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PRODUCTION OF BIOSORBENTS FROM WASTE OF PROCESSING OF PLANT RAW MATERIALS AND THEIR APPLICATION IN WATER TREATMENT TECHNOLOGIES

O. Kovalenko, Doctor of Technical Sciences, Professor, A. Kokhanska, Postgraduate student
Odessa National Academy of Food Technologies

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Abstract. The article shows the situation with the production of plant raw materials processing waste, their impact on the environment, in particular, water resources. It is noted that one of the reasons for the aggravation of water problems is the discharge of untreated wastewater into water bodies, namely, by food industry enterprises. It is substantiated that developing and implementing technologies for obtaining water treatment materials from plant processing waste can solve a number of important problems for humanity. Such materials are biosorbents, which together with activated carbon obtained from fossil fuels and charcoal, belong to the group of sorption materials with a high carbon content of organic origin. An overview of the technological schemes and processes of obtaining such materials is presented. The reagents and technological parameters for the main processes are specified. It is shown that it is possible to obtain a porous material with a high carbon content and functional groups capable of ion exchange or complexation by slow pyrolysis (or carbonization). The quantitative and qualitative composition of the biosorbent, its characteristics and ability to remove impurities from water influenced by technological modes of raw materials processing, their sequence, number and type of oxidants and other reagents, chemical composition of raw materials, etc. are presented. The properties of biosorbents and their efficiency in removing various impurities from water were analyzed on the example of biosorbents obtained from pea leaves, sunflower and vine. The technical and economic aspects of creating the production of biosorbents for water treatment are formulated. It is emphasized that in order to create efficient production of biosorbents in addition to energy efficient and environmentally friendly technology, it is important to take into account the productivity of the source of raw materials, their chemical composition and shelf life, transport conditions for processing, etc. The prospects for the use of tomato processing waste as a raw material for the production of materials for water treatment are evaluated. It is mentioned that in Ukraine there is a demand for effective solutions for the disposal of these wastes. The analysis of researches of methods of reception of biosorbents from wastes of tomatoes processing and their application for extraction from water of impurity of various nature is resulted. It is shown that this area of research is promising, but still not studied enough.

Key words: plant raw materials, processing, waste, technology, carbonization, biosorbents, properties, water, quality.

ОТРИМАННЯ БІОСОРБЕНТІВ З ВІДХОДІВ ПЕРЕРОБКИ РОСЛИННОЇ СИРОВИНИ ТА ЇХ ЗАСТОСУВАННЯ В ТЕХНОЛОГІЯХ ОБРОБЛЕННЯ ВОДИ

Коваленко О.О., доктор технічних наук, професор, Коханська А.В., аспірант
Одеська національна академія харчових технологій

Анотація. В статті показана ситуація з продукуванням відходів переробки рослинної сировини, зазначено їх вплив на навколишнє середовище, зокрема водні ресурси. Зазначено, що однією із причин загострення водних проблем є скид у водні об'єкти неочищених стічних вод, зокрема підприємствами харчової галузі. Обґрунтовано, що розробляючи і впроваджуючи технології отримання з відходів переробки рослин матеріалів для оброблення води можна вирішувати низку важливих для людства проблем. Такими матеріалами є біосорбенти, які разом з активованим вугіллям, отриманим з викопних копалин, та

