The Development of Biological Technology in Water Pollution Monitoring

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Abstract： *With the increasing of water pollution, it is very urgent to monitor the water quality and to respond to the timely warning of water safety. As an effective means to monitor and to make early warning for water pollution, biological monitoring technology has got the rapid development. This paper introduced the methods and characteristics of biological monitoring. The advances of study on the biological monitoring and its applications in recent years are reviewed, also the problems and countermeasures are summarized. Last, the perspectives of biological monitoring are discussed.*

Key words: *water pollution monitoring; biological monitoring technology; early warning*

With the rapid development of modern industry, types of pollutants in water are increasing year by year. The environmental damage caused by water pollution severe increasingly, water monitoring is becoming more and more attention [1]. At present, there are two main types of water pollution monitoring: biological monitoring and physicochemical analysis. When the environment is polluted, the biological growth and reproduction process of the living environment will be affected, and the characteristics of organism physiological activity will be changed correspondingly. In order to monitor and assess the environmental pollution, biological monitoring technology systematically makes use of biological components, individual and species response to environmental changes [2]. Biological monitoring technology, including the methods of ecology and toxicology, is an important supplement to the physicochemical method. It also plays a very important role in the process of environmental monitoring and assessment. Biological monitoring method can be used to measure the intensity of a toxic substance in environment, can evaluate the combined toxicity of a variety of pollutants. Compared with the physicochemical method, biological monitoring method has the features of direct, reliable, economical, practical, accurate and comprehensive. It can reflect the long-term contamination, can be used for comprehensive evaluation and early warning for environment pollution [3–5]. The goal of biological monitoring is to monitor the ecological of the system by the fastest speed before the pollutant harm the ecosystem, to detect potential toxic substances in system timely warning response, to prevent destruction of the ecological balance of system, and not to cause greater harm. With the increasing water pollution, it is very urgent to monitor the water pollution online and the timely warning of the water quality. As an effective water monitoring , assessment and early warning method, biological monitoring technology has been widely used and rapidly developed [6].

1. Method and study of biological monitoring. In a certain range of conditions and scope, the interactions between aquatic organism, communities and water environment maintain the dynamic equilibrium relationship. When the foreign matter enters

into the water environment, effecting the individual organisms, thereby affecting the biological conditions of ecosystems and the composition of populations and species. Thus biological monitoring can be classified by different monitoring indicators and objects [7].

1.1 Microflora monitoring method. Microflora monitoring is one of biological monitoring methods which developed and applied earlier. By monitoring the frequency and relative number of species (including bacteria, fungi, algae, protozoa, etc.) in water body, the distribution index calculated by the mathematical statistics, is evaluated as an index of water pollution. In the United States, Cairns et al. used the PFU (Polyurethane Foam Unit) as the substrate to collect the micro organism in the water body, then analyzed various parameters of the microbial community, so as to evaluate the pollution of water quality [8]. Based on this, Shen Yunfen et al. in China proposed that four biological parameters including protozoa species, mastigophores percentage, diversity index and heterotrophic index, were significantly correlated with chemical monitoring parameters. This principle established a new method of microflora monitoring for Chinese ecological environment, which became the first self-developed biological monitoring standard in China [9]. Xu Kuidong et al. improved the microbial monitoring device, using bottled polyurethane foam block to eliminate the impact of ocean tidal streams and circulation. Then monitored micro-organism in marine environment, and achieved better results [10]. Zhaoxia Li et al. employed microflora monitoring method to evaluate the static toxicity of chemical wastewater, and found that the protozoan community was very sensitive to the concentration change of chemical wastewater. With the increase of effect concentration and extension of toxicity time, the species diversity of protozoan community decreased, and the speed of the cluster was also slowed down [11]. Cheng Ding et al. made use of microflora monitoring method to the monitor the treatment of papermaking wastewater, employing Shannon-Wiener diversity index to evaluate whether the treated wastewater could be available for irrigation or not [12].

With the development of microflora monitoring method, the role of mathematical analysis in monitoring is becoming more and more important. The development of mathematical analysis and computer application can help to reveal the variation of parameters for biological communities in a greater range. The use of microbial community monitoring method is more extensive and the more accurate.

1.2 Luminescent bacteria method. Luminous bacteria method is a mature biological monitoring method, with simple, rapid, sensitive, wide range of applications. It can detect most toxic substances in the water samples, and it is a standard method of authentication [13]. Shuyue Li, etc. designed a water toxicity detector employing the luminescence characteristics of cell Vibrio fischeri to determine comprehensive toxicity levels of pollutants in water [14]. Zhisong Cui etc. selected genetic transformation of luminescent bacterium Acinetobacter sp. RecA as the indicator species, established a rapid detection method for the genetic toxicity of pollutants, which can obtain results in 3H [15]. Based on the principle of lumi-

nous bacteria, Beckman company has launched biological toxicity detector Microtox for environmental monitoring. The equipment have successfully applied in monitoring the quality of water source and tap water.

