Algological assessment of oil pollution in ecotonic ecosystems

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Abstract. The aim of the study was to determine the effect of oil pollution on the transformation of algocenoses of water-ground ecotone. The species composition, abundance, occurrence of cyanobacteria and algae in water-ground ecotone under the influence of oil pollution has been studied. A comparison of the algoflora of different ecotone sites was made taking into account the nature of the higher plants. Sixty-five taxa of algae were identified with a rank below the genus belonging to the 4th divisions. The division dominant in the number of species is Bacillariophyta (37%), Cyanoprokaryota (Cyanophyta) (31%), Chlorophyta (27%), Xanthophyta (5%). The leading families were Pseudanabaenaceae, Phormidiaceae, Cocconeidaceae. Among the genera, the genus Leptolyngbya is in first place. The littoral zone of the lake was dominated by diatomic algae. A wide range of species of cyanobacteria and green algae were observed in soil samples, leading families and genera by species occurrence were members of the families Nostocaceae, Pseudanabaenaceae. Environmental analysis has shown that hydrophilic and edaphophilic species belonging to P-, Ch-, CF-, C and B- life forms play a significant role in the formation of soil algae communities. The nature of the higher plants is less than oil pollution determines the composition of the algoflora. With the emergence of oil contamination in the ecotone, the number of cyanobacteria and algae, the survival rate of soil algae and, to a lesser extent, benthic species is reduced.

1. Introduction
Ecotonic systems have an important role in the biosphere because they act as barriers, membranes, accumulations, filters, exhibit "edge effect" and are characterized by increased bio-production and high biological diversity [1].

The most important component of the biotic communities of ecotonic systems are cyanobacteria and algae. Their role in water-terrestrial ecotones is particularly great [2]. Increasing anthropogenic load makes qualitative changes in the physical and chemical composition of soil cover and water bodies, thus causing a decrease in biological diversity.

The purpose of our research was to determine the effect of oil pollution on the transformation of algocenoses of water-ground ecotone.

2. Methodology
Algomonitoring of oil pollution was carried out on the territory adjacent to Lake Neftyanik of the Karmaskalinsky district of the Republic of Bashkortostan. Samples were taken from the lake lithoraly every 15 m to the site where the oil rockers were located. Each of the bell-cranks surrounded the earth
shaft with a height of 50 - 70 cm. Samples were taken on 8 sections on two transects: 4 - from the side of oil bell-cranks (sections 1 - 4); 4 on the opposite side of the lake (sections 5 - 8). Changes in floristic composition and spectrum of ecobiomorphs of soil algocenoses in zones of oil wells were also studied at various stages of development: exploration, operational, non-operational (areas 9-11).

From June to September 2019, we collected 72 soil and 80 benthic samples. Selection frequency - once a month. Ten phytobenthos samples were also taken once a month to study the algae of the littoral zone. Conventional and repeatedly tested methods of algological research were used [3]. Perfíliev’s sludgepump were used to sample benthos. Soil samples were taken from the 0-1 cm layer at 10 points of the test site with subsequent averaging.

Taxonomic analysis of soil algoflora was performed in cup cultures with fouling glass [4]. The abundance of aquatic and soil algae was assessed on a 5-point scale. The general (total) abundance of algae was defined as the sum of abundance of points of separate types and versions. An analysis of soil algoflora on the spectrum of ecobiomorph was also carried out [5]. The species composition of algae was compared using Serensen’s floristic community coefficient (FCC). To determine the species timing of algae, the "Brief Determination of Algae of Bashkortostan" (1995) was used [6]. The algae system is given by I I Vasilieva-Kralina (1999) with clarification (Wasser, Tsarenko, 2004). A comparison of the algoflora of different sites was made taking into account the nature of the higher plants, since the reaction of algae to environmental conditions is most similar to that of higher plants [7].

By comparison, the sites studied were combined by nature of higher plants:
1) area where vegetation was completely absent (book № 1,9,10)
2) areas with synanthropic vegetation (section No. 2)
3) plots with forest vegetation (№ 3,4)
4) areas with meadow vegetation (№ 5,6,7,8,11)

3. Results and discussion
As a result of the studies carried out, we have identified 65 species and varieties of algae. The undisturbed and disturbed ecotone areas are dominated by members of cyanoprocaryotes and green algae. In benthos, leadership belongs to diatomic. Representatives of the departments of yellow-green and diatomic algae (the most sensitive to oil pollution) were found by us only in benthos, and in control. The appearance of yellow-green algae in the littoral zone of the lake can be seen as a sign of the integrity of the aquatic ecosystem and the absence of man-made pollution. In soil, the leading families and genera by species occurrence are members of the families Nostocaceae, Pseudanabaenaceae. According to the occurrence of genera in the first place the genus Anabaena, in the second place is the genus Leptolyngbya. In benthos, the lead in occurrence belongs to algae of the family Cymbellaceae and the genus Navicula. Differentiation of species composition of algae in ecotone areas characterized by different vegetation was noted.

The most common species at the eight sites studied are Leptolyngbya boryana, Leptolyngbya notata, Leptolyngbya foveolarum. Environmental analysis has shown that hydrophilic and edaphophilic species belonging to P-, Ch-, CF-, C and B- life forms play a significant role in the formation of soil algae communities [5]. The range of vital forms of soil algae can be presented in the following form: $	ext{P}_1: 	ext{C}_6	ext{H}_8	ext{O}_6	ext{N}_5	ext{P}_4	ext{O}_7; \text{B}_1: \text{C}_2\text{H}_5\text{O}_2\text{N}_3	ext{P}_4\text{O}_7$.

