Household Waste Recycling Technologies

A A Babaeva¹, E V Grigorieva²

¹senior lecturer of the Chair of industry economics of the Chuvash State University named after I. N. Ulyanov FGBOU VO, Cheboksary, Russia
²senior lecturer of the Chair of industry economics of the Chuvash State University named after I. N. Ulyanov FGBOU VO, Cheboksary, Russia

E-mail: any9196@yandex.ru, usb78@bk.ru

Abstract. The paper touches upon the environmental issues of the modern civilization and the new technologies of waste recycling. The paper also dwells upon waste-free production where all the raw materials are transformed into products which is, at the same time, optimized in terms of process, economic, social and environmental criteria. There are also given the figures of increase of garbage volume in various countries including Russia. There are stated the most dangerous products of decomposition of plastic. In the article there are also considered the modern technologies of waste recycling which is the most prospective way to solve the issue of urban landfills. There are given the examples of recycling of combustible waste, rotting waste, medical waste and old cars without harming the environment.

1. Introduction
Currently the main source of pollution of atmosphere and environment is human economic activity [13, 14]. Environment is exposed to significant amounts of gaseous, liquid and solid waste. Various chemical substances contained in waste get to environment and then travel along environmental links from one chain to another and end up in a human body. It is impossible to find a place on Earth without any pollutants at all. Even short-term exposure of human body to pollutants may cause harm. Ingestion of toxic substances in large concentrations in human body may cause loss of consciousness, acute intoxication and sometimes death. Smog of cities or accidental release of toxic substances by industrial facilities is an example of such effect.

The development of equipment and technology for processing and using industrial and consumer waste is one of the most complex environmental problems. Abroad, there is an extensive network of standards that strictly define the possibility of processing certain wastes using a particular technology, depending on the presence of specific toxic components in them.

In Russia, the problem of complex processing and use of production and consumption waste has been intensively considered since 1975. Currently, there is a significant accumulation of scientific, technical and economic experience in using promising methods of waste management.

2. Actuality
The problem of household waste is now becoming more and more urgent for a number of reasons:
- the volume of household waste is continuously increasing both in absolute terms and per capita;
- the composition of waste is becoming more complex, including an increasing number of environmentally hazardous elements;
- the attitude of the population with increasing environmental literacy to traditional methods of garbage collection is becoming more and more negative;
- the economy of waste management is becoming more complex, and the cost of waste disposal is increasing;
- the emergence of new technologies for waste disposal, including modern separation systems, the use of waste as secondary raw materials for new production.

To build the capacity of secondary resources based on solid waste, an integrated waste management system is necessary, supported and supported by legislative acts that allow both producers and consumers of secondary resources products to be interested in creating such a system and its results.

Technologies [1] applied by humankind are primarily aimed at use of non-renewable natural resources such as oil, coal, ores, etc. Moreover, their use in production leads to disturbances in the surrounding world: reduction of soil fertility and the amount of fresh water, atmosphere pollution [2, 5].

On average, 5.1 bln. tonnes of carbon dioxide released to atmosphere annually. It leads to depletion of ozone layer and appearing of ozone holes. Ultraviolet rays causing cancer in humans pass through these holes. There is less and less oxygen on Earth and more and more exhaust gases produced by ferrous metals and chemical industries, boilers, transport.

According to calculations made by scientists as much as 11,000 freight carriages of harmful substances get to water reservoirs globally every year. It is reported that detergent has been detected even in the Arctic waters.

It took hundreds and even thousands of years to form a soil layer, but it can be destroyed overnight. According to the data about one quarter of fertile soil [5] has been destroyed on Earth through the recent century.

3. Theoretical part

Today humankind offers a diverse structure of all the kinds of household and industrial waste. Waste have been slowly accumulating and became a real disaster. Until recently the most widespread method of household waste treatment was to move it to landfill, which evidently wasn't solving the problem and even exacerbated it. Landfills present an epidemic threat and inevitably become a large source of biological pollution. The primary cause of greenhouse effect, ozone layer depletion and other global disasters is methane - the main component of biogas. A total of over one hundred of toxic substances gets to environment from the waste. Often landfills get on fire evolving poisonous gas to atmosphere.

Huge territories[11] are alienated for at least ten years for arrangement of landfills while these lands surely could be used with greater benefit. And, of course, it takes a lot of money to found a landfill and to maintain it in compliance with modern environment protection requirements. Even reclamation of landfill is an expensive thing to do. Reclamation is a complex of measures aimed at ceasing harmful impact of landfills on environment including soil, air and ground waters. Transportation costs are also significant due to landfills are located far from city [6, 7].

