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THE STRUCTURE AND PROPERTIES OF MICROBIOCENOSIS IN DUMPS OF THE FUEL AND ENERGY COMPLEX OF UKRAINE

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The work aimed to conduct complex chemical and microbiological study of the dumps of the fuel and energy complex of Ukraine. It is established that the qualitative composition of the aboriginal microbiota of the studied technogenic substrates does not to depended on the storage time, because it was determined by the chemical and mineralogical compositions and is mainly represented by the heterotrophic and acidophilic chemolithotrophic bacteria (ACB). It is noted that the number of all groups of microorganisms in dumps increased during long term storage due to internal processes and the impact of external climatic factors. In our experiment the ACB association demonstrated the maximum leaching activity when the divalent iron was as an energy source. It is also noted that the "silicate" bacteria present in the aboriginal consortium and have no leaching activity, significantly increase bioleaching rates by ACB. The results of the study indicate on the formation of resistant specific microbiocenoses in the dumps of the fuel and energy complex that can be used as sources of highly active strains obtaining for use in biotechnological processes of metal extraction.

Key words: aboriginal community, dumps, bioleaching.

The fuel and energy complex (FEC) of Ukraine produces waste products as a result of the coal mining and processing. Accumulating in huge quantities at the territories of industrial complexes, the waste creates an additional burden on the environment. At the same time, the waste of FEC contains, in particular, rare metals in industrial concentrations, which makes it a "man-made deposit", the unconventional raw materials of valuable components [1, 2]. A special aboriginal microbial community is formed under the influence of industrial and natural factors, and later affected by the storage conditions in the studied anthropogenic ecosystems. In long-term storage, the substrates change affecting the structure and composition of the microbiocenosis and the ability of the formed equilibrium systems to destruct. The available literature data suggests that the use of the aboriginal consortium associations in the leaching metals biotechnology is promising due to the effect of syntrophic relationships between individual groups of microorganisms in the community [3, 4]. The microbial biotechnologies should be implemented based on comprehensive studies of the biological and physicochemical properties of the initial solid substrate, the qualitative and quantitative assessment of the indigenous microbial community present in it, the possibility of isolating, selecting and selecting the most promising highly active strains. There is ample evidence of the microbial role in both the formation and destruction processes of geogenic substrates (natural ores and minerals, native sulfur, oil, peat, coal, etc.), accompanied by the bioextraction of useful components [5–7]. Information is limited about the life and biochemical activity of microorganisms in the raw materials of technogenic origin.

The aim of the work was to conduct a comprehensive chemical and biological research of technogenic raw materials produced by the FEC enterprises of Ukraine to establish the structure and properties of their microbiocenosis.

Material and Methods

The objects of research were dumps of the Central concentrating plant (CCP) of the Lviv-Volyn coal basin (LVCB), fly ash and ash from the burning of LVCB coal at Ladyzhinska and Dobrotvorska TPSs, respectively. The samples (more than 60 in total) were taken during 2008–2014 (April to November) on the slopes of the dumps at the 50.0 ± 5.0 cm surface layer.

To identify various physiological groups of native microbial microorganisms, enrichment cultures and specific nutrient media were used: 9K and 9K * for the acidophilic chemolithotrophic bacteria (ACB); Beyerinck for the neutrophilic chemolithotrophic bacteria; 882 for representatives of the genus *Leptospirillum;* 150a for the moderately thermophilic representatives of the genus Acidithiobacillus, such as A. caldus; Gorbenko for the heterotrophic bacteria; Czapek for the filamentous fungi; and A-27 for the "silicate" bacteria (Table 1) [8, 9].

As the energy source, either $FeSO_4 \cdot 7H_2O$ at a concentration of 44.5 g/dm^3, or elemental sulfur or thiosulfate at a concentration of 5.0 g/dm^3 was added to the mineral background of the 9K medium.

The biomass of various representatives of the dump microbiocenosis was accumulated at a ratio of solid (substrate) to liquid (nutrient medium) S: L = 1: 10. In the control experiments sterile substrate was introduced to the nutrient medium. The cultures were incubated at a temperature of 30.0 ± 0.5 °C for mesophilic (MP) and 50.0 ± 0.5 °C for moderately thermophilic (MTP) bacteria, pH 3.0–7.0 for 5 days. The development of microorganisms was evaluated by the presence of the surface film, the change in pH and the appearance of the bacterial suspension. The abundance of representatives of different microbial groups was established by sowing tenfold serial dilutions of the bacterial suspension on agar media of the same composition. The number of spore-forming bacteria was determined after heat treatment at 80.0 ± 0.5 °C for 15 minutes.

