The effect of eutrophication on human health on the example of the Gulf of Taganrog of the Sea of Azov

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Abstract. Eutrophication of water bodies has a negative impact on human health, contributing to the spread of the gastrointestinal and dermatological diseases, conjunctivitis. The increase of the anthropogenic load leads to the increase of the eutrophication level and, consequently, the increase in morbidity. The article discusses in detail the eutrophication of the Gulf of Taganrog of the Sea of Azov. The conclusions made in the work relate to the direct relationship between the degree of eutrophication of the reservoir, water temperature, salinity and the spread of gastrointestinal diseases.

1. Introduction
Eutrophication of natural water bodies is understood as the process of growth of the overall productivity of the ecosystem of the water body, including water masses, bottom sediments, organisms inhabiting them and the relations between them.

Eutrophication of waters is a peculiar phenomenon of the ecosystem, which is achieved by enrichment with nutrients, which, as a rule, stimulates the growth and flowering of algae, and this, in turn, leads to a deterioration in the quality and condition of natural waters. In recent decades, this has become a global environmental problem [1-5].

Often, the problem of waters eutrophication is considered only from the point of view of deterioration of water quality in a water body. However, the eutrophication of water bodies has a negative effect on human health, contributing to the spread of gastrointestinal and dermatological diseases.

The aim of the work is to study the effect of water eutrophication on human health using the example of the Gulf of Taganrog of the Sea of Azov.

The object of this study is the Gulf of Taganrog (figure 1), which is located in the northeastern part of the Sea of Azov and is its largest and most isolated gulf. The Gulf of Taganrog is separated from the sea by two spits. The length of the gulf is about 140 km; the width at the entrance is 31 km. The Gulf of Taganrog is shallower than the Sea of Azov and has a very smooth bottom relief. Its average depth is 4.9 m; the water volume is 25 km³. The Gulf of Taganrog has an area of 5600 km². The average annual water temperature is 8.5-11.5 °C [6].

It is important to notice that the Gulf of Taganrog is a natural extension of the Don delta, thus the drainage of the Don River plays a very large role in the formation of the hydrological indexes of the water area. In particular, the introduced fresh water has a strong influence on the salinity of the Gulf of Taganrog, causing its freshening.
The characteristic feature of the Sea of Azov, caused by climatic factors, is the high variability of the elements of the water balance and the components of the chemical runoff, which determines the significant variability of the balance of nutrients [7], and, consequently, the high degree of eutrophication of water in the warm season.

All this leads to the deterioration of the microbiological situation in the Gulf and to the increase in the disease of people with various intestinal infections.

Figure 1. The Gulf of Taganrog the Sea of Azov on the map of Europe.

2. Materials and methods

The study of the waters of the Gulf of Taganrog of the Sea of Azov included the following stages:

- Review and analysis of literature data on the negative impact of eutrophication on human health.
- Review and analysis of literature data on the hydrodynamics of a water body, temperature conditions, salinity and biogenic matter.
- Analysis of the spread of gastrointestinal and dermatological diseases in the Gulf of Taganrog.
- Collection and analysis of a database of temperature, salinity and biogenic matter.
- A comprehensive mathematical analysis of changes in the eutrophic index of the waters of the Gulf of Taganrog of the Sea of Azov.
- Analysis of the effect of eutrophication on human health.

In this way, for the first time the waters eutrophic index was calculated to the Gulf of Taganrog of the Sea of Azov [8-10]. The measurements were carried out during the vegetation period (from the beginning of April to the end of October) in 20 sampling sites (figure 1) according to the government-approved methods.

The mathematical model [9] constructing process of the Gulf of Taganrog eutrophic index change included the following typical stages: the modeling goals formulation; the gulf ecosystem qualitative
analysis, based on the formulated goals; the formulation of laws and plausible hypotheses regarding the ecosystem structure and its behavior mechanisms in general; the model identification (its parameters determination); the model verification (its operability verification and the adequacy assessment of the real ecosystem); the model study (its solutions stability analysis, sensitivity to parameters changes, etc.).

