

The Environmental Significance of Bioindicators in Sewage Treatment

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Abstract: The presentation is about the significance of the bioindicators concerning environmental protection within the process of cleaning sewage. The existence of one or multi-celled organisms indicates the presence, condition or absence of certain parts of the water cleaning process. This way the optimal operation of the purifying appliances can be checked continuously and controlled in an environment friendly way.

Keywords: The quality of an environment, sewage treatment, bioindicators, polisaprobic sewage water, mesosaprobic sewage water, oligosaprobic sewage water

1 The Total Water Supply of the Earth

Life is dependent on water: an indispensable compound for all living organisms. It provides the medium, the dissolvent substance, and reaction agent for intracellular biochemical processes. It is one of the vital temperature controllers of the biosphere.

The total water supply of the Earth is approximately 1340 million cubic km but less than 3% of that (36.8 million cubic km) is fresh water, and the ratio of surface waters, lakes, streams, rivers, and groundwater is even less, only .64%, or 8.3 million cubic km.

The population of the Earth is presently 6.1 billion (US), (or 6.1 milliard GB). Based on current tendencies, this number is growing by 70-90 million per year. One of the most pressing global environmental challenges, due to the intensive population growth, is the lack of sufficient fresh water. Overpopulation, however, is not merely a consumption issue (5500 cubic km annually). The amount of wastewater or sewage water produced by the population is also increasing in direct proportion to population growth. Consequently, the pollution of water supplies, previously assumed to be of infinite capacity, has been significantly increased in the last three decades, thus sewage treatment has become a most pressing and immediate issue presently.

There are two options for the final disposal of sewage water. It can either be entered in natural waters, or in the ground, thus returning to the natural cycle. The self-purification capacities of the natural waters and the ground, however, are no longer able to handle the constantly increasing amounts of organic matter, and they have absolutely no resistance to toxins.

Following the example of self-purification in natural waters, biotechnological procedures have been used in sewage treatment more and more extensively, both in water clarification procedures, and in the related issue of water quality qualification.

2 The Quality of an Environment

Basically, there are two approaches to examine and determine water quality, and in a broader sense, environmental quality.

One approach makes the qualifications based on the indicators of end use (e.g. the parameters of drinking, industrial, irrigation, and sewage water), and interprets the data according to the appropriate standards. This approach is not quite operative because of its oversimplification. Obviously, any entity in the environment has a “quality” not only if it is used for some purpose. This is to confuse quality with the concepts of practicability, adequacy or utility.

The other approach determines environmental quality as the totality of attributes. This means that environmental quality is not determined based on a single characteristic, and it does not single out one variable, e.g. the temperature, the light conditions, the phosphorus content, etc.

Water as an environmental element can be defined as the sum of hydrological, physical, chemical, and biological characteristics. Some factors to be considered are: the properties of currents, the temperature and translucency of water, its free oxygen content, its ionic composition, its richness in different organic matter and living organisms, and various other factors.

If one wants to determine the actual quality of an environmental element, one cannot be limited to the examination of the relevant properties of the components separately. The qualitative “junctions” of any material system are not only, and moreover not primarily, characterized by the number of and the values of the components, but rather by their specific structure, i.e. the particular system of interconnections of the components within the domains of the given system. To analyze and interpret the complexity of the specific particularities created by the interactions of the individual constituents is significantly more complicated and more intricate than to study the idiosyncrasies of the individual components.

The accumulation of organic matter in natural waters, i.e. a positive change in the trophic state, is called eutrophication. The trophic state is defined by the organic matter content of a particular body of water. This state is induced by specific attributes as variables, e.g. the available amounts of phosphorus and/or nitrogen, the chlorophyll content, the algae biomass. It would be erroneous to reduce the cause of eutrophication to a single attribute or property. The interactions of various factors are required to produce the state of increased organic matter content, such as an energy source, several micro and macro elements, living organisms.

In the waters of Hungary, the trophic state is limited and determined primarily by the phosphorus content, sometimes by nitrogen, but it can also be the level of light available. Consequently, the subsequent phases of sewage treatment (i.e. the aerobic, the anoxic, and the anaerobic) must accomplish the decomposition of organic matter, the transformation of ammonia, nitrite, and nitrate, and must remove the excess amounts of phosphorus in order to produce water that is suitable to be absorbed by natural waters without triggering eutrophication, and can be returned to the natural cycle.

