Nanosafety as a new direction of transboundary biomonitoring

V.A. Zolotarev[1]

(1) Russian Academy of Sciences, Institute for Biology of Inland Waters, Borok, 152742, Yaroslavl region, Russian Federation, email: forest753@gmail.com

1. INTRODUCTION

The recent advances in nanotechnology and the corresponding increase in the use of nanomaterials in products in every sector of society have resulted in uncertainties regarding environmental impacts. The detection of nanoparticles in virtually all water domains, including the oceans, surface waters, groundwater, atmospheric water, and even treated drinking water, demonstrates a distribution near ubiquity. The novel and potentially reactive characteristics of nanomaterials have lead to predictions on potential undesirable ramifications of exposure to these materials on human health.

The effect of these nanomaterials on microbes is an important consideration due to the role of microbes as the basis of food webs and the primary agents for global biogeochemical cycles. Bacteria are the dominant organisms in aquifers, and their occurrence and activity is related to the biogeochemical conditions, there is often a complex relation between water quality and microbial communities (Lehman, 2007). The long-term monitoring of autochthonous endokarst microbial communities during years or decades may be an interesting approach to assess the general water quality and to detect potential changes in ecosystem functioning due to chronic low level contamination or climate change (Pronk et al., 2009).

Microorganisms should be used in biomonitoring for several compelling reasons. (1) A cosmopolitan distribution facilitates comparisons of test results in geographically different regions. (2) Problems of scale are diminished. (3) Replicability is as good as, or better than, tests with larger organisms. (4) Environmental realism is higher than in tests using larger organisms... (6) Testing with microorganisms is less likely to antagonize animal rights activists (Cairns, 2005). Microscale testing methods and the earliest pollution prevention are the most cost-effective (Wells et al., 1998).

The goal of our investigation was to develop the background for microscale integrated information systems related to subterranean water quality.

The main objectives are: to find some indicator groups of ubiquitous microbial organisms suitable for multispecies toxicity testing and global integrated ecological standards for assessing water quality.

Other objectives are: assessment of toxicity and risk of NanoParticles and nanomaterials to humans and the environment, modelling and data management: including the creation and implementation of a common database in cooperation with the PCCP, EU NanoSafety Cluster and other UNESCO Programmes.

2. RESULTS AND DISCUSSION

New methods based on periphyton communities using polyurethane foam units (PFU) as artificial substrates, was included into the monitoring system of China and Korea (Shen et al., 1994; Jiang et al., 2007).

By far, the most commonly used artificial substrate has been 2.5 - 7.5 cm glass slides, which have the advantage that they can be used to detect the more fragile attached protozoans in vital microperiphyton communities, while the PFU method measures fewer attached species, because direct counting under the light microscope impossible inside the PF units (Bamforth, 1982; Duplakov, 1933; Ertl, 1970).

We have found more than 100 species of heterotrophic flagellates and more than 50 species of ciliates and sarcodines inhabiting the glass slides in different water-bodies (Zolotarev, 1985, 1988, 2007). The most widely distributed species at the initial stages of colonization of glass slides (pioneer species) were the attached colonial choanoflagellates. By undulating their flagella, choanoflagellates generate

local water currents to propel themselves through their aquatic environments and to collect bacteria and nanoparticles on the walls of their collars.
The feeding strategies of the protozoa were used to assign species to functional, trophic groups. The chief functional role of substrate-associated protozoans appears to be the processing of dead organic matter and its associated bacterial flora.
We have found three main functional groups of flagellates inhabiting glass slides:
- unicellular attached choanoflagellates, feeding by filtration, dominant in oligotrophic waters,
- colonial attached choanoflagellates, dominant in mesotrophic waters,
- vagile bodonids and euglenids, feeding by active hunting, dominant in polluted waters.

A new index of periphyton flagellates (IPF) as an indicator of the trophic status of a water-body was developed:
IPF = Sa/Sv
where Sa is the number of attached species, Sv is the number of vagile flagellate species. The index takes the greatest value in oligotrophic waters (1.0 - 3.0), decreasing in mesotrophic waters (0.3 - 1.0), and minimal in heavy polluted waters (0 - 0.3).