The analysis of the effect of eutrophication on human health was carried out using data from the Center for Hygiene and Epidemiology in the Rostov Region [11]. To obtain an objective assessment of the state of the coastal waters of the Gulf of Taganrog of the Sea of Azov, a systematic weekly laboratory monitoring of sea water samples was carried out according to microbiological indicators during the epidemiological season (from April to September).

In particular, the results of studies of bacterial contamination of coastal waters of the four most visited beaches of Taganrog city were analyzed.

Studies were carried out to establish the content of bacteria of the group of Escherichia coli, halophilic vibrios, sulfite-reducing clostridia of isotopic staphylococcus in the waters of the Gulf of Taganrog.

In addition, an extensive database for the period from 2002 to 2015 was used for the study, including the results of analyzes of samples of sea and wastewater to determine the temperature of water, salinity, nitrate, ammonium ion and phosphate concentrations obtained during the vegetation period. In total, more than 2700 test results were summarized, 735 original determinations of the content of biological, hydrological and hydro chemical indicators were carried out.

Accordingly, the uniqueness of the collected database is determined by:

- the unified sampling methods and its analysis;
- the wide coverage of sampling points on a water body (Figure 1);
- the optimized intra- and interannual sampling periods needed to assess the temporal variability of the state of the aquatic ecosystem;
- the wide range of indicators defined in the analysis of surface waters.

3. Results

Based on the database of the long-term averages during the vegetation period of in the Gulf of Taganrog northeastern part, the regression equation was obtained:

\[
T = 6.294 + 0.104(S) + 0.114(t) - 1.06(NH_4) + 0.021(NO_3) - 0.929(PO_4),
\]

where \(T\) – waters eutrophic index;
\(S\) – salinity, 
\(t\) – water temperature, \(^\circ\)C;
\(NH_4\) – ammonium concentration, mg/dm\(^3\);
\(NO_3\) – nitrate concentration, mg/dm\(^3\);
\(PO_4\) – phosphate concentration, mg/dm\(^3\).

A sample of data for a 14-year period from 2002 to 2015, including the average for the vegetative period values of the water temperature, the salinity, the ammonium, nitrate, nitrite and phosphate concentrations and, was used to construct the regression equation of the eutrophic index of the Gulf of Taganrog.

The estimated eutrophic index is compared with its constant numerical values for various environmental conditions of the water body [12]:

- \(T < 5.7\) - dystrophic water body;
- \(5.7 < T < 7.0\) - ultra-oligotrophic water body;
- \(T = 7.0\) - oligotrophic water body;
- \(7.0 < T < 8.3\) - mesotrophic water body;
- \(T > 8.3\) - eutrophic water body.

Table 1 shows the average values of the eutrophic index (EI) during the research period.
As a result, the Gulf of Taganrog of the Sea of Azov belongs to the water body of the mesotrophic type, which becomes to the eutrophic one. The lowest average eutrophic index during the vegetation period was observed in 2008, the highest one in 2011.

The increase in the number of Escherichia coli in waters of the reservoir is often associated with the increase of temperature and salinity in the summer period. Data on changes in waters salinity and temperature in the studied period are known from our database [11]. So the range of changes in salinity was 0.4-8.2 ‰, temperature 11-26 °C.

Table 1. Average values of the eutrophic index (EI) in the Gulf of Taganrog of the Sea of Azov.

| Year | EI   | S,‰ | T, °C |
|------|------|------|-------|
| 2002 | 8.17 | 1.1  | 19.6  |
| 2003 | 8.21 | 1.0  | 17.2  |
| 2004 | 8.17 | 1.3  | 17.1  |
| 2005 | 8.15 | 1.5  | 16.8  |
| 2006 | 8.16 | 0.8  | 17.7  |
| 2007 | 8.31 | 1.4  | 20.3  |
| 2008 | 7.89 | 1.5  | 15.1  |
| 2009 | 8.32 | 1.6  | 16.9  |
| 2010 | 8.56 | 1.6  | 22.2  |
| 2011 | 8.66 | 2.1  | 19.2  |
| 2012 | 8.58 | 1.7  | 17.2  |
| 2013 | 8.60 | 1.9  | 17.8  |
| 2014 | 8.16 | 3.8  | 18.1  |
| 2015 | 8.24 | 5.0  | 15.8  |