The amount of garbage is constantly growing. Today its 200 to 600 kg of garbage per urban dweller. Examples of the largest producers of garbage are given below (Table 1).

| Country                             | Amount of waste per citizen annually, kg |
|-------------------------------------|------------------------------------------|
| USA                                 | 530                                      |
| Norway, Spain, Sweden, Netherlands  | 200-320                                  |
| Russian Federation                  | 300-350                                  |

It takes long time, sometimes centuries for waste to decompose in the natural environment (Table 2).
Table 2. Waste decomposition time.

| Waste                        | Decomposition time, year |
|------------------------------|--------------------------|
| Paper                        | 2-10                     |
| Can                          | Over 90                  |
| Cigarette filter             | Over 100                 |
| Plastic bag (polyethylene)   | Over 200                 |
| Plastic                      | 500                      |
| Glass                        | Over 1000                |

Remember that before you throw a plastic bag or a bottle in the forest [6].

The content of slowly decomposing plastic (polymer materials) in contemporary household waste grows from day to day. There are modern polymer materials containing light-sensitive molecular groups that are easily digested by microorganisms. Rate of such polymer waste decomposition increases many times and, which is even better, there is no more need to incinerate it in high-temperature furnaces.

The United States generate over 150 mln. tons of garbage annually thus staying one of the most "polluted" countries of the world. If we assume we loaded that garbage to trucks then the line of trucks would stretch from Earth to Moon; if we take the disposable plastic film that Americans use every year then we can stretch it from Earth to Moon 7 times as its amount exceeds 18 bln.

Porous styrofoam used for production of disposable cups is extremely dangerous for environment. For example, if we put in a line all the cups used in the whole world during a year they will circle the Earth 465 times around equator. That plastic that can't decompose in natural environment is made of expensive oil resulting in emission of chlorocarbons to atmosphere that destroy ozone layer.

According to the data only 20% of garbage is recycled in the USA, and the rest goes to landfills. About 1/3 of that is package. If we take per cent figures of pollutants then we see that americans use 75% of produced glass, 50% of paper, 40% of aluminum, 40% of plastic and 8% of steel to make package. Every hour they use 2.5 mln. of plastic bottles. Governments of various countries start to spend more and more time discussing matters of environment protection and approving development of appropriate technologies. There develops a number of systems for territories cleaning from garbage and incineration of that garbage. However, there are many reasons to consider garbage incinerating technologies prospectless. Costs would grown if we don't apply different waste management technologies. At the same time one should hold it in mind that we need new technologies that would fulfill both customer demands of population and environment safety [10].

Medical institutions waste management. Admittedly, about 90% of waste in our country is disposed at landfills although it is strictly prohibited to do so without prior recycling. Very often landfills don't meet basic sanitation and hygiene requirements and are indeed the sources of secondary pollution. But while most of waste can relatively safely be disposed by depositing, then some types of waste, for example medical waste, is subject to mandatory recycling. They are very different from the rest of waste and require special attention as there is always a danger of presence of pathogens of various infectious diseases, toxic and even radioactive substances in it. According to the public data by 2005 there was accumulated about 1.8 bln. tons of it in the world which is about 0.3 tonn per each dweller of the planet.

Syringes and injection needles are especially dangerous as mistreatment can result in re-use of these products. Information about infecting caused by re-use of syringes is given in the Table 3.

Table 3. Information about infecting caused by re-use of syringes.

| Quantity            | Infections      |
|---------------------|-----------------|
| 20 mln. people      | HBV (34% of all new cases) |
| 2 mln. people       | HCV (42% of all new cases) |
| at least 260 000 people | HIV (6% of all new cases) |
4. Practical part

Modern technologies of solid household waste recycling. Waste recycling is the most promising way to solve the problem of urban landfills [16]. The following main areas of processing have been developed and are used to obtain:

- organic mass → fertilizers
- textile and paper waste paper → new paper
- scrap → for re-melting

The major problem in recycling is sorting of garbage and recycling processes management.

The proposed modern technologies also allow us to solve the problem of waste disposal and to develop energy sources [3]. Therefore, garbage will return to us not in the form of growing landfills and polluted water, but in the form of electricity through wires, heat in heating radiators and vegetables and fruits grown in greenhouses [12].

Preliminary sorting. This production process is division of solid household waste into fractions at waste processing plants manually or using automatic conveyors. Here they reduce the size of garbage components by crushing and sifting them, and they separate larger metal objects, tin cans, for example. Selecting them as an especially valuable secondary raw material precedes further disposal of solid household waste (for example, incineration).

Sanitary earth filling. This process approach to solid waste disposal includes extraction of biogas that is later used as a fuel. For this purpose household garbage is covered with a layer of soil 0.6 m thick and compacted according to a certain technology. Biogas landfills are provided with ventilation pipes, gas blowers and tanks for collecting biogas.