The biogeochemical activity of the aboriginal community was judged by the concentration of metals transferred from the solid phase to the culture medium. Selective nutrient media were used as leaching solutions

Table 1. **The composition of nutrient media (g/dm^3) for identification of microbial groups in waste products of the fuel and energy complex of Ukraine**

Mineral components	Culture media [8, 9]						
	A-27	Czapek	9K	9K*	150a	Beyerinck	882
KH_2PO_4			0.50	0.05	0.50		0.027
$(NH_4)_2SO_4$			3.00	0.45	3.00		0.132
$MgSO_4 \cdot 7H_2O$	0.50	0.50	0.50	0.50	0.50		
$MgCl_2 \cdot 6H_2O$						0.10	0.053
NH_4CL						0.10	
KCl		0.50	0.10	0.05	0.10		
$NaNO_3$		3.00					
K_2HPO		1.00					
Na_2HPO_4	2.00					0.20	
$Ca(NO_3)_2$			0.01	0.014	0.01		
$CaCl_2 \cdot 2H_2O$							0.147
$FeCl_3$	0.001	0.01					
$NaHCO_3$						1.00	
$CaCO_3$	1.00						
Quartz	10.00						
Sucrose	5.00	30.00					
Yeast extract				0.02			
pH	7.5–8.0	6.6–7.2	1.0–3.5	1.8–4.0	1.5–3.5	4.5–8.5	2.0–4.0

(Table 1). Sterile waste with a sterile leach solution served as controls. The bioleaching process was carried out by the vat method at a ratio S: L = 1:10, pH — 2.0, 30.0 ± 0.5 °C for MP and 50.0 ± 0.5 °C for MTP bacteria for 7 days. The concentration of metals in solid substrates and solutions was determined by atomic absorption spectroscopy on AAS-1 (Germany) and C-115PK Selmi (Ukraine) devices [10]. The reliability of obtained results was evaluated by the Student's *t*-test with a probability of $P < 0.05$.

Results and Discussion

Table 2 shows the chemical composition of the studied substrates by the main components.

To observe the development of aboriginal associations in substrates, depending on the timing of their accumulation, preliminary microbiological crops were grown on nutrient media selective for acidophilic chemolithotrophic and heterotrophic microorganisms because those are typical representatives of microbiocenosis of geogenic and technogenic origin (Table 3).

The microorganisms were not detected at all or their communities were very poor in fresh substrates, especially heat-treated ash and fly ash. In storage, the communities are formed. In dumps with an acidic environment, the conditions favor the active growth of both chemolithotrophic and heterotrophic microorganisms. In neutral or weakly alkaline ash and fly ash, the heterotrophic component forms an association faster than the chemolithotrophic one, and quantitatively the former is more pronounced, both in comparison with the dumps and in relation to its own chemolithotrophic component. However, generally, stable, numerous aboriginal equilibrium communities form during the storage of the studied technogenic substrates for longer than three years. Then it is possible to isolate active strains for biotechnological developments. For further research, ash and fly ash (storage period 24–36 months), as well as "stale" dumps substrates with different shelf life were chosen: 24–28 months (black) and more than 60 months (red).

The results of microbiological studies are shown in Fig. 1. They indicate the quantitative prevalence of heterotrophic and acidophilic chemolithotrophic bacteria, both mesophilic and moderately thermophilic, in waste products of FEC.

In all the studied substrates, especially with acidic pH (black and red coal preparation waste), ACB dominate which use bivalent iron and sulfur / thiosulfate as an energy source. In the mesophilic association of all substrates that develops on a standard 9K medium with bivalent iron or thiosulfate, a lot of small Gram-negative rod-shaped cells were noted. In the microbial associations of iron and sulfur-oxidizing bacteria, no significant differences in cell morphology were seen in accordance with the available literature data. The number of cells oxidizing bivalent iron and thiosulfate in ferrous dumps, fly ash and ash was 10^4–10^5 cells/g.

In the red "stale" dumps, their number was greater and reached 10^8 and 10^6 cells/g for iron-

Table 2. **The content of main controlled metals in waste products of FEC of Ukraine (g/ton)**

Metal	Minimum industrial content	Ash, Dobrotvorska TPS	Fly ash, Ladyzhinska TPS	Dumps of coal concentrating, CCP "Chervonohradska"	
				Black	Red
Plumbum	18–22	75.0±0.05	120.0±0.1	42.20±0.05	57.92±0.05
Nickel	80–120	110.0±0.1	170.0±0.1	134.2±0.1	132.9±0.1
Cadmium	45,0–55,0	8.5±0.05	7.5±0.05	2.82±0.05	3.63±0.05
Aluminum	$(2.5–5.0)\cdot10^3$	$(105.0±0.1)\cdot10^3$	$(37.5±0.05)\cdot10^3$	$(13.92±0.05)\cdot10^3$	$(8.92±0,05)\cdot10^3$
Cuprum	80–100	92.5±0.1	60.0±0.05	62.18±0.05	78.90±0.05
Manganese	850–1000	1750±0.1	600.0±0.1	317.7±0.1	812.9±0.1
Zinc	65–70	110–180	315.0±0.1	112.5±0.1	130.9±0.1
Germanium	15–20	30–40	45.0±0.05	26.0±0.1	30.0±0.1
Gallium	15–20	30–40	95.0±0.1	15.1±0.1	22.4±0.1

