# Benthic foraminifera as indicators of pollution in the north-western 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 (Yanko et al., 1999). Such pollution produces numerous obvious biological effects, including diseases in plant and animal species, local or complete extinction of some species, changes in community structure, and loss or modification of habitat, as well as human health complications. 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

Barely forty years have passed since Zalesny discovered the effects of pollution on foraminiferal distribution in Santa Monica Bay, California. In the forty years since Zalesny's contribution, foraminiferal ecotoxicology saw very slow growth until 1991 when the first systematic studies were undertaken with the primary objective of understanding foraminiferal response to marine pollution.

The main goal of present study is to investigate the response of benthic foraminifera to anthropogenic pollution on the north-western shelf 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 (e.g., heavy metals) on morphology and mineralogical content of foraminiferal shells

Live foraminifera in studied area 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 specimens of *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 sensitive environmental indicators. The simple diversity and abundance of foraminifera 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. If live foraminifera constitute <70% of total (live + dead) population the environment is considered as rather healthy. A decrease in number of live specimen to 50% indicates sublethal conditions. Further decrease (up to 30%) indicates lethal (critical), and below 30% - catastrophic conditions. The latter was discovered in port Ilichevskii. Dangerous environmental conditions were present in underwater exit of the sewage pipeline. Sublethal conditions were found offshore of Lanzheron beach and port Yuzhnii.

Nine types of morphological abnormalities have been discovered in polluted environment: (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 environment (Kravchuk, 2004).

Morphological deformities occur due to the damage of biomineralization system of foraminifera. The calcareous tests are formed by mineralization of organic matrix by $CaCO_3$. In the process of test mineralization, the matrix may capture various chemical elements (e.g. heavy metals Cd, Hg, Pb) from the interstitial waters which block the active centers of biomineralization and change the normal process of matrix biomineralization. This provides the changes in the size of crystallites and direction of their growth leading to morphological deformities. Mineralogical analysis of foraminiferal tests performed by 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 sulfides in their tests. The iron sulfides in the foraminiferal tests 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 metabolizing of organic matter under anaerobic conditions by sulfate-reducing bacteria, diffusion of sulfate into sediments, concentration and reactivity of the iron minerals and production of elementary sulphur.

Thus, benthic foraminifera are reliable indicators of anthropogenic pollution. They can be also used as reliable indicator of paleosterssed environments. For example, a high concentration of sulphidized, deformed and stunted foraminiferal tests on the Late Pleistocene-Holocene interface indicating transformation of brackish aerobic Late Glacial Neoeuxinian lake into semi-marine Holocene Black Sea.

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