Acta Geographica Silesiana, 13. WNoZ UŚ, Sosnowiec 2013
s. 87–92

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HUMAN IMPACT ON THE HARMFUL ALGAE BLOOMS AND ALLELOPATHIC EFFECTS OF CYANOBACTERIA AND MICROALGAE IN THE BALTIC SEA – A REVIEW

Śliwińska S., Parusel T., Latała A. **Wpływ działalności człowieka na masowe zakwity sinic i mikroglonów oraz ich oddziaływanie allelopatyczne w Morzu Bałtyckim – przegląd badań.** Antropogeniczne oddziaływanie na zasoby wodne, prowadzące do zmiany obiegu substancji mineralnych i zwiększonej ich dostawy do odbierających je wód, pociąga za sobą rozległe skutki ekologiczne. Jednym z zasadniczych efektów antropogenicznego dopływu pierwiastków biogennych (zwłaszcza azotu i fosforu) do Morza Bałtyckiego jest nadmierny rozwój fitoplanktonu. Wyniki ostatnich badań wskazują, że dostępność azotu i fosforu może wpływać również na oddziaływania allelopatyczne sinic i mikroglonów. Syntezowane przez te organizmy związki allelopatyczne mogą negatywnie oddziaływać na ryby, skorupiaki, ssaki, a także na organizm człowieka. Określenie wpływu zwiększonej dostępności soli pokarmowych na wskazane aspekty powinno stać się priorytetem przyszłych badań.

Сливиньска С., Парусель Т., Лятала А. **Антропогенное влияние на массовые появления цианобактерий и микроводорослей и их аллелопатическое воздействие в Балтийском море – обзор.** Антропогенное влияние на водные ресурсы, которое приводит к изменению циркуляции минерального вещества и увеличичению его поставки в воду, вызывает большие экологические последствия. Одним из основных результатов антропогенного поступления биогенных элементов (особенно азота и фосфора) в Балтийское море является чрезмерное развитие фитопланктона. Наличие азота и фосфора может также спровоцировать аллелопатические воздействия цианобактерий и микроводорослей. Синтезированные этими организмами аллелопатические соединениа могут негативно повлиять на рыб, моллюсков, млекопитающих и организм человека. Определение влияниа повышенной доступности биогенных солей на указанные аспекты должно стать приоритетом для будущих исследований.

Keywords: allelopathy, Baltic Sea, eutrophication, human impact, nutrients

Abstract

Human impact on water resources leads to the revised circulation and increased mineral substances. These changes involves large ecological consequences. Currently, an eutrophication has become a serious problem in many freshwater and marine habitats, also in the Baltic Sea. Recently, some authors show, that nutrient concentration has an important influence on the allelopathic interactions which cause dominance of various species of cyanobacteria and algae and forming massive blooms. Algal blooms leads to a reduction of water quality and often precludes using of this water. Moreover, secondary metabolites produced by cyanobacteria and algae may affect on the nervous system, respiratory and digestive of crustaceans, fish, marine mammals and people also. Allelopathic interaction is widespread, found in all aquatic ecosystems and occurs among all groups of aquatic primary producers therefore the effect of nutrient availability on the production of secondary metabolites should be a priority for future research.

INTRODUCTION – HUMAN IMPACT ON AQUATIC ECOSYSTEMS

Aquatic habitats are particularly vulnerable to degradation due to their wide using by people. Water consumption, in the broad sense, are often forced to consider the transformation of aquatic environments for economic purposes. The wetlands are often converted into areas suitable for agriculture (FORSBERG, 1991). Adaptation of the environment by people is generally associated with the transformation of the aquatic ecosystem through drainage of land for agricultural purposes and development.

However, anthropogenic impact on water resources leads to the revised circulation and increased mineral substances. These changes involves widespread ecological consequences (FORSBERG, 1991).

