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Aberrant Forms of Algae and Bioindication of Aquatic Ecosystem State

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Abstract

Paper presents the review of problems in the algal Teratogenesis and demonstrates the samples of aberrant forms generation in freshwater environment. Diversity of aberrant forms in green, diatom algae and cyanobacteria are demonstrated. In cyanobacteria was revealed aberrant forms in *Microcystis* and *Woronichinia* as enlarges of cell size and losses of gas vesicles. Green algae *Ulothrix* was found as dimorphic thalluses in filamentous and coccoid forms. Different diatom species were presented in diverse deformation of shells contour as well as the fine structure aberrance. Causes of teratogenesis were investigated, and revealed that absence of dissolved oxygen in water and decrease in water pH are critical factors for cyanobacteria and green algae aberrancy. But some diatom species were formed ugly cells under influence of sum of factors related to the technogenical pollution by heavy metals and boron. Therefore, these deformations of cells in diatom, green algae, and cyanobacteria can be used for bioindication of environment change.

Keywords: Aberrant form; Algae; Bioindication; Morphology; Ecology

Introduction

Algae are mainly autotrophic organisms that represent first trophic level in ecosystem pyramid [1]. They reflect all natural and anthropogenic processes occurring in water bodies. Thus, they are taken into account in using the bioindication method that consisting in the analysis of biota response to changes in the environmental conditions takes on great significance [2]. Usually is important to define which environmental factors is stressed algal diversity. In bioindication we operate with species content, its abundance in community and species-specific ecological preferences that included to our database [3].

However, the change in environmental conditions affects not only the variation of species composition (succession), but also finds reflection in the morphology of algal species. The changes in the algal cells morphology such as aberrant forms generations can reflect the environment impact on the population. But it has been so sporadically attention was given to the causes and evidences of this process in nature. The most pronounced change in the morphology of species was found in species with wide ecological amplitude such as the genera *Aulacoseira*, diatoms, and *Microcystis*, cyanobacteria, developing in mass in various reservoirs from oligotrophic to eutrophic. The observations in our studies of the morphological variability of blue-green, green and diatom algae, both in ontogeny and in connection with speciation and Teratogenesis are of greatest interest [4].

The formation of teratological, the aberrant forms by a number of researchers associate with unfavorable environmental factors [5]. Interest in the anomalous forms of algae also arises in connection with the problem of their taxonomic affiliation, as well as a material for studying the features that arise in the process of speciation. Most often there is no way to specify the causes of the abnormal structure of algal cells, as, for example, in the diatoms of Great Britain, but one can discuss the conditions that produce them [6]. The following sets of conditions can be causes of aberrant algal forms production:

1) Chemical abnormalities in the water - contamination, increased or decreased oxygen or pH;
2) Mechanical - crowding during mass reproduction;
3) Parasitism of algae and / or fungi, or protists;
4) Abnormalities in the sexual process;
5) Cells of the smallest size in the clone;
6) Cells produced under extreme conditions (light and temperature);
7) Genetic changes leading to the formation of cells of a different species or even genus.

Various causes of the appearance of aberrant forms are still remaining in the sphere of assumptions and only in a few cases are these causes can be established. Most often, the authors mention the existence of aberrant forms, unable to establish their causes due to the multifactorial effect on the morphology of cells in nature. In the same cases, when observations are made under controlled experimental conditions, gigantism and ugliness are observed in desmids and chlorococcoid algae under the influence of cultivation conditions such as glucose addition, elevated of temperature [7,8], or decreasing in cells size of diatoms as a consequence of the vegetative fission [9-13]. Deformities are sometimes associated with illness or epiphytism [14,15] or are caused by acidification of the medium to a pH of less than 3.0 [16,17]. For diatoms, the concentration of silicon in the environment is of great importance, and, as a consequence of its lack, cells of an ugly form appear [18-19]. In natural conditions, the emergence of aberrant forms is associated with unfavorable changes in habitat conditions, for example, slowing down the course and increased insolation, pollution by oil products, gamma-ray irradiation, high atmospheric CO_2, the growth of biomass during "flowering", the salt composition of the medium or sensing of nitrate or ammonium balance [20-27]. In natural systems, where the ugliest forms are most diverse, it is usually difficult or impossible to relate their occurrence to any specific indicators but heavy metals were revealed and recommend as percent aberrant diatoms for its monitoring [28-30]. Apparently, a complex of factors operates here [31,32]. Aberrant forms, arising as a response to habitat conditions, can serve to assess environmental conditions [25], as well as mucosal diatoms and greens as a protective device [33]. Changes in the structure of the ugly cell in comparison with normal are very diverse.

