expect system transition to be driven by enthusiasm of small group of people.

As it was mentioned, local authorities see business to be the main driving force for waste infrastructure development. There are two reasons behind this. First, administration has insufficient budgetary funds to make significant investments in this area. On the contrary, recycling industry is seen as a profitable field of work. Thus, it is waste processors responsibility to invest in the infrastructure. Since in the end of the transition, they will obtain benefits from material recovery.

However, habitually, administrative body, on the one hand, is willing to control the waste management process as it always was. Leonid Shimarek marked the absences of legal instruments in waste management field as one of the main deterrent of system development. The Saint Petersburg operates waste management system without any changes since Soviet Union period. However, the waste processing companies were mainly changed from state owned to private sector. Thus, the financing source was changed. (Television channel "St.Petersburg", 2015)

Denis Zavyalov explained that the Federal Law 89 doesn't set municipal waste collection as one of communal services. It is open to concurrent market of private service providers. Thus, the service price depends on agreement between house management company and waste collection company. As a result, since it is contract relations between these two companies, no money allocates to infrastructure support. By doing this, the system significantly differs from the one in Soviet Union, when everything was under governmental control. (Television channel "St.Petersburg",2015)

On the other hand, there is a certain experience that it would be more effective if the business fully set the rules for the market. Leonid supported this idea by the EU example. He mentioned that there is Extended producer responsibility (EPR) principle in Europe. In general, meaning that production industry invest in waste treatment industry development by taxation system. Russian waste management industry is currently lacking such funding. However, the amendments to national legislation on waste management is foreseen to improve this pattern. (Federal Law 89-FZ)

In general, development of national regulation system in the related field is going to bring significant improvements to the overall system.

On the contrary to business involvement, the level of environmental consciousness among citizens is marked as high. Thus, once the convenient and reliable system is in operation, the participation rates in household waste source separation is expected to rapidly increase.

Summarizing, city's administration see the major challenge of current MSWM system in absence of waste market in the city. It is construed by a low level of business involvement in this process. Hence, the local authorities regard private entrepreneurship in waste management field to be the prior transition force.

*Most possible development pathway*

The development of effective waste management system is one of the top priorities in Environmental policy of Saint Petersburg for 2030. (St.Petersburg Administration, 2015) To meet this objective administration is planning to introduce source separate waste management programs as part of overall management. Moreover, they plan educational work with citizens by means of various festivals, forums open meetings and lectures. (St.Petersburg Administration, 2016)

At this moment, Committee for development of Saint Petersburg working on estimation of costs for containers sites' modernization. The outcomes are going to show whether it is feasible to implement transition to source separated containers over whole city or only decided districts. (Television channel "St.Petersburg", 2016)

Currently, the Saint Petersburg authorities are rather unite in the opion on the most possible waste management scenario in the city. They firmly believe in the efficiency of source separation only to two waste fractions: dry and wet. Loshechko reasoned that the transition would be the most effective in this case. Firstly, the city has basis for development of industrial capacities to treat these segregated waste streams. Even though technologies require some improvements, the investments will be minimized. Secondly, the segregation of biodegradable waste fraction was implemented during Soviet Union period. Thus, it would be easy to switch to this waste management system from the community perspective.

While these changes should be introduced by governmental motives, other waste material recovery it out of their responsibility. Bring in point for source separated waste materials acceptance from the citizens should be developed by business and market mechanisms.

### 4.3.4 Public opinion survey in Saint Petersburg

Citizens of Saint Petersburg is the most interest stakeholder when it comes to waste management system modernization. House management companies (HMC) that legally represent their interests, in turn, are the major customer on the waste market. As a result, success of citywide source separation program significantly depends on their attitude.

If there is a person in charge who actively support waste recycling, there is a positive transition towards waste separation at the source. On the contrary, when house management company see no point engaging to waste separation, even public interest won't be able to change the system.

Viewpoints regarding public opinion on waste source separation and recycling is extremely controversial. While community leaders claim 70 percent of citizens to be ready for system transition, administrative body incline this figures. They argue that there already was pilot project on waste separation with negative outcomes in 2006. (Banin, 2008) Hence, Russian community is not willing to change their habits regarding waste management and engage in waste separation at their kitchens.