The excessive growth of phytoplankton is the one of the main effects of anthropogenic inflow of biogenic elements to aquatic ecosystems, especially nitrogen and phosphorus. Anthropogenic source of these substances in the aquatic environment are primarily drain waste water treatment, industrial, and leaching of fertilizers from agricultural fields (RZYMSKI, 2009). These compounds cause rapid increase of the water fertility referred to an eutrophication (LAMPERT, SOMMER, 1996). An eutrophication is natural process, but in unaffected conditions it courses very slowly. An eutrophication in normal circumstances would take thousands of years. However, human activity has accelerated this process (anthropogenic eutrophication) and has become a global problem in many aquatic habitats, including the Baltic Sea (FORSBERG, 1991).

THE EFFECTS OF EUTROPHICATION IN THE BALTIC SEA

The most well known effect of eutrophication is algal bloom. Bloom is called the mass development of phytoplankton in water bodies often causes a visible change of water colour (BEDNARZ et al., 2002). Bloom is characterized by low stability and heterogeneity of systematic, biological and physiological properties (REYNOLDS, 1984; BURCHARDT, 1987; PAWLIK-SKOWROŃSKA et al., 2004). Usually the most spectacular and even dangerous blooms is caused by cyanobacteria and dinoflagellata but in different seasons also can occur blooms of *Chlorophyceae*, *Bacillariophyceae*, *Cryptophyceae*, *Dinophyceae* and *Chrysophyceae* (BURCHARDT, PAWLIK-SKOWROŃSKA, 2005).

Intense algal blooms were recorded in the open waters of the Baltic Sea (fig. 1) since the middle of the 20th century. The study of the final years of this century and the beginning of the 21st century showed mass occurrence of cyanobacteria *Nodularia spumigena* and *Aphanizomenon flos-aquae*. The occurrence of these blooms was explained by the effect of nutrient supply from rivers and coastal waters. Contemporary, the same species of algae blooms cause spreading over wide areas of the Baltic Sea, as shown by satellite observations (FORSBERG, 1991). In summer 1991, in the open waters of the Baltic Sea and along the southern and south-eastern coast of Sweden, there was a very intense blooms of *N. spumigena*. Mortality of land animals caused by *Nodularia* blooms were recorded in Denmark, Gotland and the southern and south-east coast of Sweden (fig. 1). In the 1980 number of strong blooms of toxic genera of *Prorocentrum*, *Prymnesium* and *Chrysochromulina* was found in the Kattegat Strait and the other more saline parts of the Baltic Sea. The most known *Chrysochromulina* bloom occurred in 1988 along the coasts of Denmark and Sweden and came to Bergen in Norway (fig. 1). Algae blooms are recorded in many different places in the Baltic Sea. It is obvious that these blooms were caused by an increase of nutrients in water. We can therefore anticipate that strong blooms will appear to continue, and many of them will be harmful in natural aquatic environment (FORSBERG, 1991).

Fig. 1. The Baltic Sea
Rys. 1. Morze Bałtyckie

THE IMPACT OF CYANOBACTERIA AND MICROALGAE BLOOMS

Curently, much attention is given to phytoplankton blooms in the seas and oceans around the world (SMAYDA, SHIMIZU, 1993; BURCHARDT, PAWLIK-SKOWROŃSKA, 2005). The massive and uncontrolled growth of phytoplankton leads to drastic reduction of water quality and often precludes its using. The production of toxic substances and filter clogging by intensively growing phytoplankton causes problems in resources drinking water management (KAWECKA, ELORANTA, 1994; KABZIŃSKI, GRABOWSKA, 2003). In shallow reservoirs, decomposing algae can cause weight loss in oxygen and therefore death of small invertebrates and fish. Abundantly growing filamentous algae clogs the fishing nets and it is difficulty in fishing (GRABOWSKA, 2008).

Secondary metabolites produced by phytoplankton may affect on the nervous system, respiratory and digestive of crustaceans fish and marine mammals (GRABOWSKA, 2008). There are dangerous to human health also. The most common poisoning occurs by consumption of contaminated water or aquatic organisms, such as crustaceans, molluscs, fish and seaweed, which accumulate in their tissues harmful substances. Contact with toxins may also be made through the skin while swimming in the waters during the bloom of cyanobacteria and algae (RZYMSKI, 2009).