However, for each specific genus or species, it is necessary to distinguish features that are not teratology, but appear as a result of realizing the potential for variability of a particular species. For example, cell diameter in a population of *Microcystis aeruginosa* , the shape of the seam and the number of stigmas in the central field of *Cymbella* , the shape of the suture and the length of the wing and the width of the axial field in *Pinnularia* [34-36]. It is necessary to approach critically to the structures observed on the diatoms. Spines, for example, on the valves *Coscinodiscus* were taken for the manifestation of teratology based on finding a species in only two samples [37]. In the latter case, the technique of processing diatoms before microscopy is of great importance, and also the study of a large number of shells of the species in ontogeny in mass production in a pond or in a culture.

Results and Discussion

On our material among green algae, it was found in various water bodies of *Ulothrix zonata* (F.Weber & Mohr) Kützing both in normal, filamentous and in palmelloid form. The latter form can probably be attributed to the aberrant. Whereas in normal form *Ulothrix* represented by sole filament attached to the substrate, we found in periphyton of the Rudnaya River (Primorsky district of Russian Far East) also whole plant consisted of a sole filament attached to the substrate mucous bag containing spherical cells of equal size. We try to identify the pallmelloid form when it was found as sole alga during two years of research. We compare it with known mucilage forms of Chrysophyta such as later was found in the Baikal Lake [38]. However, it was not same. We try to explore the reproductive cycle of *Ulothrix zonata* and to compare our form with autospore generation stage, but no, it cannot help us to define species. The autospore production with change the cell shape of cells was found in other reservoirs of Far East [39-44].

Only after two years of sampling was found combined filament and mucilage forms in one plant individual. This transition form of the *Ulothrix* to the palmella-like form was preceded by thickening of the cell membrane and mucus, which can serves as a protection against fouling organisms and increases the stability of cells in the colony [33]. Thus, *Ulothrix*, by change the filament form to palmelloid, reacts to unfavorable environmental conditions, which was noted by V.M. Arnoldi in connection with the lack of dissolved oxygen in the water [45]. This it can be thru for the Rudnaya River in the sites that placed below of the river below the tailings pond of the Combine “Bor” [46].

A special case of the formation of abnormal cells was observed by us at the Artemovsky reservoir for blue-green plankton algae. Cells that reproduced from the middle of July to the end of October at pH = 7.4-7.8 in a mass amount of *Microcystis aeruginosa* underwent significant changes under conditions of dilution with rainfall and a pH drop till 6.8. Coloniality persisted; however, the peripheral cells of the colony first acquired a drop-shaped form with simultaneous loss of a part of the gas vacuoles and an increase in volume, followed by a crescent shape and lost the gas vacuoles definitively. If the colony was small, it sometimes consisted entirely of cells of the latter type. Such colonies could be attributed to *Rhabdogloea smithii* (Chodat & F. Chodat) Komárek, which, apparently, takes place in publications. Interesting in this regard, it seems that *Rhabdogloea smithii* in reservoirs is defined as a companion of *M. aeruginosa*, but not always where *M. aeruginosa* vegetate, was marked by *Rhabdogloea smithii*. M. Gollerbach characterizes the genus *Dactylociccopsis*, to which *Rhabdogloea* was previously classified as prefabricated and artificial. Some taxa have already been removed from the genus [47]. For a variety of ponds and reservoirs of the European part of Russia, the phenomenon of explosive cell destruction in vegetating species of the genus *Anabaena* was also revealed [48,49]. The phenomenon of the formation of "dactylococcoid" cells, similar to that described in *M. aeruginosa* from the Artemovsky reservoir, has not yet been encountered, or, most likely, did not attract the attention of researchers. According to our observations, it can be assumed that the main factor contributing to the formation of abnormal cells in *M. aeruginosa* is the pH of the medium [41].