деревним вугіллям, відносять до групи сорбційних матеріалів з високим вмістом вуглецю органічного походження. Представлено огляд технологічних схем та процесів отримання таких матеріалів. Зазначено реагенти і технологічні параметри для основних процесів. Показано, що шляхом повільного піролізу (або карбонізації) можна отримати пористий матеріал з високим вмістом вуглецю та здатними до іонного обміну чи комплексоутворення функціональними групами. Зазначено, що на кількісний і якісний склад біосорбенту, його характеристики і здатність вилучати домішки із води впливають технологічні режими процесів оброблення сировини, їх послідовність, кількість і вид окисників та інших реагентів, хімічний склад вихідної сировини тощо. На прикладі біосорбентів, отриманих з горохових ступок, соняшнику та виноградної лози проаналізовано властивості біосорбентів та їх ефективність щодо вилучення різних домішок із води. Сформульовано техніко-економічні аспекти створення виробництва біосорбентів для оброблення води. Зазначено, що для створення ефективного виробництва біосорбентів крім енергоефективної і екологічнобезпечної технології важливо враховувати продуктивність джерела сировини, її хімічний склад та терміни зберігання, умови транспортування до переробки тощо. Оцінено перспективи використання відходів переробки томатів в якості сировини для виробництва матеріалів для оброблення води. Зазначено, що в Україні є попит на ефективні рішення щодо утилізації зазначених відходів. Наведено аналіз досліджень способів отримання біосорбентів з відходів переробки томатів та їх застосування для вилучення із води домішок різної природи. Показано, що цей напрямок досліджень перспективний, але ще мало вивчений.

Ключові слова: рослинна сировина, переробка, відходи, технологія, карбонізація, біосорбенти, властивості, вода, якість

Introduction. Ukraine is an agrarian country whose potential is constantly growing. However, the intensive development of agriculture and food industry without effective disposal of waste is the cause of environmental degradation. One of the promising areas for solving the issue of utilization of such waste is their processing into useful products, in particular, into materials for natural and wastewater treatment.

Literature review. The cultivation and processing of vegetable raw materials into food products using various processes, materials and reagents lead to the accumulation of thousands of tons of waste in the world every year. (Table 1 according to [1]).

Table 1 – The scale of plants waste production in the agricultural sector and at food enterprises [1]

Waste	Waste production, t / year	Geographical location waste sources
Wastes from vegetable oil production	50 000–100 000	UK
Tomato processing waste	5 700 000	European countries
Remains of unprocessed wheat straw	4 000 000	EU countries
Barley grain used in brewing	3 400 000	EU countries
Pea pods	54 000	UK
Used coffee grounds	15 600	UK
Potato skins	100 000 (in dry form)	UK

A significant amount of waste from the processing of plant raw materials and low efficiency of their utilization lead to the accumulation of significant amounts of waste on agricultural lands and landfills. Under the influence of environmental factors, they are subject to decomposition. Thus, in the process of decomposition of plant biomass, carbon dioxide is released into the atmosphere. It has a negative impact on the ozone layer of our planet. The formed new organic and inorganic substances, including toxic, get into the soil and from there into underground and surface reservoirs. As a result – deterioration of soil fertility and pollution of drinking water sources.

Other anthropogenic pollutants, in particular heavy metals, also contribute to the deterioration of drinking water quality. They often end up in natural reservoirs with untreated industrial and domestic wastewater. It would be noted, that food companies produce a lot of wastewater with an excess of heavy metals (According to Table 2).

The quality of drinking water is also negatively affected by the use of old technologies, disrupted water infrastructure, secondary pollution and water loss during transportation.

The problem of rapid pollution of water sources has become very relevant today also because the world has seen a decline in fresh water in recent decades. The main reason is a significant increase in the population of the planet. According to experts, in 2030 the world's population will need 30% more water, 45% more energy, 50% more food than today [8].

Table 2 – Concentrations of heavy metals (HM) in untreated wastewater from food enterprises

Production	Wastewater costs per unit of output	HM concentrations in effluents, g/m ³
Sugar factory [7]	2,5 m ³ /t sugar	Fe (gen.) – 1,35; Cu – 0,05; Zn – 0,014
Beverage production [9]		Fe (gen.) – 2,6–4,4; Cu – 1,0; Ni – 0,8; Zn – 3,8–5,1; Cr (gen.) – 0,7–2,8; Cd – 1,3–1,8; Pb – 0,9–2,8; Hg – 0,9...1,6; As – 1,8...2,2
Oil and fat plant [8]	(0,2–1,5) m ³ /t unrefined oil; (0,75 – 2,0) m ³ /t margarine	Fe(gen.) – 1,8–2,8; Cu – 0,9; Ni – 0,6; Zn – 8,3–9,7; Cr (gen.) – 1,1–1,7; Cd – 0,3–0,8; Pb – 2,1–2,5
Yeast production [10]	(116 – 184) m ³ /t yeast	Fe (gen.) – 5,0 –45,0; Cu – 25,0–26,0
Permissible concentrations of heavy metals in effluents accepted into domestic urban sewerage networks, g/m ³ [4]: Cu – 0,5; Pb – 0,1; Zn – 1,0; Cd – 0,01; Cr ³⁺ – 2,5; Cr ⁶⁺ – 0,1; Ni – 0,5; Co – 1,0; Fe – 3,0; As – 0,1; Hg – 0,005		