Table 3. **Microbial characteristic of waste products of FEC of Ukraine**

Sub-strate	Storage time	pH of water extract	Microbial abundance, cell/g			
			Heterotrophic		Acidophilic chemolithotrophic	
			Bacteria	Fungi	Oxidizing Fe(II)	Oxidizing S0
Dumps	Freshly produced	1.8–2.0	100±5	50±2	(5.3±0.4)×102	15±5
Dumps	10–14 months	2.0–2.4	$(3.60\pm0.65)\times10^3$	$(1.50\pm0.25)\times10^2$	$(4.70\pm0.85)\times10^3$	$(1.55\pm0.25)\times10^2$
Dumps	24–28 months	2.6–3.3	$(7.80\pm1.65)\times10^5$	$(8.70\pm0.75)\times10^2$	$(7.50\pm1.56)\times10^5$	$(7.70\pm0.55)\times10^4$
Dumps	≥ 36 months	3.0–3.6	$(5.60\pm1.25)\times10^7$	$(6.70\pm1.35)\times10^3$	$(9.35\pm1.85)\times10^7$	$(4.80\pm0.95)\times10^5$
Dumps	≥ 60 months	3.5–4.5	$(9.30\pm1.85)\times10^7$	$(1.50\pm0.30)\times10^4$	$(3.70\pm0.75)\times10^8$	$(3.95\pm0.75)\times10^6$
Ash	Freshly produced	5.8–6.2	15±3	n/o*	n/o	n/o
Ash	10–14 months	6.0–7.0	$(8.20\pm1.65)\times10^3$	$(2.70\pm0.55)\times10^2$	$(5.80\pm1.15)\times10^2$	$(3.50\pm0.70)\times10^2$
Ash	20–24 months	6.2–7.4	$(7.95\pm1.58)\times10^5$	$(8.75\pm1.75)\times10^2$	$(2.80\pm0.55)\times10^4$	$(4.30\pm0.85)\times10^3$
Ash	24–36 months	6.4–7.8	$(4.70\pm0.96)\times10^7$	$(2.10\pm0.45)\times10^3$	$(3.55\pm0.75)\times10^5$	$(4.55\pm0.95)\times10^4$
Fly ash	Freshly produced	6.4–8.0	9±1	n/o	n/o	n/o
Fly ash	10–14 months	7.0–9.5	$(5.20\pm1.1)\times10^3$	$(4.30\pm0.85)\times10^2$	$(9.70\pm1.95)\times10^2$	$(4.15\pm0.80)\times10^2$
Fly ash	20–24 months	7.8–10.2	$(8.55\pm1.75)\times10^5$	$(2.75\pm0.55)\times10^3$	$(1.25\pm0.25)\times10^3$	$(9.70\pm1.95)\times10^2$
Fly ash	24–36 months	9.0–10.8	$(2.55\pm0.55)\times10^8$	$(7.70\pm1.55)\times10^3$	$(8.70\pm1.75)\times10^4$	$(1.40\pm0.25)\times10^3$

* — not observed.

and sulfur-oxidizing bacteria, respectively. The obtained data suggest the presence of representatives of the genus *Acidithiobacillus* (*A. ferrooxidans* and *A. thiooxidans*), widely distributed in natural sulfide ores in the studied technogenic raw material and actively participating in metal leaching processes [11].

In mesophilic conditions of medium 882, morphologically different cells — spirillus, vibrios, and small curved rods — were observed. Their number in black waste, fly ash, and ash was 10^3–10^4 cell/g, in the red "stale" dumps it was 10^5 cell/g. This suggested the presence of representatives of the genus *Leptospirillum* in the studied microbiocenosis. The genus includes iron chemolithotrophic bacteria [12]. These results are consistent with the available literature data, according to which bacteria of the genus *Leptospirillum* are always present in natural and man-made mineral raw materials and do not make a significant contribution to the bioleaching processes themselves, but in an aboriginous consortium with *A. ferrooxidans* and *A. thiooxidans* they contribute to the efficiency of extraction metals [13].

In mesophilic conditions of Beyerinck's medium, the development of small Gram-negative rods was observed in the amount of 10^2 cell/g (black dumps, fly ash and ash) and 10^4 cell/g in red "stale" dumps. This suggested the presence of neutrophilic thionic bacteria of the genus *Thiobacillus* in the studied microbiocenoses. There is no data on the presence of this group of bacteria in technogenic raw materials, as well as any information about their ability to leach metals. However, it is known that in nature, *Thiobacillus thioparus* in association with *Thiobacillus ferrooxidans* are active agents of corrosion of metallic and non-metallic products. Therefore their presence in biocenoses with quantitative advantage of acidophilic bacteria is quite possible [14].

The microbiocenosis of FEC waste products is formed in widely ranging temperatures during storage. There is also the self-heating and self-ignition phenomena. Thus it was interesting to identify bacteria for which the optimum temperature for growth is 45.0–50.0 °C. An insignificant amount (10^3–10^4 cell/g) of small gram-negative rod-like cells was noted in all substrates in the cumulative culture based on the medium 150a. This can be attributed to the genus *Acidithiobacillus*, in particular *A. caldus*. According to a number of studies, *A. caldus* is always, albeit slightly, present in mineral raw materials and, together with *A. ferrooxidans* and *A. thiooxidans*, contributes to the efficiency of metal extraction [15].

