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利用污水恢复土壤肥力
THE USE OF SEWAGE TO RESTORE SOIL FERTILITY

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注解。　随着世界人口的增长和科学技术的进步，人类社会对环境的影响程度必然加大。 越来越多的矿物质被开采，越来越多的产品（工业、蔬菜、动物）被生产，工业和生活用水的使用量不断增加，肥沃土地的面积不断减少，等等。

人类的经济活动伴随着各种生产废物的积累，包括在城市市政经济中，这些废物污染了环境。　此类废物的其中一种是污水，其未得到适当利用，会对全球生态系统（地球的生物圈）造成重大损害。

对此，本文对上述问题进行了调查，并就如何将污水转化为提高土壤肥力和确保人类粮食安全的工具提出了建议。

关键词：uTerra　生物腐殖质、活性污泥、剩余污泥、土壤、污水、污水处理技术。

Annotation. *With the growth of the world population and the development of scientific and technological progress, the degree of human society's impact on the environment is necessarily increasing. More and more minerals are extracted, more and more products (industrial, vegetable, animal) are produced, the use of natural water for industrial and domestic purposes is increasing, the area of fertile land is decreasing, etc.*

The economic activity of mankind is accompanied by the accumulation of various kinds of production wastes, including in the urban municipal economy, which pollute the environment. One of the varieties of such wastes is sewage, which are not properly utilised and cause significant damage to the global ecosystem - the biosphere of the planet.

In this regard, the article investigates the mentioned problematics and gives recommendations on the use of sewage effluents for their transformation into a tool to increase soil fertility and ensure food security of mankind.

Keywords: *uTerra biohumus, activated sludge, excess sludge, soil, sewage, sewage effluent, processing technology.*

Introduction

Food security of mankind can be ensured both by increasing yields and improving the quality of plant products grown on agricultural soils and by restoring the fertility of existing arable land and using deserted areas for agricultural needs.

The main carrier of fertility in soil is organic matter - biohumus. Insufficient amount of humus in the soil leads to its biodegradation, thus making arable land less fertile. It is established that soils under grain crops annually lose 0.5-1.5 t/ha of humus, under row crops - losses are 1.5-3 times higher [1].

At the same time, in deserted areas humus is absent or present in very small amounts. In this regard, it is necessary to search for solutions to restore the fertile layer of soils.

Main part

One of the most effective solutions to this global problem was proposed by the Belarusian scientist-inventor, engineer A.E. Unitsky [2, 3].

The author of the technology notes that oil shale and lignite can be used not so much for generation of electric and thermal energy as for obtaining relict living humus - the basis of fertility of any soil, as such biohumus will have the same chemical composition as the ancient plants that took everything necessary for life from the ancient (relict) soil. According to A.E. Unitsky's technology it is proposed to burn combustible fossils not completely, but only 50-75%. Then combustion wastes (ash, slag, sludge, dust, flue gases) should be mixed with unburned 25-50 % of oil shale or brown coal (with addition of any raw materials of organic origin - grass, peat, sawdust, dung, litter, plant residue, household rubbish, sewage and others). The obtained multi-component mixture, which contains both organic and mineral raw materials, is finally processed into living fertile biohumus in bioreactors with the help of specially selected aerobic and anaerobic associations of soil agronomically valuable microorganisms. The obtained relict biohumus uTerra can be applied to the soil in the proportion from 2 % - with such a content even desert sand will become fertile [2, 3].

The question arises: are there any other ways of obtaining a cost-effective and environmentally friendly organic fertiliser that can meet the needs of mankind?

Sewage is a huge resource on the scale of the planet, the potential of which has not been fully unlocked in comparison with other types of natural resources. At the same time, the living nature has already created biotechnologies, which mankind needs to reproduce - after all, any soil humus is the result of previous bioprocessing of organic wastes of all living organisms inhabiting the biosphere, including humans.

Recycling of domestic, industrial, surface runoff, as well as sewage waste can help resolve crisis situations, prevent their possible occurrence, and significantly save natural resources.

Thus, for sewage treatment, each production/city has treatment facilities, the appearance of which is shown in Figure 1.

Based on the existing practice, in most cases the biological method of wastewater treatment is used, the essence of which is the ability of activated sludge microorganisms to use a variety of substances contained in wastewater as a source of nutrition in the process of vital activity [4].

Figure 1. *General (panoramic) view of the wastewater treatment plant*

Microorganisms free the water from contaminants, and the metabolism of these substances in the cells of microorganisms provides their energy needs and biomass growth. During the regeneration of activated sludge, excess sludge is produced and then sent for disposal. The excess sludge consists of bacteria, dead microorganisms and their waste products. The dry residue of activated sludge is 70-90 % organic and 10-30 % inorganic. The organic carbon content is more than 60 % [4].

