Biotechnology of solid waste disposal (anaerobic processing) in the urban environment

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Abstract. The intensive impact of human activity on the environment, as a rule, is combined with the use of environmentally harmful methods of processing household waste, sewage sludge, waste from various types of industry, as well as the discharge of untreated water into water bodies. By the beginning of the XXI century. this has led to soil and soil pollution and, in general, to a global shortage of clean water sources. The sustainable development of the world community requires a systematic approach to solving this problem. In developed countries in recent decades, a breakthrough has been made in the development and implementation of new technologies that prevent barbaric environmental pollution. Unfortunately, in the application of municipal waste disposal methods, which include sewage sludge and municipal solid waste, Russia has not yet reached the modern world level.

1 Introduction

Even in ancient times, urban garbage, which was much less than in our time, was gradually covered with ravines and wetlands, for example, “Sukovo swamp” in the southeast of modern Moscow. Later, with the growth of cities, more or less organized landfills appeared, and then - landfills for municipal solid waste (MSW). With the beginning of the use of centralized water supply and sanitation (sewerage) in cities at the end of the 19th century, wastewater treatment technologies were developed - first by filtration through the soil (filtration fields), and then at aeration stations. The resulting sludge was transported to sludge sites for compaction, then taken to landfills and landfills, which are mainly intended for the disposal of municipal solid waste. This practice of disposal of sewage sludge continues to be used in Russia at the present time. The study of the processes occurring at MSW landfills and sludge sites, and their impact on the environment in our country, was started in the first half of the 1980s of the last century [1]. Organized by Academician of the Russian Academy of Sciences G.A. Zavarzin, a geological and microbiological survey of solid waste landfills and silt checks, in which A.N. Nozhevnikov, made it possible for the first time in the world to describe in detail the processes of microbial degradation of organic waste, the formation and migration of decay products in the thickness of garbage and silt deposits, and the emission of the final product, methane, into the atmosphere [2].

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The results of the work performed showed that these objects are environmentally extremely harmful. The monograph offered to the reader describes new modern biotechnological methods for processing organic waste from cities and large settlements into useful products. The branch of biotechnology aimed at protecting the environment has received the name of environmental or environmental biotechnology (the term "ecobiotechnology" has recently taken root) (fig.1). All over the world, much attention in ecobiotechnology is paid to waste processing in anaerobic bioreactors isolated from the environment to produce methane and organic fertilizers.