Changes in the cells of the alga *Woronichinia naegeliana* (Unger) Elenkin from the Artemovsky reservoir were traced for several years, when this alga from planktonic blue-green algae reached a mass development in the warmest period of the summer. Under the same conditions as *Microcystis aeruginosa*, after the rainfall, the algal colonies were fragmented, with a sharp decrease in pH, the amount of gas vacuoles decreased, the cells increased slightly in volume, and in some small fragments of colonies consisting of 5-7 cells, there were no gas vacuoles and it was clearly visible that in the center of the colony the cells are connected by thin, not long strings. This phenomenon, observed simultaneously with the above described in *M. aeruginosa*, reveals the mechanism of cell connection in the colony of *W. naegeliana* - the cells are not only in the tubes, but also connected by strands in a single colonial center.

To the changes in the shape of the cells, the species needs a weighted approach. Not all morphological variations can be elevated to taxonomic rank or referred to aberrant ones [50]. An example of this is, in our opinion, the variability of *Mucidosphaerium pulchellum* (H.C.Wood) C. Bock, Proschold & Krienitz, whose cells on our material in the period of active fission under favorable conditions in July and August did not have time to acquire a spherical shape and before the next division still remained oval. This form, apparently, should not be considered ugly, although it is elevated to the rank of taxa *Hindakia tetrachotoma* (Printz) C. Bock, Pröschold & Krienitz (synonymic was *Dictyosphaerium pulchellum* var. *ovatum* Korshikov) according to Korshikov also there are no grounds [51].

Diatom algae most often in the studied floras are the most rich in species and are capable of mass development of species. On our material, ugly forms were observed in various species. So, for example, *Eunotia* noted a violation in the arrangement of the fine structure elements, although the overall shape of the valve remained normal, within the diagnosis. In *Epithemia* repeatedly encountered the formation of internal underdeveloped shells (septas). The genus *Cocconeis*, whose species prefer non-polluting waters, often formed shells with recesses at the poles or with concavity of the valves in the middle. Elements of fine structure remained within the limits of the norm. *Hannaea* is a monotypic genus and a shells form of its species *H. arcus* (Ehrenberg) RM Patrick ranges from straight to arcuate-bent with a convex lateral middle field. We met the valves with a concave lateral middle field and the absence of the hyaline part of the valve. Some specimens had a hyaline convex lateral middle field, but they had a notch next to this structure. While retaining the fine structure elements of the armor in *Hannaea*, the recess in the middle of the flap is its irregular shape, as other researchers have previously noted [20]. Similar forms of deformities were also found in the Lake Superior in the USA [31] in those years (1970s) when the ecological situation in the American Great Lakes was not restored after the peak of pollution as a result of the development of industrial centers on the coast of the lakes.