High-temperature pyrolysis. This method of solid waste disposal is, in fact, gasification of garbage. Treatment process of this method implies:

\[ \text{Biological component (biomass)} \xrightarrow{\text{extraction}} \text{waste of secondary synthesis gas} \xrightarrow{\text{application}} \text{steam, hot water, electricity.} \]

Solid products in the form of slag, i.e non-pyrolyzable residues are a combined part of the high-temperature pyrolysis process.

Incineration. Widely known method of solid waste disposal used from the end of the 19th century to the present day. The issue of direct disposal of solid household waste is defined by its exceptional multicomponent nature on one hand, and by increased sanitary requirements to the recycling process on the other hand. Based on this, incineration is still the most popular method of primary treatment of household waste. Incineration of household garbage, in turn, reduces mass and volume, and gives additional energy resources that can be used for district heating and electricity generation.

Processing of combustible waste. The proposed gasification technology makes it possible to process combustible waste in a closed reactor to produce flammable gas (Table 4).

Gasification process is a modular technology. Flammable gas produced in the amount of 80 to 100 m³ per minute is an important and valuable product of recycling. Gas can be used for production of heat and electricity for related industries or for export.

| Table 4. Examples of waste management. |
|--------------------------------------|
| Waste                               | Examples                                                                 |
| 1. Combustible fraction of solid household waste | is separated during sorting plastic, cardboard, paper, etc.               |
| 2. Solid industrial waste, non-toxic solid waste produced by industrial, trade and other centers | most of automotive industry plastics, rubber, foam materials, fabric, wood, etc. |
| 3. Combustible solid products of cars recycling | the highest efficiency of wastewater treatment is achieved by application of bio-thermal technology |
| 4. Wastewater after drainage | working waste, sawdust, bark                                               |
| 5. Dry biomass |                                                                         |
Rotting waste recycling. Methane and compost suitable for agricultural and horticultural application can be produced using the following method: solid household waste sorting → organic fraction of solid household waste, farm waste and water treatment facilities waste → anaerobic processing.

Organic waste is processed in reactors where methane-producing bacteria transform organic substances into biogas and humus that is the essence of processing [15].

Used tires recycling. One of the most common methods of tires recycling is production of crumbs from them. Every year an average of 34 mln. tires become crumbs which are used to make coatings and surfaces, added to mortar or used for manufacturing of new tires, mats, soles. Also this cost-demanding method is used for making roads. Only 8% of used tires is recycled in Russia while the global average is 25-30%. Another method of tires recycling is low-temperature pyrolysis resulting in production of electricity, sorbent for water purification or high-quality soot suitable for production of car tires.

Used cars dismantling lines. Recycling of old cars is done using the industrial dismantling technologies allowing to re-use some parts. Car parts and sorted materials can be sold thus ensuring company economic efficiency. In order for plant operation to be effective and depending on transportation cost rates there shall be 25,000 old car bodies within 20-30 km radius around a plant. In general, such a plant requires a site of at least 15,000 m². Industrial dismantling line scope of supply includes:

1) operating staff training at customer's site;
2) training in plant management;
3) training in arrangement of old cars collecting;
4) selling of parts and materials.

Medical waste disposal. This technology of medical waste purification sterilizes the following types of medical waste: needles, syringes, lancets, metal probes, glass, biological cultures, physiological substances, medicines, medical containers, filters, vials, catheters, laboratory waste, etc. The proposed technology of medical waste purification crushes and sterilizes waste so that they become dry, uniform, odorless dust (granules of 1-1.9 mm in diameter). The resulting residue is an entirely noble product containing no microorganisms and having no bactericidal properties. Residue can be used for landscaping or can be disposed with regular urban waste.

Establishment and development of waste-free production. What are the ways to solve the global problem of environment pollution with waste? Construction of the best treatment facilities, development of various technologies can't solve the problem of environment protection. The best way to solve the global environmental problem is to reduce resource-rich production and to transfer to production and technologies producing less waste [4].

A waste-free production is a production where all the raw materials are transformed into products which is, at the same time, optimized in terms of process, economic, social and environmental criteria. The main innovation of this approach to further development of industrial production is limited by impossibility of effective solving of issues of environment protection and rational use of natural resources only by development of methods of neutralization, recycling or disposal of waste. The concept of waste-free production proposes to include consumption in the raw material resources use cycle. In other words, products shall return to production after physical or moral wearing out. As we see, waste-free production is essentially a closed system organized with the natural environmental systems [9] of a kind which are based on the biogeochemical cycle of matter.

Waste-free production intends to cooperate productions giving large amounts of waste (thermal power plants, phosphorous fertilizers production, metal, mining and refining plants) with productions consuming this waste, e.g. with construction materials production companies. In this case waste completely meets the definition given by D. I. Mendeleev who called it "the disregarded products of chemical transformations which will eventually become a starting point for a new production".