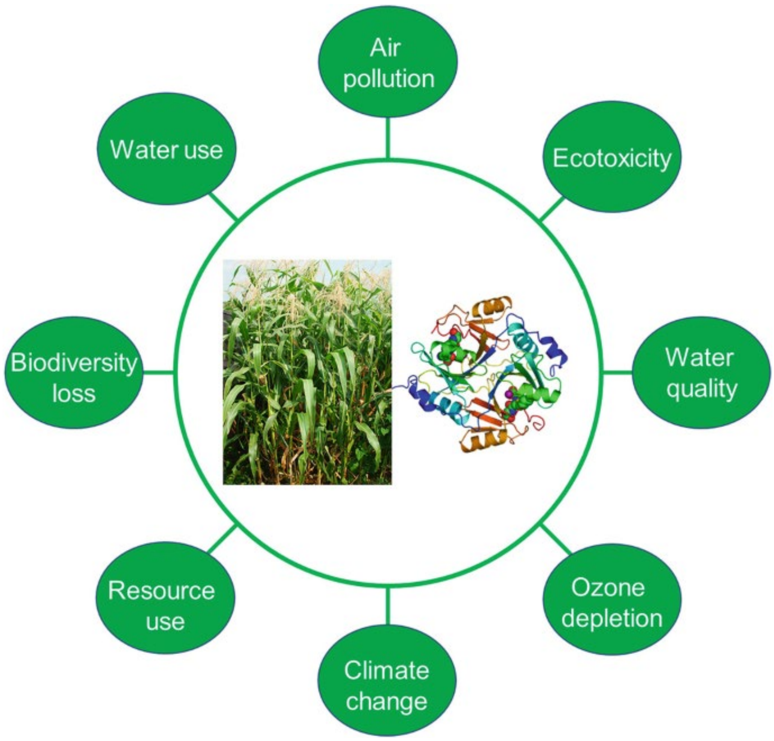

Fig. 1. Environmental Aspects of Biotechnology

The main focus of the book offered to the reader is the consistent generalization of fundamental and practical knowledge underlying the developed technologies for processing municipal organic waste. The authors do not offer detailed engineering schemes, design norms and rules, but describe general modern approaches to the creation of efficient technologies and give good examples of them. The active tool, or biocatalyst, in the technology of processing (degradation) of organic waste are microorganisms [3]. In Russia, MSW includes household waste, commercial enterprises, medical and educational institutions, municipal services, as well as waste from local heating devices, estimates, fallen leaves and large household items [4]. In Moscow, the annual production of MSW and bulky waste per capita is about 2 m3, or 400 kg. The total volume of MSW accumulation in cities and towns of Russia is about 150 million m3, or 30 million tons per year [4]. The average increase in the volume of various waste generation over the past 10–15 years is quite stable and amounts to 3–4% per year [2]. Serious environmental problems associated with the processing of MSW in Moscow reflect the situation that has developed in most Russian cities [4]. Urban MSW is characterized by a high content of organic components (up to 50–60% of the total mass of waste). The basis of the landfill is paper, cardboard, packaging materials and food waste. The composition of waste OM can be divided into five main components: biodegradable carbohydrates (cellulose, hemicellulose, starch, mono- and oligosaccharides), proteins, fats, as well as hardly decomposable lignin and practically non-degradable plastics [3-4]. The calorific value of MSW, the composition and quality of the organic fertilizer or biofuel obtained in the process of MSW processing depend on the chemical composition of the initial waste. Detailed studies of the morphological, fractional and chemical (elemental) composition of MSW were carried out and summarized by A.N. Mirny et al. [5]. The composition of MSW in large cities, especially Moscow, is characterized by a higher content of packaging materials (paper, plastics, non-ferrous metals) and a lower content of food waste. Over time, the composition of MSW changes towards an increase in the content of paper and polymeric materials. At the same time, the ratio of biodegradable OM to the total mass of MSW decreases. The content of non-ferrous metals in MSW has significantly increased due to the appearance of aluminum cans for beer and other drinks. The composition of food waste is also changing in recent years. In winter and autumn, the content of fine screenings (street estimates) is reduced from 15 to 5% in the cities of the southern zone and from 10 to 5% in the middle zone. The humidity of the collected food waste is on average 72–85% [6]. It varies somewhat depending on the season of the year. In autumn, due to the predominant content of vegetable and fruit residues in food waste, their moisture content is usually about 80%, in spring it does not exceed 70%. Humidity of food waste from public catering does not change according to the seasons of the year and is 85–90% [7]. In the DM of food waste, protein is 1.7–4.4%, fat is 0.4–1.6%, carbohydrates, including fiber, are 12–18.5%. Food waste collected in Russia in urban residential buildings contains up to 8–15% of ballast impurities (polymer packaging, glass, rubber, paper of various grades, metals, etc.). Food waste generated at public catering establishments, the food industry, vegetable stores, as a rule, does not contain ballast impurities. Wastes generated at the enterprises of the fish, meat and dairy, bakery industries, containing whey, flour estimates, malt grains and sprouts, brewer's yeast, etc., can be used as additives to animal feed [8].

2 Research Methodology

Currently, in the world practice, various technologies for the disposal of solid waste are already being used, as well as being developed, as alternatives to waste disposal at landfills. These technologies can be divided into thermal (incineration, incineration-pyrolysis, pyrolysis) and biotechnological (burial in sanitary and bioreactor landfills, composting, vermicomposting, anaerobic fermentation or methane digestion) [9]. For the disposal of MSW using the above technologies, preliminary separation of MSW is required. Sorting of waste (separation into fractions, separation) with the allocation of a part suitable for reuse is a prerequisite for efficient and cost-effective biotechnological disposal of MSW. The first step in the separation of various MSW fractions is the introduction of separate collection of waste materials, i.e. waste suitable for reuse. The collection and processing of waste paper into paper and cardboard is accepted in all, without exception, developed and not very developed countries. The same applies to the collection of glass and plastic containers, as well as scrap metal. High-quality sorting of waste should be considered a separate technology that requires special equipment and trained personnel [7-8]. It should be noted that even with a generally high awareness of the population, separate collection of waste cannot provide complete high-quality sorting, therefore, a mandatory organization of waste sorting stations in cities is required. However, organizing the collection of waste paper, glass containers and scrap metal from the population does not present big problems. The fractional composition of MSW (the percentage of the mass of components passing through sieves with cells of various sizes) affects both the technology for collecting and transporting MSW, and the parameters of equipment operation at waste processing plants. Preliminary separation and sorting of waste with the release of useful recycled materials (ferrous and non-ferrous metals, plastics, building materials, broken glass and glassware, etc.) is the most modern, economically and environmentally sound option for processing solid waste [5]. It is important to separate hazardous materials containing mercury, compounds of chlorine, bromine and serving as a source of formation of dioxins and dibenzofurans in the case of waste incineration at low temperature (700–1000 °C), the organic part subject to biological processing, and fractions burned at high temperature (1200–1400 °C) with subsequent disposal or disposal of ash and slag. From 100 thousand m3 of MSW, it is possible to obtain 10 thousand - 15 thousand tons of compost or soil, about 2000 tons of glass products, 2000 tons of iron and iron products, 7000 tons of plastics and products from them by extrusion or casting [6]. Deep fractional separation of MSW makes it possible to obtain separately non-ferrous metals [8]: Sn, Al, Pb, Cu, etc. Currently, in the world practice, various technologies for the disposal of solid waste are already being used, as well as being developed, as alternatives to waste disposal at landfills. These technologies can be divided into thermal (incineration, incineration-pyrolysis, pyrolysis) and biotechnological (burial in sanitary and bioreactor landfills, composting, vermicomposting, anaerobic fermentation or methane digestion) [7]. For the disposal of MSW using the above technologies, preliminary separation of MSW is required. 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3 Results and Discussions

Solid waste, which is a product of human activity, is stored in city dumps (fig.2). Their number is currently enormous. Not only landfill areas are increasing, but also uncontrolled release of waste into the environment, in particular due to spillage during transportation.

