IRSTI 34.27.23 https://doi.org/10.26577/EJE.2024.v80.i3-012

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STUDY OF SPECIES COMPOSITION OF ALGOFLORA FROM NATURAL THERAPEUTIC MUD IN ZHANAKORGAN DISTRICT

There is currently a global increase in interest in the use of natural therapeutic muds. Therapeutic mud is a natural product that has a beneficial therapeutic effect on the skin and a lower incidence of adverse effects on the human body. The object of the study was water from two wells and a medicinal swamp in the settlement of Zhanakorgan district of Kyzylorda region. The present study examined the species composition of microalgae and cyanobacteria in two wells and in therapeutic swamps within the settlement of Zhanakorgan district. The objective of this study was to examine the species diversity, morphological and cultural characteristics of cyanobacteria, green and diatom algae in the Zhanakorgan district settlement, and to introduce them into axenic cultures for storage in a collection for potential utilization in industrial biotechnology, in the pharmaceutics, as well as in textile and food industry due to their rich chemical composition. The study yielded seven new axenic cultures of cyanobacteria, green algae, and diatoms, which were identified as *Dunaliella salina*, *Chlamydomonas sp.*, *Scenedesmus sp.*, *Trichormus variabilis*, *Calothrix epiphytica*, *Nostoc oryzae*, *Navicula sp*.

Key words: therapeutic mud, microalgae, cyanobacteria, isolation, axenic cultures, morphological properties.

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Жаңақорған ауданындағы табиғи емдік балшықтары Альгофлорасының түрлік құрамын зерттеу

Қазіргі уақытта бүкіл әлемде табиғи емдік балшыққа қызығушылық артып келеді. Емдік балшық – теріге оң емдік әсері бар және адам ағзасына жанама әсерлері аз табиғи өнім. Зерттеу объектісі Қызылорда облысы Жаңақорған ауданы елді мекеніндегі екі құдық пен емдік батпақтың суы болды. Бұл зерттеуде Жаңақорған ауданына қарасты елді мекендегі екі құдықтан және емдік батпақтардан микробалдырлар мен цианобактериялардың түрлік құрамы зерттелді. Бұл зерттеудің мақсаты Жаңақорған аймағындағы цианобактериялардың, жасыл және диатомды балдырлардың алуан түрлілігін, морфологиялық және дақылдық қасиеттерін қасиеттерін зерттеп, оларды аксеникалық дақылдар қатарына енгізу және коллекцияларда сақтау, және химиялық құрамының бай болуына байланысты өнеркәсіптік биотехнологияда, фармацевтикада, сондай-ақ тоқыма және тамақ өнеркәсібінде қолдану. Зерттеу нәтижесінде цианобактериялардың, жасыл және диатомды балдырлардың 7 жаңа аксенді дақылдары бөлініп алынды және морфологиялық ерекшеліктеріне қарай олар *Dunaliella salina*, *Chlamydomonas* sp., *Scenedesmus* sp., *Trichormus variabilis*, *Calothrix epiphytica*, *Nostoc oryzae*, *Navicula sp*. ретінде анықталды.

Түйін сөздер: емдік балшық, микробалдыр, цианобактерия, бөліп алу, аксендік дақылдар, морфологиялық қасиеттері.

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Изучение видового состава Альгофлоры природных лечебных грязей Жанакорганского района

В настоящее время во всем мире растет интерес к природным лечебным грязям. Лечебная грязь — это природный продукт, которая оказывает положительное лечебное воздействие на кожу и имеет меньше побочных эффектов на организм человека. Объектом исследования были воды из двух скважин и лечебное болото населенного пункта Жанакорганского района Кызылординской области. В данном исследовании был изучен видовой состав микроводорослей и цианобактерий в двух скважинах и в лечебных болотах населенного пункта Жанакорганского района. Целью данного исследования было изучение видового разнообразия, морфологические и культуральные свойства цианобактерий, зеленых и диатомовых водорослей населенного пункта Жанакорганского района и введение их в аксеничные культуры для хранения в коллекции и для возможного использования в промышленной биотехнологии, в фармацевтике, а также в текстильной и пищевой промышленности благодаря их богатому химическому составу. В результате исследования были выделены 7 новых аксеничных культур цианобактерий, зеленых и диатомовых водорослей, и были идентифицированы как *Dunaliella salina*, *Chlamydomonas sp.*, *Scenedesmus sp.*, *Trichormus variabilis*, *Calothrix epiphytica*, *Nostoc oryzae*, *Navicula sp.*

Ключевые слова: лечебная грязь, микроводоросли, цианобактерии, выделение, аксеничные культуры, морфологические свойства.