The need to reduce waste, the search for new renewable resources, the desire to reduce the impact on the environment, including water resources, and concern for the society have accelerated the development of such a research as processing plant biomass waste into products necessary for mankind. It is known that the waste from the processing of vegetable raw materials contains various chemical components: mono- and disaccharides, organic acids, cellulose, hemicelluloses, lignin, pectin, waxes, ash, amino acids, lipids, polyphenols and others. Because of processing of vegetable waste with the use of such processes as chemical catalysis and biocatalysis, synthesis, bioconversion, thermochemical and hydrothermal treatment and others, you can get many useful products for humans. Today in industrial conditions food additives, alcohols, chemical monomers, building materials, cellulose nanocrystals, bio-glue, nanocomposites, bio-surfactants, biosolvents, materials for replacement of PVC, lubricating fuel additives, antioxidants synthesis gas, biofuel, activated carbon and biosorbents are received [1]. The development of new and improvement of existing technologies for obtaining biosorbents from plant waste for water purification from various impurities is of a particular interest from the point of view of solving water problems. This question is attracting the attention of more and more scientists around the world. After all, the creation of such industries will solve a number of environmental problems, promote better water supply and curb rapid global climate change.

The purpose and objectives of the study. The aim of the study was to summarize the information on technologies for obtaining biosorbents for water treatment. The objectives of the study were:

- to review the technological schemes and processes of obtaining sorption materials with high carbon content of organic origin;
- to analyze the properties of biosorbents and their effectiveness in removing various impurities from water;
- to formulate technical and economic aspects of production of biosorbents for water treatment;
- to evaluate the prospects of using tomato processing waste as a raw material for the production of biosorbents.

Review of technological schemes and processes of obtaining sorption materials with a high carbon content of organic origin. Charcoal, activated carbon from fossil fuels (brown coal, peat) and biocarbon from agricultural and food waste, algae, nut shells are pyrogenic materials with a high carbon content. What unites them is that they are all derived from plant biomass, obtained by its thermochemical transformation and contain some organic carbon. They are similar in elemental composition and predominant chemical bonds. However, depending on the processes and technological modes used to obtain them, have different properties and applications [9].

The main process of obtaining solid pyrogenic materials with high carbon content is pyrolysis. Auxiliary processes are washing, grinding, drying, activation, modification, application to the retaining surface. Depending on the raw material and the purpose of the final product, different combinations of processes in the technological scheme are possible (Fig. 1).

Raw materials → Grinding → Pyrolysis → Packing → Finished products

a)

Raw materials → Washing → Grinding → Drying → Pyrolysis → Activation → Modification → Washing
→ Grinding → Application on the retaining surface → Packing

b)

Figure 1 – Possible technological schemes for obtaining pyrogenic carbonaceous materials

There are many variants of technological schemes for obtaining pyrogenic carbonaceous materials [9]. Using various schemes it is possible to receive charcoal for household needs and metallurgy; activated carbon for soil remediation, food industry or medicine; reductants; electrodes; biosorbents for water treatment, etc.

In the process of pyrolysis, the formation of solid porous carbonaceous material is a consequence of thermal destruction of organic compounds. Pyrolysis is traditionally carried out in an oxygen-free environment. The important process parameters are temperature, duration, presence and properties of oxidants (Table 3, [9]). Pyrolysis conditions, as well as the chemical composition of raw materials greatly affect the amount of the final solid product, the chemistry of its surface, the structure. Therefore, changing the conditions of the process, you can get products with different properties and for different applications. During the pyrolysis of raw materials, its specific surface area increases due to the formation of a porous structure, mainly macroporous.