As a result, activated sludge is quite a valuable secondary resource. In essence, excess sludge, fragments of which are shown in Figure 2, is a type of biohumus, which, based on the current practice, is disposed of in landfills or incinerated instead of being reused effectively.

Figure 2. *Excess sludge (fragments)*

So far, the main factor restraining the large-scale use of activated sludge on the planet is the presence of heavy metal salts, oil products, surfactants, pathogenic microorganisms, the effect of which on soil, plants and harmlessness of food products is not fully studied, which is confirmed by the results of the analysis of numerous scientific papers on the studied area in open sources of information. At the same time, it should be noted that salts of heavy metals are present in all plant and animal organisms (any living cell includes more than 80 chemical elements of the Mendeleev table), which is also not accidental: their complete absence in plants and other living organisms leads to their diseases and even death.

It should be noted that a number of scientists have proposed measures for the use of activated sludge, including the extraction of excessive amounts of harmful substances from it.

In particular, one of the methods is sludge purification with the help of microscopic soil fungus [5, 6]. Active sludge can be mixed with the fungus culture, incubated, after which detoxification of heavy metals and pre-oxidation of petroleum products takes place. In addition, the fungus has a number of other unique properties: it stimulates the development of the root system of plants and cleans the soil of parasitic fungi by feeding on them.

Another option for improving the quality of sewage sludge is liming. The addition of lime increases the pH value and slows down or temporarily stops microbial activity, particularly fermentation with the formation of foul-smelling gases. The content of pathogenic microorganisms is significantly reduced by liming, but only at a lime dose of 30 per cent of the dry matter of the sludge can their almost complete disappearance be achieved [7].

There is also known a method of reclamation of disturbed lands according to [8], which includes introduction on a soil surface of wastes of chemical productions, as which sludge - a waste of a soda plant in the quantity of 10–40 kg/m^2 is used. Then ploughing is carried out, after which additionally active sludge of chemical plant treatment facilities is applied in the amount of 4–5 kg/m^2 with subsequent sowing of plant seeds.

However, in general, these methods, as well as other methods, have not found wide practical application so far and are used at the laboratory (local) level.

In addition, it should be noted that about 360 billion cubic metres of wastewater is generated annually worldwide, with about 48% of this water currently discharged without treatment [9]. At the same time, the secondary utilisation of treatment products is less than 6%. Table 1 summarises the quantification of sludge per person, which can be used as secondary raw materials, in different countries.

Table 1

Sewage sludge from wastewater treatment plants by country [9]

Country	Amount of sludge per year by dry matter, tonnes/year		Population of the country as of 2020, million people	Kilogramme of sludge per inhabitant
	2005	2020		
Belarus	150 000	190 000	9,355	20
Latvia	23 950	50 000	1,908	26
Estonia	33 000	33 000	1,328	24
Lithuania	71 252	80 000	2,790	28
Sweden	210 000	250 000	10,313	24
Denmark	130 000	140 000	5,762	24
Finland	147 000	155 000	5,526	28
Poland	523 000	950 000	38,313	24
Germany	1 523 674	1 950 000	83,349	23
Russia	2 059 000	2 000 000	146,171	13

As shown in Table 1, in general, over the last 15 years, almost all European countries (out of those considered) have experienced negative dynamics related to the increase in the amount of sewage sludge generated in wastewater treatment plants. In this regard, it is necessary to introduce projects and technologies for the use of activated sludge as an initial technological raw material for the production of organic fertiliser/plant feed at treatment plants.

However, based on the results of the analysis, the following negative peculiarity was revealed in this direction: in the Republic of Belarus, the Russian Federation, the countries of the Shanghai Cooperation Organisation (SCO) as a whole, there is still no or not fully developed regulatory and technical base, allowing at the legislative level to place sewage sludge in the environment, to use it in accordance with the requirements of environmental safety. For this reason, activated sludge, which is such a valuable resource on a global scale, is not used within the framework of a closed cycle, but - in practice - is utilised and harms nature due to its high concentration in the settling areas, or is simply incinerated.

At the same time, EU countries are currently making serious attempts to use treatment products as fertiliser and to recycle sewage sludge to produce valuable products, while other regions in general do not make much use of this opportunity. Thus, according to the European Commission report, the average percentage of sludge used in agriculture in the EU countries is about 40 %, which is presented in Table 2 [9], and various methods of sewage sludge utilisation are used.

