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AUTECOLOGY OF MICROORGANISMS OF TYPICAL ECUADOR BIOTOPES

34 strains of aerobic chemoorganotrophic microorganisms were isolated from 23 soil and plant samples selected from highland biotopes of Ecuador - Andes massif (Papallacta, 4020 m), ash at the foot of the volcano Tungurahua, mountainous jungle (La Favorita, 1600 m), as well as in humid tropic botanical garden (state Puyo, 950 m). In mountain jungle samples the high number of bacteria - 10^5-10^7 CFU/g of sample were represented by 2-5 morphotypes. In highland (4020 m) samples the bacterial counts made from 10^2 to 10^7 CFU/g of sample.

The current study describes resistance of isolated strains to high salinity, UV radiation and toxic metal ions. The majority of isolated strains were halotolerant. Isolates from volcanic ash showed high resistance level to UV radiation - $LD_{99,99}$ made 1000-1440 J/m^2; resistance level for isolates from the soil of Puyo Botanical Garden and isolates from rock lichen (Papallacta) $LD_{99,99}$ made 1160 and 800 J/m^2 respectively. Strains isolated from mountain jungle (La Favorita) showed lower UV- resistance. In highland biotopes of Ecuador occurred bacteria resistant to toxic metal ions. The highest resistance to Hg^{2+} was shown by isolate of lichen from mountain jungle, the maximal growth concentration was 0.025 g/L; to Cr(VI) - by isolate from lichen rock massif – 3,0 g/L. Correlation between metal-resistance, halotolerace and UV resistance for studied strains was not detected, probably because of different microbial cell damage/repair mechanisms under the action of these factors.

Keywords. Ecuador, microorganisms, quantitative counting, resistance, UV, NaCI, toxic metals.

Traditionally studies of resistance to extreme factors examine the effect of the single one. However, under natural conditions, microorganisms may be exposed to several extreme factors simultaneously. Therefore, we studied resistance of microbial isolates from Ecuadorian ecosystems to UV radiation, NaCl, and toxic metals. Previously, we isolated highly resistant to extreme factors (UV and toxic metals) microorganisms from terrestrial ecosystems of the Dead Sea [14] and coastal Antarctica [15, 17, 18] which are extreme regions possessing high level of solar radiation. The current study is devoted research of microorganisms of Ecuador ecosystems, located in the northwest of South America and also characterized with the high level of solar radiation. At a distance of 25 km north from the capital Quito the country crosses the equator. In the west along the Pacific coast stretched lowlands and foothills of the Andes; Andes located in the center of the country, include two parallel ridges (Western and Eastern Cordillera) with cones of extinct and active volcanoes. One of the highest volcanoes is an active volcano Tungurahua (altitude 5023 m). The eastern part of the country lies within the Amazon. Natural zones are savanna, woodlands, semi-arid, desert and of altitudinal zones.

The climate is characterized by absence of seasonality (25° C in July, 24° C in January). By climatic and biological features Ecuador is divided into four areas: the Costa (coast), Sierra (mountain side), Oriente (Amazonia - jungle) and the Galapagos Islands. Microbiological studies in Ecuador cover various groups of microorganisms: yeast [7, 9], pathogenic bacteria [6], and viruses [11]. There also papers that concern taxonomic position and other aspects of the biology of saprophytic bacteria [10, 13, 16], antibiotic resistance [5], the formation of biofilms that grow on wet surfaces benthos [4]. Among effects of physico-chemical factors and xenobiotics on the bacteria, the influence of water regime on the bacteria in highland forests in Ecuador [8], the effect of oil pollution on the number of bacteria in the Ecuadorian Amazon [2] and organophosphorus pesticides on soil microflora [3] are studied.

The aim of this study is investigation occurrence of aerobic chemoorganotrophic bacteria in mountain Ecuador ecosystems and isolation of dominant representatives; study resistance of isolates from specified ecosystems including the ashes of the volcano Tungurahua to extreme factors such as UV radiation, NaCI and toxic metals.

Materials and Methods. *Research objects* were microorganisms isolated from Ecuador ecosystem. Yeast strains (*Candida krusei 736, C. albicans 2681, Rhodotorula glutinis 63*), obtained from the collection (Department of Industrial Microorganisms Physiology, Institute of Microbiology and Virology of the National Academy of Science of Ukraine) were used as control to compare resistance to extreme factors.