Taking into account the fact that the upper boundaries of these indicators are quite high, and at the same time, they are the main predictors for determining the waters eutrophication level, as well as the eutrophic index of the waters of the Gulf of Taganrog also remained at a fairly high level of 8.0-8.4 during this period, we can to conclude that the effect of eutrophication of waters on the development of pathogens of intestinal infections, and, consequently, human health, is confirmed.

To obtain the most objective assessment of the state of the coastal waters of the Gulf of Taganrog of the Sea of Azov, the Center for Hygiene and Epidemiology in the Rostov Region carried out a systematic laboratory monitoring of sea water samples on a microbiological basis during the epidemic season (from April to September) [11].

In particular, the results of studies of bacterial pollution of the coastal waters of the four most visited urban beaches for 2011-2014 were analyzed. During the four analyzed years, the microbiological laboratory [11] studied 443 samples of the seawaters.

The analysis of the results of the sanitary-microbiological study of the coastal seawaters showed a high level of its bacterial pollution. For example, in 2013-2014 the number of non-standard samples for the General Coliform Bacteria (Enterobacteriacea) and E. coli samples was 93.6% and 65.5%, respectively. In 2011-2012, the situation was more negative and the number of non-standard samples for the General Coliform Bacteria and Thermo-tolerant Coliform bacteria was 97.6% and 100%, respectively.

The highest number of non-standard samples was observed in summer months. Moreover, samples taken in the spring period almost completely corresponded to the standard ones.

It should be noted that in summer months according to two standardized indicators (the General Coliform Bacteria and Thermo-tolerant Coliform), 75-95% of all samples was non-standard. The summary results for the entire vegetation period are presented in table 2.

Table 2. The proportion of unsatisfying water samples by microbiological indicators
In consequence, the monitoring data showed:

- The bacterial pollution of the coastal waters of the Gulf of Taganrog of the Sea of Azov in 2011-2014 remained at a high level (from 65.5% to 100%), especially in the summer months.
- In the spring period, all samples almost completely corresponded to the standard ones, which is explained by the low temperature of the environment and seawaters, low eutrophic index at the beginning of the vegetation period.
- The maximum bacterial pollution of the coastal waters of the Gulf of Taganrog of the Sea of Azov was observed in July-August. It is connected with the increase in water temperatures, salinity and eutrophic index to the highest values during this period, as well as the active use of beaches by the population.
- The increase in the bacterial pollution of the coastal waters of the Gulf of Taganrog is directly proportional to the increase in water temperature and eutrophic index during the vegetation period.

4. Discussion

There are direct and indirect effects of eutrophication on the state and health of a person. Indirect exposure is realized through the pollutants that are accumulated in the eutrophied reservoir, the surface micro layer, which concentrates surfactants, and the increases of the toxicity of some substances in the eutrophied reservoirs. Drinking water from a eutrophic reservoir can cause a person to have a strong gastrointestinal upset. Gastrointestinal diseases arise because of the toxic effects on the body of secretions of blue-green algae contained in water. Besides, in cases of poisoning, fatalities were noted. Indirect exposure is also observed during the passage of the toxic substances through a number of trophic links: when eating meat of predatory fish from the eutrophic reservoirs, cases of gastrointestinal diseases were recorded.

A direct effect on a person is observed after the contact with the eutrophied water or its evaporations. If a person runs the risk of swimming in a "flowering" water body, some dermatological lesions may appear on his skin, which in some cases can lead to non-healing ulcers. Because of inhalation of evaporations from a eutrophic reservoir, there are cases of rhinitis, allergic bronchitis, and bronchial asthma that may develop. Allergic rashes may appear on the skin of exposed areas of the body - face, hands, and microscopic fungi that cause infectious diseases and severe skin lesions can get into the wounds [13-14].