Luminescent bacteria method has widely application prospect in the field of detecting toxic organic matter, heavy metal and other substances, but it has some shortcomings such as complicated operation, large error and so on. The development of electronic technology has provided a guarantee for the research and application of luminescent bacteria method. Combining with the method of fluorescence spectrophotometry, ultraviolet spectrophotometry and gene operation technology, luminous bacteria method will have more extensive development and application space.

1.3 Biological reaction monitoring method. Through monitoring biological behavioral or physiological changes response to pollution, biological reaction monitoring method could evaluate water pollution, determine the safe concentration of pollutant, and make timely response to early warning. The aquatic organisms commonly used in biological monitoring are mainly fish, bivalve mollusks, and Daphnia and so on. Fish as monitoring indicator is most commonly used.

Zebrafish is a tropical freshwater fish which is very sensitive to water quality change. Once the water pollution occurs, it will make the appropriate behavioral response within a few minutes. Zebrafish is a very good biological monitoring indicator, and zebrafish gene and human gene have a high degree of similarity. So the water quality monitoring results obtained by zebrafish as the indicator in most cases can be applied to human beings. Zhihui Song et al. used zebrafish as the test organism employing semi-static method to study comprehensive toxicity of heavy metals to aquatic organisms. It was found that the heavy metal ions Cu^{2+}, Cd^{2+} and Cr^{6+} had different toxic effects to zebrafish. The activity of catalase CAT in zebrafish and Cu^{2+}, Cd^{2+} and Cr^{6+} had a significant dose-response relationship. Therefore, zebrafish can be used as the bio-indicator to monitor the heavy metal pollution [16]. Water group of Shenzhen in China developed the water toxicity monitoring system by monitoring zebrafish activity in water by video cameras online. Computer could analyze the trajectory of zebrafish by real-time video recording. If the fish appears abnormal activity or death, the system will respond in time and give a warning. In addition, using carp, goldfish and other organisms as the monitoring indicator was also reported. According to the change of fish respiratory, the pollution in environment can be indicated. Hongjun Wang et al. found that in the presence of contaminants, the gill respiration of fish would become accelerate or no rules. Jie Sun et al. proposed that the calculation of time-variable half lethal concentration fora variety of small fish in pollution wastewater can determine the level of water biological toxicity [17].

As the indicator in biological monitoring fish is mainly used for freshwater, but in ocean the physiological or behavioral of double shell is generally used as the biological responses to water pollution. This has made good progress in research and appli-

cation [18]. Schuring introduced electromagnetic induction technology to monitor mussel bivalve distance change as the indicator of the toxicity of the water body [19], while Jenner used high-frequency electromagnetic induction system to monitor the movement of its shellfish, which improved the monitoring efficiency. Based on the principle that the frequency of the mussel double shells will change with the water pollution variation, Holland made the monitoring equipment Mosselemonitor. It can monitor the biological toxicity of water body on line monitoring and send early warning using the electromagnetic conversion system to detects status of mussel double shells. It has successfully applied to the pollution monitoring for rivers and coastal waters [20, 21].

In addition to fish and bivalves, Daphnia are also often used as the indicator organisms for biological monitoring. Early warning systems employed photoelectric detector to measure the displacement capacity of Daphnia, judge Daphnia life activities, be aware of the water pollution status [22]. Additionally Daphnia mortality or reproductive capacity can also be used as the testing index of toxic pollutants. Persoone et al. in Belgium employed high-speed camera system to measure the velocity of Daphnia, used the change of velocity to indicate the toxicity of water [23].

Biological monitoring method based on biological behavior monitoring technology can be achieved online monitoring and early warning. It has high practical value, has already formed commercial products in some areas. With the development of computer graphics technology and automation technology, the research of monitoring biological dynamic behavior is more accurate, the problem of analyzing the trajectory data of biological dynamic behavior is solved. The establishment of biological behavior model is more convenient. On this basis, the biological behavior monitoring technology will get better development.