Introduction

Therapeutic muds are naturally occurring formations of various genesis, which are utilized for therapeutic purposes in the form of baths and applications. Natural therapeutic muds include sediments of marshes, lakes, estuaries and sea bays, which consist of water, mineral and organic substances and represent a homogeneous fine-dispersed plastic mass with certain thermal and other physical and chemical properties. Salt dome landscapes exhibit considerable potential for recreational and balneological applications, given the formation of geosystems characterized by distinctive lithofacial formations (mineral muds), natural waters (natural brines), and the subterranean atmospheric environment (speleotherapy) [1-2]. Sanatoriums in Kazakhstan employ the use of local therapeutic waters and sulphide mud in the treatment of specialized diseases. The development of therapeutic tourism in Kazakhstan was based on the utilization of natural mineral springs and deposits of therapeutic muds. The resort complex of Kazakhstan boasts a plethora of distinctive natural therapeutic resources, which have been proven to be highly efficacious in the treatment of a vast array of diseases, facilitating the recuperation of the population [3].

One of the spa regions renowned for its natural resources and therapeutic muds is Zhanakorgan (Kyzylorda region), situated in the southern part of Kazakhstan. The therapeutic bogs of Zhanakorgan were first identified and employed for therapeutic purposes during the Soviet era, in the mid-twentieth century [4]. The soils in question typically comprise substantial quantities of organic matter and mineral components that possess therapeutic properties, thereby creating optimal conditions for the growth and reproduction of a multitude of microorganisms, including microalgae [5].

The chemical composition of microalgae from the therapeutic bogs of Zhanakorgan is such that they have a wide range of potential applications. These include the production of biologically active additives, cosmetics, and pharmaceuticals for the development of new drugs [6, 7]. Furthermore, these algae can serve as a basis for the creation of environmentally friendly biotechnologies, such as the bioremediation of polluted water bodies and biofuel production [8-10]. The microalgae that flourish in the therapeutic bogs of the Zhanakorgan district constitute a distinctive biological resource with considerable potential for scientific investigation and practical application [11]. The study and further utilization of these organisms has the potential to make a significant contribution to the development of biotechnology and the improvement of the ecological situation in the region.

While microalgae and cyanobacteria from a number of other therapeutic springs have been the subject of some research [12-14], numerous sites, including Zhanakorgan, Elton, Baskunchak, Inder, Shalkar, and Zhaltyrkol, remain largely un-

explored. Furthermore, the isolation, purification, taxonomic characterization and axenic cultivation of new strains of microalgae and cyanobacteria may prove to be a valuable source of novel organisms to produce enzymes, proteins and pigments [15]. The objective of the present study was to examine the diversity of microalgae and cyanobacteria in the therapeutic bogs of the Zhanakorgan district, in addition to their morphological and cultural characteristics, and to introduce them into axenic cultures for potential utilization in industrial biotechnology.

Materials and methods

Study sites and sampling

Water samples were collected from two wells and a medicinal swamp in the Zhanakorgan district (Kyzylorda region) (43.900451, 67.243723) for subsequent analysis. The pH values observed in Zhanakorgan exhibited a range from slightly acidic to neutral. The temperature of the medicinal muds in Zhanakorgan exhibited a range of 20°C to 40°C, contingent upon seasonal and climatic conditions. The water samples from these sites were collected in pre-sterilized one-litre plastic bottles. The water samples were filtered through 0.45 μm membrane filters, transported to the laboratory, and stored at 4°C in a refrigerator until further processing. Biological mats, concretions and sediments were randomly collected from the sampling locations using sterile forceps and a spatula and placed in sterile glass containers. Water samples for the detection of planktonic cyanobacterial strains were collected in sterile glass vials and test tubes. Sampling was conducted between the dates of 15 and 30 July 2024. The temperature of the water was determined at the point of collection using a thermometer, while the pH was ascertained through the use of a digital pH meter (HM Digital PH-80, USA) [16].

Determination of species composition and morphological analysis of microalgae cultures

The biological mats from the two selected wells and the medicinal swamp were subjected to repeated washing with double-distilled water and subsequent transfer to 250 mL and 500 mL flasks containing Zarrouk, BG-11, Gromov, Artari, and Tamiya media [17]. For subsequent work, particularly the isolation and purification of microalgae and cyanobacteria strains, solid media (agar) were employed. Conventional microbiological techniques were employed to obtain algologically pure cultures, while the accumulation of cyanobacterial cultures was conducted in accordance with standard procedures. The identification of species was conducted using existing taxonomic keys [18-24] and a MicroOptix microscope with image output to a monitor.