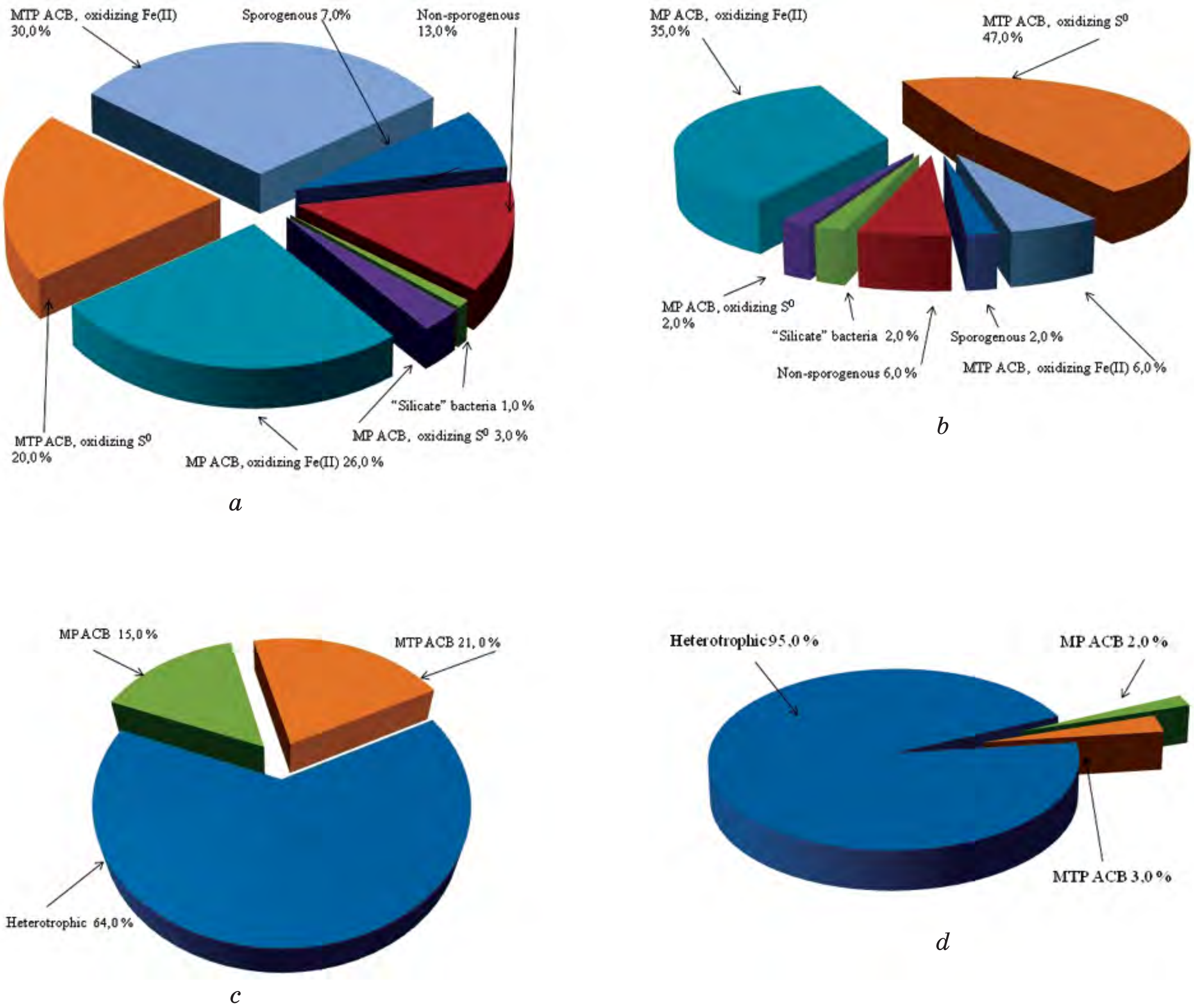


Fig. 1. **Quantitative and qualitative content of microbial cenoses:**
a — black dumps of CCP; *b* — red dumps of CCP; *c* — fly ash of Ladyzhinska TPS; *d* — ash of Dobrotvorska TPS

Mixotrophic, moderately thermophilic bacteria were found in all studied waste substrates. In a cumulative culture based on a modified 9K medium with thiosulfate or bivalent iron, an abundant development of Gram-positive short round or cocco-like spore-forming cells was recorded, which can be attributed to the genus *Sulfobacillus*. Their numbers were much higher in red "old" waste and reached almost 10^9 cell/g. This is the maximum quantitative indicator among all the iron- and sulfur-oxidizing bacteria identified in the studied substrates, possibly associated with the processes leading to self-heating of the dumps.

The FEC waste products are bio-inert systems. However, an intensive development of heterotrophic bacteria, both spore-and non-spore-forming (Fig. 1) was observed there, with numerical predominance in ash and fly ash with neutral and weakly alkaline pH (up to 10^8 cell/g), as well as in the "stale" coal enrichment dumps, up to 10^7 cell/g. These results are consistent with available reports on the ability of certain representatives of heterotrophic bacteria to grow in mineral solutions in the presence of trace amounts (μg/dm^3) of organic substrates, as well as the activity of the representatives of the genera *Pseudomonas* and *Bacillus* in the leaching of gold and uranium [16].

