

# Methodology of research for qualitative composition of municipal solid waste to select an optimal method of recycling

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**Abstract:** the article offers research methodology for qualitative composition of municipal solid waste to select an optimal method of recycling. The resource potential of waste directly depends on its composition and determines effectiveness of using various techniques, including separation and separate collection of refuse. The decision on re-equipment of waste-separating enterprise, which decreases the supply of waste to the burial site and provides economy of non-renewable energy sources, is well-grounded, because it allows to diminish an anthropogenic load on environment.

## 1. Introduction

The situation, which has developed recently in connection with steady annual growth in the amount of waste produced in Russia, brings to the start of irreversible process resulting in degradation of environment and creates real threat to health of population. At present the most widespread method of recycling is burial of waste. According to Eurostat average statistics figures for 27 EU countries, 40 % of MSW (municipal solid waste) is taken to the burial site, for Russia this figure is more than 90 %.

The key point of our research is connected with the necessity of taking immediate decisions for decrease in supply of MSW to the burial sites, taking into account available capacities of the waste-processing enterprises and the situation, when formation of litter is on the stable increase, but waste-processing industry is not sufficiently developed. The purpose of research is to decrease anthropogenic load on the environment at the expense of modernization and re-equipment of waste-processing enterprises.

We offer the methodology of research for qualitative composition of solid waste, that allows to choose an optimal method of waste recycling. Also we offer the technology of complex processing for municipal solid waste and production of alternative fuel.

Theoretical value of this research is in offering of new research methodology for qualitative composition of solid waste to choose an optimal method of waste recycling.

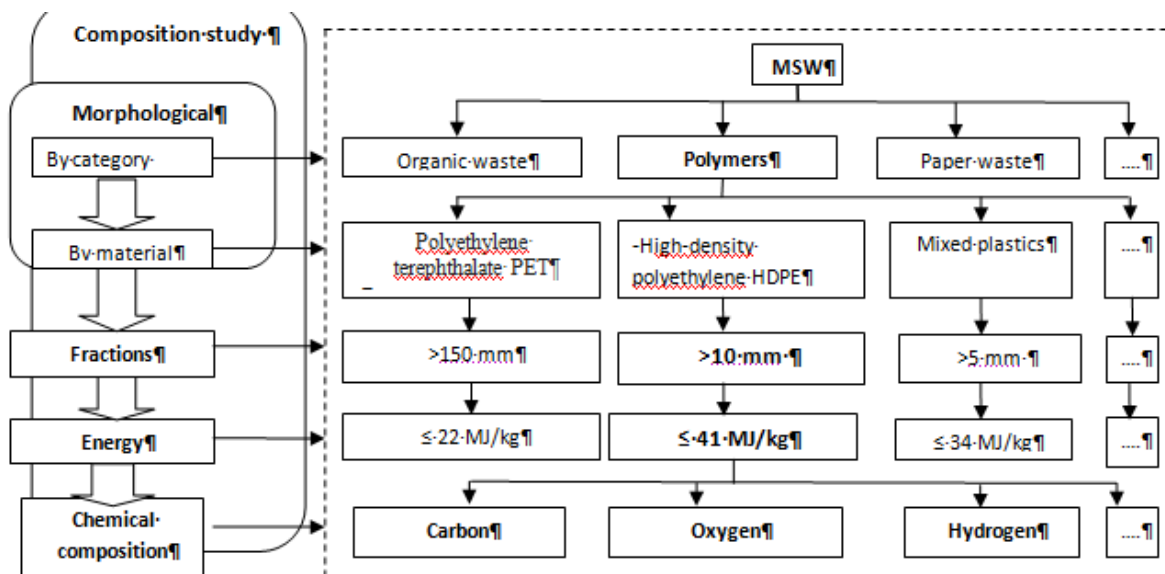
Practical importance of project implementation: solutions of modernizing waste-processing enterprises, offered in this scientific paper, will allow to decrease anthropogenic load on the environment at the expense of decreasing waste supply to waste-processing enterprises and economizing on non-renewable sources of energy.