ALLELOPATHIC INTERACTIONS OF CYANOBACTERIA AND MICROALGAE

It is commonly believed that the allelopathic effects are part of the competition in the terrestrial environment, but this process in aquatic ecosystems is inadequately understood. Allelopathy includes both a stimulating and inhibiting effect on the growth and physiological functions of a target by produced and released secondary metabolites by donor organisms. Allelopathic interaction is widespread, found in all aquatic ecosystems and occurs among all groups of aquatic primary producers (GROSS, 2003). However, allelopathic interactions between photoautotrophs are still relatively poorly studied in the aquatic environment due to methodological difficulties. Production of reactive organic compounds is an adaptation, by which some species of phytoplankton can achieve a competitive advantage over other primary producers (LEGRAND et al., 2003). In addition, available studies indicate that the Baltic cyanobacteria may be allelopathic to other species of microalgae, and this effect is dependent not only on the selected species, but even a strain of cyanobacteria (ŚLIWIŃSKA et al., 2011). Allelopathy can be one of the key factors that cause seasonal variation, and the dominance of various freshwater and marine species, forming massive blooms in many waters, including the Baltic Sea (GROSS, 2003).

An allelopathic interactions in aquatic ecosystems may affect in various ways by a great number of environmental factors. Unfortunately, influence of abiotic and biotic factors, such as light, temperature, UV radiation and pH-reaction on the production and release of allelopathic compounds is relatively poorly recognized Many studies were focused only on the interaction between the organisms. However, some author showed that nutrient concentration has an important influence on the allelopathic interactions (GRANÉLI, JOHANSSON, 2003a, 2003b; LIU et al., 2006; ŚLIWIŃSKA et al. this issue; fig. 2). Moreover, several studies have indicated, that both the history of environmental and physiological status of plant cells, microorganisms can affect the impact of allelopathic interaction (GROSS, 2003). The mechanism and mode of action of allelopathic compounds also not been carefully examined, but it is believed that they may affect the inhibition of growth and physiological functions and cause lysis of the target cells. To assess the ecological importance of the phenomenon of allelopathy, the need for detailed studies of environmental factors such as availability of nutrients that affect the production and secretion of active allelopathic compounds by cyanobacteria and microalgae (SMITH, DOAN, 1999; GROSS, 2003).

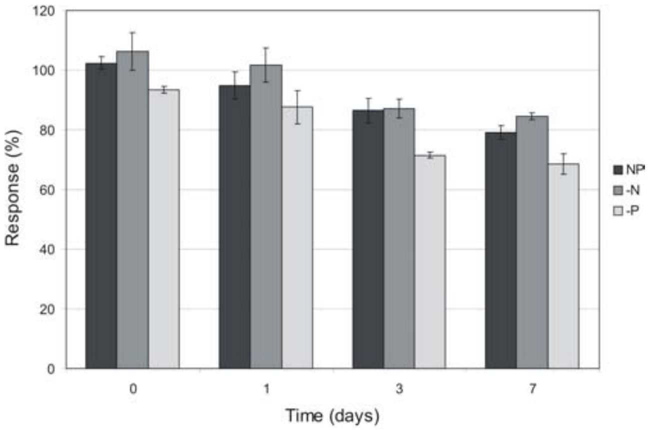

Fig. 2. Cell-free filtrate of *Synechococcus* sp. growing in nutrient-sufficient (NP), nitrogen-deficient (-N) or phosphorus-deficient (-P) culture medium was added to a culture of *C. vulgaris* growing in nutrient-sufficient culture medium. The effect is shown as response (%) of *C. vulgaris* cells compared to the controls after 0, 1, 3 and 7 days of exposure (means ±S.D., n=3)