Of particular interest was the study of *Aulacoseira granulata* (Ehrenberg) Simonsen of a mass species in many water bodies, identification of which is difficult due to fuzzy criteria for the allocation of taxa within the genus, insufficient knowledge of the variability and significance of the characteristics of each species. Often this species in spring and autumn develops in mass, forming a "flowering" of water in small and large artificial and natural water bodies. Among the many investigated, the Artemovskoe reservoir has been the object of our attention since its filling and for more than a decade, so it has been possible to identify the pioneer species that are the first to acquire the water column [52]. One of these species, the most abundant, was *A. granulata* [53]. In shallow water reservoirs that existed in the flood zone, the population of this species was represented by cells 13-17 microns in diameter and 22-27 microns in length. The shells was of medium thickness, and its analysis in light microscopy corresponded to the diagnosis of F. Hustedt [54,55]. Occasionally, there were colonies of the three types mentioned by F. Hustedt, containing shells of different degrees of silica saturation. This is an indication of the population, increasing their numbers, but not dominant in the community, because the diameter of the valves is average and the rate of division is obviously low. Auxospore formation was not observed in this stage. After filling the reservoir for a year and a half, *A. granulata* was almost the only plentiful species in the pond, except for the species of blue-green algae *Aphanizomenon flos-aquae*. The development of a new ecotope - the water column, accompanied by active vegetative reproduction, led to the fact that the diameter of the valves *Aulacoseira granulata* decreased to 2.9 microns. There was no similar phenomenon in other studied artificial or natural reservoirs of Eurasia, and the minimal size of the valves by diagnosis was 4 μm. The length of the valves remained within 17-27 μm. When observed in a light microscope (LM) in an moisture preparation of *A. granulata*, in the first two years it population was difficult to determine because the chloroplasts yellowed and become pale, cell sizes were close to certain types of yellow-green filamentous algae of the genus *Tribonema*, areoles in the shells indistinguishable, the shell wall is so thin that the colony lost its stiffness in longitudinal axis cells bent, while not losing cylindricality and not tearing the threads. When observed in the LM in constant preparation to aniline-formaldehyde medium areolas were barely visible as a thin wall shell was shallow areolas camera, which almost does not refract light rays at the edges. The location and frequency of areolas were within the limits corresponding to the diagnosis. When studying such valves in a scanning electron microscope (SEM), the structure, the nature of the location and the size of the areolas were the same as in the populations from other water bodies investigated by us, and on the edge of the valve clear connective spines were found that were in LM not visible at all [53].

The bloom of *Aulacoseira granulata* f. *curvata* (Hustedt) Simonsen in the Artemovskoye reservoir was sporadically but very intensive [52]. Population was turn to the normal cells form after auxospore generation. The causes of forma *curvata* bloom were not revealed.

Special attention should be paid to the populations of *Fragilaria rumpens* (Kützing) G.W.F. Carlson and *Synedra goulardii* var. *telezkoensis* Poretzky ex Proschkina-Lavrenko from the Rudnaya River, all of whose cells are aberrant [41,43]. We observed not only disruptions in the arrangement of elements of a fine structure, but also in the outlines of the valves. Teratological deformities were repeated from generation to generation during the entire observation period. Ugly cells accounted for up to 95 percent of the population in the *Fragilaria* and up to half the population in *Synedra*. Formation of populations with ugly shells occurred in the same stations as in green alga *Ulothrix zonata*, below the tailing dump of the "Bor" Combine. We cannot pinpoint the origin and maintenance of a stable teratology of diatom species *Fragilaria* and *Synedra* in the Rudnaya River, but this is clearly not only the absence of oxygen, and, probably, the presence of boron and heavy metals, but most likely the influence of a complex of factors, that can be natural climatic factors also [56].

Conclusion

The examples of the formation of teratological, aberrant forms in part of the population or the entire abundance of cells described in our material can be referred to the first six positions mentioned above when the organism reacted by changing the shape to a change in the environment. So, in cyanobacteria *Microcystis aeruginosa* the cells increased slightly in volume and lost gas vacuoles when water was sharp decrease in pH. *Woronichinia* was formed abnormal volume of cells in the warmest period of the summer. It let us to assume that increasing of water temperature and decreasing of water pH was critical factors as causes for the aberrant cells formation in cyanobacteria. Active fission under favorable conditions did not have time to acquire a spherical shape and before the next division still remained oval in green alga *Mucidosphaerium pulchellum*. Rare dimorphic teratology in green algae *Ulothrix* is associated, most likely, with the absence of dissolved oxygen in water and a decrease in water pH. Therefore, these deformations of cells in diatom, green algae, and cyanobacteria can be used for bioindication of environment change.