It is important to note that often cholera outbreaks also occur during the “flowering” period, that is, to the period of the highest eutrophic indexes in recent years.

Accordingly, the following conclusions were made:

1. The Gulf of Taganrog of the Sea of Azov belongs to the water body of the mesotrophic type, turning into eutrophic, which indicates its high degree of eutrophication. Moreover, the upper limits of temperature and salinity are also high.
2. The maximum bacterial pollution of the coastal waters of the Gulf of Taganrog of the Sea of Azov were observed in July-August. The maximum values of the eutrophic index were also observed in during period, which is associated with the increase in water temperature. Thus, the correlation between the growth of the intestinal infections of people and the eutrophication of the water area is displayed.
3. The active use of beaches by the population during the summer period also has a significant impact on this process.
4. Moreover, before the start of the beach season, up to 85% of the samples of the seawater corresponds to the normative indicators, which is explained by the low water temperature and low eutrophic index during this period.

5. There is a direct correlation between the level of eutrophication of the reservoir, water temperature, salinity and the spread of gastrointestinal diseases.

The conclusions made in the work relate to the need for a comprehensive implementation of measures to decrease the eutrophication processes, taking into account a detailed study of the fundamental possibility of combining different ways of the eutrophication decrease.

References

[1] Arhonditsis G, Eleftheriadou M, Karydis M, Tsirtsis G 2003 Eutrophication risk assessment in coastal embayments using simple statistical models Marine Pollution Bulletin 46 1174-8
[2] Carlson R E 1977 A trophic state index for lakes Limnology and Oceanography 22 361-9
[3] Chapelle A, Lazure P, Menesguen A 1994 Modelling eutrophication events in a coastal ecosystem. Sensitivity analysis Estuarine, Coastal and Shelf Science 39(6) 529-48
[4] Estrada V, Parodi E R, Diaz M S 2009 Determination of biogeochemical parameters in eutrophication models with simultaneous dynamic optimization approaches Computers and Chemical Engineering 33(10) 1760-9
[5] Nobre A M, Ferreira J G, Newton A, Simas T, Icely J D, Neves R Management of coastal eutrophication: Integration of field data, ecosystem-scale simulations and screening models Journal of Marine Systems 56(3-4) 375-90
[6] Kosolapov A E, Dandara N T Bespalov L A Ivlieva O V 2012 The Taganrog Gulf of the Sea of Azov: Current state and problems of nature management (Rostov-on-Don: Southern Federal University) 556
[7] Averictev V G et al 2002 Ecosystem studies of the Sea of Azov and the coast (Kola Science Center RAS) 447
[8] Zhidkova A Y, Gusakova N V 2017 Assessment of the internal nutrient load on the waters of the Gulf of Taganrog of the Sea of Azov from the position of the eutrophication Russian journal of resources, conservation and recycling 4(4)
[9] Zhidkova A Y, Petrov V V, Gusakova N V 2018 The Research of Waters Eutrophication of the Gulf of Taganrog of the Sea of Azov For Ecological Monitoring Purposes Exploration and Monitoring of the Shelf Underwater Environment (Wiley-Scrivener) 318
[10] Guseva A Yu, Gusakova N V 2017 Assessment of the total load on the water area of the Taganrog Bay Natural and technical sciences 11 148-53
[11] Morozova M A 2019 Proceedings of the conference Environmental Management Conflict: Role in the Evolution of the Noosphere 62-7
[12] Tsvetkova L I et al. 2001 Ecology: Textbook for technical universities (Moscow: ACV) 552
[13] Kuznetsova M A, Subbotina Yu M 2010 Microbiological self-cleaning of water bodies Anthropogenic impact on ecosystems of various levels 142-50
[14] Kasparov A A, Sanotsky I V 1986 Toxicometry of polluting chemical (Moscow) 426