The presence of so-called "silicate" bacteria capable of destroying silica and silicates was first established in the heterotrophic component of FEC waste products. In bacterial suspension on nutrient A-27 medium, Gram-positive large rods capable of forming spores were recorded, on agarized A-27 medium they were formed in almost identical round transparent colorless colonies. Their number was in the range of 10^3–10^4 cell/g, reaching a maximum in ash (10^5 cell/g), which may be due to the increased content of silicon and aluminum in this substrate (Table 1) [17].

Thus, the qualitative composition of the microbiocenoses of the FEC waste products under study does not depend on the storage time, since it is determined by the chemical and mineralogical composition of the substrates. As they accumulate and are stored under the influence of external factors, quantitative differences arise in the microbiocenoses, which are affected by the accumulation time, composition and pH of waste products. When comparing substrates with the same storage time but different pH, it is obvious that in ash (pH 6.4–7.8) and fly ash (pH 9.0–10.8) the conditions are more favorable for the development of heterotrophic microorganisms both in comparison with the black dumps (pH 2.6–3.3), and in relation to the development of own acidophilic chemolithotrophic component (Fig. 1). It should be noted that the abundance of the ACB community in fly ash (amorphous, finely dispersed, with a large specific surface), despite its alkaline pH, is comparable to the coarse ash. This is another important factor for bioleaching associated with the presence of microorganism cells, either free or attached to the surface of solid particles. The presence of defects in the crystal structure and a large specific surface of the substrate contribute to faster growth and development of all possible microorganisms of the consortium [18].

The biotechnological potential of representatives of the consortium of FEC waste products was determined by their ability to create favorable conditions for certain groups of microorganisms to destroy substrates and extract valuable metals from those.

Representatives of acidophilic chemolithotrophic bacteria oxidizing bivalent iron and thiosulfate were the most numerous group of practical interest in the aboriginal consortium of FEC waste products. The results on leaching of metals from FEC waste products by the most numerous groups in the aboriginal consortium, the mesophilic and moderately thermophilic association of ACB, are presented in Fig. 2 and 3 respectively. In the control experiments with sterile substrates and nutrient mediums the leaching of Ge, Ga, Cd, Ni, Cu, Zn, Mn and Al did not exceed 2–4%, the leaching of Pb did not exceed 0,3–0,5%.

Hence, the association of moderately thermophilic bacteria of the studied substrates, regardless of their nature, was distinguished by a higher leaching activity compared to the mesophilic community. However, maximum leaching rates of metals, both rare and heavy, were achieved using bivalent iron as an energy source similarly in mesophilic and moderately thermophilic conditions. This confirms the leading role of *A. ferrooxidans* in the processes of bacterial leaching metals under mesophilic conditions [9, 18, 19]. It is established that the black coal dumps is the most "accessible" to microorganisms; the degree of leaching of almost all registered metals exceeds the similar indicators for other substrates.

The change in the microbial landscape and the number of bacteria was studied during the entire experiment of metal bioleaching of from the black dumps (Fig. 4). Thus, during the first day, the number of bacteria in the mesophilic association did not exceed 4.5×10^{2} cell/g. Gram-negative short thin cells prevailed in the stained microscopic preparation, sometimes larger Gram-positive cells with rounded ends were encountered (Fig. 4, *a*). After five days, the number of bacteria increased significantly and reached 7.8×10^{7} cell/g. During this period of time, bloated round cells with thickened membrane and unstained contents were recorded in the bacterial suspension (Fig. 4, *b*). Bipolar inclusions were present on the surface of some cells. According to available literature data, those are globules of sulfur resulting from the oxidation of mineral raw materials [20].

The appearance of rounded large cells was also observed during longer-term cultivation of the studied strains (Fig. 4, *c*). After 7 days their total amount in the bacterial suspension decreased to 5.7×10^{4} cell/g. This was accompanied by lysis of the cells, a shift in the pH of the leach solution towards neutral values and the beginning of deposition of insoluble Fe^{+3} compounds.

When using the moderately thermophilic association of ACB, the number of bacteria was slightly higher. At the beginning of the experiment it was 5.7×10^{4} cell/g, within five days it reached a maximum of 7.3×10^{10} cell/g and at the end of the experiment (after 7 days) decreased to 3.9×10^{5} cell/g. This changing pattern of biomass amount is a reflection of the classical phases of growth and development of microorganisms: exponential, stationary, dying off and cell lysis phases [9].

Despite the quantitative advantage of the heterotrophic component in the waste product microbiocenosis (Fig. 1), its leaching activity was insignificant and the extraction of metals into the solution did not exceed 15.0%. Extraction of metals into the solution as a result of the activity of "silicate" bacteria was also