1.4 Benthic fauna and amphibian monitoring method. Benthic fauna and amphibian as the indicator are also suitable for biological monitoring. By recording the appearance , disappearance and the number of organisms in the water can monitor the water quality. The parameters used in the evaluation of the water quality of the benthic animals are Saprobic index, BI (Biotic, Index), and community diversity index. Among them, Saprobic index and BI index have been listed as an important index for water quality assessment in Europe and America. But there is still a lack of similar biological index for monitoring technology in China [24, 25]. Kun Cai et al. evaluated the ecological health of Taihu through the index of benthic animal integrity in China. The research found that the reliability of evaluation index and rationality of the results can be improved by continuous data collection [26].

Amphibian animal behavior and physiological indicators can be used in monitoring water quality. Especially during the development process, they are sensitive to the changes in environmental factors [27]. Shixia Xu et al. used amphibians as indicator organisms to monitor water pollution caused by pesticides in China, established the monitoring platform water pollution and the corresponding criteria of monitoring [28].

1.5 Other biological monitoring methods. In the study of classical biological monitoring methods, people still actively research and develop new technology and methods of water monitoring. For example, use larval metamorphosis, biological activity of the molecule etc. as indicators to monitor changes in ecological environment. In marine benthic invertebrate larvae metamorphosis has a higher sensitivity to pollutants. The development of embryos and larvae is easily affected by environmental pollution, which affects the process of metamorphosis. Compared with the monitoring of mortality, whether the organism can be attached to the base surface smooth and metamorphosis is a sensitive indicator to monitor toxic contaminants. Mohamed Dellali et al. utilized cholinesterase activity in vivo to assess the polluted water, and got good results [29]. Mirjana Pavlica et al. observed the DNA damage in blood cells of mussels to monitor PCP (pentachlorophenol) pollution in water. The results showed that the high concentration of PCP can lead to water mussel blood cells DNA breakage [30].

Biosensors and bio-electrochemical monitoring technology is the identification of various substances by molecular components. Then biochemical signaling molecule perceived by Molecular recognition element is converted to electrical signals can be measured. This allows for monitoring enzymes, antibodies, hormones, DNA and others in vivo, and make further evaluation and prediction on the impact of pollution on the environment [31, 32].

2. Problems and Countermeasures of water biological monitoring technology. A large number research and application of water biological monitoring provide the reliable theoretical basis and practical experience for the development of biological monitoring, also provide researchers with a certain amount of research ideas and theoretical guidance. At present, the main factors that restrict the research applications of water biological monitoring are mainly the following factors:

1) The growth and distribution of the organisms have a large difference in personality, and the reaction of the same organism to the pollutant may be not the same. Therefore, in the application of biological monitoring system need to set test cycle according to the characteristics of the water body, growth status of indicating biological and others. Application of biological monitoring in different regions or different seasons, in order to adapt to different areas of monitoring standards, preliminary experiments should be conducted to determine the frequency of monitoring and extent of biological responses. Establish the large data of global Biological Monitoring network, analysis and processing of the monitoring results, will help to eliminate regional differences.

2) Some low concentration of pollutants in aquatic ecosystems have potential hazards, but in a short time biological effect is not obvious. In the field of biological monitoring mostly rely on simulation experiment, this is different from the actual situation of the complex aquatic ecosystems. How to make the relationship between water environment and aquatic organisms to be more systematic and real in the process of the study, how to quickly monitor the chronic

toxicity of pollutants is worth further study. It should establish an effective monitoring from biomolecules to biological communities at different levels. In the case of abnormal conditions, then targeted physicochemical analysis, and timely monitoring of pollutants in order to make early warning [33].

3) Study the contact mechanisms between biological monitoring results and human health. From the molecular structure to the ecosystem, there are huge differences between individual organisms. How to make different life forms as an object, establish the applicable monitoring standards of human toxicity level, will be essential for future research [34].

3. Summary and Outlook. Biological monitoring is an important method of environmental monitoring, which has been widely used in water quality monitoring. Although limited to the region, species physiological changes and other reasons, biological monitoring techniques can not accurately quantitative analysis. But as an effective method to evaluate the comprehensive toxicity, in future the studies and application are bound to be paid close attention, especially in the new type of toxic substances monitoring reflect a great advantage. Biological monitoring methods combined with physical and chemical detection method, will not be only able to detect the composition and concentration of pollutants, but also to evaluate the comprehensive toxicity effects of pollutants. Thus it can accurately monitor the comprehensive pollution of water quality [35]. With the development of computer technology, image video capture and various sensor technology, the use of biological monitoring will be more and more simple and convenient, the monitoring results of pollutant toxicity will become more and more accurate. Study on monitoring and early warning of water pollution accident by using biological monitoring results, improve the capacity of monitoring and early warning for water quality, has important economic and social significance.

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