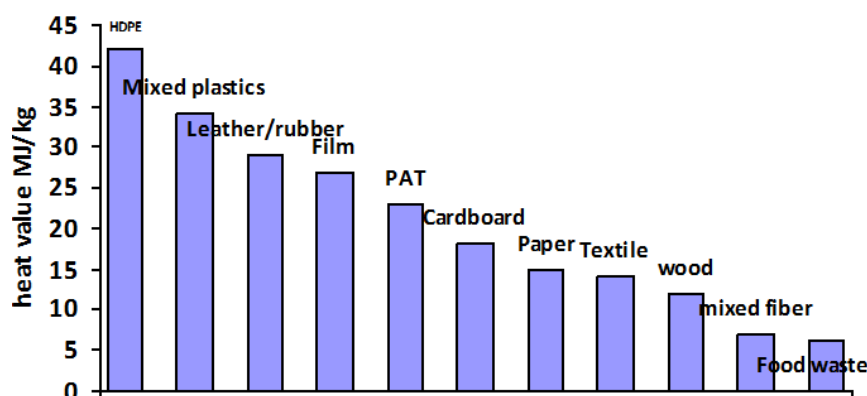
## 2. Theory

The paper offers **methodology of research for qualitative composition** of solid waste to choose an optimal technique of waste recycling; methodology is based on the analysis of several **levels: morphological, fractional, power and chemical** (figure1).

Results of MSW composition study show, that consumer waste possesses high resource potential, since more than 32 % of their weight is taken by food waste, more than 35 % are non-edible secondary material resources (SMR), which can be recycled. More than 60 % of consumer waste volume is taken by energy fractions (cardboard, paper, wood, textiles, polymeric waste (figure 2)), from which alternative renewable fuel can be produced (table.1).



**Figure 1.** Levels of study for choosing the optimal method of waste recycling



**Figure 2.** Heat content of MSW components

**Table 1.** Comparison of MSW energy fraction with other kinds of fuel

Type of fuel	Heat value, MJ/kg	Humidity, %	Ash content, %
MSW Energy fraction	12-16	15-25	10-22
Brown coal	21-32	3-10	5-10
Composite MSW	11-12	30-40	25-35

Comparison of MSW energy fraction with other kinds of fuel shows that SCW possesses less energy potential than coal. But in comparison with composite MSW it possesses a greater energy potential and better ecological characteristics in the process of burning due to smaller ash content. Thus, the major part of MSW can be used for secondary recycling, composting. At the same time it's possible to produce alternative renewable fuel from it.

The analysis of impact, produced by those methods of recycling MSW, which are most widespread in the world, has shown, that the least harmful for the environment are secondary processing, composting and production of solid fuel.

From results of qualitative analysis of MSW one can conclude, that MSW contains plenty of power-intensive components. That, in turn, proves expediency of burning SCW with the purpose of economizing renewable energy sources. As a result of search for patented technologies of burning SCW, there were found modern methods of producing solid fuel from SCW, resulting in production of an alternative kind of fuel for cement furnaces.

The analysis of statutory and regulatory basis in the sphere of specifications and classes of solid fuel, produced from waste, shows, that according to the universally accepted system of classification (table 2) solid fuel, produced from municipal waste, is subdivided into classes depending on values of the following parameters:

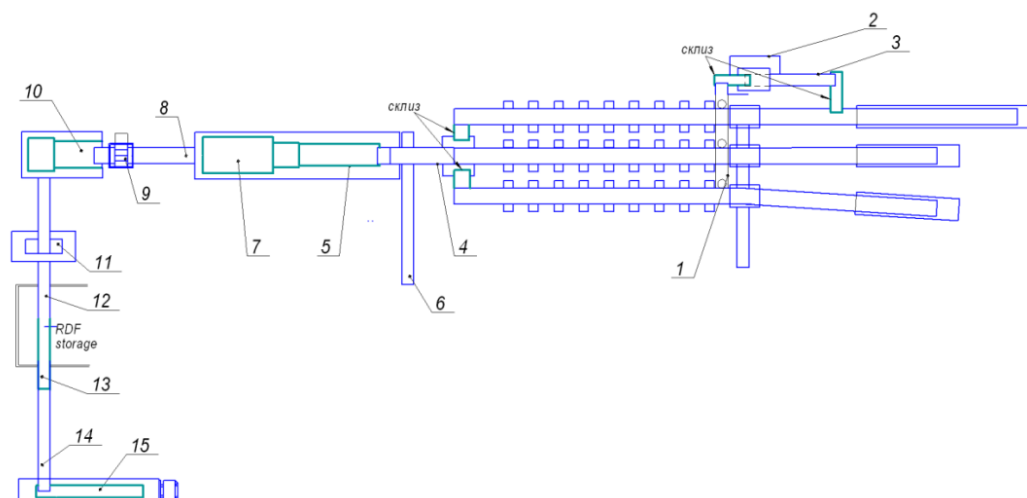
- arithmetic average of the lower heat value ( $Q_i$ );
- arithmetic average of chlorine content (Cl);
- arithmetic average and 80<sup>th</sup> percentile content of mercury (Hg).

**Table 2.** Parameters of solid fuel produced from waste according to Russian technical standard GOST P 54236—2010

Parameters	Statistics characteristics	Units of measurement	Class				
			1	2	3	4	5
Lower heat value Q, not less than	arithmetic average	MJ/kg	25	20	15	10	3
Content of Cl, not more than	arithmetic average	%	0.2	0.6	1	1.5	3
Content of Hg, not more than	averaged	mg/MJ	0.02	0.03	0.08	0.15	0.5
	80 <sup>th</sup> percentile	mg/MJ	0.04	0.06	0.16	0.30	1.00

On the basis of Russian technical standard GOST P 54236-2010 one can make a conclusion that for producing fuel from waste, the waste itself should possess high parameters of heat value.

Waste-recycling enterprise LLC "POVTOR" in the municipal district of Tolyatti in Russia gives an example of using methodology of qualitative composition of municipal solid waste. Research of morphological composition of MSW and WAS (waste after separation) allows to come to a conclusion, that after separation in the content of waste there are still plenty of components, possessing high calorific value. It proves expediency of using WAS for production of alternative fuel. Calculations of WAS heat value allow to make a conclusion, that on the basis of heat value parameters, solid fuel, produced as a result of recycling municipal solid waste by LLC "POVTOR", can correspond only to the 5th class of quality - that is the lowest limit of RDF quality (table. 2). For producing fuel of high quality it is necessary to improve technology of fuel preparation, adding the following kinds of equipment to technological process: a pulping engine, roll and air separators, a magnetic separator, an optical sorter, a crusher. The scheme of equipment arrangement is presented in figure 3.



**Figure 3.** The technological scheme of producing solid fuel from MSW (1-3 - the equipment for gathering and pulping bags with garbage; 5,7,9 and 10 - separators; 11 - crusher; 4, 6, 8, 10, 12-15 - supporting equipment (conveyors))

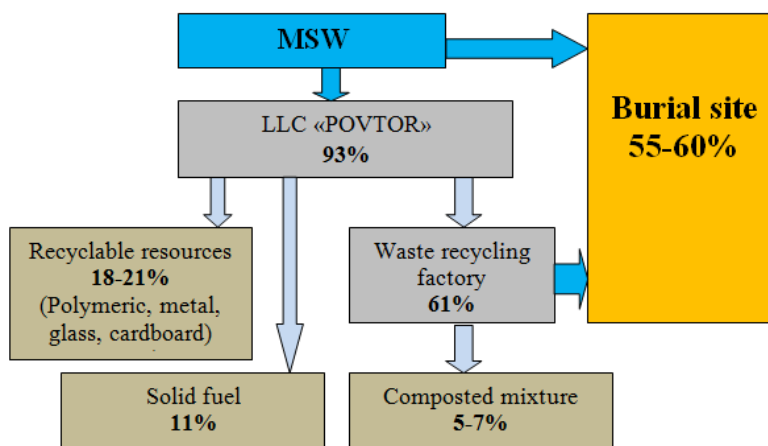
**Table 3.** Ecologic and economic efficiency of technological upgrading