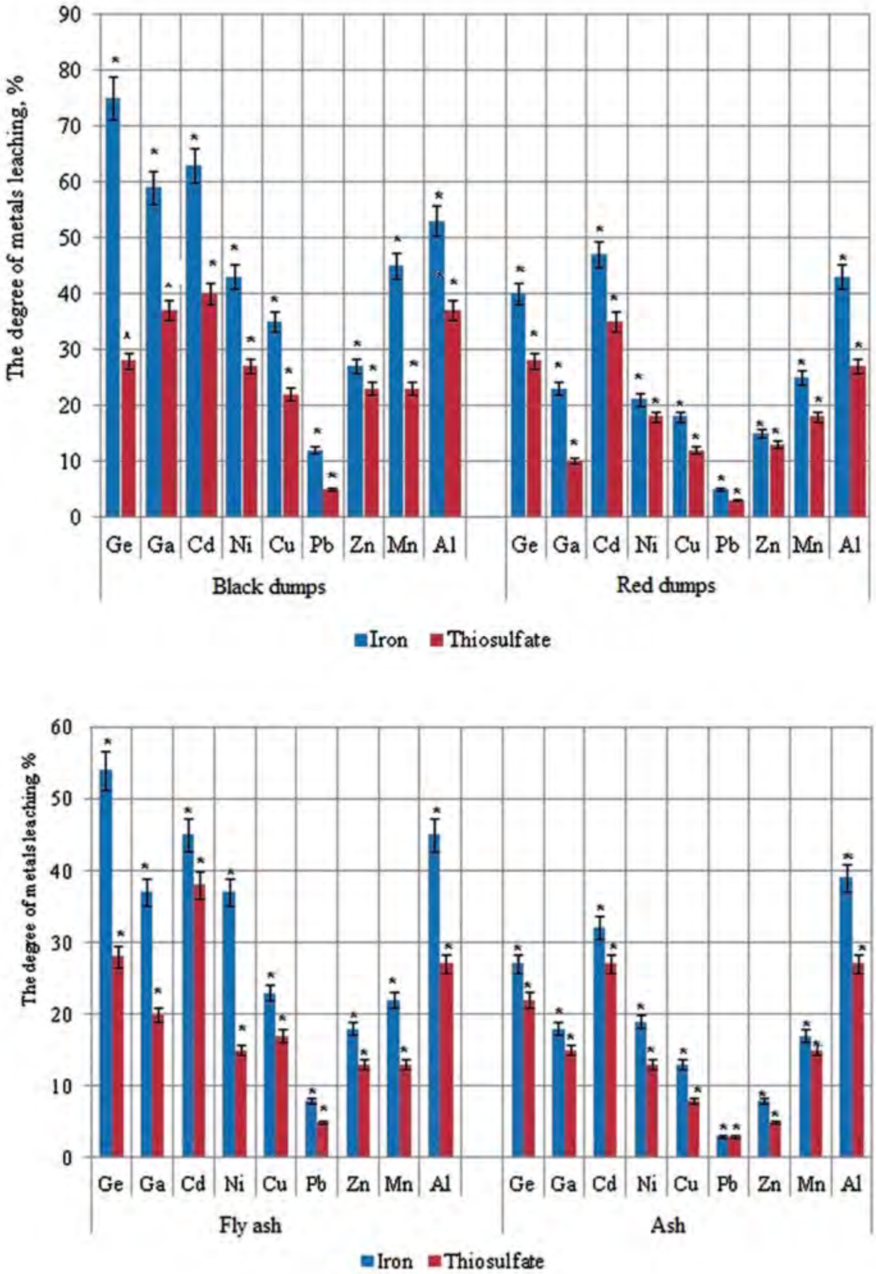


Fig. 2. **Metal leaching by the mesophilic association of acidophilic chemolithotrophic bacteria from the FEC waste products**

Hereinafter: *$P < 0.05$ compared with control

In the control experiments with sterile substrates and nutrient mediums the leaching of Ge, Ga, Cd, Ni, Cu, Zn, Mn and Al did not exceed 2–4%, the leaching of Pb did not exceed 0,3–0,5%

low (it did not exceed 12%). However, it was obvious that the substrates were destroyed and their appearance changed after contacting with the nutrient medium A-27, creating favorable conditions for the growth and activity of "silicate" bacterial consortium (Fig. 5).

The waste products contained a lot of silicon-containing phases (silica, aluminosilicates). Hence our assumption that the association of "silicate" bacteria at the initial stage of processing the FEC dumps due to the destruction of stable crystalline silicate structures can enhance the effectiveness of the further action of the chemolithotrophic component of the consortium in relation to metal recovery. This idea was confirmed (Fig. 6), the results are patented [21].

Thus, the complex chemical and microbiological studies of waste products of FEC of Ukraine showed that the physico-