Morphological studies of microalgae and cyanobacteria strains were conducted at various growth stages in both liquid and solid Zarrouk, BG-11, Gromov, Artari, and Tamiya media [25, 26]. The morphological identification of microalgae and cyanobacteria isolates was conducted using an optical light microscope (MicroOptix MX 300T, Austria) equipped with a digital camera and visualization system. The enumeration of cyanobacterial cells was conducted using a Goryaev chamber [27, 28].

Results

Microalgae community structure in therapeutic muds

Therapeutic muds, or peloids, are classified as a mineral resource. They are natural organomineral colloidal formations of various genesis (mud, peat, sap, etc.), exhibiting notable plasticity, high heat capacity, and slow heat dissipation. They contain therapeutically active substances (salts, gases, biostimulants) and live microorganisms [29, 30].

The Zhanakorgan therapeutic muds contain 50% silica (SiO_2), 15% aluminium (Al_2O_3), 7% iron (Fe_2O_3), 8% calcium (CaO), 8% magnesium (MgO), 4% potassium (K_2O), 3% sodium (Na_2O), and traces of sulphur (S). The water content is 65%. The amount of salt in Zhanakorgan medicinal muds can vary, but it is usually about 1–5% of the total mud composition. Salts, such as sodium (Na) and chloride (Cl), play an important role in the therapeutic properties of the mud, having anti-inflammatory and antiseptic effects [31, 32].

A total of 11 species were identified in the water samples from the study area, which were classified into three taxonomic groups. The dominant group was identified as *Chlorophyceae* (46.7%), comprising five species. This was followed by *Cyanophyceae* (35.4%), comprising four species, and *Bacillariophyceae* (9.7%), comprising two species (Fig. 2).

The results of the study of selected samples indicate that the algocenosis of the medicinal muds of the Zhanakorgan district is characterized by the predominance of green algae at the taxon level. The microflora of medicinal muds of Zhanakorgan includes many specific microorganisms, namely, sulphate reducing bacteria (Desulfovibrio, Desulfotomaculum), autotrophic bacteria (*Nitrosomonas, Nitrobacter*), heterotrophic bacteria (*Pseudomonas, Bacillus, Clostridium*), cyanobacteria (blue-green algae) *Anabaena, Nostoc, Oscillatoria,* diatoms (*Navicula,*

Nitzschia), green algae (*Chlorella, Scenedesmus*), actinomycetes (*Streptomyces, Nocardia*), mould fungi (*Aspergillus, Penicillium*). These microorganisms play a significant role in maintaining biogeochemical cycles and the formation of the therapeutic properties of the mud.