On the one hand, group of public activists might be too enthusiastic in their estimations. Since they firmly believe in compulsive need of transition to waste separation, they might overestimate the general public mindset. While authorities, on the other hand, tend to decrease the actual magnitude of public tone. Since any municipal system change require monetary investments, they are reluctant to admit the need for modifications.

Thus, it was decided to conduct a public opinion survey in order to eliminate a possibility of private interest interference. To assess a public opinion on waste source separation a questionnaire was developed, attached at Appendix 1.

The objectives were to estimate the overall level of environmental consciousness among average households in Saint Petersburg as well as the state of art in environmental education in the city. Then, the share of households that already have knowledge about waste separation was evaluated.

The poll project has certain boundaries, though. Group of people that was questioned includes a wide age range as well as diversity of social statuses. However, the enquiry was held in Moskovskyy district of Saint Petersburg. Hence, mostly all households under assessment live in block of flat houses in dormitory suburb of Saint Petersburg. Since city's architecture significantly differs in central and outskirts districts, waste management infrastructure differentiate as well. Hence, some tendency to more spacious environment for waste management (container site construction) might occur in the overall opinion.

The opinion of 60 households living in Saint Petersburg were examined. After poll results assessment the following conclusion can be made.

The level of involvement in waste source separation among young and old generations is rather equal. The youth is ready to get involved because ecofriendly lifestyle is becoming more popular these days around the world. One of the consequence is that environmental problems are brought to light more often. As a result, people is more aware about environmental hazards and risks of week waste management system.

Moreover, young people travel extensively. Thus, they see good examples of European waste management system and level of community involvement. They see the quality of rural environment abroad and want the same conditions back home.

Respondents after 40 years mainly have a good memory of a Soviet Union waste management system. They called back that in previously organic waste was segregated at their houses. Moreover, there was a network for paper, cardboard, glass, metal collection from citizens. After Soviet Union collapse these bring in points mainly shut down, as there was no industrial demand for these recovered materials. Thus, in general, waste source separation is not a totally forgotten habit of Saint Petersburg.

Overall, more than two third of citizens are quite ready to engage in source separated waste management. Public is aware of environmental consequences of irrational waste management. Moreover, neighbor EU countries is a good example for Saint Petersburg citizens. They are willing to engage in waste separation in order to have a safe natural environment similar to foreign examples.

For instance, hazardous waste management system has a great development over five past years. From the outset, a tiny share of community in Saint Petersburg was aware of rules and risks of hazardous waste management. With the help of volunteers and local authorities there was developed a sound system for collection from the households. Along with informational campaigns. As a result, participation rates increased significantly in five-year period. (St.Petersburg Administration, 2016)

# 5 MOST POSSIBLE PATHWAY FOR INTRODUCTION OF SOURCE SEPARATED MSWM IN SAINT PETERSBURG

## 5.1 Current situation

Interviews showed that waste management stakeholders adhere to different opinions regarding transition in MSWM. One see initial source separation to be the only option to sustainable system, others would prefer sorting mixed waste without any changes. Highlighted change drivers as well as major obstacles are vary depending on touched area of waste management. Responsibilities for further development are delivered differently as well.

However, certain similarities among such diversity are traced. Almost every waste management party considers law enforcement as the corner-stone empowering transition process. Only the accents are put differently.

To summarize the general picture regarding waste management system and development patterns Tables 5-6 were developed.