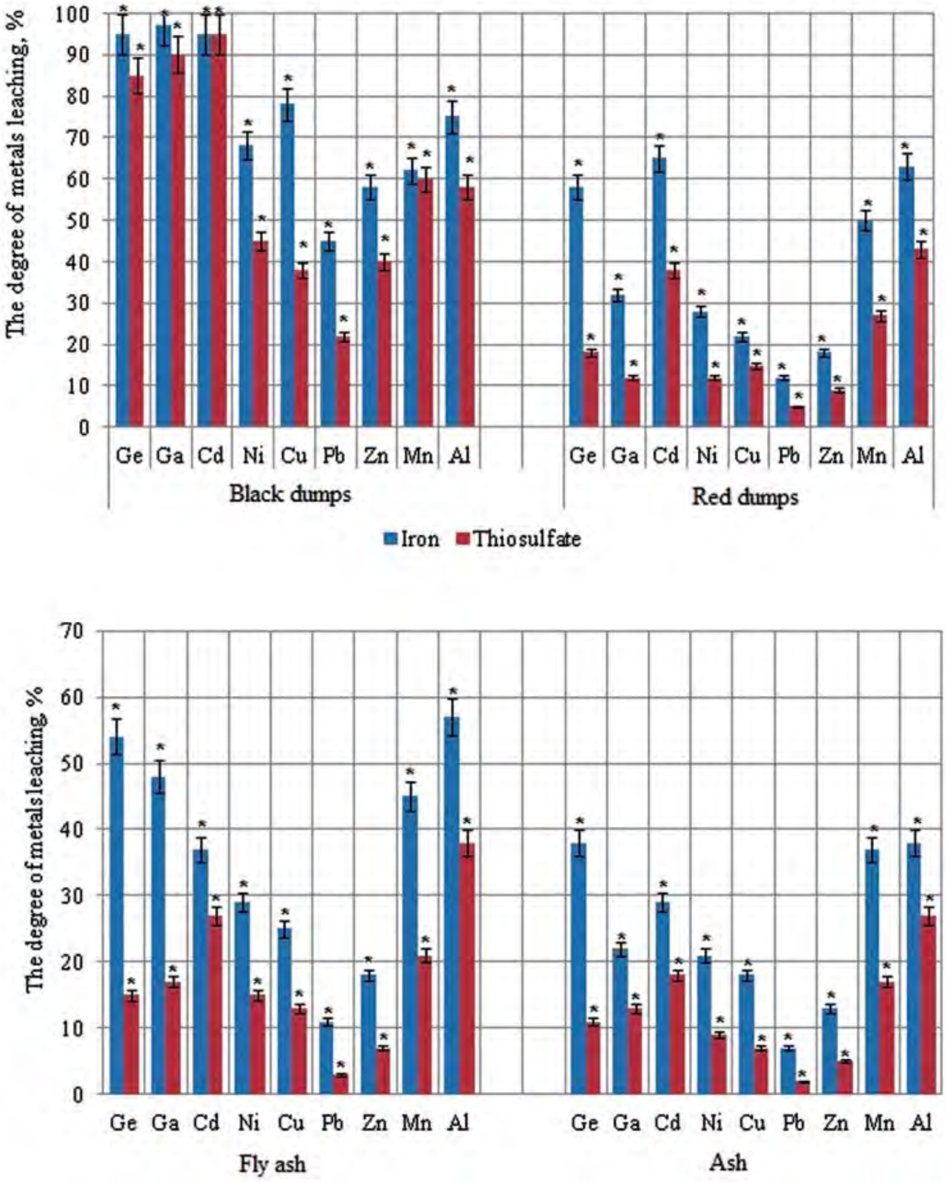
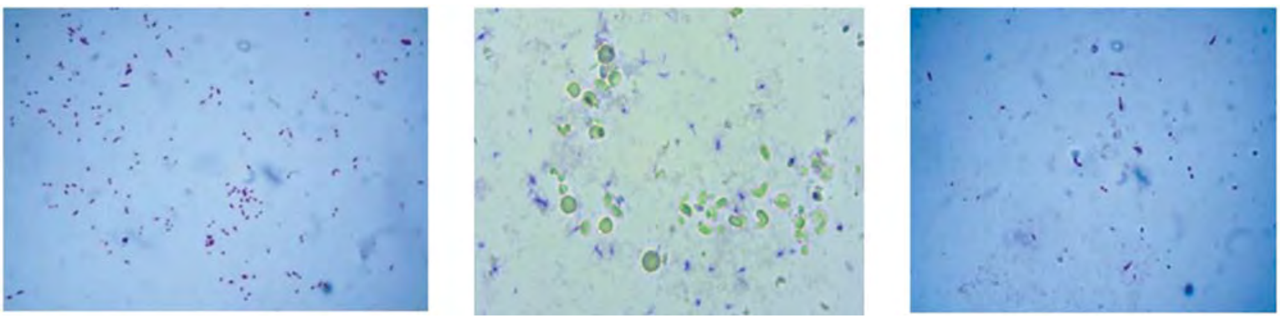


Fig. 3. **Metal leaching by the moderately thermophilic association of acidophilic chemolithotrophic bacteria from the FEC waste products**



a *b* *c*

Fig. 4. **Micrographs of the association of mesophilic ACB in the metal leaching from the black dumps:** at the beginning of the process (*a*), after 5 (*b*) and 7 (*c*) days; ×1000

Fig. 5. **Appearance of black waste dumps:**
before (*a*) and after (*b*) bacterial leaching with nutrient medium A-27