The sampling sites. Samples for microbiological studies were collected from 4 typical mountain ecosystems Ecuador (sampled in Oct.2013 and stored at 22°C) - (1) mountain massif (Andes near Papallacta, altitude 4020 m); (2) mountain jungle (research base La Favorita, Northern Technical University, altitude 1600 m); (3) volcanic ash after the eruption (the foot of the active volcano Tungurahua, altitude 4020 m); (4) Botanical Garden “Las Orquideas” Humid Tropics (state Puyo, altitude 950 m).

Isolation of microorganisms. Sample preparation was carried out by standard methods. For isolation and counting of aerobic chemoorganotrophic bacteria was used NA medium (Nutrient Agar, HiMedia Laboratories Pvt. Ltd), cultivation parameters - 30°C during 1-3 days. To suppress micromycete growth 50 mg/L of nystatin was added to nutrient medium.

The number of microorganisms in the samples was determined by inoculating serial ten-fold dilutions on NA and cultivating at 30°C. In Petri dished where CFU number didn’t exceed 50 were carried microbiological counting and evaluated morphotype diversity. The main criteria for morphotype identification were the features: colony form, size (mm), pigmentation, water-soluble pigment and mucus production, texture, the presence of air and the substrate mycelium etc. Counting was carried out daily. As a result there were collected data about highly occurred microbial morphotypes dominating in studied sample.

Resistance to UV radiation (UV-C[1]). The strains were cultivated in tubes containing 5 ml of liquid NB medium (Nutrient broth HiMedia Laboratories Pvt. Ltd), on the shaker (220 rpm., 20 h, 30°C). Ten-fold dilutions (from 10^{-2} to 10^{-9}) of microbial suspension was plated (100 μL) in Petri dishes containing NA medium and dispensed with a spatula across agar surface. Open cups were placed at a distance of 1 m from the UV radiation source (bulb BUV-15 λ= 254 nm). The dose range of UV irradiation was 40-2400 J/m^2. After irradiation microorganisms were incubated at 30°C in the dark to avoid photoreparation. The counting of survived CFU was carried out in 1-3 days and compared to control plates - the same serial tenfold sample suspension dilutions on NA that were not irradiated. Survival ability of the microorganisms and also lethal dose was evaluated by the change in the percentage of surviving cells after UV irradiation from their original amount. To compare sensitivity of isolated strains to UV radiation was used dose curve method representing relationship between the number of surviving cells and UV dose and calculated two lethal doses: LD_{90} - UV dose which causes damage of 90% cells; and $LD_{99,99}$ - UV dose which causes damage of 99.99% cells.

Halotolerant microorganisms were studied using standard methods by growing isolates on NA medium containing 1, 25, 50, 100, 150 and 200 g NaCl/L.

Resistance to toxic metals[2]. Toxic metal solutions were prepared as described previously [17]. Toxic effect of metal ions towards strains was studied on liquid medium Nutrient broth (NB). Metal solutions were sterilized for 10 minutes in a boiling water bath, and then cooled to 30°C. In nutrient media it was prepared 5 monometal solutions containing following concentration range (in g/L): Hg^{2+} – 0.005-0.05; Cu^{2+} – 0.05-1.0; Ni^{2+} – 0.05-1.0; Co^{2+} – 0.05-1.0; Cr(VI) in a form of CrO_4^{2-} – 0.05-4.0. Then, in metal-containing nutrient media was added bacterial suspension and cultivated in tubes (10 ml of NB, 21 days, 30°C). Beginning of bacterial growth was monitored visually by increasing of the culture liquid optical density. The test was performed in three replicates. Results were compared to 3 controls: (1) a sterile medium without inoculum and metals; (2) sterile metal-containing medium without inoculum; (3) metal-free medium inoculated with sample bacteria.

In assessing the results, we considered concept of “maximal allowable concentration” (MAC) as the metal concentration that allows surviving at least one strain from all sample microbial diversity.