Comparison of algoflora of the listed sites with use of coefficient of Serensen showed the greatest similarity (52%) of algoflora on site 2 with vegetation of the class ARTEMISIETEVA VULGARIS, order - ONOPODETALIA ACANHII, and site 5 with vegetation class MOLINIO-ARRHENATHERETEAE R. The smallest percent of similarity (9%) was noticed when comparing site 1 where vegetation completely was absent, with site 6, the class MOLINIO-ARRHENATHERETEAE. That is, the nature of the higher plants is less than oil pollution determines the composition of the algoflora. Although the species composition of the dominant algae complex, the spectrum of life forms (Table 1) at the sites with the meadow and synanthropic vegetation varied significantly. This is due to the fact that only in site 1 (directly under the oil bell-crank) the level of man-made load is high.
Table 1. Characteristics of studied sites by various indicators.

| Site | N (Number of species) | Spectrum of life forms | C_xer | PC (%) |
|------|----------------------|------------------------|-------|--------|
| Vegetation was absent | | | | |
| 1 | 5 | C_3P_1CF_1 | 0.20 |
| 2 | 12 | Ch_3C_2P_3CF_2 | 0.25 | 51 |
| 3 | 15 | P_10C_2Ch_2Hyd_1 | 0.67 | 61 |
| 4 | 15 | P_5CF_2Ch_2C_2B_2X_1H_1 | 0.33 | 74 |
| 5 | 15 | P_6CF_3M_1X_2B_2M_2Amph | 0.47 | 76 |
| 6 | 22 | P_11CF_3Ch_3X_2H_1C_1 | 0.50 | 82 |

Designations: C_xer - xerophyl coefficient; N - number of algae species on site; PC - projective covering;

The study of algocenoses in the zones of the sites at different stages of oil development showed minimal species diversity of algae at the site of the exploration well, where in preparation for oil production the humus soil layer was completely removed and salt solution was poured (Table 2). Here there was a clear suppression of algoflora, species characteristic of the initial stage of succession on man-made substrates were encountered. Plectonema boryanum (Cyanophyta), Chlamydomonas atactogama, C. gloeogama, Chlorococcum infusionum, Chlorella vulgaris, C. minutissima (Chlorophyta), Botryochloris minima (Xanthophyta). The spectrum of ecobiomorph on this site is dominated by members of Ch-form - single-cell species of ubiquitist, found everywhere [5]. R. R. Kabirov (1984) found that Plectonema boryanum under laboratory conditions in variants with oil doses of 0.00015-0.015 cm^3/g grew intensively and formed a solid "carpet" on the fouling glasses, and only doses of oil of 0.15 cm^3/g suppressed its development. The oil doses he tested did not have an inhibitory effect on the two species of colonial blue-seeded Nostoc linckia, N. punctiforme. When microscoped, their colonies were found even inside oil spots. Some cyanobacteria have been shown to grow at an oil concentration of up to 10% and withstand concentrations of up to 50% of soil weight [8].

The only representative of the Cyanophyta division - Phormidium autumnale (P- form) is characterized by quite frequent occurrence. There is also a small number of algae species in the production well, but in the future the succession of algocenosis follows the model of stimulation, when every settling species improve the conditions for the settlement of new ones [9]. The process of recovery of algocenosis is at the final stage at the non-operational well: this is evidenced by the large species diversity, the appearance of filamentous green algae.

Table 2. Taxonomic structure and spectrum of ecobiomorph of sites algoflora at various wells

| Departments of algae | Exploratory well | Operational well | Unexploited well |
|----------------------|------------------|------------------|------------------|
| Cyanophyta           | 1                | 3                | 9                |
| Chlorophyta          | 5                | 7                | 14               |
| Xanthophyta          | 1                | -                | 3                |
Bacillariophyta - 2 9

| Total number of species | 7 | 12 | 35 |
|-------------------------|---|----|----|
| Spectrum of ecobiomorf  | $\text{CH}_4$,$\text{C}_2$,$\text{P}_1$ | $\text{CH}_3$,$\text{C}_2$,$\text{P}_1$,$\text{M}_4$,$\text{CF}_1$,$\text{B}_2$ | $\text{CH}_7$,$\text{P}_1$,$\text{CF}_5$,$\text{C}_3$,$\text{H}_1$,$\text{B}_2$ |

There is a well-expressed dominant complex comprising members of various divisions: species of genera Phormidium, Microcoleus, Nostoc (Cyanophyta), Chlamydomonas, Chlorella, Chlorhormidium (Chlorophyta), Heterothrix (Xanthophyta), Navicula, Hantzschia amphioxys (Bacillariophyta). The rich spectrum of life forms of algae is explained by favorable conditions for their development. The process of recovery of algocenoses here is in the final stage, as evidenced by the appearance of filamentous green and green-yellow algae (H-form), which are the first to disappear in case of contamination and man-made disturbance of the soil cover: representatives of the orders Ulotrichales, Tribonematales, Heterocloniales.

4. Conclusion

Based on the obtained data, it can be concluded that with the emergence of oil contamination in the ecotone, the number of cyanobacteria and algae is reduced, the survival rate of soil algae and, to a lesser extent, benthic species, which is caused by pollution of the sphere with oil and petroleum products, resulting in disruption of dynamic equilibrium in the ecosystem due to changes in the structure of the soil cover, geochemical properties of soils, as well as toxic action on living organisms.

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