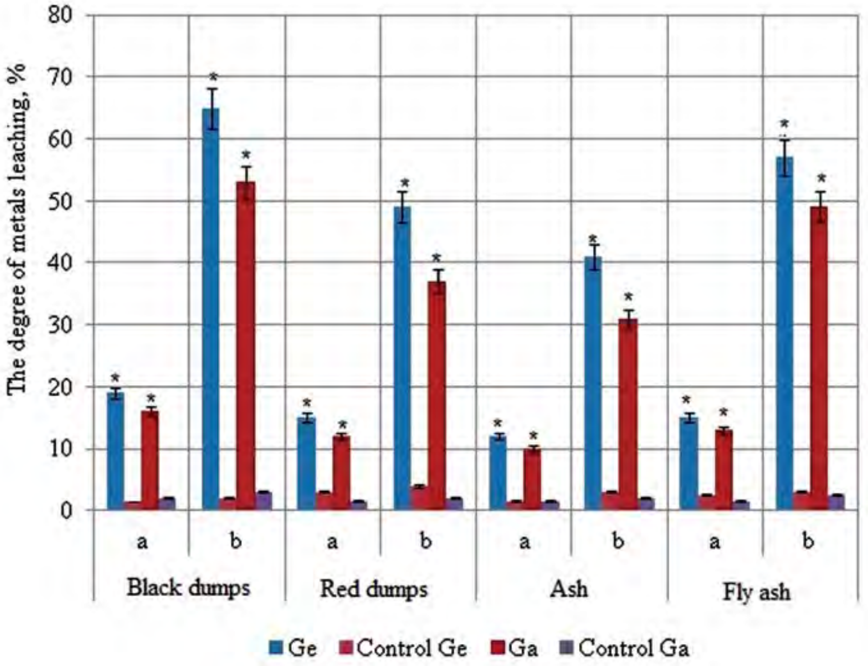


Fig. 6. **Extraction of germanium and gallium from the waste dumps:**
by the mesophilic association of acidophilic chemolithotrophic bacteria (*a*), after pre-treatment with medium A-27 (*b*). Leaching time 24 hours

chemical composition and the conditions of their formation and storage determine the structure of their microbiocenosis. The qualitative composition of the native microbiota does not depend on the storage time. The microbiota is determined by the chemical and mineralogical composition of substrate, and is represented mainly by heterotrophic and acidophilic chemolithotrophic bacteria. An increase in the number of all groups of microorganisms in long-term stored waste products is established, which is a result of internal processes and the influence of external climatic factors. The maximum leaching activity is observed in the ACB associations, especially when using bivalent iron as an energy source. The "silicate" bacteria found in the structure of the aboriginal consortium are not capable of leaching metals on their own. However in combination with ACB they contribute to a significant increase in the bioleaching rates. The research results indicate the formation of stable specific microbiocenoses in FEC waste products. The coenoses can be sources of obtaining highly active strains for use in biotechnological processes of metal extraction.

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СТРУКТУРА ТА ВЛАСТИВОСТІ МІКРОБІОЦЕНОЗІВ ВІДХОДІВ ПАЛИВНО-ЕНЕРГЕТИЧНОГО КОМПЛЕКСУ УКРАЇНИ

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Метою роботи було проведення комплексного хіміко-мікробіологічного дослідження відвальних продуктів паливно-енергетичного комплексу України. Встановлено, що якісний склад аборигенної мікробіоти досліджених техногенних субстратів не залежить від термінів зберігання, оскільки визначається хімічним і мінералогічним складом, і представлений переважно гетеротрофними і ацидофільними хемолітотрофними бактеріями (АХБ). Виявлено зростання чисельності всіх груп мікроорганізмів у відвальних продуктах тривалого зберігання, що є результатом внутрішніх процесів і впливу зовнішніх кліматичних факторів. Показано, що максимальну вилуговувальну активність мають асоціації АХБ, особливо в разі використання двовалентного заліза як джерела енергії. Виявлені в структурі аборигенного консорціуму «силікатні» бактерії, що не здатні вилуговувати метали самостійно, в поєднанні з АХБ сприяють значному підвищенню показників біовилуговування. Результати досліджень свідчать про формування у відвальних продуктах паливно-енергетичного комплексу стійких специфічних мікробіоценозів, що можуть бути джерелами отримання високоактивних штамів для використання в біотехнологічних процесах вилучення металів.

Ключові слова: аборигенне угруповання, відвали, біовилуговування.

СТРУКТУРА И СВОЙСТВА МИКРОБИОЦЕНОЗОВ ОТХОДОВ ТОПЛИВНО-ЭНЕРГЕТИЧЕСКОГО КОМПЛЕКСА УКРАИНЫ

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Целью работы было проведение комплексного химико-микробиологического исследования отвальных продуктов топливно-энергетического комплекса Украины. Установлено, что качественный состав аборигенной микробиоты исследованных техногенных субстратов не зависит от сроков хранения, поскольку определяется химическим и минералогическим составом, и представлен в основном гетеротрофными и ацидофильными хемолитотрофными бактериями (АХБ). Выявлено возрастание численности всех групп микроорганизмов в отвальных продуктах длительного хранения, что является результатом внутренних процессов и воздействия внешних климатических факторов. Показано, что максимальной выщелачивающей активностью обладают ассоциации АХБ, особенно при использовании двухвалентного железа в качестве источника энергии. Обнаруженные в структуре аборигенного консорциума «силикатные» бактерии, не способные выщелачивать металлы самостоятельно, в сочетании с АХБ способствуют значительному повышению показателей биовыщелачивания. Результаты исследований свидетельствуют о формировании в отвальных продуктах топливно-энергетического комплекса устойчивых специфических микробиоценозов, которые могут быть источниками получения высокоактивных штаммов для использования в биотехнологических процесах извлечения металлов.

Ключевые слова: аборигенное сообщество, отвалы, биовыщелачивание.