1 UV-C Germicidal Ultraviolet 280nm - 200nm

2 Hereinafter, the term "toxic metals" means " of toxic metal ions "

Results and discussion. Environmental studies include characteristic of highland and soil-plant ecosystems in specified Ecuador regions: soil with moss, soil at the foot of the cliff, soil in the pockets of the rock cliffs (Papallacta, 4020 m), rainforest soil, volcanic soil (a mixture of volcanic ash and sand), humus soil with wood, white-brown or green-orange lichens and green moss (Table 1). Given the fact that such ecosystems as moss and lichens contained a small amount of soil, we considered them as plant-soil samples.

Each of the 23 samples showed presence 1-5 dominant morphotypes of microorganisms; generally from all samples using standard methods were isolated 34 strains (Table 1). Plant-soil samples of mountain jungle contained a significant amount of microorganisms - 10^5–10^7 CFU/g of sample. In these samples were present from 2 to 5 dominant microbial morphotypes. In highland samples (4020 m) revealed significant fluctuations in the microorganism number (10^2–10^7 CFU/g of sample). However, they contained the single dominant microbial morphotype (Table 1), which probably can be explained by “severe” extreme physical and chemical conditions in highland ecosystems.

In volcanic ash at the foot of the volcano Tungurahua detected considerably lower number of microorganisms (10^3–10^5 CFU/g of sample). These samples contained the single dominant microbial morphotype (Table 1). On the contrary, in the soil of the Botanic Garden in the Humid Tropics revealed three dominant morphotypes, and the number of microorganisms was 10^6 CFU/g of sample.

All isolated bacteria were aerobic, chemoorganotrophic, didn’t produce extracellular pigments, and didn’t form a mycelium. Most of them were Gram-positive rods, arranged separately or in chains; oval rods and cocci, usually non-pigmented, but rarely occurring pigmented (orange, yellow) colony morphotypes. Up to 25% of studied strains were Gram-negative bacteria.

Table 1.

Number of aerobic chemoorganotrophic microorganisms in samples of typical Ecuador ecosystems

Sampling site	Sample description	Number of	
		Morphotypes	CFU/g of sample
La Favorita, highland rainforest, altitude 1600 m	Dry lichen (white-brown)	3	1.3×10^5
	Lichen (green-ginger)	5	1.2×10^7
	Dry lichen (green)	2	5.0×10^6
	Rock lichen	2	3.4×10^5
	Soil with green moss	3	2.0×10^5
	Soil from foot of the cliff	3	3.0×10^6
	Forest soil	2	2.3×10^6
Andes mountain massif, foot of Tungurahua volcano, altitude 4020 m	Volcanic ash	1	2.8×10^3
	Sand and ash mixture	1	1.1×10^3
	Black soil in the riverbed	1	1.9×10^5
	Black soil with moss	1	1.3×10^5
Andes near Papallacta, altitude 4020 m	Black soil with moss	1	1.8×10^6
	Green moss and black soil	1	3.8×10^6
	Black soil with roots	1	9.7×10^7
	Crustose white lichen,	1	1.2×10^6
	Soil under white-brown lichen	1	2.0×10^2
	White-brown lichen from the rock	1	4.0×10^4
	Lichen with rock particles	1	1.2×10^3
	Soil with moss from rock cliff	3	4.8×10^6
Botanic Garden “Las Orquideas”, state Puyo, altitude 950 m	Soil with digested timber	3	1.1×10^6

Significant characteristics of microbial ecophysiology are quantitative indicators of homeostasis, i.e. ability of microorganisms to keep stability of their functioning under the influence of extreme factors. We determined stability parameters for strains isolated from Ecuador ecosystems to high levels of UV radiation, as well as high concentrations of NaCl and toxic metals.

UV-resistance. Taking into account the high level of solar radiation in mountainous regions of Ecuador, we have assumed presence of UV-resistant microorganisms. As follows from the data (Fig. 1), bacteria express various levels of UV-resistance.