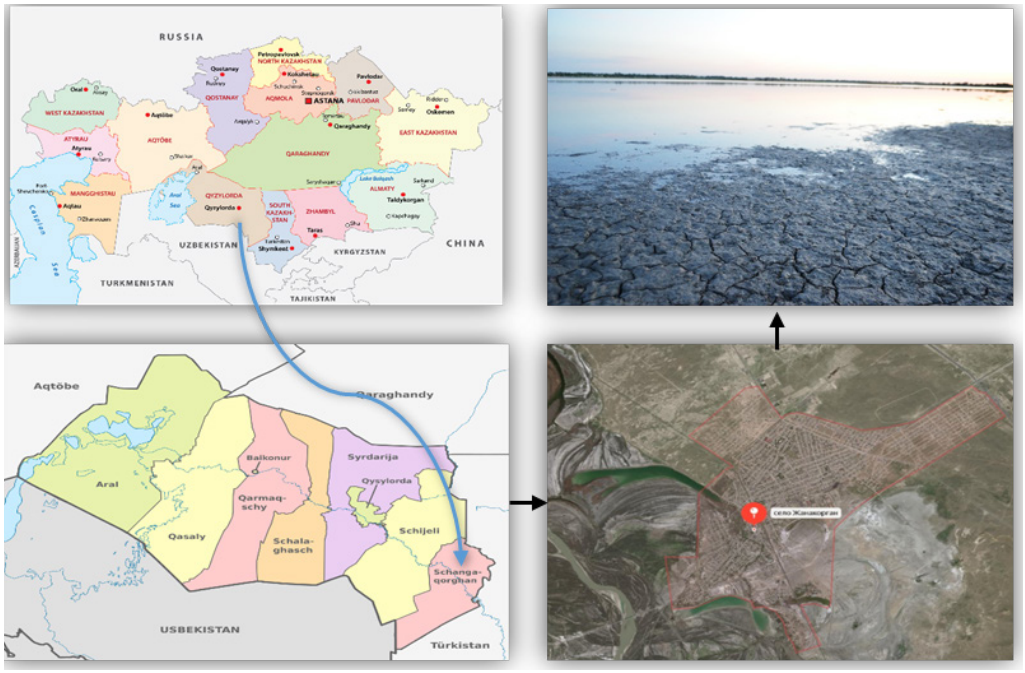

Figure 1 – The geographical location of sampling sites (Zhanakorgan 43.900451, 67.243723.)

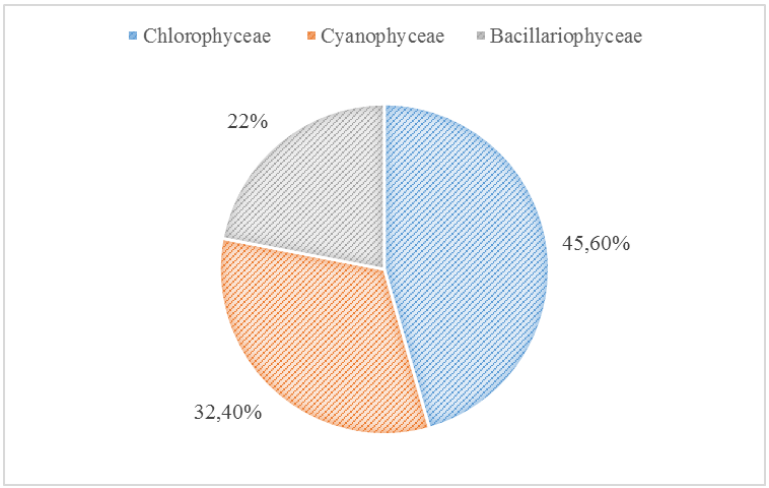

Figure 2 – Abundance of various groups of algoflora in therapeutic muds of Zhanakorgan

Samples were collected from water sources in different sanatoria of Zhanakorgan – "Tau samaly" with water temperature 20°C and pH 6.7. The most common microalgae genera isolated from these water samples were *Phormidium, Chlorella, Scenedesmus, Synechococcus, Anabaena, Calothrix, Dunaliella, Chlamydomonas, Trichormus, Nostoc, Navicula*.

The following study was conducted on the territory of the sanatorium "Zhanakorgan". The temperature of the water ranged from 20 to 23°C, with a recorded pH of 6.5. The following genera were

identified from this sampling site after microscopy analysis: *Anabaena, Calothrix, Dunaliella, Chlamydomonas, Trichormus, Nostoc, Navicula, Scenedesmus, and Chlorella*.

In the "Akshuak" sanatorium, the pH of the water was recorded at 6.5, with a temperature of 22°C. The most found genera from these water sources include *Calothrix, Dunaliella, Chlamydomonas, Trichormus, Nostoc, Navicula, Scenedesmus,* and *Anabaena*. Microalgae from this source have been classified into 57 species and subspecies, belonging to 3 divisions (*Cyanophyta, Chlorophyta, Bacillariophyta*), 7 classes, 7 orders, 15 families, and 22 genera.

The dominant species were cultivated on distinct nutrient media in order to facilitate further isolation and purification from associated microflora.

Isolation of axenic cultures of microalgae

To obtain axenic cultures from the enriched culture, traditional microbiological methods were employed. The cultivation was conducted by accumulation under optimal conditions, which ensured the growth and development of microalgae while maintaining the appropriate temperature and lighting. Subculturing was conducted on liquid and solidified agar media, including Zarrouk, BG-11, Gromov, Artari, and Tamiya media, utilizing Petri dishes and test tubes, which were illuminated [33,34]. Subcultures were subsequently transferred from the grown microalgal colonies to liquid nutrient media or slanted agar. The isolation of individual pure cultures was achieved through the utilization of the streak plate method. A small quantity of the sample was then transferred with a microbiological loop and distributed across the surface of the nutrient medium. At the outset, the streaks exhibited a considerable population of cyanobacteria and microalgae. However, as the loop traversed the surface, the number of cells diminished until only single cells remained. Following inoculation, the Petri dishes were incubated until colony growth was observed.