**Table 5.** Summary of opinions on the areas of current system that primary hinders transition to source separated waste management

| Stakeholder | Main challenge area | | |
|---|---|---|---|
| | **Economic** | **Management** | **Social** |
| City administration | budget constraint | | |
| Volunteers of source separated collection | | lack of motivation at House management companies level<br>inconvenient infrastructure | |
| Citizens | no renumeration for separately collected materials | inconvenient waste management infrastructure (for source separated materials) | |
| MSW collection company | no financial support | | |
| MRF | no financial support | | |
| Disposal site (landfill) | | no new sites<br>illegal waste dumping<br>laws – old landfills | |
| Private recycling business | no incentives (subsidy tariffs) | no secured operation | low participation rates |

**Table 6.** Summary of opinions on the major drivers for transition in MSWM system

| Stakeholder | Main driving force | | |
|---|---|---|---|
| | **Economic** | **Management** | **Social** |
| City administration | · increase in taxation<br>· introduction of extended producer responsibility (EPR)<br>· ecological dues | | · pay-as-you-throw principle for households |
| Experts on waste management | · EPR | · infrastructure development<br>· law development and enforcement | · better environmental education<br>· increase in community involvement |
| Citizens | · remunerative approach to sorted waste materials | · infrastructure development<br>· better waste collection services<br>· data availability on waste treatment | · better environmental education |
| MSW collection company | · external financial support (tariffs, subsidy) | · law development and enforcement | · better environmental education |
| MRF | · external financial support (tariffs, subsidy) | · law development and enforcement | · better environmental education |
| Disposal site (landfill) | | · law development and enforcement | · better environmental education |
| Private recycling business | · external financial support (tariffs, subsidy) | · law development | · social support |

Even though there is no harmony in the opinions regarding best stage to introduce MSW source separation to the management system, the compromise decision on further development need to be made urgently.

However, discussions with various interested parties highlighted several common weak spots in overall management system. Moreover, even though the united pathway hasn't been drawn yet, there is a harmony in fundamental initiators of these changes. The information is shortly covered in tables above.

Almost all the respondent stakeholders see legislation as the key driver of changes. They expect that proper development and correspondence with environmental requirements, accompanied with laws enforcement to cut the possibility of illegal activities and make waste industry not so criminal.

## 5.2 Most possible development scenario

Study focus areas were current Russian waste management system concerning development option. Hence, assessment of Saint Petersburg waste management infrastructure was held parallel to summary analysis of various stakeholders' opinions. Technological facilities of current system as well as European experiences were taken into account.

Based on collected data as well as European practices several possible scenarios for MSWM system development were concluded. Table 7 summarizes these options. (Filho W et al. 2015)

It represents four most possible pathways for introduction of changes to waste management system in Saint Petersburg. The overall boundary is the risk of subjective personal opinion of respondents. (The conclusions regarding present waste management system as well as most possible development pathways are based on private conversations with different stakeholders) However, since there was notable coherence in key attitudes, the conclusions might be seen as reliable. Moreover, the focus was to the most possible options to implement immediately, as the system requires urgent improvements.

**Table 7.** Possible pathways for development of MSWM in Saint Petersburg

| **Scenario*** | **Number of containers** | **Separated fractions** | **Further treatment facilities** | **End product** | **Quality**** (Banin, 2009; Subov et al. 2011b; Subov, Borisova 2013) |
|---|---|---|---|---|---|
| **A** | 6 | · biowaste,<br>· paper& cardboard<br>· metals,<br>· glass,<br>· plastics;<br>· mixed waste | · MBT (for organic)<br>· waste recycling companies<br>· landfill | ·compost<br>·paper& cardboard<br>· metals,<br>· glass,<br>· plastics;<br>· residue waste | ·High for compost<br>·Highest for segregated recyclables<br>·Low generation of residue waste during treatment |
| **B** | 3 | · biowaste;<br>· commingled recyclables<br>· mixed waste | · MBT (for organic)<br>· MRF (for commingled)<br>· landfill | ·compost<br>·paper& cardboard<br>· metals,<br>· glass,<br>· plastics;<br>· residue waste | ·High for compost<br>·High quality of recyclables<br>·Low generation of residue waste during treatment (at MBT) |
| **C** | 2 | · commingled recyclables<br>· mixed waste | · MRF (for commingled)<br>· MRF (for mixed waste)<br>· landfill | ·paper&cardboard<br>· metals,<br>· glass,<br>· plastics;<br>· residue waste | ·High for commingled recyclables<br>·Low for materials recovered during mixed waste treatment |

| | | | | | |
|---|---|---|---|---|---|
| | | | | ·compost | ·High generation of residue waste during treatment |
| **Scenario*** | **Number of containers** | **Separated fractions** | **Further treatment facilities** | **End product** | **Quality**** |
| **D** | 1 | · mixed waste | · MRF (for mixed waste)<br>· landfill | ·paper& cardboard<br>· metals,<br>· glass,<br>· plastics;<br>· mixed waste<br>·compost | ·Low quality of materials recovered during mixed waste treatment<br><br>·High generation of residue waste during treatment |