The composition of waste disposed of in city landfills is becoming more and more uniform [5-6]: the volume of paper and plastics is increasing against the background of a decrease in the share of organic and plant waste. Studies of the chemical composition of the contents of landfills have shown that the biodegradable fraction is up to 70% of the total amount of solid waste.

Process	Conditions	Products		
		liquid	coal	gas
Fast pyrolysis	Moderate temperature, low residence time	75% Water 25%	12%	13%
Slow pyrolysis (carbonation)	Moderate temperature, long process	30% Water 70%	35%	35%
Gasification	Heat	5% 5% resin	10%	85%
Torrefaction	Low temperature, long process	10%	80%	10%

Fig. 2. Waste treatment pyrolysis equipment, waste processing complex

The landfill is constantly layering new material at various time intervals [3-4].

Thermal methods of MSW processing at waste incineration plants. The main advantages of waste incineration are: the speed of disposal of household, biological and medical waste and the production of energy. Almost all modern waste incineration plants (WIP) are equipped with heat recovery equipment. The main problems of waste incineration are: the difficulty and high cost of cleaning gases emitted into the atmosphere from extremely harmful gaseous impurities, disposal or disposal of toxic ash and slag remaining after incineration (up to 30% of the dry mass of MSW) [8]. The calorific value of MSW, the composition and quality of the organic fertilizer or biofuel obtained in the process of MSW processing depend on the chemical composition of the initial waste. For incineration, it is necessary to provide a system for the selection of fractions that complicate the process of thermal disposal of solid waste (aluminum, polymeric materials, etc.), i.e. pre-sorting of waste is also a necessary condition for MSW incineration. The calorific value of MSW, the lowest for the working mass, is 5000–6000 kJ kg–1 [8-9]. In world and domestic practice, various methods of thermal disposal of MSW are used. The main factors influencing the choice of the method of thermal processing of MSW are the morphological and fractional composition and thermal properties of MSW, the permissible performance of equipment, possible capital and operating costs, reliability and efficiency, the possibility of automation and reduction of emissions of toxic substances into the environment [7].

The classification of pyrolysis plants is based on the temperature level of the process. There are [10]:

• low-temperature pyrolysis (semi-coking) carried out at 450–550 o C with the formation of maximum amounts of liquid product and solid residue (semi-coke) and a minimum yield of pyrolysis gas. The gas formed during low-temperature pyrolysis has a maximum heat of combustion;

• medium-temperature pyrolysis at temperatures up to 800 o C, at which the gas yield increases, but its combustion heat decreases, and the yield of solid and liquid products decreases;

• high-temperature pyrolysis (coking) at 900–1050 o C with maximum gas yield and minimum yield of liquid and solid than those for natural fuel boilers. At the same time, it should be taken into account that the fuel component of the costs of traditional power plants is 60–70%, while for waste incineration boilers it is small. Determination of capital costs for the construction of incinerators causes the greatest difficulties. The experience of building such plants in our country is very limited. It is especially difficult to foresee the corresponding costs when the prices of materials, equipment and labor are constantly rising [9] Capital costs for the construction of WIPs depend on the capacity of the units, the type of gas treatment equipment, the waste preparation and storage system, the type and quality of thermal energy obtained from waste incineration, geographical location, economic conditions in the region and other factors. Operating costs also depend on a number of factors. These include the composition of MSW, their moisture content, the method and quality of sorting, the cost of transporting MSW [8]. Obviously, the lower the humidity and the less non-combustible impurities contained in the combusted raw material, the lower the cost of operating costs. Potential consumers of energy received at the MSZ are the housing stock (heating, warm water supply, air conditioning), some industrial enterprises (warm water, refrigeration units, etc.). The unit cost of waste disposal decreases with the growth of the plant productivity [10]. However, at the same time, transport costs for the delivery of solid waste increase. The ability to use heat from waste incineration depends on local conditions. One of the requirements for the economical operation of the plant is, if possible, a uniform and year-round sale of the produced energy, which is limited by the necessary condition for its low cost, reliability of supply, and compliance with the level of generation to the level of demand.

4 Conclusions

The expansion of the scope of biotechnology has a significant impact on improving the standard of living of a person. The fastest way to introduce biotechnological processes is in medicine, but, according to many experts, the main economic effect will be obtained in agriculture and the chemical industry.

Microarrays, cell cultures, monoclonal antibodies, and protein engineering are just a few of the current biotechnological techniques used at various stages of the development of many products. Understanding the molecular basis of biological processes makes it possible to significantly reduce the cost of developing and preparing the production of a particular product, as well as improve its quality.

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