There is a slow pyrolysis (or thermal carbonization), fast and ultra-fast one. The temperature range of these processes does not differ significantly. The rate of heating of raw materials and the duration of the process are different. The highest yield of solid biocarbon and the highest percentage of carbon fixation can be obtained by slow pyrolysis [10].

Table 3 – Types and conditions of the pyrolysis process. Products of pyrolysis of plant biomass [10]

Process	Temperature range, °C	Heating rate, °C/sec	Processing time	Quantitative and phase state of the obtained products
Slow pyrolysis	350–700	0,1–100	from 5 minutes up to several days	(15–40)% – solid biocarbon, (20–55)% – liquid bio-oils, (20–60)% – non-condensed gases, (0–5)% – moisture, (2–10)% – ash

The increase in the carbon content in the final product is achieved by removing hydrogen, oxygen and other elements from the raw material. Thermal destruction of sugars, organic acids, alcohols, cellulose and hemicelluloses and occurs faster and at lower temperatures. The destruction of lignin occurs more slowly, at high temperatures in a wide range. According to [11] during pyrolysis, the destruction of hemicellulose occurs at temperatures in the range (220–315) °C, cellulose – at (315... 400) °C, lignin – in the range from 160 to 900 °C. The process of cellulose pyrolysis is endothermic, and hemicellulose and lignin are exothermic.

Of the polymers of plant biomass it is transformed in the process of pyrolysis lignin is the basis of porous carbon-containing material. In the process of pyrolysis, in addition to the destruction of lignin macromolecules, there is also their “crosslinking”. This is possible due to the splitting of the side benzene rings and their connection in places of unsaturated bonds with carbohydrate fragments and aldehyde groups of other polymers (Fig. 2, [12]). From gaseous substances, the highest yield of CO₂ is given by the destruction of hemicellulose, CO – cellulose, H₂ and CH₄ – lignin [11]. In fig. 3, [13] shows the changes that occur under different conditions of pyrolysis of raw materials such as corncobs.

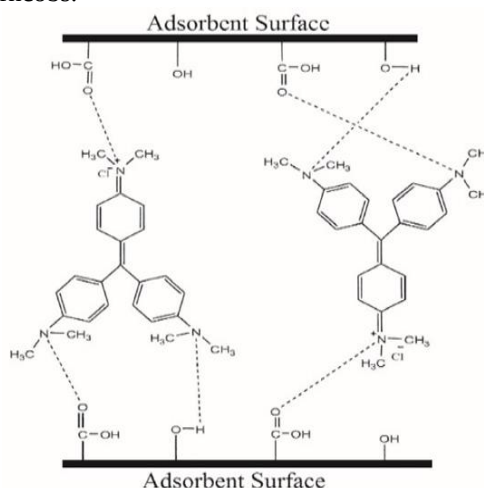


Figure 2 – Example of a structural fragment of solid biocarbon [12]

Activation is a process of increasing the sorption capacity of carbonaceous material by increasing the surface area of sorption. Chemical or thermochemical activation can be used in biosorbent production technologies. The choice of method of activating the material is determined by its further application in practice [9].