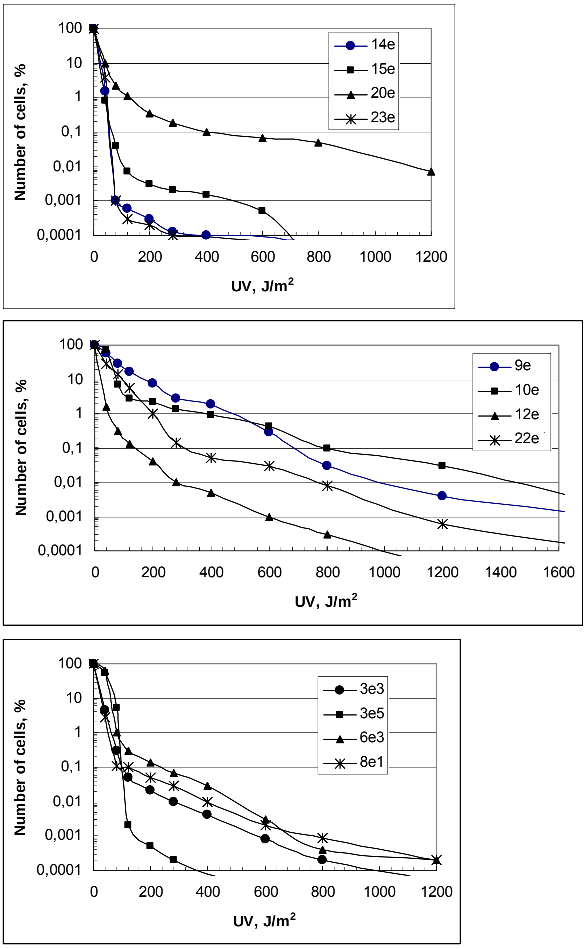

Fig. 1. Survival (%) of the bacteria isolated from the Andes mountain range, Papallacta, 4020 m (strains 14e, 15e, 20e, 23e); ash of the volcano Tungurahua (strains 9e, 10e, 12e); soil of Botanic Garden (strain 22e); mountain jungle (strains 3e3, 3e5, 6e3, 8e) at decreasing UV doses. Symbols in figures correspond to the numbers of tested strains.

For comparative evaluation UV-resistance of different isolates have been calculated lethal UV doses (LD_{90} and $LD_{99,99}$) (Table 2). The high level of UV-resistance showed strains 9e, 10e (similar to Actinobacteria) isolated from volcanic ash and sand after the eruption of Tungurahua volcano ($LD_{99,99}$-1000-1440 J/m^2) as well as cliff lichen isolate 20e ($LD_{99,99}$- 1160 J/m^2) and isolate 22e from soil of Botanical Garden ($LD_{99,99}$ - 800 J/m^2). Spore-forming soil isolate from mountain jungle (6e3, bacilli-shape morphotype) was moderately resistant to UV ($LD_{99,99}$- 500 J/m^2). Other isolates from soil and plant samples from mountain jungle (La Favorita) were less resistant to UV radiation ($LD_{99,99}$ - 280-400 J/m^2). The most UV-sensitive were non-pigmented Gram-negative bacteria (14e, 15e, 23e) isolated respectively from moss, soil and biofilm collected from rock biotop near Papallacta ($LD_{99,99}$ - 80-120 J/m^2) (Table 2).

The majority of studies strains were resistant to high concentrations of NaCl. Maximal concentration of NaCl for their growth ranged from 25 to 100 g/L for various isolates (Table 2), i.e. can be considered halotolerant.

One of the isolates (13e, soil from rock massif, Papallacta) - non-pigmented yeast was slightly resistant to UV radiation ($LD_{99,99}$ - 220 J/m^2) (Fig. 2). UV-resistance of Equador yeast isolate 13e was compared to collection yeast strains (*Candida krusei* 736, *C. albicans* 2681, *Rhodotorula glutinis* 63). Only pink-pigmented strain *Rhodotorula glutinis* 63 showed higher UV-resistance which made $LD_{99,99}$ - 850 J/m^2. Survival of non-pigmented yeast (both collection strains and 13e isolate) were similar ($LD_{99,99}$ - 180-220 J/m^2) (Fig. 2). Presumably pigments of *R. glutinis* 63 minimize cellular damage under UV irradiation.

Table 2.

