INNOVATIVE SOLUTIONS IN WASTE PROCESSING
ИНОВАЦИОННИ РЕШЕНИЯ ПРИ ПРЕРАБОТВАНЕТО НА ОТПАДЪЦИ

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Abstract: *The current report aims to provide insight into the different innovative solutions in waste processing. It outlines that the new technologies for solving the waste issue should be consistent with the current requirements for saving resources and minimizing the waste going to landfills. First, the paper discusses that one of the most serious challenges of the modern world is linked to the daily disposal of hundreds tonnes of waste. They are not only a national, but a global problem, the uncontrolled disposal and accumulation can cause serious pollution of the environment and lead to worsening health. That is why the issue of their effective management is of utmost importance. The report gives special attention to the global problem with waste collection and disposal that imposes an urgent need for innovations. Next, different innovative solutions in waste processing are also analyzed in the paper. A new, better model of waste management needs to be created and innovative methods (instruments) for disposal and treatment of municipal solid waste are needed. The author identifies that scientific progress allows for the implementation of new waste management technologies such as radio-frequency identification (RFID), GPS systems, underground waste treatment facilities, multistage waste recycling system, etc. Finally, on the basis of the analysis, recommendations for waste management on a global level are outlined. A conclusion is made that when choosing a new and effective waste management technology, the ecological (safety and ecological risks) and economic (efficiency, capital and operational expenses) factors should be considered.*

Keywords: INNOVATIVE SOLUTIONS, INNOVATIVE TECHNOLOGIES, ENVIRONMENTALLY FRIENDLY TECHNOLOGIES, WASTE MANAGEMENT, WASTE PROCESSING, RECYCLING METHODS, ENVIRONMENT

1. Introduction

Global systems of production and consumption continue to impose considerable consequences on the environment and public health. Most of the used natural resources return to the environment in the form of waste, which in most cases is toxic and unsuitable for recycling. Waste is a global issue and if not properly dealt with, waste poses a serious threat not only to the biosphere, but also to public health. It is a growing issue linked directly to the way society produces and consumes. Meanwhile, global trends such as population growth, urbanization and the emerging 'consumer middle class' in many developing countries are expected to drive steady growth in global competition for resources in coming decades. The problem is further exacerbated by the consequences of the enhanced technological progress which leads to generation of more waste products which do not dissolve.

Addressing these challenges will require fundamental changes in global systems of resource use and economic growth. That is why one of the pressing issues for developing countries will be a shift away from a linear (take-make-dispose) model of resource consumption towards a circular economy where nothing is wasted. Proper waste management is one of the most important contributions humanity can make to reducing its impact on the natural world. Environmental sustainability is the core issue that will need to be addressed for development to focus on human well-being and yet stay within the limitations of planet's capacity. Environmentally sound waste management is one of the key elements for sustainable development. The first priority is to bring wastes under control but that on its own is not enough – it is also necessary to move from waste management in a linear economy to resource management within a circular economy.

New technologies for solving the waste issue should be consistent with the current requirements for saving resources and minimizing the waste going to landfills. Eco-innovation also has a crucial role, enabling producers to reduce their resource use or shift to less harmful or scarce substitutes (for example in the transition from fossil fuels to solar or wind power). When choosing a new and effective waste management technology, the ecological (safety and ecological risks) and economic (efficiency, capital and operational expenses) factors should be considered. In many cases, the shortage of funds for waste management leads to further deepening of the problem especially in the least developed countries.

2. Preconditions and means for resolving the problem

In the past, the municipal waste management is limited primarily to the collection, disposal, landfill or incineration. Over time, however, the environmental awareness of the population has increased, caused by various reasons such as technological development and interest in activities that pollute and harm health. Along with this the problem of limited resources comes to the fore and the conclusion is made that only landfilling and incineration are not sufficient to cope with the ever-increasing amount of waste worldwide. All these issues and the emergence of the concept of sustainable development give impetus to the idea of recycling as a way to reduce the amount of waste.

"[Despite different assessments global generation of municipal solid waste (MSW) is estimated at about 2 billion tonnes per annum. MSW generation rates vary widely within and between countries. They depend on income levels, socio-cultural patterns and climatic factors, factors such as population expansion, urbanization, economic and technological development. MSW generation per capita is strongly correlated with national income. In high-income countries, MSW generation rates are now beginning to stabilize, or even show a slight decline, which may indicate the beginning of waste growth 'decoupling' from economic growth. However as economies continue to grow rapidly in low- and middle-income countries, it can be expected waste generation per capita to rise steadily.]"