Rys. 2. Odpowiedź (%) komórek *C. vulgaris* uzyskana dla kontroli i w doświadczeniach z dodaniem przesączu uzyskanym z kultur *Synechococcus* sp. hodowanych na pożywce mineralnej zawierającej nadwyżkę soli odżywczych (NP), niedobór azotanów (-N) oraz niedobór fosforanów (-P) po 0, 1, 3 i 7 dniach ekspozycji (wartości średnie ±SD przy n=3 powtórzeniach)

THE INFLUENCE OF EUTROPHICATION ON AN ALLELOPATHY OF CYANOBACTERIA AND MICROALGAE

There is some evidence that the availability of nutrients can have a major influence on cyanobacterial and microalgal allelopathic activity (GRANÉLI, JOHANSSON, 2003a, 2003b; FISTAROL et al., 2005). In aquatic habitats the availability of nitrogen (N) and phosphorus (P) is rarely in Redfield ratio (optimal balanced ratio N:P=16:1). Its results in nutrient limited growth of phytoplankton species coexisting at the same time and space (GRANÉLI et al., 2008). Therefore the nutrient that is in the lowest concentration in relation to the species need will limit their growth. Thus, the ability to compete for the limiting nutrient is important for the spread of a specific species of cyanobacteria and microalgae (GRANÉLI et al., 2008). However, some authors show that production of allelochemicals increased by stress factors, such as N and P at unbalanced ratios (RENGEFORS, LEGRAND, 2001; GRANÉLI, JOHANSSON, 2003a, 2003b; TILLMANN, 2003; GRANÉLI, HANSEN, 2006; fig. 3). E. VON ELERT and F. JÜTTNER (1997) report that under phosphorus-limited conditions the release of allelopathic compounds by *Trichormus doliolum* increases 30-fold compare to the control. M. SHILO (1971) reported an increase in the intracellular concentration and release of antimicrobial components by *Prymnesium parvum* under the influence of phosphorus deficiency. A similar effect has also been clearly identified in this study (fig. 2). The release of biologically active compounds under the influence of nutrient deficiency was also observed in *Nostoc muscorum* and *Scytonema* sp. (GRANÉLI et al., 2008). Further investigations of the ecological significance of allelochemicals released by cyanobacteria and microalgae, among other species, due to altered nutrient conditions, are needed (GRANÉLI et al., 2008).

