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Benthic foraminifera as indicators of pollution in the north-western shallow part of the Black Sea

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Population growth and the resultant acceleration of domestic, municipal, industrial, agricultural and recreational activity are the primary causes of anthropogenic pollution of the marine realm. The marine environment, as the ultimate destination of virtually all terrestrial runoff, is especially affected by pollution, and the shallow nearshore marine environment is particularly subject to frequent and extensive industrial and municipal pollution. Marine protozoa, especially Foraminifera, play a significant role in global biogeochemical cycles of inorganic and organic compounds, making them one of the most important animal groups on earth

The main goal of this study is to investigate the response of benthic foraminifera to anthropogenic pollution on the north-western shallow part of the Black Sea, e.g., Danube delta, Dniester mouth, Dnieper-Bugsky liman, and Odessa Bay. The main objectives include: (1) analysis of recent sedimentary and geochemical system, (2) study of foraminiferal assemblages and identification of species-indicators of pollution, (3) determination of toxic effects of pollution on taxonomy of foraminifera, and (3) discovery of influence of toxic substances on morphology and mineralogical content of foraminiferal shells

Live foraminifera are represented by 33 species from 19 genera and 10 families. The number of species is smaller compared to other areas of the basin (55 species). The highest number of species has *Elphidiidae* (8 species) and *Ammoniidae* (4 species). Agglutinated foraminifera are represented by rare *Ammobaculites ponticus* and *Discammina imperspica*.

The number of species (simple diversity), specimens (abundance) as well as morphological deformities, stunting and pyritization of foraminifera are among the most sen-

sitive environmental indicators. The simple diversity and abundance decreases with increase of pollution. The concentration of deformed tests increases with decrease of salinity and increase of pollution. The number of pyritized tests increases in oxygen depleted environments.

Nine types of morphological abnormalities are discovered: (1) irregular chamber shape, (2) stunting of the tests, (3) undeveloped chambers, (4) irregular coiling, (4) additional chambers, (5) lack of sculpture, (6) protuberances, (7) multiple apertures, (8) irregular keel, and (9) twinning. The presence of deformed tests is typical for stressed/polluted environment.

Morphological deformities can be explained by the damage of biomineralization system. The calcareous tests are formed by mineralization of organic matrix by $CaCO_3$. In the process of test mineralization, the matrix most probably captures various chemical elements (e.g. heavy metals Cd, Hg, Pb) from the interstitial waters. These elements block the active centres of biomineralization. They also change the normal process of matrix biomineralization. As a result, the size of crystallites and direction of their growth change causing morphological deformities of foraminiferal test. Mineralogical analysis with the use of diffractometer DRON-3 shows that carbonate constituent of normal foraminiferal tests is dominated by stoichiometric calcite. On diffractometrical diagrams the non-deformed tests have lower reflex (0.3031-0.3036 nm) than deformed ones (0.3337-0.3348 nm). The latter is typical for quartz, which was captured by matrix during the process of biomineralization. This damaged biomineralogical function of the cytoplasm and disorganized the process of biomineralization. The more mechanical particles are present in mineral substance, the more intense are morphological deformities. Important, genetically programmed mechanism of calcite formation seems not to be disturbed.

A high percentage of live and dead foraminifera have iron sulphides in their tests. The iron sulphides are represented by fromboidal aggregates of pyrite and greigite. The main reason for sulphidization of foraminiferal tests is not clear. It can be related to metabolising of organic matter under anaerobic conditions by sulphate-reducing bacteria, diffusion of sulphate into sediments, concentration and reactivity of the iron minerals and production of elementary sulphur.

Our study shows that benthic foraminifera are powerful indicators of marine pollution.

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