Components	MSW %	MSW ton/year	SMR (secondary material resources) ton/year	Fuel ton/year	WAS(waste after separation) ton/year
<b>Paper for recycling</b>	<b>5.3%</b>	<b>6 625</b>	<b>2 800</b>	<b>3 213</b>	<b>613</b>
Cardboard	4.0%	5 000	2 800	1 750	450
Composite fiber	1.3%	1 625	0	1 463	163
<b>Plastics</b>	<b>20.3%</b>	<b>25 375</b>	<b>14 631</b>	<b>10 490</b>	<b>254</b>
PAT	4.3%	5 375	4 838	484	54
HDPE+LDPE	5.0%	6 250	5 625	563	63
Composite plastics	10.5%	13 125	4 069	8 925	131
film	0.5%	625	100	519	6
<b>Organic waste</b>	<b>27.0%</b>	<b>33 750</b>	<b>0</b>	<b>375</b>	<b>33 375</b>
Wood waste	1.0%	1 250	0	188	1 063
Rubber/leather	1.0%	1 250	0	188	1 063
Food waste	25.0%	31 250	0	0	31 250
<b>Textiles/fabric</b>	<b>3.0%</b>	<b>3 750</b>	<b>0</b>	<b>0</b>	<b>3 750</b>
<b>Glass</b>	<b>9.2%</b>	<b>11 500</b>	<b>7 360</b>	<b>0</b>	<b>4 140</b>
<b>Metals</b>	<b>1.8%</b>	<b>2 250</b>	<b>1 969</b>	<b>0</b>	<b>281</b>
Ferrous metals	1.5%	1 875	1654	0	221
Nonferrous metals - aluminum	0.3%	375	315	0	60
<b>Other waste</b>	<b>33.4%</b>	<b>41 750</b>	<b>0</b>	<b>0</b>	<b>41 750</b>
<b>Total</b>	<b>100.0%</b>	<b>125 000</b>	<b>26 760</b>	<b>14 078</b>	<b>84 163</b>

On the basis of undertaken calculations one can make a conclusion, that in case of upgrading the enterprise LLC "POVTOR" with the purpose of producing solid fuel from MSW, this waste-

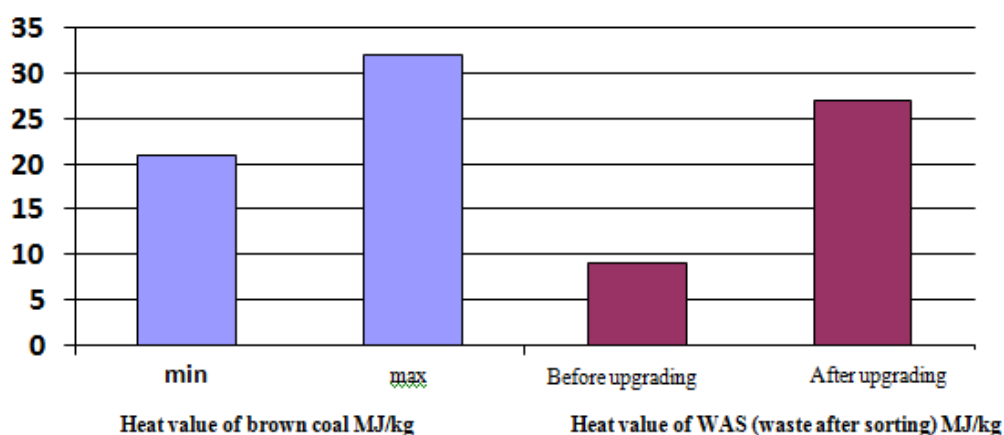
separating enterprise will produce more than 14 000 tons/years of solid fuel. The quantity of the formed tailings will decrease from 110652 to 84 163 tons/year. At the same time the quantity of selected secondary material resources will increase from 14348 up to 26 760 ton/year (table 3).