3 The Bioindicators in Sewage Treatment

The purity level of water, the current relevant properties of water quality can be determined in a fast, efficient, and cost effective way using bioindicators

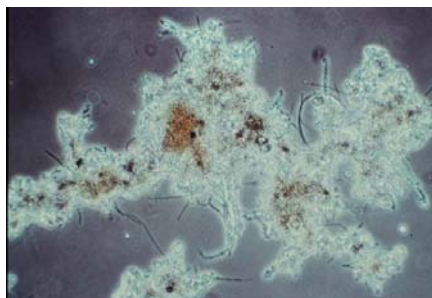


Figure 1

Cluster formed by bacteria (magnified 100 times)



Figure 2

Ciliata (magnified 400 times)

Many different living beings live in sewage water. Bacteria represent the most populous group. Some bacteria form conglomerates or clusters (See Fig. 1), others float as individual cells or threads in the interconglomeratic fluid. Bacteria clusters include every group of protozoa (Protozoa): flagellates (Zooflagellata), rhizopods (Rhizopoda), heliozoans (Heliozoa), ciliates (See Fig. 2), sucterians (Suctoria). Metazoans are represented mostly by worms: nematodes (Nematoidea), rotifers (Rotatoria), and oligochaetes (Oligochaeta). Plantlike protocysts are represented

by a few Cyanophyta, Euglenophyta, Bacillariophyceae, and some fungoids (Protofungi). These living organisms stimulate bacterial activities in the process of water clarification. They regenerate the surface of the bacteria clusters, they support the formation of clusters, and have a positive effect on the adsorption of dissolved and delicately suspended substances. A significant increase in the number of these organisms, however, can also be detrimental (e.g. they can make the clusters loosen and collapse), and it serves as an immediate alert of changes in the operations of the system. The presence or absence of these organisms can determine and predict the causes producing the effect.

3.1 The Bioindicators in Polysaprobic Sewage Water

An increased number of several different bacteria, the presence of Cyanophyta, Zooflagellata, and Ciliata, is an indication of water overloaded with organic matter, i.e. an indication of polysaprobic processes and oxygen deficiency. Our observations can determine if the nutrient content of the sewage water was insufficient, or toxic substances entered the system. Water like that has a high concentration of organic matter, the nutrient to microorganism load ratio is between .4 and 1.5. The load per volume is excessive, thus aeration is inefficient with very little oxygen present. The sludge forming time is between .5 and 2 days, resulting in poor sewage treatment efficiency. As a consequence of the overload, only small clusters of sludge are forming, and they are settling slowly, with lots of bacteria floating freely in the water.

Microorganism indicators are considered excellent water qualifiers because although they all call attention to a system overload, they indicate the cause and gravity of the situation in their own specific way.

The presence of nematode bacterium *Thiotrix nivea* (See Figs. 3 and 4) is an indication of the final stage, the ultimate putrefaction of water: hydrogen sulphide indicator. In this case it is necessary to empty and clean the aeration tank. This stage can be avoided if the other indicators are paid attention to in a timely manner.

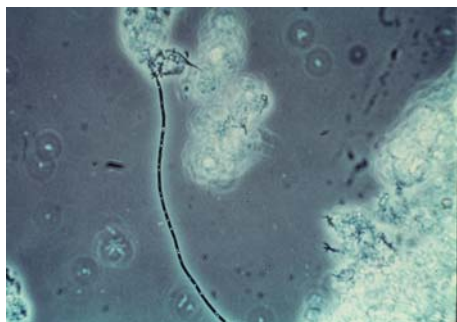


Figure 3
Thiotrix nivea (magnified 400 times)

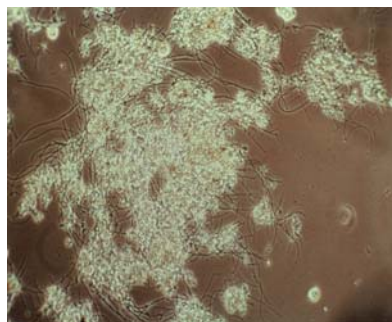


Figure 4
Thiotrix cluster (magnified 100 times)

The presence of *Spirillum* and *Spirochaeta* species (See Fig. 5) signals the first stage of oxygen deficiency and an increase in the load. The *Sarcina* and *Streptococcus* phyla indicate a shift toward overload, alert of anaerobic processes, and the creation of stagnant “dead zones.”