Periphyton biodiversity and relative abundance of ciliates and other protozoans can be used also as indicators of toxic pollution and acidification. Naturally derived periphyton communities were collected from the natural water-body and transported to the laboratory for use in designed experiments. Multivariate statistics were used to design the model of microbial communities development across a gradient of toxicant stress and organic compounds (Zolotarev, 2007).
So, microperiphyton communities can be very useful indicators of the water quality. Their ability to rapidly colonise artificial substrates, the cosmopolitan distribution and other advantages, provide an assessment capability not generally available for higher organisms.
Nanoflagellates are common and abundant in most natural and artificial periphyton communities and fulfil every trophic role from primary producer to carnivore. This relationship, together with rapid reproductive rate and their intimate contact with the environment, make them more useful monitors of aquatic environments than the more frequently studied macroinvertebrates and fish.

3. CONCLUSIONS

The necessity of having an effective international automated biomonitoring network for benchmarking anthropogenic changes in aquatic environments is rapidly growing alongside the development of global water crisis. We use methods for water quality assessment based on biodiversity of microbial organisms having cosmopolitan distribution, so the outputs of the project could be employed globally.
For the foreseeable future, with the development of online biosensors and implementation of information technology, a major application of microscale methods will be to predict, developing the new integrated standards, as a "Dow Jones" for water quality. Simplified methods for education and training (the "Microcosm" project and video library) are available. Several advantages of utilizing the new methods are discussed http://biomonitoring.narod.ru
As implications of the work, we developed some new methods (two patents) and suggest the project "Automated Biomonitoring International Network (ABIN) - integrated information system for benchmarking the health of aquatic ecosystems".
The main features of the project are:
design and implementation of information technologies for international monitoring networks (advancing monitoring technology),
global strategies (promoting interdisciplinary approaches for integrated transboundary water resources management),
modelling aquatic ecosystems (moving from monitoring to prediction), interdisciplinary educational resource.
New trend of IT development - online biosensors (peripheral equipment), or standard multispecies microscale "eco-sensors" (MES), using robotics for collecting data from automated monitoring stations.

4. ACKNOWLEDGEMENT

The author greatly appreciates the advice of Dr. Alexander Mylnikov, Institute for Biology of Inland Waters, Russian Academy of Sciences.

REFERENCES

Cairns, J. (2005): Biomonitoring: The Crucial Link Between Natural Systems and Society. *Mankind Quarterly*, XLV(3), 289-308.
Duplakov, S. (1933): Materialien zur Erforschung des Periphytons. *Arb. der Limnol. Station zu Kossino*, 16 (in Russian with German summary), 1-136.
Ertl, M. (1970): Zunahme der abundanz der Periphyton-mikrofauna aus der Donau bei besiedlung der substrate. *Biol. Prace*, XYI(3), 1-127.
Jiang, J., Wu, S. and Shen, Y. (2007): Effects of seasonal succession and water pollution on the protozoan community structure in an eutrophic lake. *Chemosphere,* 66(3), 523-532.
Lehman, R. (2007): Understanding of aquifer microbiology is tightly linked to sampling approach. *Geomicrobiol Journal*, 24(3–4): 331–341.
Pronk, M., Goldscheider, N. and Zopfi, J. (2009): Microbial communities in karst groundwater and their potential use for biomonitoring. *Hydrogeology Journal*, 17(1): 37-48.
Shen, Y., Feng, W., Gu, M., Wang, S., Wu, J. and Tan, Y. (1994): *Monitoring of River Pollution: Evaluation of Water Pollution by Using PFU Microbial Communities in Hanjiang River.* Centre File 91-0176-02, Institute of Hydrobiology, The Chinese Academy of Science, China Architecture and Building Press, Wuhan, 346 pp.
Wells, P., Lee, K. and Blaise, C. (1998). (Eds) *Microscale Testing in Aquatic Toxicology: Advances, Techniques, and Practice.* CRC Press, Boca Raton, FL, 451 pp.
Zolotarev, V. (1988): *Periphyton Heterotrophic Flagellates of Inland Water-bodies*. PhD thesis, Department of Ecology, Moscow University (in Russian).
Zolotarev, V. (1991): The main features of microbial food webs response to the toxic stress in aquatic environment. In: *The Second All-union Conference on Fishery Toxicology*. St. Petersburg, 222-224 (in Russian).
Zolotarev,V. (2003): WATER CRISIS: The Quest for International Collaboration of Engineers and Scientists. *INES Newsletter*, 40, 12-15.
Zolotarev,V. (2007): Water quality monitoring in wetland ecosystems using microbial model communities. *Int. J. Water*, 3(3), 231-242.