The volume of waste is mainly determined by two factors – the size of the population and the structure of consumption. "[According to the United Nations' data, the current world population of 7.3 billion is expected to reach 8.5 billion by 2030, 9.7 billion in 2050 and 11.2 billion in 2100. Most of the projected increase in the world's population can be attributed to a short list of high-fertility countries, mainly in Africa, or countries with already large populations. With the highest rate of population growth, Africa is expected to account for more than half of the world's population growth between 2015 and 2050. During 2015-2050, half of the world's population growth is expected to be concentrated in nine countries: India, Nigeria, Pakistan, Democratic Republic of the Congo, Ethiopia, United Republic of Tanzania, United States of America (USA), Indonesia and Uganda, listed according to the size of their contribution to the total growth.]" However, the concentration of population growth in the poorest countries imposes

challenges on the success of the global sustainable development. Population growth will inevitably lead to higher rates of urbanization (on a global scale it is projected that urban population will be around 65 % of the total) and the formation of large areas filled with poor people in the big cities and in their surroundings. As a result, the number of people in poor blocks will double by 2025 and will reach 1.5 billion people.

According to the other estimates, some 80 % of this growing population will live in cities, most of which are yet to be built. Of this projected almost 9 billion people, 3 billion will belong to the middle class, with sufficient disposable income to purchase the consumer goods that others enjoy elsewhere in the world, further draining the planet's already strained natural resources. Moving to a circular development model – which works to reduce waste before it is produced, but which treats waste as a resource when it is – is essential, and holistic and integrated sustainable waste management will be crucial.

"[The considerable growth in population and the upsurge in global GDP will inevitably trigger an increase in the amount of waste. It is estimated that a 1 % rise in national income leads to an increase by 0.69 % in solid waste.]" Nonetheless, there are positive prospects for the future. It is a well-known fact that the larger the GDP of a country, the more complicated and efficient its waste management system is. Against this background, it can be claimed that GDP growth will certainly force governments of the new members of the group of developed countries to take measures for enhancing waste collection and management. The current economic situation, however, shows that it is cheaper for developed countries to export their waste to third world countries rather than to spend large amounts of money on recycling waste on their own. Thus, there are fears that technology advance without supporting measures will not resolve this problem. This also raises the question to what extent new technologies will be accessible for the developing countries. Therefore, one of the most serious challenges of the modern world is linked to the daily disposal of hundreds tonnes of waste. They are not only a national, but a global problem, the uncontrolled disposal and accumulation can cause serious pollution of the environment and lead to worsening health. That is why the issue of their effective management is of utmost importance.

In addition to population growth, globalized markets and increasing consumption of materials, rising energy prices and increasing commitment worldwide to reduce greenhouse gas emissions and landfill drive the development of new approaches to waste management. More and more countries restrict or even prohibit landfilling, heading towards alternative solutions for waste to combinations of maximum recycling and alternative energy production. The concept of integrated waste management now emerges as a mature strategy that can cope with ever-increasing complexity of processing large volumes of waste.

The global problem with waste collection and disposal imposes an urgent need for innovations. In recent years it has become clearer that the existing waste management systems cannot handle that task. The 2008-2009 world financial and economic crisis has further worsened the situation – waste processing has always been expensive and the worsening economic environment drove many processing enterprises out of business, especially in developing countries. At the same time, the volume of waste is rapidly increasing and as a result the huge landfills in many countries inevitably cause environmental disaster.