*Scenario A: Source separation of biowaste, paper&cardboard, metals, glass, plastics; Scenario B: Biowaste separation at the source plus commingled recyclables collection from households; Scenario C: Commingled source separation of recyclables (plastic, paper&cardboard, glass, metal) only; Scenario D: No initial waste separation with mixed waste sorting at MRFs.
** Quality of segregated waste materials is estimated on the technological treatment potential basis only. Even though, personal factor (level of community involvement and following the rules) has a significant role in the material quality, it was omitted during this evaluation due to a high level of unpredictability.

The more detailed assessment of benefits and disadvantages of each scenario is summarized at the Table 8. The estimation of recovered material quality was made for the waste management system that is fully in operation. Hence, the high contamination level in the introduction stage is not taken into account.

**Table 8.** Summary of strengths and weaknesses of possible waste management scenarios. (Sources: Babin 2009; Rospotrebnadzor, 2013; Subov et al., 2011b)

| **Scenario*** | **Number of containers** | **Separated fractions** | **Strengths** | **Weaknesses** |
|---|---|---|---|---|
| **A** | 6 | · biowaste,<br>· paper& cardboard<br>· metals,<br>· glass,<br>· plastics;<br>· mixed waste | 1.High quality of recovered material<br>2.Possibility to develop private businesses separately for different waste streams<br>3. High material recovery rates | 1. High expenses on renovation of container sites<br>2. Sophisticated and expensive transportation logistics for many waste flows<br>3. Burden on average households (separation to many different components)<br>4. Harder for public to change habits. Hence, |

| | | | | |
|---|---|---|---|---|
| | | | | higher risk of contamination<br>5. Require huge investments into new industrial capacities for separated waste materials treatment |
| **Scenario*** | **Number of containers** | **Separated fractions** | **Strengths** | **Weaknesses** |
| **B** | 3 | · biowaste;<br>· commingled recyclables<br>· mixed waste | 1.High quality of recovered material<br>2. Require only insignificant modification of current waste treatment technologies city has<br>3. Less segregated fractions – less confusion among public (easier to get used to) | 1. Investments for industrial sites modification is needed |
| **C** | 2 | · commingled recyclables<br>· mixed waste | 1.Easy to implement transition<br>2.Easy for households to get used to only one container | 1.Biodegradable fraction is landfilled |
| **D** | 1 | · mixed waste | 1.Waste management system stays as it is | 1.Biodegradable fraction is landfilled<br>2. If there is still material recovery at landfill sites, the material quality is extremely low as well as recovery rates. |

Sequencing the transition towards source separated waste management should begin from the industrial capacities city poses. First thing is to identify recycling and treatment capacities city has for each separated material.

Hence, the initial segregation of biodegradable waste fraction is seen as most technically sound option. First, it is beneficial in terms of obtaining better rest material quality. Meaning, that it will lead to increase in recovery rates of mixed waste coming for further treatment. Moreover, successful European cases prove this step to be a good first move in MSWM system transition. Furthermore, Saint Petersburg has two MBT plant: MPBO-2 and MBPO Pilot plant, at this moment. Although, facilities required modernization in order to process pure organic wastes stream, the joint industrial capacity of two facilities is around 400 thousand tonnes. Even though this figure is less than biodegradable fraction (assessed in

Table 4 based on Rospotrebnadzor data), it is expected to be sufficient for initial recovery rates. Afterwards, when the transition process is launched, the more possibilities for system development will occur. Moreover, the investors will be more interest when the system is stable and operating environment is secured.