The scheme of disposing waste after carrying out upgrading of waste-recycling enterprise LLC "POVTOR" is presented in figure 4.



**Figure 4.** The modernized system of disposing municipal solid waste in the municipal district of Tolyatti city

Calculations of heat value for produced fuel allow to draw a conclusion that on the basis of heat value parameter, according to classification of solid fuel produced from consumer waste in accordance with Russian technical standard GOST P 54236-2010, quality of the solid fuel, produced as a result of recycling MSW on the upgraded conveyor of waste recycling in the enterprise LLC "POVTOR", will raise in 4 points and will correspond to the 1st class of quality - that is the highest limit of RDF quality. Comparison of heat value of the produced fuel with brown coal (figure 5.) evidently proves expediency of using solid fuel, produced from MSW, as an additive to brown coal.



**Figure 5.** Comparison of heat value of solid fuel made from MSW, produced by the upgraded MSW waste-recycling enterprise LLC "POVTOR", with brown coal

**Table 4.** Economic substantiation of expenses for upgrading

Parameters, input items	Current technology rub.	Upgraded technology rub.
<b>Production:</b>	<b>197 195 700</b>	<b>293 775 240</b>
Sorting recyclable resources on conveyer	81 554 900	161 334 440
Payment for recycling MSW	115 640 800	115 640 800
Fuel production	0	16 800 000
Basic wages	26 511 948	80 113 254
Deduction from basic wages	6 627 987	20 028 313
Amortization of equipment	4 822 732	14 242 732
Repair of equipment	2 476 191	4 704 763
Electric energy	1 704 000	5 057 153
Materials for pressing	1 633 377	4 976 506
Load and discharge	3 692 756	8 401 961
Working costs of mechanisms used for loading from the submitting conveyor to the sorting conveyor belt	9 048 310	15 557 296
Transporting MSW to the place of neutralization	57 263 708	43 555 340
Expenses for neutralization and burial of non-processed waste	61 933 950	47 107 572
Overhead charge	17 539 283	21 924 105
Expenses total	193 254 244,20	265 668 995
<b>Profitability</b>	<b>2%</b>	<b>11%</b>
<b>Profit</b>	<b>3 941 455.80</b>	<b>28 106 245</b>

Economic calculations allow to make a conclusion, that upgrading waste sorting complex of the enterprise LLC "Povtor" to the status of a wholesale MSW recycling enterprise, producing solid fuel, will be repaid in 3 years and 8 months.

### 3. Conclusions

During research the following problems are solved and the following **results** are achieved:

1. The research methodology for qualitative composition of MSW, that allows selecting an optimal method of recycling waste in any region, is offered. On the basis of this methodology research of SCW qualitative composition was conducted, it shows, that waste contains 35 % of materials, suitable for secondary recycling; it also shows, that some waste components possess high heat value. Thus, the major part of MSW can be used for secondary processing, composting and production of alternative renewable fuel from it.

2. Analysis of modern methods of waste processing discloses significant backlog of Russia in the sphere of handling waste (Germany has achieved the top position, using three basic methods: secondary processing, composting, safe burning (using MSW as RDF fuel), less than 3 % of municipal waste is sent to burial sites)).

3. On the basis of the undertaken analysis of consumer waste recycling system, it is necessary to note, that the average annual increase of MSW, formed in the city of Tolyatti, is 3 %, while the level of recycling remains unchanged in the course of many years. The existing scheme of processing MSW does not allow recycling more than 15 % of waste weight.