Thus, from the water samples collected in Zhanakorgan, through multiple subcultures, the following algologically and bacteriologically pure cultures of microalgae were obtained, primarily belonging to the genera *Dunaliella* sp., *Chlamydomonas* sp., *Calothrix*, *Trichormus*, *Nostoc*, *Navicula*, and *Scenedesmus* sp.

Morphological evaluation of isolated isolates of cyanobacteria

In terms of their primary morphological characteristics, representatives of the genus *Dunaliella* are classified within the class *Chlorophyceae* and are extensively employed for the production of carotenoids, glycerol, polyunsaturated fatty acids, lipids, vitamins, and other biologically active substances. Furthermore, they are of practical and theoretical interest as a model for studying several processes, including β-carotene biosynthesis, osmoregulation mechanisms, salt tolerance, and frost resistance. The cell sizes of *Dunaliella* exhibit considerable variation between strains, with lengths ranging from 2.8 to 40 μm and widths from 1.5 to 20 μm, as documented in the literature [35]. During our experiment, the cell sizes observed ranged from 11 to 25 μm in length and 6 to 15 μm in width. The cells were observed to be ellipsoidal or ovoid in shape, with two flagella located at the apical end. A significant morphological feature of *Dunaliella* is its high degree of variability, which enables the cells to readily alter their shape and size in response to environmental stimuli. It was observed that the cells exhibited high levels of motility, with a uniform distribution throughout the medium. Additionally, no palmelloid colonies (cell clusters) were present. The observed reproduction occurred vegetatively by transverse cell division.

The next species, *Chlamydomonas* sp., represents unicellular green algae with flagella, which are documented to form microcolonies of cells designated as palmelloids. The formation of palmelloids is typically associated with adverse environmental conditions, including the presence of predators, salt stress, and organic acids. No palmelloids were observed in the present study. The cells were oval in shape, with a large green chloroplast occupying the entire cell and a thin cell wall. The observed range in cell size was between 5 and 8 μm in width and 8 and 15 μm in length. At the anterior end, two whip-like flagella were observed, with lengths varying from 15 to 30 μm. An eyespot was observed in close proximity to the anterior edge of the chloroplast, situated just beneath the membrane and protruding slightly from the chloroplast as a small bulge. The eyespot, which was yellow or orange in color, consisted of two or three rows of granules that were composed of a homogeneous lipid-carotenoid substance. When cultivated in a liquid medium, the cells exhibited a high degree of motility.

Scenedesmus sp. is a colonial green alga with cell dimensions ranging from 5–13 μm in length and 2.3–6 μm in width. The cells are cylindrical, flat, and slightly curved, forming cenobia consisting of 4-5 cells. The alga is characterized by spines of 180-200 μm in length, is non-flagellated, and remains immobile.

Calothrix epiphytica is a filamentous thallus that attaches basally to substrates, forming bristle-like clusters or thin mats. The filaments are heteropolar,

with a wider basal part containing heterocysts (sometimes associated with akinetes and/or enlarged basal vegetative cells) and an apical part that forms an elongated, tapering, hair-like structure. Heterocysts develop at the base of the filament. The trichomes measure 5–10 µm in width at the base and 0.05–4 mm in length, dividing perpendicularly to their long axis, and reproduce by forming hormogonia.

The trichomes of isolated *Trichormus* strains intertwined and settled at the bottom of culture flasks. Under the light microscope, the trichomes appeared unprotected, typically immobile, straight, and sometimes curved. The cells of *T. variabilis* ranged from 4.1 to 5.8 µm in length and from 3.5 to 5.6 µm in width, with a length-to-width ratio varying from 0.85 to 1.19. The trichomes were cross- and intercellularly divided and consisted of cylindrical cells. The morphology of the terminal cells of the *Trichormus* strains was rounded, conical, and tapered.

Nostoc oryzae, belonging to the family *Nostocaceae,* features curved trichomes ranging from 6 to 8 µm in length and 3 to 5 µm in width. These trichomes are twisted or coiled, unbranched, and isopolar, with ends that do not taper and are moniliform, narrowing at the transverse walls. The cells vary in color from pale to bright blue-green or olive-green, and are spherical or barrel-shaped, though sometimes cylindrical. The terminal cells are rounded, similar to the other vegetative cells. *Nostoc oryzae* consists of numerous filaments made up of spherical cells arranged in chains, encapsulated in a gelatinous mass and covered by a mucilaginous sheath.