The next step to organize sorting and pretreatment facility (MRF). At this moment, Saint Petersburg has industrial capacities. However, investments to building new sites would be needed. These units might be utilized as mixed waste sorting facilities until the source separated system is fully introduced. Then, logistic should be properly planned.

The collection of separately collected household waste is one of the fundamental parts of overall MSWM system. It should be charged the same price (or slightly lower) as mixed wastes. By doing this, budgetary funds will be secured to invest in further infrastructure development as well as support for waste recycling entrepreneurship.

To conclude, need to be remarked that current Saint Petersburg system requires only slight modifications to launch the transition to IMSWM. The prior area for improvements is national and regional legislative base. On the one hand, the focus should shift on mitigating environmental impacts of each separate step of MSWM. Moreover, law enforcements to a notable extend are needed. Since it is the only tool to decrease the share of criminal business.

## CONCLUTION

It is obvious that field of municipal solid waste management requires an urgent modernization all over Russia. Being a European megalopolis, Saint Petersburg has a benefit of good neighboring examples from the one hand. There is an opportunity for research and adaptation of the best European practices. On another hand, the accelerating swell in city's population requires MSW system transition as soon as possible. To make the matters worse, existing waste management infrastructure is not able to meet the city's growing demands in waste disposal. While operating landfills are running out of capacities, there is no space for construction of new ones. Hence, the demand to invest in waste treatment (rather than disposal) technologies is acknowledged.

Gradually, the need for improvements in waste management system was finally admitted on the governmental level. Currently, Russian legislative system undergoes a significant modernization regarding municipal waste management. Amendments of existing laws are coming in force on 1st of January 2017. However, even though the modernization ideas are sound enough, experience shows that to secure a transition process strong subordinate legislation is required locally.

With this objection in mind, the working group of professionals involved in the area of waste management was formed. The objective was to draw main operators of existing in the city waste market in order to get a vision for mutual cooperative development. Hence, governmental representatives, transportation operators, waste processors and community leaders became members of this working group.

As a result, the project of "Territorial scheme in the field of waste management" for Saint Petersburg was designed in summer 2016. Currently, it is under proceedings on the reference with Saint Petersburg authorities. Once it is approved the framework for the development will be announced to all market players. By doing this, since there is pointed out pathway for development, business will be more willing to invest in precise technologies. Thus, the development of waste management market environment will be secured.

Moreover, approved Territorial scheme will become a planning tool for Regional operators in field of waste management. This new players for Russian waste market are going to come in force from year 2017. Even though current waste management stakeholders doubt about positive outcomes to be expected, this innovative chief player might bring structure and efficiency in overall waste management system in Russia.

With relation to municipal waste source separation, there are certain thresholds for straightaway implementation. First, Saint Petersburg has 5,2 million inhabitants. (Rosstat, 2016) This results in massive waste generation rates.

Taking into account the conducted assessment, the most feasible way to introduce municipal waste sorting in such megacity is to start with biodegradable waste segregation from the general stream. This first step proved to be efficient on European examples such as Tallinn case or Finland.

Moreover, separate treatment of biowaste is a common-sense step for Saint Petersburg, considering current waste treatment facilities in operation. Municipality has two treatment facilities PP MPBO and MPBO-2, which perfectly suits for organic waste treatment. The

joint capacity of these units after modernization is claimed to cover the total city's demand in organic waste treatment. Hence, the segregated fraction processor is already present in the market.

Once biodegradable matter is segregated from the start, the rest mixed MSW flow is cleaner. As a result, mixed waste sorting units would be able to significantly increase material recovery rates.

However, considerable change in industrial capacity is required. The number of sorting facilities is insufficient for total waste volumes treatment. Moreover, technologies in operation are targeted mainly to separation of organic matter, with low material recovery. So not only new sorting facilities but also technological development of existing units is needed.

The level of environmental consciousness in society is rather high. Large share of citizens are aware of benefits of waste separation (based on public opinion survey). Mostly, people are ready to participate once a convenient and sound infrastructure for source separated waste management is established.