Stable generated teratology of diatom species *Fragilaria* and *Synedra* in the Rudnaya River can be result the influence of complex of environmental factors including boron, absent of oxygen and presence of heavy metals in the river water after tailing dump of the “Bor” Combine. So, the causes of the last sample of diatom teratology can be assigned to item 8 of the above list. To determine how much the changes are inherited could have been possible only in the experiment of the behavior of these populations in a medium with changing parameters.

References

1. Barinova S (2017) On the Classification of Water Quality from an Ecological Point of View. Int J Environ Sci Nat Res 2(2): 1-8.

2. Barinova S (2017) Essential and practical bioindication methods and systems for the water quality assessment. Int J Environ Sci Nat Res 2(3): 1-11.

3. Barinova S, Fahima T (2017) The Development of the a World Database of Freshwater Algae-Indicators. Journal of Environment and Ecology 8(1): 1-7.

4. Jelinek R (2005) The contribution of new findings and ideas to the old principles of teratology. Reproductive Toxicology 20(3): 295-300.

5. Saboski EM (1977) Effects of mercury and tin on frustular ultrastructure of the marine diatom *Nitzschia lielthrutti*. Water Air and Soil Pollut 8(4): 461-466.

6. Barber HG, Carter JR (1981) Observation on some deformities found in British diatoms. Microscopy 34(3): 214-226.

7. Rodrigues-López M (1963) Gigantism-inducing factors in *Chlorella pyrenoidosa*. Nature 199(4892): 506-507.

8. McMillan R (1957) Morphogenesis and Polymorphism of Ankistrodesmus spp. J Gen Microbiol 17: 658-677.

9. Geitler L (1962) Alle Schalenbildugen der Diatomeen als Folge von Zell – oder Kernteilungen auf. Ber Dtsch Bot Ges 75(10): 393-396.

10. Geitler L (1980) Zellteilung und Bildung von Innenschalen bei *Hantzschia amphioxys* und *Achnanthes coarctata*. Plant Syst and Evol 136(3-4): 275-286.

11. Hostetter HP, Rutherford KD (1976) Polymorphism of the diatom *Pinnularia brebissonii* in culture and a field collection. J Phycol 12(2): 140-146.

12. Saito S (1981) Reduction of cell length in two species of *Synedra* (Bacillariophyceae) in laboratory culture. Soruy. Jap J Phycol 29(3): 197-200.

13. Barbosa LG, Araujo GJM, Barbosa FAR, Bicudo CEM (2014) Morphological variation in *Staurastrum rotula* (Zygnemaphyceae Desmidiales) in the deepest natural Brazilian lake: essence or accident? Braz J Biol 74(2): 371-381.

14. Joint IR, Pipe RK (1984) An electron microscope study of a natural population of picoplankton from the Celtic Sea. Mar Ecol Prog Ser 20: 113-118.

15. Andrews JH (1979) Conclusion: the seaweed pathosystem. Experientia 35(4): 448-450.

16. Kwandras J (1985) Die durch den Säuregehalt des Wassers beding te Strukturdiatomer Algengesellschaften. Wiss Hefte Päd Hochsch 12(1): 27-29.

17. Furey PC, Lowe RL, JohansenJR (2009) Teratology in *Eunotia* taxa in the Great Smoky Mountains National Park and description of *Eunotia macroglossa* sp. Nov. Diatom Research 24(2): 273-290.

18. Booth B, Harrison PJ (1979) Effect of silicate limitation on valve morphology in *Thalassiosira* and *Coscinodiscus* (Bacillariophyta). J Phycol 15 (3): 326-329.

19. Jahnke J (1982) Teratologischen Valvenformen bei der merinen Planktondiatomee *Biddulphia sinensis*. Mikrokosmos 71(6): 174-178.