Resistance to extreme factors of microbial isolates from representative Ecuador biotopes

Strain No	Biotop	Morphotype		Lethal UV doses, J/m^2		Growth in NaCl range, g/L	Maximum allowable concentrations for toxic metals, g/L				
		Cell microscopy (Gram stain, size μm, spores, motility)	Colony description (pigments, mucus production, size mm)	LD_{90}	$LD_{99,99}$		Hg^{2+}	Cu^{2+}	Co^{2+}	Ni^{2+}	Cr(VI)
La Favorita, highland rainforest											
3e3	Lichen	G+, rods, 6-2 × 1, nonmotile	Ginger, **5-8**	40	280	1–50	0,025	0,15	0,075	0,1	2,0
3e5	Lichen	G+, oval rods, 1.5 × 0.8	Yellow, **2-3**	80	120	1–100	0,005	0,1	0,05	0,05	1,0
6e3	Soil, moss	G+, oval rods, 3 × 1.5, spores	White, rhizoid **9-15**	70	500	1–25	n/t	n/t	n/t	n/t	n/t
8e1	Forest soil	G+, rods, 4-2 × 1.3	Nonpigmented, flat, **5-7**	40	400	1–25	n/t	n/t	n/t	n/t	n/t
Tungurahua volcano											
9e	Ash	G+, cocci, 2.5 × 1.5	Light brown, pulvinate, **9**	180	1000	1–100	0,01	0,1	0,1	0,1	0,5
10e	Sand	G+ rods 10-2 × 1.2 nonmotile	Nonpigmented, **3-4**	80	1440	1–50	0,005	0,15	0,1	0,15	1,0
12e	Soil, moss	G+, rods, [1]14-2 × 1	White, mucous, **5-7**	30	280	1–50	n/t	n/t	n/t	n/t	n/t
Andes mountain massif, Papallacta											
14e	Green moss	G-, rods, 2.5 × 0.8	White, mucous, **5-7**	30	80	1–50	n/t	n/t	n/t	n/t	n/t
15e	Black soil	G-, cocci, 0.8 × 0.5	Nonpigmented,mucous, **8-9**	30	120	1–50	0,005	0,15	0,1	0,1	0,05
17e	Lichen	G+, rods, 3.5 × 1.3	Nonpigmented,pulvinate **2-3**	n/t	n/t	n/t	0,005	0,15	0,075	0,1	0,15
20e	Lichen	G+, rods, 5-2 × 1.3	Light brown, flat, **7**	40	1160	1–50	0,005	0,1	0,1	0,1	3,0
23e	Biofilm	G-, rods, 1.5 × 0.8	White, mucous, **5-7**	30	80	1–50	n/t	n/t	n/t	n/t	n/t
Botanic Garden "Las Orquideas, state Puyo											
22e	Soil	G+, rods, 5-2 × 1, nonmotile	Light brown, flat, **8**	100	800	1–50	0,005	0,15	0,1	0,15	0,1

Note: G+ – Gram-positive cells; G- – Gram-negative cells; n/t – growth was not tested. [1]14-2 × 1.2 μm – long chain-forming rods (14 μm or less), often segmented (2 μm).

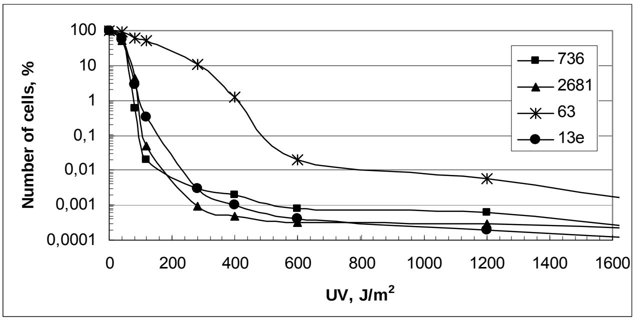

Fig. 2. Survival (%) of yeast: isolate 13e and collection strains (*Candida krusei* 736, *C. albicans* 2681, *Rhodotorula glutinis* 63) at increasing UV doses. Symbols in figures correspond to the numbers of tested strains.

Resistance to toxic metals. We hypothesized that Ecuador isolates resistant to high concentrations of NaCl (up to 100 g/L) may also be resistant to toxic metals. Therefore 8 isolates from all Ecuador regions were studied on the subject of metalresistance. Bacteria were isolated on the metal-free medium and so were not adapted to their toxic effects.

We used five of the most toxic metal ions, possessing all described damage mechanisms: oxidizing metal ion Cr (VI) in the form of CrO_4^{2-} (CrO_4^{2-}, E_o' = +555 mV), replacing metal ions (Ni^{2+}, Co^{2+}) and metals of "combined action" (Hg^{2+}, Cu^{2+}), which exhibit the properties of both specified mechanisms (E_o' for $Hg^{2+}$and Cu^{2+} is equal +920 and +440 mV, respectively)[3] [12]. The negative effect of metal ions with replacing properties appears in exchange of divalent cations in the active enzyme sites and cellular structures to metal ion; oxidizing metals cause irreversible imbalance of redox enzymes.