Recently, one of the most pressing environmental issues in the world is related to the recycling and utilization of the so-called electronic waste. Waste electrical and electronic equipment (WEEE) is currently considered to be one of the fastest-growing waste streams. WEEE contains a number of hazardous substances and at the same time valuable materials. The revised EU WEEE Directive (2012/19/EU) sets out measures to reduce generation of WEEE, and enhance collection, reuse, recycling and recovery, applying producer responsibility as key implementing mechanism. "[This kind of waste includes all types of high-technology electronic devices, from mobile phones and music players to computers and television sets. The increasing amount of old electronics raises concerns as these products contain a number of substances which are harmful for both people and nature. They contain a large quantity of cadmium which can be found in semiconductors, resistors, and all sorts of transmitters. There is mercury in the fuses and commuters, chromium in the hull, and bromine in the power and connecting cables.]" "[It is a well-known fact that batteries are made of nickel, cadmium, lithium, and other harmful chemical substances. The problem is worsened by the fact that the quantity of e-waste in the world is growing.]" "[According to several studies, the volume of high-tech waste, including only computers, mobile phones, and TVs, will enhance to 9.8 million tonnes. In addition, it is projected that the rapid development of nanotechnologies and the emergence of new types of materials will increase the quantity of hazardous waste which is not naturally degradable.]"

The reduction of hazardous substances in newly produced electrical and electronic equipment taking place currently is an important step in reducing the environmental and health risks from disposal, also in the countries of destination. In addition, it is however, necessary also to incorporate in the overall consideration the risks from the use of auxiliary products from the handling (e. g. leaching agents, cyanide), as well as the emissions from handling and recycling processes (e. g. PCDD/F emissions from thermal processes, wastewater, secondary wastes such as, for example, sludge). Separate collection of WEEE and its subsequent recovery and treatment in an environmentally sound manner will help achieve not only reduction of environmental impacts, but also better resource efficiency.

The abovementioned trends in waste management will be present in the future, as well. The rising quantity of waste cannot be stopped because of the increase in the global population. Furthermore, consumerism will continue spreading among the society along with bigger progress achieved by some developing countries with huge population. The current economic system requires constant growth which can be achieved with a constantly rising consumption. Stagnation in consumption and thus in growth will lead to the collapse of many economies, to unemployment, and to famine. This creates a vicious circle which cannot be broken without innovations which will change dramatically the way resources are utilized as well as waste management and recycling.

As regards the changes in waste composition, prospects are once again far from optimistic. The attempts to replace plastics with easily degradable materials have failed to produce any significant results. A lot of artificial materials cannot be replaced and in those which can the costs for producing environmentally-friendly substitutes are 4 to 5 times higher.

3. Results and discussion

Innovation is always a good thing, improving the recycling process is constantly welcome and thankfully there are individuals and organizations who are dedicated to doing just that. As waste management climbs the political and environmental agenda, bright sparks in the industry respond with innovation. These are some of the ideas that have changed our industry over the past few years, and given us potential answers to global problems.

We are continuing to see new developments, innovations, and even new problems in sustainability ventures and recycling efforts. To get a better sense of where we are headed in the near future, for good or bad, we have to know the forthcoming trends and expectations. All organisations must deal with their waste appropriately, but they shouldn't stop at compliance. Smart organisations innovate by setting targets that drive them towards best practice.

Waste management generally comprises operations related to collecting, transportation, sorting, and treating of waste, but the active work with the population, government authorities, and business organizations is also part of it. Numerous issues in the field of waste management need to be resolved. They include, among others, creating effective waste management system, providing financing, and defining the right government instrument

(administrative, economic, etc.) that need to be implemented. Of course, the national legislation and state regulations regarding waste management need to be considered. Different standards and limitations might hinder the introduction of new technologies. Another important condition for successful waste management is the relationship between the public and the private sector, between institutions, organizations, and society. A new, better model of waste management needs to be created and innovative methods (instruments) for disposal and treatment of municipal solid waste (MSW) are needed.

"[Anaerobic digestion came about as the result of a long process of people searching for the best way to deal with biowaste. Even before awareness of climate change came to the fore, we had problems with leachate and gas. So, early technologies found ways to convert organic waste into compost and fertilizer instead. This process was completed on open air windrows until odour became a problem and 'in-vessel' composting plants were developed. Anaerobic digestion is the latest and greatest process of in-vessel treatment of waste, and is generally considered to be one of the most innovative and useful technologies developed by our industry in recent years. Not only does it give us a large-scale solution to our organic waste but it allows us to turns the resulting gases into energy. The process, put simply, is the degradation of waste by microorganisms in an environment starved of oxygen. It can be used to treat organic solid waste and wastewater of almost any kind. The process works quickly and the remainder can be used as fertilizer while the biogas produced is converted into energy. As people will always produce biowaste, whether it be food or sewage, anaerobic digestion is seen not only as a waste management process but also as a source of renewable energy.]"