Navicula is a genus of diatoms within the class *Bacillariophyceae*. Morphologically, the valves exhibit highly variable shapes, ranging from elliptical to linear-elliptical or lanceolate, with lengths from 4.6 to 13.4 µm (average 8.3±1.7 µm) and widths from 2.1 to 3.8 µm (average 2.7±0.4 µm; n=3). The ends of the valves also vary, from capitate to spread, and are somewhat asymmetrical or irregular. The keel (filamentous and straight) is simple, with filamentous ends and well-visible proximal ends. The axial area is almost invisible, while the central area is variable in size, rhomboid, and slightly asymmetrical. Striae on the valve are rarely noticeable.

As a result of morphological studies, the newly isolated axenic cultures of cyanobacteria, green algae, and diatoms were identified as *Dunaliella salina, Chlamydomonas* sp., *Scenedesmus* sp., *Trichormus variabilis, Calothrix epiphytica, Nostoc oryzae,* and *Navicula* sp.

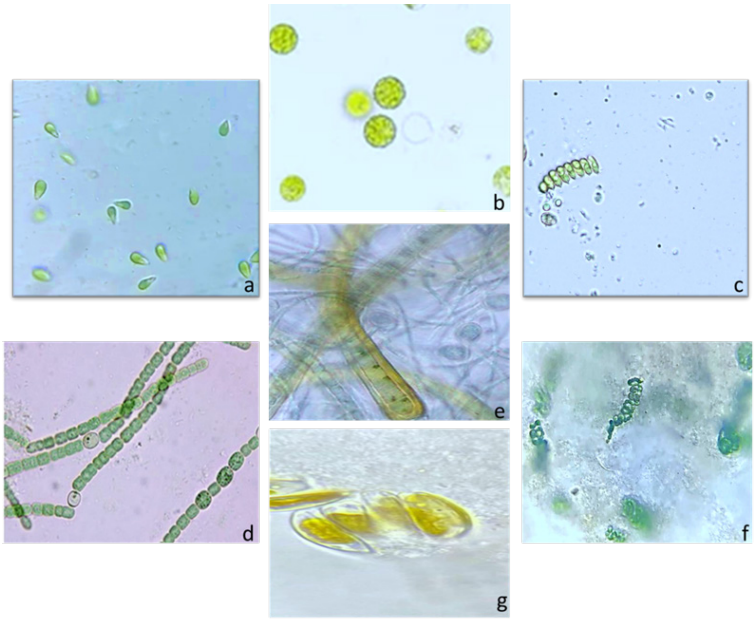

Figure 3 – Cells images (100x) of new isolated microalgae strains:
a-*Dunaliella salina*, b-*Chlamydomonas* sp., c-*Scenedesmus* sp., d-*Trichormus variabilis*,
e-*Calothrix epiphytica*, f-*Nostoc oryzae*, **g**-*Navicula* sp.

Discussion

The present study examined the species composition of microalgae and cyanobacteria in two wells and in treatment bogs of the settlement of Zhanakorgan district. The objective of this study was to examine the species diversity, morphological and cultural characteristics of cyanobacteria, green and diatom

algae in the Zhanakorgan district locality, and to introduce them into axenic cultures for storage in the collection for potential utilization in industrial biotechnology due to their rich chemical composition.

For several years, microalgae and cyanobacteria have been the subject of considerable interest due to the diverse range of bioactive compounds they contain, which have the potential to be utilized in a number of biotechnological applications, particularly in the biomedical, pharmaceutical, nutraceutical and cosmetic sectors. Several studies have demonstrated that the polysaccharide, lipid, pigment, micronutrient and nutrient contents of microalgae and cyanobacteria have significant potential as antiviral, antibacterial and antioxidant compounds.

Scientific data in this area is now a reference for the increased use and growing economic interest in microalgae and cyanobacteria. In this regard, we have isolated new potential strains of microalgae and cyanobacteria in the therapeutic bogs of Zhanakorgan district. Organic and mineral substances of the therapeutic mud with therapeutic and preventive properties can influence the composition of the algoflora. The isolated microalgae and cyanobacteria may have the same properties and similar composition as therapeutic mud and water. In the current study, we isolated new axenic cultures of microalgae and cyanobacteria including *Dunaliella* sp., *Chlamydomonas* sp., *Calothrix*, *Trichormus, Nostoc, Navicula, Scenedesmus* sp. with antioxidant, hepatoprotective, neuroprotective, anti-inflammatory and anti-aging activities. This is an example of the potential of microalgae and cyanobacteria that awaits further investigation. We will continue to explore their uniqueness and potential and their applications in various biotechnological and medical fields.