For all strains were determined maximum allowable concentrations (MAC) of each metal. The widest MAC range was shown for oxidizing Cr(VI) ion (E_o' = +555 mV) – the upper limit for strains isolated from lichens 3e3 (mountain jungle, La Favorita) and 20e (rock, Papallacta) made 2.0 and 3.0 g/L, respectively; the lower limit for strain 15e (soil Papallacta) made 0.05 g/L. Strain 22e (soil from tropic Botanic Garden) comparing to other strains was sensitive to chromium ions: MAC made 0.1 g/L (Table 2). At a concentration of 0.05 g/l Cr (VI) it was observed growth of all strains, but with increasing chromium concentrations the number of resistant bacteria reduced, only one strain 20e grew at 3.0 g/L. Concentration of 4.0 g/L was lethal for all studied strains (Fig. 3).

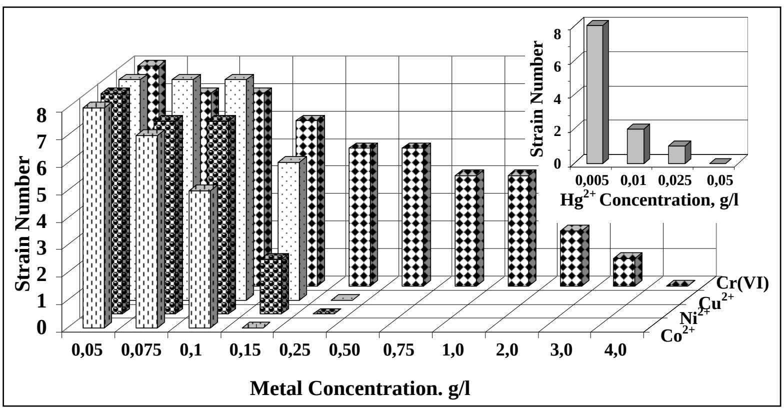

Fig. 3. Resistance of dominant bacteria of typical Ecuador ecosystem to concentration range of representative toxic metals

Cobalt and nickel concentration of 0.05 g/L did not inhibit the growth of tested strains. But at a concentration of 0.1 g/L Co^{2+} the number of resistant strains decreased from 8 to 5 (Fig. 3). Strains showed higher resistance to Ni^{2+} ions – at concentration of 0.1 g/L growth of 7 strains was observed. Two strains 10e (isolated volcanic sample) and 22e (moist soil with wood, Botanic Garden) grew at

3 $2Hg^{2+} + 2e = Hg_2^{2+}$; E_0 = +920 mV, at pH=2,0 and 0,1 mM Hg^{2+}
$2Cu^{2+} + H_2O + 2e = Cu_2O + 2H^+$: E_0 = +440 mV, at pH=4,0

a concentration of 0.15 g/L of Ni^{2+} (Table 2). At the same time the equal concentration of Co^{2+} was lethal to other strains (Fig. 3). Strain 3e5 appeared the most sensitive to replacing metals - MAC of Co^{2+} and Ni^{2+} ions made 0.05 g/L (Table 2).

Strains showed the lowest resistance level to mercury ions (metal of combined action, E_0 = +920 mV). The only Hg^{2+}concentration that didn't inhibit strain growth made 0.005 g/L (Figure 3). By increasing the concentration up to 0.01 g/L the number of resistant strains decreased from 8 to 2. Strain 3e3 (lichen from mountain jungle) grew at Hg^{2+} concentration 0.025 g/L (Table 2). It should be mentioned that such mercury concentration is lethal for most chemoorganotrophic bacteria [1].

Copper cation also belongs to metal of combined action being high-potential oxidizing metal (E'_0= +440 mV) and replacing ions in active enzyme sites [12]. All bacterial isolates showed similar resistance to Cu^{2+} ions; MAC value made 0.10 - 0.15 g/L (Table 2).