The manufacture of biogas from organic waste has the following advantages: biogas with high saturation can be used to produce both power and heat; the anaerobic treatment of materials from plants and animals facilitates the manufacture of mineral fertilizers which are high in nitrogen and phosphorus (unlike the conventional production of natural fertilizers by compositing waste where between 30-40 % of the nitrogen is lost); all pathogenic microbes are removed and the residue fully complies with the environmental requirements after the anaerobic treatment is completed; biogas production facilities can easily be installed in any region and they do not require expensive and complex pipe infrastructure. These facilities can fully replace the small steam generators which produce heat and power in rural areas.

Given the oil crisis and the ever-increasing price of fossil fuel, turning waste into fuel is a fantastic solution. Biofuel is the most common form, and the term encompasses a range of different fuels derived from organic matter, including biowaste. Biofuel can be solid, liquid or gas and be used to power vehicles or used to enhance other types of fuel. Biogas – a product of anaerobic digestion – and syngas – which is produced during gasification – are both types of biofuel.

Landfill gas also has an up-and-coming role in this field. Most landfill-gas-to-energy projects involve turning otherwise harmful emissions into electricity to power homes. But it is also being increasingly used as a vehicle fuel or as a substitute for mains household gas supply.

Waste to energy (WTE), sometimes known as energy from waste has seen some of the most interesting developments in the industry, as it has the advantage of being able to completely remove waste, rather than reuse or process it. Traditionally, WTE plants have operated by incinerating waste and converting the resulting heat into energy – and most plants still use this technology today. But public opposition to incinerators, which are often seen as dangerous and noisy has meant new types of WTE – such as gasification, pyrolysis, thermal depolymerization and plasma arc gasification – have been developed and are leading the way forward in this area.

"[Gasification and plasma arc gasification are used to convert organic materials into a synthetic gas (syngas) made up of carbon monoxide and hydrogen. The gas is then burnt to produce electricity and steam. A plasma gasification plant uses plasma torches which operate at approximately the same temperature as the surface of the sun to create an environment in which solid or liquid waste is turned into syngas. The process breaks down the molecular bonds of the waste and leaves it in elemental components. This syngas is then converted to energy, and the waste completely disappears.]"

"[Many countries have made efforts to develop pyrolysis systems over the past few years in order to maximize the production of methane and liquid petroleum products from MSW.]" High-heat thermal pyrolysis (producing gas from solid wastes) might lead to liquid and solid slag separation. There are two types of liquid slag separations: slag-forming retort with air supply and slag-forming retort with oxygen supply. A typical example of processes which include air introduction is the Torrah method developed in the USA in which the MSW stream is fed into the slagging gasifier (a vertical furnace). The waste stream which flows into the reactor prevents air leakage. The decomposition of organic waste in a hermetically closed environment through pyrolysis is taking place in oxygen-poor conditions with a constant flow of heat gases from the primary combustion and melting zone. The liquid slag which is the end product of the pyrolysis is removed in a hermetical chamber of the water cooled vessel where the black sterile granular residue is formed. After waste is treated using this method its amount is reduced by 95 %.

The experience of oil companies in the past decades shows that the residue waste of oil refineries is rising. Currently, the only way to treat waste oil is to burn it which has a devastating impact on the ecosystem in that region. In addition, wastes detoxification is carried out by using the most primitive method, namely transporting them to industrial zone and even protected areas which are near the refinery.

Recycling waste oil in a safe and environmentally friendly way by using the right technologies is one of the most pressing issues of today. Given the difficulties in the recycling of heavy oil in Western Europe and the USA, the technology to treat waste oil with sulfuric acid was rarely used. Instead, it was replaced with modern selective hydrogenation and cleaning solvents. There are almost none environmentally friendly industrial technologies for treatment of acid tars as they are burned in the thermal power plants to generate heat which has an adverse impact on the environment. The most rational way to treat heavy oil is the controlled thermal destruction of saturated hydrocarbons. The high temperature, the high pressure, and the little time for thermocracking allow for the production of asphalt and resin from the saturated hydrocarbons. In industry, the thermal cracking of heavy oils is used to produce tar, coke, and bituminous materials. The prospects for implementing this technology are supported by the thin film deposition of heavy oil in the composition of the original structure. The technologies and facilities for heavy oil processing might be used in refineries which already have huge quantities of heavy oil.