20. Antoine SE, Benson-Evans K (1983) Morphological variation in *Cocconeis placentula* Ehr. from the river Wye Wales. Nova Hedwigia Z Kryptogamenk 38(1-4): 555-567.

21. Mironov OG (1970) The division of some diatoms in seawater containing oil products. Scientific. Doc. Supreme Schools Biol Science 7: 69-72.

22. Kondratieva NV (1986) Morphological approach to the study of the variability of algal populations of continental reservoirs. Hydrobiol Journal 22(2): 7-13.

23. Kaylee A, Beauchamp B (2010) The Origin and Ecology of Late Paleozoic Palaeoaplysina in Arctic Canada: An Aberrant Ancestral Coralline Algae (?) that Grew at a Time of High Atmospheric CO_2. Geo Canada 2010 – Working with the Earth 1-4.

24. Gerola FM, Grilli-Caiola V, Pellegrini S (1982) Some different aspects of natural populations of *Microcystis aeruginosa*. Ist Int Phycol Congr. Sci Progr and Abstr SL.

25. Schmid AM (1979) Influence of environmental factors on the development of the valve in diatoms. Protoplasma 99(1-2): 99-115.

26. Tuchman M, Theriot E, Stoermer EF (1984) Effect of low level salinity concentrations on the grown of *Cyclotella meneghiniana* Kütz. Arch Protistenkunde 128: 312-326.

27. Sanz-Luque E, Chamizo-Ampudia A, Llamas A, Galvan A, Fernandez E (2015) Understanding nitrate assimilation and its regulation in microalgae. Front Plant Sci 6: 899.

28. Dziengo-Czaja M, Koss J, Matuszak A (2008) Teratological forms of diatoms (Bacillariophyceae) as indicators of water pollution in the western part of Puck Bay (southern Baltic Sea). Oceanological and Hydrobiological Studies 37(2): 119-132.

29. Cantonati M, Lange-Bertalot H (2011) Diatom monitors of close-to-pristine very-low alkalinity habitats: three new Eunotia species from springs in Nature Parks of the south-eastern Alps. J Limnol 70(2): 209-221.

30. Barbour MT, Gerritsen J, Snyder BD, Stribling JB (1999) Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton benthic macroinvertebrates and fish. Environmental Protection Agency, pp: 339.

31. Feldt LE, Störmer EF, Schelske CL (1973) Occurrence of morphologically abnormal Synedra populations in Lake Superior phytoplankton. Proc. 16th Conf. Great Lakes Res. Huron Ohio 1973 Ann. Arbor, pp: 34-39.

32. Watanabe Y, Watanabe MF, Watanabe M (1986) The distribution and relative abundance of bloom forming *Microcystis* species in several eutrophic waters. Jap J Limnol 47(1): 87-93.

33. Boney AD (1981) Mucilage: the ubiquitous algal attribute. Brit Phycol J 16(2): 115-132.

34. Gajiyeva MA, Kovalenko OV, Kislova OA (1978) Effect of Sea Water Supplements on *Microcystis aeruginosa* Kütz. Emend. Elenk. and *M. wesenbergii* Komarek (Cyanophyta) in culture. Ukr. Botanist Journ 35(2): 142-145.

35. John J (1982) Valve structure of *Cymbella sumatrensis* Hust from Northern Australia. Bacillaria 5: 117-126.

36. Germain H (1976) *Pinnularia major* (Kütz.) Cl. *Pinnularia viridis* (Nitzsche) Ehr. et quelques espéces voisines. Bull Soc Bot France 123(3-4): 179-185.

37. Martinez MJ (1973) Caracteristicas teratologicas en *Coscinodiscus bouvet* Karst. en Puerto Paraiso y estrecho Bismark Antarktida. Contrib Inst Antart Argent 1-9.