Conclusion. From soil and plant samples of typical highland Ecuador ecosystems (mountain massif, volcano foot, mountain jungle, and rainforest) are isolated dominant morphotypes of aerobic chemoorganotrophic microorganisms and studied their resistance to a complex of extreme factors. High altitude biotopes (4020 m) are characterized by the dominance of single morphotype. Presumably, low biodiversity can be explained by simultaneous action of extreme physical and chemical factors. In ecosystems with less extreme conditions observed higher diversity of microbial communities: from 2 to 5 morphotypes.

A considerable part of the strains isolated from representative Ecuador ecosystems showed resistance to high UV doses, as well as increasing concentrations of NaCI and toxic metals.

Correlation between occurrence of UV-resistant bacteria and the level of solar radiation was not observed. UV-resistant isolates were detected both in samples of rock massiff (Papallacta, 4020 m) with a high level of solar radiation and in gloomy mountain jungle (La Favorita). The highest UV-resistance ($LD_{99,99}$ - 800-1440 J/m^2) showed isolates from volcanic ash and lichen from the rock, as well as soil of tropical rainforest. Other isolates from soil and plant samples from mountain jungle (La Favorita) showed lower UV-resistance ($LD_{99,99}$ - 280-400 J/m^2). The majority of strains were halotolerant (growth at 50-100 g/L NaCl).

Among dominant bacteria isolated on nonselective metal-free medium were found out metal-resistant strains. It can be noted that the most resistant to toxic metals from all tested strains was isolate 3e3 from lichen of mountain jungle, which MACs (g/L) were 0.025 and 0.15 respectively for Hg^{2+} and Cu^{2+}, and 2.0 for Cr(VI). The most Cr(VI)-resistant isolate was strain 20e from rock lichen (Papallacta): MAC - 3.0 g/L (Table 2). Previously, we studied metal-resistance of the West Antarctic ecosystems dominant strains [18]. Comparing to Ecuador Antarctic bacteria were more resistant to oxidative metals Cr(VI), resistance values were in range of 1.25-20.0 g/L. MACs of replacing metal ions made Ni^{2+} - 2.0 g/L, Co^{2+} - 0.1 g/L. In the presence of metals of combined action Antarctic strains grew in range: Hg^{2+} - 0.005-0.05 g/L, Cu^{2+}- 0.1-1.25 g/L. We compared toxicity ranges of specified metals towards bacteria of two regions differing in physical, chemical and climatic parameters (Ecuador and Antarctica), MAC (g/L) is indicated under the metal symbol.

Dominant bacteria of Ecuador biotopes:

$Hg^{2+} > Co^{2+} > Ni^{2+} > Cu^{2+} >$ Cr(VI).
0.025 0.1 0.15 0.15 3.0

Dominant bacteria of Anatrctic biotopes:

$Hg^{2+} > Co^{2+} > Cu^{2+} > Ni^{2+} >$ Cr(VI).
0.05 0.1 1.25 2.0 20.0

Comparative analysis shows that the isolates from the West Antarctic are more resistant to toxic metals than isolates from Ecuador.

Clear correlation between metal-resistance, halotolerance and UV-resistance for Ecuadorian bacteria is not revealed. Thus, metal-resistant strain 3e3 was poorly resistant to UV radiation ($LD_{99,99}$ = 280 J/m^2) and grown at 50 g NaCl/L, while one of the most metal-sensitive strain 9e showed high halotolerance (100 g NaCl/L) and high UV-resistance ($LD_{99,99}$ = 1000 J/m^2) (Table 2). The exception made strain 20e highly resistant to oxidative metals Cr (VI) (MAC = 3.0 g/L), UV radiation ($LD_{99,99}$= 1160 J/m^2) and NaCl (50 g/L), which may indicate the simultaneous functioning of the various protection mechanisms from these extreme factors. The lack of correlation between metal-resistance, halotolerance and UV resistance for most of the studied isolates is expected, by the reason that damaging mechanisms of these three extreme factors are different. Accordingly, the mechanisms of cellular damage repair or protection may also vary.

Received results testify to ability of microbial communities of typical ecosystems Ecuador to keep their natural homeostasis under the influence of studied extreme factors. High level of metal-resistance of selected strains provides perspectives for their application to environment protection technologies.