The halophytic microalga *Dunaliella salina* is a recognized object of industrial cultivation in many countries due to its high content of β-carotene, lipids and glycerol. The products derived from this microalga are utilized in a variety of applications, including as food and feed additives, food coloring agents, cosmetics and vitamins. An important application of *Dunaliella* biomass is the production of biologically active additives, pharmaceuticals and cosmetics. *Dunaliella* contains essential phospholipids and a number of beta-carotene derivatives, including highly effective antioxidants [6].

Additionally, *Dunaliella salina* contains ω-3 unsaturated eicosapentaenoic acid (EPA), which is not known to occur in any terrestrial carotenogenic plant. EPA, along with other unsaturated fatty acids, including linoleic acid and linolenic acid, has been demonstrated to possess anti-glycation properties [36].

The isolation of *Chlamydomonas* sp. therapeutic mud represents a significant potential for the sustainable reduction of pollutants and contributes to the recovery and valorization of microalgae biomass resources. The use of *Chlamydomonas* sp. and its bacterial consortia as biofertilisers offers a number of potential benefits, including increased crop yields, crop protection, maintenance of soil fertility and stability, and contribution to CO2 mitigation, as well as promotion of sustainable agricultural practices. Additionally, they play a pivotal role in the production of premium-quality products, particularly biofuels and enhanced hydrogen production. *Chlamydomonas* sp. are a source of bioactive compounds, including essential amino acids, polyunsaturated fatty acids and antioxidants, which have been demonstrated to have beneficial effects on nutritional status and health. *Chlamydomonas* sp. has been employed in the investigation of a multitude of research areas, including photosynthesis, respiration, sulphur and phosphorus metabolism, nitrogen metabolism, amino acid and metal metabolism, biosynthetic pathways of starch, carotenoids, lipids, glycerolipids, haem groups and chlorophyll [37].

Scenedesmus sp. was studied with main emphasis on fatty acid composition. Most results demonstrated that *Scenedesmus* sp. exhibited the highest biomass productivity, carbohydrate, fat, protein, chlorophyll, and carotenoid content. The lipid profile also demonstrated that the highest percentage of polyunsaturated fatty acids was present. Therefore, they demonstrated considerable potential for use in the fields of nutraceuticals and pharmaceuticals, given their high productivity, capacity for biopigmentation, protein, lipid, antioxidant activity, long-chain polyunsaturated fatty acids and α-linolenic acid, as well as their status as a rich source of bioactive substrates such as proteins, lipids and pigments [38].

The research community has directed considerable attention towards *Trichormus variabilis* due to its potential to fulfil dual industrial functions in bioenergy production and bioremediation. This species is capable of efficiently utilizing energy from sunlight to reduce CO_2 levels in the atmosphere and generate valuable chemical compounds, including carbohydrates and fatty acids, which can be converted into biofuels. Given its ability to flourish in nutrient-rich wastewater (industrial effluents), this species can serve as a bioabsorbent, thereby supplanting the costly chemical catalysts and nanomaterials that have traditionally been employed for the removal of nutrients and metals [39].

Calothrix epiphyticola is a blue-green filamentous algae comprising a basal heterocyst. It is found

in both saltwater and freshwater environments, as well as subaerially and aerially. The ability to survive in a multitude of environmental conditions is a defining feature of this organism. It is capable of thriving in a range of habitats, including terrestrial, saline, and freshwater environments, as well as in highly competitive ecosystems. Furthermore, it is exposed to a diverse array of predators and microbial pathogens, including bacteria, viruses, and fungi. Their flexible metabolism is the foundation for their capacity to adapt to diverse growth conditions and habitats, as well as their ability to respond to varying environmental stresses and nutrient sources. This versatility may be the underlying reason for the variety and quantity of chemical compounds that have been isolated from them. Secondary metabolites of *Calothrix epiphyticola* have been reported to have pharmaceutical potential, belonging to a wide range of structural classes, including alkaloids, aromatic compounds, peptides, terpenes, and others, all of which exhibit some biological activity [40].