38. Vishnyakov VS, Timoshkin OA, Izhboldina LA, Volkova EA Zaytseva EP (2012) A taxonomic list of macroalgae in the near-shore zone of Bol'shyeKoty and Listvenichny Bays (Southern Baikal). Izvestia of the Irkutsk State University Series "Biology Ecology" 5(3): 147-159.

39. Medvedeva LA, Barinova SS, Kukharenko LA (1986) Algae of the Rudnaya River Basin (Primorskiy Region). Flora and Systematic of Spore Plants in Far East Vladivostok Russian Academy of Science Far East Branch Press, pp: 36-48.

40. Medvedeva LA, Barinova SS, Kukharenko LA (1986) Sanitary and Biological characteristic of the Rudnaya River Basin. Benthic Organisms in Fresh Waters of Far East Vladivostok Russian Academy of Science Far East Branch Press, pp: 108-115.

41. Barinova SS (1987) On anomalous forms in algae of continental reservoirs of southern Far East. Current Problems of Modern Algology, pp: 26.

42. Barinova SS, Medvedeva LA (1989) Sanitary-biological analysis of modern state of the Rudnaya River. Ecological Problems in Dalnegorsk Region and Possible Solutions (Abstr.). Sci. Appl. Seminar 6-8 December 1989, Dalnegorsk, pp: 22-23.

43. Barinova SS, Medvedeva LA (1992) A long-term assessment of seasonal pollution dynamics in the Rudnaya River Primorskiy Region on the basis of algal diversity. Ecological Regulation. Problems and Methods, Moscow, Inst Nat Cons Press, pp: 10-12.

44. Kukharenko LA, Medvedeva LA, Barinova SS, Batenok IN (1986) Algae. Flora and Vegetation of Bolshekekhzirskiy Reserve (Khabarovsk Region) Vladivostok, Russian Academy of Science Far East Branch Press: 13-29.

45. Arnoldi VM (1925) Introduction and study of lower organisms. Moscow Leningrad Gosizdat.

46. Barinova SS, Medvedeva L, Nevo E (2008) Regional influences on algal biodiversity in two polluted rivers of Eurasia (Rudnaya River Russia and Qishon River Israel) by bio-indication and Canonical Correspondence Analysis (CCA). Applied Ecology and Environmental Research 6(4): 29-55.

47. Gollerbach MM (1951) Algae their structure life and meaning. Moscow MSIP Publishing House.

48. Kondratieva NV (1967) "Explosive" destruction of cells of planktonic species of *Anabaena*. Ukr Botanist Journ 24(3): 66-73.

49. Kondratieva NV, Kovalenko OV (1975) Brief determinant of toxic blue-green algae species. Kiev Naukova Dumka.

50. Klymiuk V, Barinova S (2016) Phytoplankton Cell Size in Saline Lakes. Research Journal of Pharmaceutical Biological and Chemical Sciences 7(1): 1077-1085.

51. Korshikov AA (1953) Identifier of freshwater algae of the Ukrainian SSR. Vol. V. Subclass Protococcineae (Protococcineae). Vacuolales and Protococcals. Publishing house of the Academy of Sciences of the Ukrainian SSR Kiyiv.

52. Barinova SS (1989) Analysis of algoflora in Artemovsk Reservoir (Primorskiy Region). Cryptogamic studies in Far East Vladivostok, Russian Academy of Science Far East Branch Press, pp: 29-44.

53. Barinova SS (1988) Polymorphism of connective structures in diatom algae. Evolutionary Research. Vavilov's Themes Vladivostok, Russian Academy of Science Far East Branch Press, pp: 110-122.

54. Hustedt F (1930) Bacillariophyta (Diatomeae). Jena Gustav Fisher.

55. Simonsen R (1987) Atlas of the Diatom types of Friedrich Hustedt (3). pp: 1741.

56. Barinova S (2017) Influence of Macro-Environmental Climatic Factors on Distribution and Productivity of Freshwater Algae. Int J Environ Sci Nat Res 4(1): 1-5.