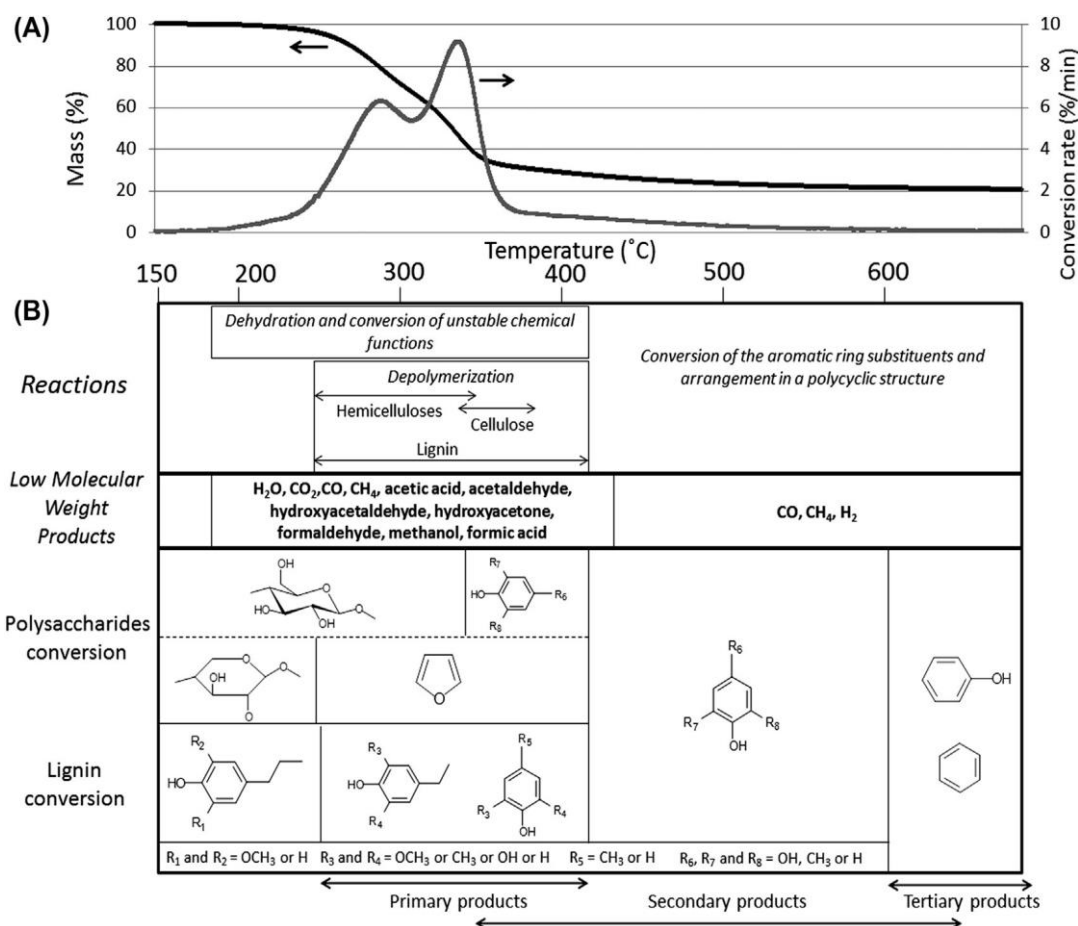


Figure 3 – Change in the mass and rate of chemical transformations of organic components of raw materials (corncobs) in the process of its carbonization (A). Substances formed during the carbonization of raw materials (B) [13]

Chemical activation is carried out mainly in order to form a more microporous sorption material. It is carried out either together with pyrolysis or after. Reagents are used for chemical activation – aqueous solutions of salts, alkalis, and acids (including solutions of $ZnCl_2$, KOH , H_3PO_4 and others). The ratio between the raw material for activation and the reagent is in the range from 1:0.5 to 1:3. The degree of activation depends on the chemical composition of the substance and the reagent, the stirring intensity, temperature and duration of activation. After chemical activation, the product is washed with clean water. Therefore, it is necessary to dispose of flushing effluents and exhaust gases to minimize their impact on the environment. In addition, this increases the cost of the process of obtaining the final product [9].

At thermochemical activation, also the specific surface of sorption of firm material due to formation of new porous space increases. Thermochemical activation of carbonaceous material is carried out using water vapor, carbon dioxide or a mixture of gases. When using carbon dioxide for thermochemical activation, materials with predominant microporosity are obtained. Activation of the material with carbon dioxide is accompanied by burnout, i.e. weight loss during activation. When using water vapor, a carbonaceous material with pores of different sizes is formed. Thermochemical activation, as well as chemical, is carried out either together with pyrolysis or after it [9].