One of the cyanobacteria species, *Nostoc oryzae,* has been consumed by the Chinese population as a food delicacy for hundreds of years due to its perceived herbal value. This historical use provides a sound basis for its potential incorporation into nutraceuticals. Several studies have corroborated the role of *Nostoc*, which contains auxiliary light-gathering, water-soluble, and fluorescent proteins, as well as phycobiliproteins. Phycobiliproteins are water-soluble auxiliary pigments that consist of highly fluorescent proteins with linear prosthetic groups (bilins) that are bound to specific cysteine residues, collectively known as phycoerythrins. Phycobiliproteins exhibit a range of colours, including bright blue (phycocyanin and allophycoerythrin) and fuchsia (phycoerythrin). They possess high commercial value as natural dyes in a multitude of industries, including nutraceuticals, cosmetics, medicine, pharmaceuticals, textiles and food production [41].

Furthermore, diatom algae are regarded as the most successful group of phytoplankton in modern reservoirs, oceans and waters. They can store carbon in the form of natural oils. In accordance with standard growth conditions, the primary carbon storage product of diatom algae is lipids, with approximately a quarter of their biomass consisting of triacylglycerides (TAGs). In this study, *Navicula* sp. is a benthic diatom algae from which several bioactive compounds of commercial interest, including polysaccharides, can be obtained. Many studies have demonstrated that microalgae polysaccharides exhibit considerable potential as antiviral, antibacterial and antioxidant compounds, among other properties [42]. Despite the existence of a few studies on this subject, the available information on sulfated polysaccharides derived from species within the genus *Navicula* sp. remains limited.

Accordingly, the strains isolated by our research group show great promise for use in a variety of research areas, as evidenced by the literature. It is likely that microalgae and cyanobacteria will assume a pivotal role in the nutraceutical, food, cosmetic, medical and pharmaceutical industries in the near future, in accordance with the changes in lifestyle and diet of all mankind.

Conclusion

This article examines the species diversity, morphological, and cultural characteristics of microalgae, cyanobacteria, green algae, and diatoms from the Zhanakorgan district (Kyzylorda region). The study demonstrated that during the investigation of the microflora of therapeutic muds from Zhanakorgan, cyanobacteria (*Nostoc, Calothrix epiphytica, Trichormus variabilis*) and diatoms (*Navicula*), as well as green algae (*Scenedesmus* sp., *Dunaliella salina, Chlamydomonas* sp.), were identified. The dominant group was identified as *Chlorophyceae* (46.7%), comprising five species. This was followed by *Cyanophyceae* (35.4%), comprising four species, and *Bacillariophyceae* (9.7%), comprising two species.

Seven axenic cultures of microalgae and cyanobacteria were isolated and identified, including *Dunaliella* sp., *Chlamydomonas* sp., *Calothrix*, *Trichormus*, *Nostoc, Navicula*, and *Scenedesmus* sp. This discovery has the potential to expand the utility of microalgae and cyanobacteria in various biotechnological applications. There has been a notable increase in interest in microalgae and cyanobacteria as a source of pharmacologically active and industrially important compounds in recent years. The bioactive compounds of microalgae and cyanobacteria, including those with cytotoxic, antitumor, antiviral, antibiotic, antimalarial, antifungal, multidrug resistance-restoring, antifungal, herbicide and immunosuppressant properties, have the potential for use in a range of pharmaceutical, agricultural and biological applications. Microalgae play a significant role in the composition of therapeutic muds, as they are actively involved in the processes of biochemical transformation and decomposition of organic matter. The addition of algae to the mud enriches it with a variety of bioactive components, including vitamins, amino acids, trace elements and antioxidants, which collectively enhance the mud's therapeutic properties. Furthermore, algae facilitate

the accumulation of oxygen and other biologically active gases, thereby enhancing the efficacy of the mud in therapeutic applications.

The elevated microalgae content of therapeutic muds can be attributed to their capacity to augment the biochemical characteristics of peloids and augment their therapeutic impact on the human body. This renders mud therapy a potent natural approach to recuperation and restoration of health.

Acknowledgements

This work was support by the grants AP23485416 “Creation of a biobank of microalgae and cyanobacterial collections, and study of their biotechnological potential for application in applied research” (2024-2026) funding by the Ministry of Science and Higher Education of the Republic of Kazakhstan.

Conflict of interest

All authors have read and are familiar with the content of the article and have no conflict of interest.

Acknowledgements

This work was support by the grants AP23485416 “Creation of a biobank of microalgae and cyanobacterial collections, and study of their biotechnological potential for application in applied research” (2024-2026) funding by the Ministry of Science and Higher Education of the Republic of Kazakhstan.

2022EO1032 «Research and development of Chinese-Kazakh agricultural products in the antibiotic production system, research on adaptability and application», supervisor Zayadan B.K.

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Received June 05, 2024
Accepted September 26, 2024