Despite all negatives, nuclear power makes up a significant part of total power output in the world. As a result, the treatment of hazardous waste from nuclear power plants is a significant problem. Nuclear waste could be used to fuel the reactors of the rising number of alternative energy companies in the future. At that moment, however, it is stored in underground nuclear waste dumps. Scientists from various organizations strive to improve the technologies for treatment of that kind of waste and to create new ways to process them with the aim to make residue less hazardous and toxic. According to one of the latest works in this field, nuclear fueled will be converted into very dense solid-glass blocks which will make it easier and safer to store.

For years scientists have developed and tested various kinds of nuclear weapons and created nuclear power plants which are in constant danger of suffering accidents. The case with the Chernobyl nuclear power plant, among others, showed that nuclear waste might have an adverse impact on both the environment and mankind. Therefore, the focus should be put not only on the effects potential accidents might have, but also on the storage of nuclear waste. Scientists from the University of Sheffield presented an innovative approach to convert nuclear waste into solid glass. The new method comprises mixing of frozen plutonium with furnace

slag with the aim to produce glass. Currently, the nuclear waste is contaminated under concrete but in the future it might be used in glass production. It is noteworthy that for now the method of the scientist from the University of Sheffield is applied with cerium instead of plutonium because they are very similar. If tests prove successful, then the mankind will have a simpler and safer way to treat nuclear waste.

"[Scientific progress allows for the implementation of new waste management technologies such as:

- Radio-frequency identification (RFID) which is used to gather information on the transportation and disposal of waste in towns and cities. Collected data are used to develop new types of waste containers for recycled raw materials, recycle bins, among others. The essence of this technology is the automatic identification of the objects which is done by using radio signals. Thus, data is received and analyzed by the so-called RFID tags. In fact, each RFID system includes a reader device.
- GPS system used primarily for transportation of waste which has already been sorted. GSP (Global Positioning System) is a satellite navigation system which measures the distance and the time necessary to reach specific point. The system can be used in almost every spot on the Earth (excluding the polar regions) in all weather conditions. The GPS system was developed by the United States Department of Defense.
- Underground waste treatment facilities. In contrast to conventional burning appliances, this device is a semi-round container with a tube that reaches a depth of 3.5 meters. It is equipped with a special waste compaction mechanism which reduces the volume of the waste five times. Thus, the container can hold a total of 50 m3 of waste. More than fifty devices of that type are already installed in Finland where they are becoming increasingly popular.
- Multistage waste recycling system – this type of technology derives from the traditional sorting and recycling systems in Western Europe, the USA, and Japan. For other countries, however, it still remains innovative and quite expensive. Usually, waste is treated in a facility which is very close to the waste source (or potential source of waste) which makes this technology quite useful for consumers as it requires minimal effort and capital.]"

4. Conclusion

The analysis of new waste management technologies in the world focuses the attention on the following trends in the process of modernization in this sphere:

- environmental safety – nearly all new technologies focus, albeit to different extents, on minimizing resource use and the harm on the environment;
- economy – the innovative technologies in this sphere largely contribute to the reduction (minimization) of waste treatment and disposal costs. Costs of using these technologies are usually much lower than costs incurred in implementing traditional technologies;
- saving resources and energy efficiency – minimizing the quantity of resources used in waste recycling and treatment;
- automation which is expressed in increased use of new technologies in the recycling with the help of innovative, high-tech tools: computer programs, satellite communication, etc;
- information transparency and publicity. This trend is typical for the developed countries where the waste management process is increasingly open, democratic, and covered by the media. State agencies and local authorities present plans and forecasts in this sphere, inform the society about events, run active campaigns promoting waste minimization, encourage the population to have social responsibility for waste disposal and treatment, express the public opinion, and conduct effective exchange of information between the authorities and the civil society.

Using waste management as a way to combat GHG and climate change is one of the most innovative and common-sense concepts in waste today. The role that the waste industry can play in helping to avert climate change must not be underestimated. Given the correct legislation to work to the technologies which are already making great leaps in this area will show how much good they can really do. Although the costs of implementing these processes is often seen as prohibitive, the cost to the planet and the resulting financial cost of dealing with this, make all of these moves more than worthwhile.

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