The porosity of activated carbon depends on many factors, including raw materials, temperature, and duration of the activation process, type and amount of oxidant. In particular, the oxidation of a limited amount of air also modifies the properties of the carbonaceous material obtained from vegetable waste.

Both chemical and thermochemical activation changes the surface chemistry of the carbonaceous material. Oxidized functional groups are formed on the aromatic rings of the compounds that make up the material. Among them are phenolic hydroxyl $-OH$, carboxyl $-COOH$, carbonyl and other groups. Due to these groups, it is possible to use the obtained carbonaceous materials for sorption of ionic impurities, in particular metals. They are extracted from aqueous solutions by the mechanisms of ion exchange and complexation (Fig. 4, [14]).

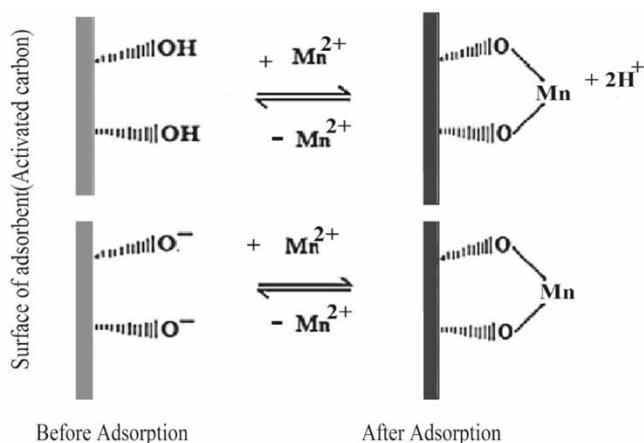


Figure 4 – Possible mechanisms of sorption of metal ions from aqueous solutions [14]

It should also be noted that in the process of carbonization of plant biomass ash is formed. It adsorbs anions, but can also adsorb high-charge cations, in particular Fe^{3+} or Al^{3+} , related to hydroxyl groups. Therefore, such a mechanism of extraction of HM from aqueous solutions by biosorbents in the form of carbonates should not be excluded from possible [15].

Modification is the process of introducing non-carbon fragments to the surface of carbon materials to improve their sorption capacity for specific sorbates. This process can be performed after or instead of activation. It is important to understand that the modification of carbonaceous materials is not an activation, although the oxidation process can occur. This occurs in particular when processing carbonaceous raw materials H_2O_2 or HNO_3 at temperatures up to 100°C . The modification is aimed at creating additional oxidized functional groups. It is mainly used to obtain carbonaceous materials with high sorption capacity to metals. To modify the material, if necessary, in addition to the above reagents, also use SO_2 or H_2S , ammonia, ozone [9].

In addition to the processes described above, others can be used in the technology of obtaining pyrogenic carbonaceous materials. Their purpose is to improve the properties of materials, such as selectivity to certain water impurities, to create conditions for more efficient implementation of subsequent technological processes, cheaper technology, etc. Therefore, for example, drying of raw materials is carried out for the purpose of its dehydration and partial decomposition of the organic and inorganic substances available in insignificant quantity in cellular juice of vegetable waste. The purpose of grinding dried raw materials is to obtain small fragments of raw materials and increase the availability of functional groups of plant polymers for impurities, such as metals [15]. It is known that if before heat treatment mix wet and dry raw materials, it is possible to optimize the moisture content in the raw material. This will reduce the duration or even avoid the energy-intensive drying process. The original plant biomass can be treated with metal salts to obtain biosorbents with high sorption capacity, for example to arsenic. It is known that in contrast to chemical activation, the dosage of salts in the raw material is much lower. In addition, the metal salt is not used as a catalyst, but in order to form specific places for the sorption of certain impurities in the finished product. It is possible to create additional places for sorption of impurity if after heat treatment the received pyrogenic carbonaceous material is in addition processed by metal-containing reagents. For example, treating the material with iron hydroxide can increase its selectivity, for example to arsenic [9].