In European countries, where IWMS is balanced system, every citizen pays a reasonable price for the management of his/her wastes. While the price is high for collection of mixed and organic waste, recyclable materials (such as paper, plastics, metals) are collected half priced or free of charge. The cost of these materials collection is covered by fund backed by packaging waste regulations. Thus, overall cost-efficiency of waste management system is supported.

On the contrary, Russian waste management system not only charge extremely low price from municipal waste generators. Along with that, there is no financial funds for packaging waste transportation or any infrastructure development, since there is no responsibilities on packaging producers.

Apparently, the tax revenues coming from citizens are insufficient to introduce any serious changes in municipal waste management system. Construction of powerful industrial complex for waste treatment requires significant monetary support. Municipal budget cannot afford these expenditures. Hence, private investors should be involved to the area of waste recycling. Investments might be from local as well as foreign interest parties.

Environmental law enforcement of 2017 is going to tighten the control over waste management area. Hence, the illegal businesses will gradually disappear, leaving space for market players. As Russian waste management market is at the early stage, it might be appealing for European companies. It can be seen as a new distribution area. Since there are hight demand for alter service providers, no competition is marked. As a result, better profits can be obtained.

Summarizing, the clear understanding of MSW volume, composition and generation spot is required prior to designing alternative industrial capacities in MSWM sector. Moreover, there should be a precise decision on the source of investments in this developments.

Even though there is no harmony in the opinions regarding best stage to introduce MSW separation to the management system, it is high time to implement changes. Once the

development cannot be postponed, it should be based on EU experience of several decades. By doing this, avoidance of making the same mistakes can be obtained.

To conclude, Saint Petersburg's environment (both technological facilities as well as community mindset) is favorable to introduce transition in waste management system. The prior objective is to improve working relations between different stakeholders. The local authorities should fully appreciate the benefits of source separated waste management as well as imminence of coming changes. Recycling entrepreneurship should realize the benefits of partnership and cooperation. The community should push harder to motivate overall changes. On a broader scale, proper sanitation in megapolis is a key to save urban environment and healthy life with everyone being responsible.

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Appendix 1. Public opinion poll regarding source separated waste management transition

1. Do you care about quality of natural environment?/ Интересуетесь ли Вы вопросами качества окружающей среды?
    a. Yes/ Да;
    b. Tend to yes/ Скорее да;
    c. Tend to noСкорее нет;
    d. No/ Нет;
2. Would you agree with the following statement: municipal solid waste is the major influence of human during daily activities?
   /Согласны ли Вы с тем, что именно твердые отходы есть основной фактор влияния человека на окружающую среду в повседневной деятельности?
    a. Yes/ Да;
    b. Tend to yes/ Скорее да;
    c. Tend to noСкорее нет;
    d. No/ Нет;
3. Do you feel confident with knowledge on waste source separation and treatment methods? /Достаточно ли полно Вы информированы о проблемах раздельного сбора и утилизации твердых отходов?
    a. Yes/ Да;
    b. Tend to yes/ Скорее да;
    c. Tend to noСкорее нет;
    d. No/ Нет;
4. Are you wiling to change habitual waste management patterns at your daily life? / Готовы ли Вы к рационализации системы сбора отходов в своей повседневной хозяйственной деятельности?
    a. Yes/ Да;
    b. Tend to yes/ Скорее да;
    c. Tend to noСкорее нет;
    d. No/ Нет;
5. Are you wiling to make efforts in order to popularize source separated waste management approach? / Готовы ли Вы приложить усилия для популяризации раздельного сбора мусора и централизованной утилизации отдельных видов отходов?
    a. Yes/ Да;
    b. Tend to yes/ Скорее да;
    c. Tend to noСкорее нет;
    d. No/ Нет;
6. Which stakeholders should engage mostly in waste management transition towards source separation? / Как, по Вашему мнению, должна осуществляться сепарация разнотипных отходов коммунальных хозяйств?
    a. Households and Housing companies / Совместными усилиями жильцов и коммунальных служб;
    b. Households on their own/ Самостоятельно жильцами;
    c. Housing companies on their own/ Силами коммунальных служб;
    d. Waste processing business/ Непосредственно организациями по переработке мусора;