4. During research of technological processes of manufacturing fuel from MSW and capacities of processing MSW, available in the city of Tolyatti, it has been discovered, that there are similarities of

fuel production technologies and technologies of waste sorting complex, used on the enterprise LLC "POVTOR". To follow the purpose of decreasing expenses for the equipment of hi-tech manufacture of solid fuel from MSW, there was made a decision to upgrade waste sorting complex of the enterprise LLC "POVTOR" to a hi-tech complex to manufacture solid fuel from MSW. The developed technology represents multiphase separation of waste with extraction of secondary material resources, suitable for secondary use, further crushing of residual fractions and loading fuel into motor transport.

5. On the basis of the undertaken calculations, the conclusion can be made, that in case of upgrading waste separating complex of the enterprise LLC "POVTOR" to a hi-tech complex, that will manufacture solid fuel from MSW, more than 14 000 tons/years of solid fuel will be produced. The quantity of the formed tailings will decrease from 110 652 to 84 163 tons/years. At the same time the quantity of selected secondary material resources will increase from 14 348 up to 26 760 tons/year.

6. On the basis of the undertaken calculations one can make a conclusion, that according to parameters of heat value, according to classification of solid fuel made from consumer waste in accordance with Russian technical standard GOST P 54236-2010, quality of solid fuel, produced from recycling MSW on the upgraded conveyer of waste recycling enterprise LLC "POVTOR", will increase in 4 points and will correspond to the 1st class of quality - that is the highest parameter of RDF quality.

7. The undertaken calculations of upgrading waste sorting complex of the enterprise LLC "POVTOR" to the state of enterprise, producing solid fuel from MSW, show, that the above described measures are effective for decrease in waste supply and increase in efficiency of a waste-recycling enterprise.

8. The undertaken ecological and economic assessment showed, that the offered upgrading allows to produce more than 14 000 tons/years of solid fuel, to lower quantity of the formed tailings from 110 652 to 84 163 tons/years, to increase quantity of selected secondary material resources from 14 348 up to 26 760 tons/year, to raise profit of the enterprise in more than 24 million rub/year.

## References

- [1] Vasilyev A V Khamidullova L R Hyukhtina L V Environmental control of toxicity of urban territories using biological monitoring methods *Proc of the international scientific conference (X International forum) Architecture Design Landscape "Le vie dei Mercanti"* 30 May – 4 June 2012 Aversa-Capri Italy (2012) pp 1245-1252
- [2] Ezeah C Fazakerley J A Roberts C L Emerging trends in informal sector recycling in developing and transition countries *Waste management* 2013 – Elsevier
- [3] Zen I S Noor Z Z Yusuf R O The profiles of household solid waste recyclers and non-recyclers in Kuala Lumpur Malaysia - *Habitat International* 2014 – Elsevier
- [4] Bernal M P Albuquerque J A Moral R Composting of animal manures and chemical criteria for compost maturity assessment *A review Bioresource Technology* 100 (22) pp 5444-5453
- [5] Moniruzzaman S M Bari Q H Fukuhara T Recycling Practices of Solid Waste in Khulna City Bangladesh *The Journal of Solid Waste Technology and Management* 37 (1) pp 1-15
- [6] Franchetti M J The Solid Waste Analysis and Minimization Research Project-A Collaborative Economic Stimulus and Environmental Protection Initiative in Northwest OHIO USA *The Journal of Solid Waste Technology and Management* 35 (2) pp 88-94
- [7] Fruergaard T Ekvall T Astrup T Energy use and recovery in waste management and implications for accounting of greenhouse gases and global warming contributions *Waste Management & Research*
- [8] Kopyscinski J Schildhauer T J Biollaz S Production of synthetic natural gas (SNG) from coal and dry biomass—*A technology review from 1950 to 2009 Fuel* 89 (8) pp 1763-1783
- [9] Boldt E Franchetti M Total Sustainability Assessments for Manufacturing Operations Using the Lean Six Sigma Approach *Science Journal of Environmental Engineering Research* 2013
- [10] Franchetti M J Spivak A Concepts Methods and Strategies for Zero-Waste in Manufacturing Green Manufacturing Processes and Systems pp 73-102