Properties of biosorbents and their efficiency in removing various impurities from water. Preparation of biosorbents from waste processing of vegetable raw materials (peas, sunflower and vine) was carried out in the laboratory of the Department of Bioengineering and Water ONAFT. Place of cultivation of raw materials – Odessa and Mykolaiv regions. Pea processing wastes (leaves, stems, leaves) were initially partially dehydrated under environmental conditions. Next, the raw material was further dried in an oven at a temperature of $t = 120^\circ\text{C}$. The dried raw material was placed in a sealed stainless steel capsule and carbonized in a muffle furnace at a temperature of $t = 600^\circ\text{C}$ for 30 min in an oxygen-deficient environment. After grinding to a particle size (1–2) mm, the prepared raw material was used as a biosorbent. Wastes from sunflower processing (namely stalks and baskets) and vines were subjected only to carbonization under similar conditions and crushed [16].

The properties of the obtained biosorbents have been studied. For example, it was determined that the content of chemical elements in the biosorbent from pea leaves is as follows: C – 64.1 wt.%; N – 3.6 wt.%, H – 2.5 wt.%, S – 0.2 wt.%. This biosorbent has a microporous structure. The average pore radius is 22 nm, the porosity is $0.39\text{ cm}^3/\text{g}$, and the specific sorption surface area is $1.9\text{ m}^2/\text{g}$. The main functional groups on the

surfaces of the biosorbent are carboxyl and amino groups, the latter three times more. The percentage of adsorption of various HM ions by carbonized pea leaves during the processing of model solutions is above 90% [17].

To research the effectiveness of biosorbents in real conditions used: natural artesian water with high mineralization, pre-treated using membrane technology; natural artesian water with low mineralization; sewage of a cannery for processing vegetables. The enterprises that provided the opportunity to conduct research in production conditions are located in the Odessa region. The dosage of biosorbent in this study was 2 g / dm³. The contents of a hermetically sealed container with a sample of water and biosorbent were continuously stirred for two hours. Then the contents of the container were filtered. Physico-chemical quality indicators of biosorbent-treated water were determined immediately after filtration [16].

The data analysis showed that biosorbents derived from processing waste from peas, sunflowers and vines, can effectively treat natural and wastewater from iron, copper, manganese, fluorides, sulfates and polyphosphates. For example, by treating natural and wastewater with a biosorbent from grapes, it is possible to achieve a reduction in the initial iron content by a total of (50–90)%, manganese content – by (50–100)%, copper content – by (68–97)% source water quality. Biosorbents do not remove nitrates and chromium ions (VI). The degree of extraction of impurities from water by biosorbents depends on the type of biosorbent and the chemical composition of water. Biosorbents from grapevine remove impurities of natural and sewage better, worse – from baskets and sunflower stalks. Regarding the effect of pH and water mineralization, the efficiency of the biosorption process increases with decreasing water mineralization and increasing its pH. The negative point is that after treatment of water with biosorbents (from sunflower and peas) there is an increase in overall hardness, alkalinity and dry water residue, chloride content. For grapevine biosorbent, the change in these indicators is not significant or absent [16].

Technical and economic aspects of creating the production of biosorbents. The processing technology should be such that the potential of the components of plant waste is used to the maximum. It is necessary to make a careful choice of raw materials and consider the use of raw materials. It is important to consider the availability and quantity of raw materials for processing in a particular region. After all, fluctuations in the chemical composition of plant waste due to seasonal changes, high rate of their accumulation, rapid bacterial contamination and various technologies for processing raw materials can create problems with the management of their processing and increase the cost of biosorbents. From these positions, the advantages are on the side of mobile technological systems. It is also important to follow the principles of logistics in the organization of production. They will avoid both deterioration of quality of initial raw materials, and will allow optimizing expenses for its transportation and processing.

When choosing plant waste treatment processes, it is important to focus not only on obtaining a material with the best sorption properties. It is important to consider the impact of selected processes on the environment and economic performance of the final product. Preference should be given to low-energy technologies and technologies that will not contribute to the formation of toxic emissions and effluents. After all, the cheapness of raw waste should not be offset by high costs for their processing. It is obvious that the successful creation of production for the processing of plant waste into biosorbents is not possible without comprehensive research.