Secondary resources of production in Russia. Waste generation capacity of the Russian economy is 3.4 bln. tonnes a year (Table 5).
Table 5. Content of waste generated by economy of Russia.

| Quantity, tonns/year | Type of waste                  |
|----------------------|--------------------------------|
| 2.6 bln.             | industrial waste               |
| 700 mln.             | liquid waste of poultry and livestock production |
| 30-40 mln.           | solid household waste          |
| 30 mln.              | wastewater treatment residue   |

Average level of their use is about 26% which includes recycling of 35% of industrial waste, 3-4% of solid household waste. Other types of waste are not actually recycled [8].

5. Conclusion
Low level of waste recycling (except for particular types - ferrous and non-ferrous metals scrap, high-quality waste paper, textile and polymer waste) can be explained not by absence of technologies but by the fact that recycling of most types of waste features low profitability or unprofitable at all.

According to the data of the Ministry of industrial development of Russia there are registered 2,500 facilities of dangerous waste disposal in Russia. In many cases the conditions of waste disposal don't meet the environmental requirements and global standards accepted in Russia. As a result the environmental effect of waste accumulation and disposal facilities is often exceeding the established maximum allowed concentration values [8].

Our objective is to stimulate every initiative and activity to develop and implement modern technologies to cope the environmental problem by any available method. Humankind has reached understanding that further technical progress is only possible in case of assessment of new technologies effect on environment.

In conclusion we would like to recall a statement of a french philosopher Saint-Simon: "Happy would be the age when ambition starts seeing greatness and glory only in obtaining new knowledge and leaves the dirty springs it was trying to quench the thirst with". These were the springs of misery and vanity that quenched the thirst of only ignorants, conqueror heroes and exterminators of the human race.

6. References
[1] Dergacheva K V, Dergacheva E A 2020 Social and Technogenic Development of the World and its Problems International science and technology conference "EarthScience"; IOP Conf. Series: Earth and Environmental Science 459 062022 doi:10.1088/1755-1315/459/6/062022
[2] Khetsuriani E D, Larin D C, Khetsuriani T E 2020 Methodology of New Ideas Formation in Water Resources Utilization Technology International science and technology conference "EarthScience"; IOP Conf. Series: Earth and Environmental Science 459 022014 doi:10.1088/1755-1315/459/2/022014
[3] Nemov V Y, Filimonova I V, Komarova A V 2020 Assessment of the Mutual Influence of Energy Intensity of the Economy and Pollutant Emissions International science and technology conference "EarthScience"; IOP Conf. Series: Earth and Environmental Science 459 062025 IOP Publishing doi:10.1088/1755-1315/459/6/062025
[4] Babaeva A A, Grigorieva E V 2018 Environmental problems of modern civilization and modern technologies for their solution Technosphere processes: regional aspect: materials of the 1st All-Russian scientific and applied conference (Cheboksary) pp 58-64
[5] Gorshkov S P 1982 Exodynamic processes at developed territories (M.: Nedra)
[6] Grigoriev A A 1982 Cities and environment Space research Mysl
[7] Grigoriev K A, Babaeva A M, Osipov D G 2017 Modern aspects of international cooperation in terms of technosphere safety Condition and perspectives of innovative technologies development in Russia and abroad: materials of the 2nd International scientific and applied conference (Cheboksary) pp 120-123
[8] Mirkin B M, Naumova L G 2006 Environment of Russia
[9] Mityugina M M 2011 Environmental safety as a basis for provision of the quality of life of population Vestnik Chuvashskogo Universiteta 2 pp 449-453
[10] Nikitin D P, Novikov Y V 2007 Environment and human
[11] Nikonov V V, Babaeva A M, Babaeva A A 2017 Modern technologies of technosphere waste recycling and their relation to economic problems Condition and perspectives of innovative technologies development in Russia and abroad: materials of the 2nd International scientific and applied conference (Cheboksary) pp 229-235
[12] Odum Y 2004 Environmental science fundamentals (Mir)
[13] Osipov D G, Agapova Y Y 2017 Structure of region technosphere and the main regional economic problems of safety (on the example of the Chuvash Republic) Condition and perspectives of innovative technologies development in Russia and abroad: materials of the 2nd International scientific and applied conference (Cheboksary) pp 236-240
[14] Pimurzin V G, Babaeva A A, Osipov D G 2017 Main problems and objectives of labor protection in modern conditions Quality and innovations in the XXI century: materials of the XV International scientific and applied conference (Cheboksary) pp 272-279
[15] Radzevich N N, Pashkang K V 2005 Environment protection and modification Prosveshenye
[16] Sherstobitov M S, Lebedev V M 2010 Solid household waste: problems and methods of recycling Industrial power engineering 4 pp 60-64