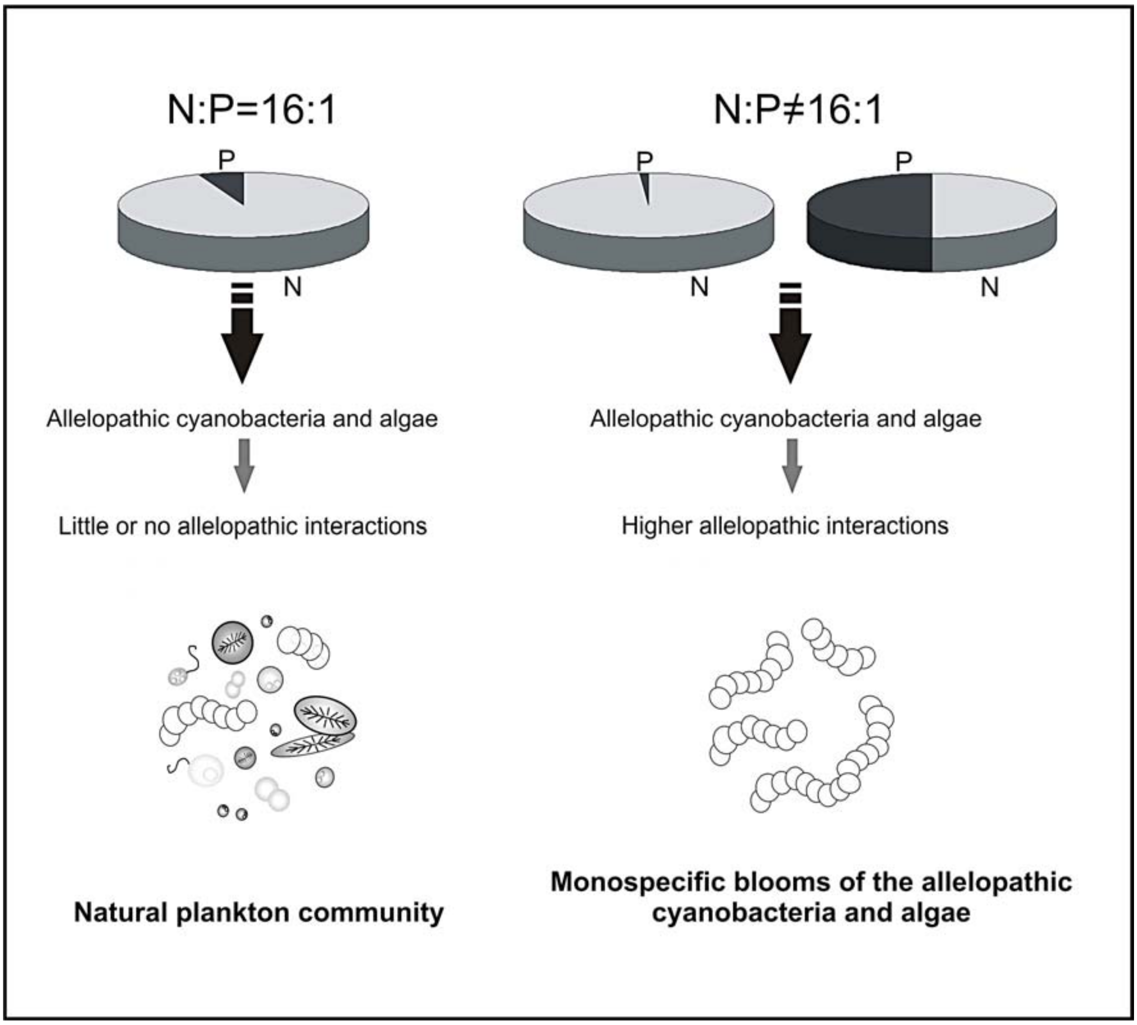

Fig. 3. Possible scenarios showing how eutrophication can affect the natural phytoplankton community: when availability of N and P in aquatic ecosystem are relatively balanced (N:P=16:1) and availability of N and P are disturbed (from: GRANÉLI et al., 2008)

Rys. 3. Możliwy wpływ eutrofizacji na oddziaływanie allelopatyczne sinic i mikroglonów: kiedy zawartość N i P w środowisku wodnym jest zbalansowana (N:P=16:1) oraz w sytuacji, kiedy równowaga pomiędzy tymi pierwiastkami zostanie zakłócona (za: GRANÉLI et al., 2008)

CONCLUSION

The strong human activity have a decisive influence on Baltic Sea natural aquatic habitat since the hundred years. Human impact in the aquatic environment are mainly related to the increase of mineral substances in water. Therefore, we can sign that nutrient enrichment caused by the increase of eutrophication is an important factor supporting many blooms of allelopathic algae by altering the N:P balance. To predict the presence of blooms we need more study of the impact of selected environmental factors, which may affect the production and secretion of active allelopathic compounds by phytoplankton. Providing information on the effect of many factors, such as an availability of nutrients, on the occurrence of allelopathic effects of microalgae and cyanobacteria may have an important role in the meaning of the appearance of massive blooms in the Baltic Sea, especially in the summer period.

Acknowledgements
This study was partly supported by Ministry of Science and Higher Education (MNiSW) grant, Poland, no. 2952/B/P01/2011/40 and no. N R14 0071 06. One of authors, T. Parusel, is a scholarship holder of the Project „UPGOW – Uniwersytet Partnerem Gospodarki Opartej na Wiedzy" („UPGOW – University is the Partner of Knowledge-Based Economy"). The Project is co-financed by the European Union within the European Social Fund – Human Capital Operational Programme, priority IV, task no 55, item no 483.

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