Prospects for the use of tomato processing waste as a raw material for the production of biosorbents for water treatment. Tomatoes are one of the most widely used vegetables in the world, both raw and processed. They produce juices, sauces, purees, and pastes, canned and pickled tomatoes. Tomato processing waste – peel and seeds [18]. In the southern regions of Ukraine, there are powerful agricultural holdings, in the structure of which there are enterprises for processing tomatoes. Communication with representatives of such enterprises showed that it is important for them to implement energy-saving and environmentally friendly waste treatment technologies, including materials for water treatment. These companies use a lot of water and in the conditions of its growing deficit and prices they increasingly use the technologies of circulating water supply. In addition, the use of cheap materials for water treatment will reduce the cost of wastewater treatment and reuse, as well as help improve the environment [19].

A review of the literature showed that the industrial technologies for obtaining materials for the treatment of water from waste tomato processing to date have not been created. One of the reasons is that little research has been done to study the methods of obtaining, properties, morphology, selectivity and resource of such materials. Although the chemical composition of tomato waste and the possibility of removing contaminants from water, in particular by chemisorption with the participation of functional carboxyl, nitro- or hydroxyl groups, allows us to consider such raw materials promising to obtain the above materials. This is noted by the authors of one of the few studies on this topic [20]. They investigated the process of purification of aqueous solutions from substances of the group of chlorophenols and nitrophenols, synthetic dyes, as well as a number of heavy metals. The water was purified with a material obtained from the skin of tomatoes. The peel was pre-washed with water, treated with propanol to remove anthocyanins, crushed and dried. The study examined the mechanisms of adsorption

and desorption of impurities, the effect of pH and temperature of the solution, as well as the duration of the process on the adsorption of substances from the aqueous medium, the process of material regeneration. It was found that the biosorbents obtained by the above method are good at removing cationic dyes, Pb^{2+} and Ni^{2+} ions from solutions, and somewhat worse – anionic dyes, As^{3+} and Cr^{6+} ions, organic micropollutants. However, we should note that the amount of adsorption varies depending on the pH of the medium. Sorption properties of the material do not change during five cycles of its reuse under the same initial conditions.

The disadvantages of the obtained biosorbent, in our opinion, are: the use of reagents in the processing of raw materials and the need for its washing, which contributes to the formation of additional wastewater; most likely the material is hygroscopic and this will complicate its industrial storage and use; the use of the material requires periodic organization of water treatment cycles, and hence the use of larger production areas. Our further research will be devoted to the solution of these and other questions.

Conclusions

1. Due to the significant volume, cheapness, availability and special chemical composition of plant processing waste in agriculture and food industry is a promising raw material for the production of biosorbents for water treatment. Establishing the production of biosorbents will slow down the pollution of soils and water sources with toxic substances, as well as undesirable climate change.
2. It is shown that different combinations with pyrolysis of other technological processes (washing, grinding, drying or activation of raw materials, etc.) allow obtaining biosorbents with different qualitative and quantitative characteristics and practical use. The technological parameters of processes and the chemical composition of raw materials have a significant impact on the properties of biosorbents.
3. It is revealed that with the use of carbonization (slow pyrolysis) of vegetable processing waste, it is possible to obtain microporous biosorbents with numerous surface carboxyl, amino and other functional groups. Due to these properties, such biosorbents effectively remove ionic impurities, in particular heavy metal ions, from both model and real waters.
4. When creating the production of biosorbents for water treatment, it is important to take into account the following technical and economic aspects: maximum use of the potential of plant waste components; availability and security of production of regional raw materials; mobility of the technological system for obtaining biosorbent; energy efficiency and environmental safety of technology processes; availability of modern information on the properties of biosorbents from certain types of raw materials and features of their use in treated water of different quality.
5. It is realized that the utilization of tomato processing waste is an urgent issue for agricultural holdings both in Ukraine and in the world. Establishing the production of biosorbents for water treatment is a promising way to solve this problem. However, the restraining factor on this path today is the lack of scientific information on effective technologies for obtaining and using such biosorbents.

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