Table 2

Main methods of sewage sludge utilisation in EU countries, %

Country	Use in agriculture as organic fertiliser	Placement on sludge sites	Incineration	Discharge to the sea, ocean and other technologies
England	53	16	7	24
Austria	20	49	31	–
Germany	25	55	15	5
Denmark	45	28	18	9
USA	25	25	35	15
Italy	20	60	–	20
Sweden	60	30	–	10
France	23	46	31	–

Agricultural application of treated sewage sludge (excess sludge) is a more economical and environmentally friendly alternative to chemical fertilisers, for which there is no need to invest significant financial resources, as it is a by-product of water treatment. Sludge after treatment can be applied to the soil in any form (liquid sludge, dewatered dried sludge). Table 3 shows that sewage sludge is not only as good as organic fertilisers in terms of organic matter content, but in some respects exceeds them.

Table 3

Content of main elements of plant nutrition in sewage sludge and organic fertilisers, % per dry matter [9].

Fertiliser	Organic substance	N	P_2O_5	K_2O
Cattle manure	70–85	1,9–4,3	0,6–2,8	1,3–5,2
Swine manure	75–85	2,6–6,5	1,4–3,7	1,4–5,4
Litter	50–75	3,6–8,0	3,0–6,7	1,3–4,0
Upper peat	95–98	0,2–0,5	0,03–0,3	0,01–0,1
Transitional peat	90–95	1,4–2,5	0,02–0,4	0,05–0,2
Lowland peat	85–92	1,6–4,0	0,1–0,4	0,02–0,3
Sewage sludge	48–75	1,4–4,3	1,14–4,44	0,28–0,64

Harmful environmental impact of sewage sludge can be eliminated when it is used together with uTerra biohumus. When composting freshly produced sludge, it is dried (to a moisture content of about 50%), kept at a temperature of about +60°C to kill all pathogenic organisms, their eggs, etc., and then mixed with biohumus. The earthworm and its cultivated associations of agronomically valuable thousands of species of aerobic and anaerobic microorganisms in uTerra biohumus also contribute to the destruction of pathogenic microflora and microfauna in the resulting mixture and convert heavy metal salts into insoluble salts of humic acids, which are safe for the soil.

The percentage ratio of sewage sludge to biohumus is calculated based on the possibility of application for specific purposes. Composting as a method of sewage sludge utilisation is characterised by simplicity, accessibility and relatively low cost. Processing of sewage sludge based on the use of a special species of earthworm, which are used in the implemented in practice technology of biohumus production uTerra [2, 3] (see Figure 3), has shown its high efficiency. They are able to accumulate heavy metals in the body and transfer them into bound forms inaccessible for plants, which allows to expand the application area of products of such processing. The technology excludes the use of chemical reagents, which makes biological recycling environmentally safe and does not lead to secondary pollution of groundwater and soils. The research in these areas is currently being carried out in the Belarusian scientific-engineering company "String Technologies". The results of experiments and approbation of the corresponding technology will be presented in the following scientific papers.

Figure 3. *Fragment from the video film "Anatoly Unitsky spoke about biohumus" [10]*

Also, as recommendations on the possible use on the planet (by the example of individual regions and countries, including the SCO countries) of sewage effluents with the subsequent processing of activated sludge into organic feed for plants, the following is proposed:

a) increasing the amount of budgetary funds allocated in the regions (countries) for conducting scientific research (research, development and technological work) by relevant organisations to enable implementation of the results of developments at individual experimental sites/enterprises for sewage effluent processing, use of optimal application technology, monitoring of soil, water and plant quality indicators; holding thematic competitions (ideas, start-ups) on a permanent basis on a grant basis on the above topics in order to search for optimal solutions

b) adoption of regulatory legal acts in the regions in order to enable the implementation of the results of the research, development and technological work carried out at enterprises/individual regions for sewage processing;

c) adoption of legislative acts at the level of individual states for the introduction of proven technologies and their scaling up at the level of the national economy.

Conclusions

The processing of sewage waste, the volume of which is constantly increasing on a global scale, by applying sewage sludge (activated sludge) into the soil together with uTerra biohumus, represents a significant potential for mankind to improve soil fertility. In particular, the application of sewage sludge (activated sludge) into the soil can increase crop yields by up to 30%-40% [11], contributes to the renewal of the fertile soil layer. Also, the use of wastewater treatment products can be used in landscaping of desert territories and other lands without fertile layer. At the same time, the sewage treatment cycle itself becomes closed and practically waste-free. The use of sewage sludge will free up significant areas currently occupied by sludge pads, which fulfil only an accumulation function.

Application of increasing amounts of excess sludge on agricultural soils, on deserted territories within the framework of landscaping programmes on the basis of the technology proposed by the authors and recommendations on their implementation/scaling within the framework of improved legal field is one of the ways to preserve planetary ecology and improve food security of mankind.

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