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АУТЕКОЛОГІЯ МІКРООРГАНІЗМІВ ТИПОВИХ ЕКОСИСТЕМ ЕКВАДОРУ

Р е з ю м е

З 23 ґрунтово-рослинних зразків Еквадору, відібраних на висоті 4020 м гірського масиву Анди (м. Папаякта), вулканічного попелу біля підніжжя вулкана Тунгурауа, в гірських джунглях (Ла-Фаворита, 1600 м), а також у ботанічному саду з вологим тропічним кліматом (м. Пуйо, висота 950 м), ізольовано 34 штами аеробних хемоорганотрофних мікроорганізмів. У рослинно-ґрунтових зразках гірських джунглів спостерігалася висока кількість бактерій: до 10^5-10^7 клітин/г зразка, представлених 2-5 морфотипами. У високогірних (4020 м) зразках кількість бактерій варіювала від 10^2 до 10^7 клітин/г зразка. Практично всі досліджені бактерії є галотолерантними. Високу резистентність до УФ ($ЛД_{99,99}$ становила 1000-1440 Дж/м^2) показали ізоляти з вулканічного попелу біля підніжжя вулкана Тунгурауа, а також ізоляти з наскального лишайника (Папаякта) і з ґрунту Ботанічного саду (м. Пуйо), $ЛД_{99,99}$ становила 1160 і 800 Дж/ м^2, відповідно. Ізоляти з ґрунтово-рослинних зразків гірських джунглів (Ла-Фаворита) показали більш низьку резистентність до УФ. Серед мікроорганізмів високогірних екосистем Еквадору виявлені бактерії, резистентні до токсичних металів. Найбільша стійкість до Hg^{2+} була показана для ізоляту з лишайника гірських джунглів, максимально допустима концентрація (МДК) становила 0.025 г/л; до Cr (VI) - для ізоляту з наскального лишайника гірського масиву - 3.0 г/л. У досліджених бактерій не виявлено кореляції між металрезистентністю, галотолерантністю та УФ-резистентністю, мабуть тому, що механізми репарації клітинних пошкоджень або захисту, які реалізують клітини при дії цих факторів, різні.

Ключові слова: Еквадор, мікроорганізми, кількісний облік, резистентність, УФ, NaCI, токсичні метали.

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АУТЭКОЛОГИЯ МИКРООРГАНИЗМОВ ТИПИЧНЫХ ЭКОСИСТЕМ ЭКВАДОРА

Р е з ю м е

Из 23 почвенно-растительных образцов Эквадора, отобранных на высоте 4020 м горного массива Анды (г. Папаякта), вулканического пепла у подножья вулкана Тунгурауа, в горных джунглях (Ла-Фаворита, 1600 м), а также в ботаническом саду с влажным тропическим климатом (г. Пуйо, высота 950 м), изолировано 34 штамма аэробных хемоорганотрофных микроорганизмов. В растительно-почвенных образцах горных джунглей наблюдалось высокое количество бактерий: до 10^5–10^7 клеток/г образца, представленных 2–5 морфотипами. В высокогорных (4020 м) образцах количество бактерий варьировало от 10^2 до 10^7 клеток/г образца. Практически все исследованные бактерии являются галотолерантными. Высокую резистентность к УФ ($ЛД_{99,99}$ составляла 1000–1440 Дж/м^2) показали изоляты из вулканического пепла у подножья вулкана Тунгурауа, а также изоляты из наскального лишайника (Папаякта) и из почвы Ботанического сада (г. Пуйо), $ЛД_{99,99}$ составляла 1160 и 800 Дж/м^2, соответственно. Изоляты из почвенно-растительных образцов горных джунглей (Ла-Фаворита) показали более низкую резистентность к УФ. Среди микроорганизмов высокогорных экосистем Эквадора выявлены бактерии, резистентные к токсичным металлам. Наибольшая устойчивость к Hg^{2+} была показана для изолята из лишайника горных джунглей, максимально допустимая концентрация (МДК) составляла 0.025 г/л; к Cr(VI) – для изолята из наскального лишайника горного массива – 3.0 г/л. У исследованных бактерий не выявлено корреляции между металлрезистентностью, галотолерантностью и УФ-резистентностью, видимо потому, что механизмы репарации клеточных повреждений или защиты, которые реализуют клетки при действии этих факторов, различны.

Ключевые слова: Эквадор, микроорганизмы, количественный учёт, резистентность, УФ, NaCI, токсичные металлы.

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