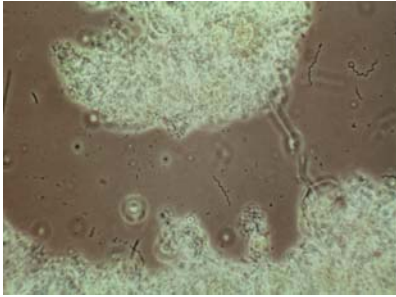


Figure 5
Spirochaeta (magnified 250 times)

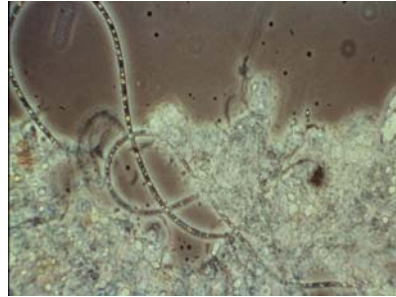


Figure 6
Beggiatoa thread (magnified 400 times)

Sulphur bacteria, *Thiocystis*, *Chromatium*, and *Beggiatoa* species (See Fig. 6) point to insufficient clarification level, the formation of hydrogen sulphide, and the stage of putrefaction due to oxygen deficiency. A significant increase in the number of these bacteria results in a white, “furlike” coating.

The swelling and movement of the sludge, usually caused by the decomposition of nitrogen compounds, are indicated by the presence of *Nocardia* (See Fig. 7), Zooglea (See Fig. 8), and Cyanophytes. Cyanophytes are autotrophic feeders, and a large increase in their number is not primarily a result of the concentration of organic matter, but that of a sudden and extreme change in some environmental factors, such as a change in the composition of sewage water, a rise in temperature, or an increase of the salt content.

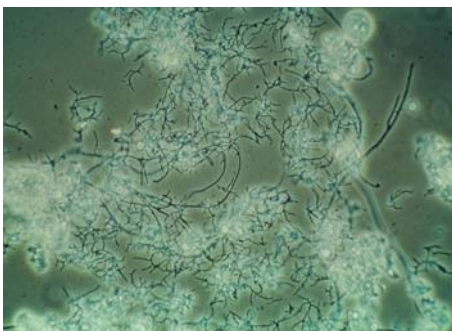


Figure 7
Nocardia (magnified 250) times)

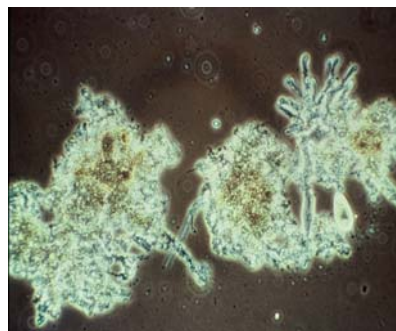


Figure 8
Zooglea (magnified 400 times)

The flagellate protozoa indicator organisms (*Oikomonas*, *Trigonomonas*, *Trepomonas*, and *Bodo* species, (See Fig. 9) found in heavily loaded water rich in organic matter, show characteristics of both fauna and flora. They are mobile and heterotrophic bacteriophage, but they can also behave in autotrophic manner metabolizing nutrients dissolved in the water. At the beginning of the sewage treatment process, these organisms are always present in large numbers (maximum 50,000 entities per ml) but later on their number is decreasing. A large increase in their number (i.e. several million entities per ml) during the treatment operations indicates the start of an advanced stage of the putrefaction processes.



Figure 9
Zooflagellata (magnified 250 times)

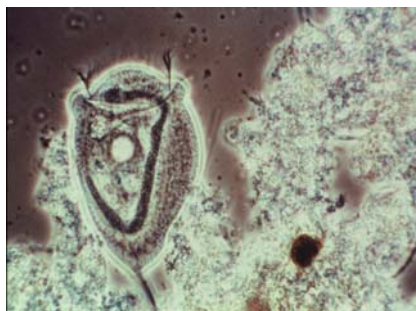


Figure 10
Vorticella (magnified 400 times)

Besides bacteria and flagellate protozoa, the most significant indicator organisms are ciliate protozoa. Most of them have a cytostome, two nuclei, and one or two contractile vacuoles, all of which are important distinguishing characters. Trophologically most of them are bacteriophage but some are predatory. The absence of these organisms indicates the presence of toxic substances, such as phenols, cyanids, and heavy metals. The presence of these organisms indicates oxygen deficiency, system overload, and putrefaction. Ciliates most common in polysaprobic water are the *Paramecium* and *Vorticella* species (See Fig. 10).

3.2 The Bioindicators in Mesosaprobic Sewage Water

In mesosaprobic sewage water the organic matter load is medium, the nutrient to microorganism ratio is 50% less than in polysaprobic water where the organic matter content is high. Sewage sludge is formed in 3.5 to 7 days, big clusters are formed that settle easily, and the freely floating bacteria are few. The free oxygen content is 4 to 6 mg per liter, which means sufficient aeration. Optimal conditions are indicated by the presence of certain ciliate protozoan: *Chilodonella* (See Fig. 11), *Litonotus* (Fig. 12), and *Aspidisca* species. They signal the process of nitrification, decreased ammonia level, and favorable aerobic (i.e. pertaining to the amount of oxygen) conditions.



Figure 11
Chilodonella (magnified 400 times)



Figure 12
Litonotus sp. (magnified 250 times)

3.3 The Bioindicators in Oligosaprobic Sewage Water

Oligosaprobic water is poor in nutrition, and the decomposition of organic matter is at a low level. It may be characterized by excessive aeration, and the clusters floating in the water are small and loosely structured. This condition is indicated primarily by the thread bacterium *Microthrix parvicella* (See Fig. 13). This bacterium occurs frequently in the winter months, and can become a dominating organism. *Epistilis* ciliate protozoa (See Fig. 14) are present in large numbers when the efficiency of sewage treatment is above 65%.

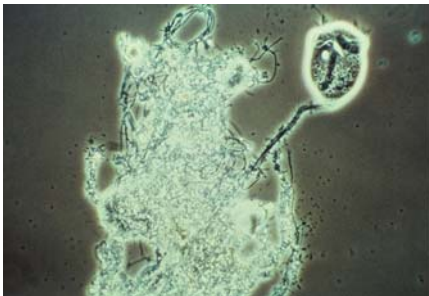


Figure 13
Microthrix thread and *Vorticella* sp (magnified
150 times)

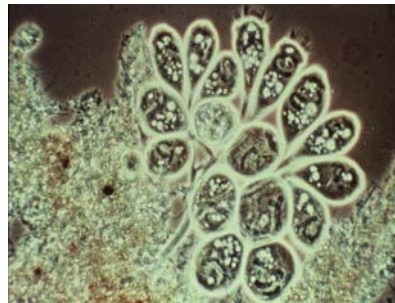


Figure 14
Epistilis sp. (magnified 100 times)

3.4 The Bioindicators in Stabilized Sewage Sludge

Stabilized (aged) sewage sludge is indicated by the presence of metazoan organisms since they need more time to reproduce than the protozoic protocysts and bacteria. The most characteristic indicators are *Tubifex tubifex* of the

nematodes (See Fig. 15), and the rotifer group (Rotatoria) (See Fig. 16). Due to their filtering feeding method they reduce the number of bacteria outside the clusters, they loosen the structure of the clusters thus the bacteria inside the clusters have access to more oxygen.

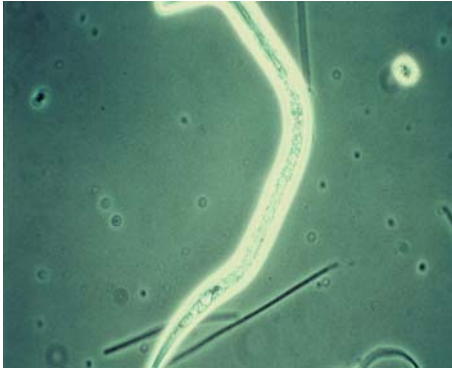


Figure 15
Nematoda sp. (magnified 250 times)

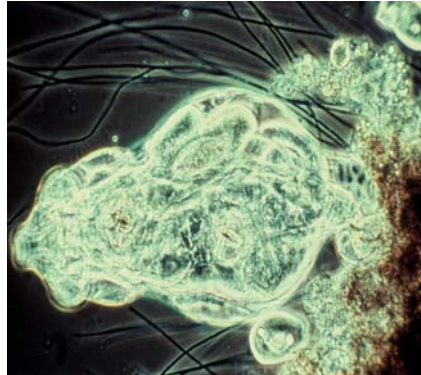


Figure 16
Rotatoria (magnified 150 times)

Conclusions

Bioindicators indicate the presence and condition of the different stages of sewage treatment, also indicating the absence or excessive level of an entity. Observing the bioindicators, the quality of water, and the condition and operations of the treatment equipment can be continuously checked and controlled in a cost effective way. Thus the study of bioindicators is absolutely justifiable.

References

- [1] Árpád Kárpáti: Sewage Sludge under the Microscope Aerobic Sewage Treatment Methods: Using Sewage Sludge and Other Methods, Veszprém, Hungary, 2002, pp. 3-55
- [2] Judit Németh-Katona: The Biological Fundamentals of Environmental Sciences, Budapest, Hungary, 2003, pp. 5-260
- [3] Miklós Pesti: Comprehensive Microbiology Dialo Kampus, Hungary, 2001, pp. 3-89