



Review Paper

Toxicity Tests to Check Water Quality

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Abstract

Water is essential for all biological life. The health and well-being of humans and other organisms of ecosystem depend heavily on the quality of water. Quality of water refers to the physiochemical, and biological characteristics of water. Quality of water often deteriorates due to the presence of hazardous substances such as industrial chemicals, consumer products and pharmaceuticals. The quality of water and the presence of hazardous contaminants can be assessed by toxicity testing. In recent years toxicity testing has grown steadily, as a useful tool in environmental risk assessment. The most commonly used toxicity tests include direct toxicity assessment, water quality index, in-vitro and in-vivo bioassays. Biological tools like Bioassays, Biomarkers, and Biosensors provide us with a detection system for signaling a potential damage in the environment. Although these toxicity tests provide important information about contaminants concentration and consequent toxicity, yet the specific biological functions altered are often not apparent. New test systems need to be developed that provide information about not only the overall toxicity induced but also the specific biological pathway that are disrupted due to the contaminants.

Keywords: Water quality, toxicity testing, bioassays, pollution.

Introduction

Water Quality: The most abundant substance on earth is water¹. It is a transparent fluid and can appear in three forms solid, liquid, and gas. At standard ambient temperature water is liquid but can co-exist in its solid state as ice or in gaseous state as water vapors. 70.9% of Earth surface is covered by water. It is one of the most essential resources for the survival of human beings. Apart from drinking, water is used for washing, cooking, and farming activities. Approximately 70 % of the fresh water is used for agriculture². It is essential that water used for drinking be free from chemicals and germs as impure water may lead to many diseases. The water born diseases includes cholera, typhoid, malaria, polio, hepatitis A, dysentery, giardia and botulism. The term water quality describes the condition of water, specifically the chemical, physical, radiological, biological characteristics of water. When water contains excessive amount of contaminants and is not suitable for human use, it is known as water pollution³. In drinking water, pollutants include organic pollutants, heavy metals, phenols, pesticides etc⁴. The organic pollutants include a group of man-made chemicals including pesticides, industrial chemicals, detergents, consumer products, and pharmaceuticals⁵. Some heavy metals such as CO, Cr, Mn, Mo, se, are essential for growth, but may cause serious impairment in biological functions when present in high concentration⁶. Pollution also occurs due to sewage leaks, oil spillage, toxic waste disposal, deforestation, mining, household chemicals, animal waste, radioisotopes, chemical fertilizers and pesticides. Human activities like agriculture, industrialization and household

disposal also lead to water pollution. Water pollution often leads to toxicity in water.

Toxicity

Toxicity can be defined as adverse or harmful effect of a chemical substance upon the biological system of an organism over a designated time period. Toxicants can be of three types: chemical, biological and physical. Chemical toxicants include lead, mercury, hydrofluoric acid, chlorine etc. Biological toxicants include viruses, bacteria, fungi and other pathogens. Physical toxicants include the substances that occur due to the physical nature. The increasing amount of hazardous chemicals in water and damage caused by them, make it necessary to assess biological affects as well as identify the chemical compounds present⁷. Different expressions of toxicity are Aquatic toxicity, Geno toxicity and Estrogenicity. Aquatic toxicity is the "harmful effect of chemicals on aquatic organism". On the other hand chemicals found in environmental samples could cause a variety of effects such as 'Genotoxicity'⁸ that is harmful effect on genetic material. Estrogenicity is defined as the physiological response of organisms to a compound that induces estrus in-vivo. Estrogenic chemicals include some industrial chemicals, alkyl phenols, phthalates, bisphenol and some organochemical pesticides such as o,p'-DDT and methoxychlor⁹⁻¹⁰. It's difficult to predict estrogenicity of these chemicals on structural basis because chemical structure of these chemicals varies substantially. Estrogenicity is a form of endocrine disruption that is change in hormone function due to exposure of harmful chemicals.

Toxicity Testing

Toxicity tests are important components in assessing the impact of chemicals on aquatic ecosystems because they reveal toxic effect of complex chemical mixtures¹¹. Toxicity tests should be carried out in the natural environment.

To monitor the toxic pollutants and hazardous compounds in water and predict their effect, many approaches and methods for toxicity testing has been developed¹². Chemical toxicity testing (CTT), Direct toxicity assessment (DTA), Water effluent toxicity (WET), and Water quality index (WQI) are tests that are routinely used worldwide. Biological tests such as bio-analytical systems, bioassays, biomarkers and biosensors provide us with detection system for signaling a potential damage in the environment¹³. A wide variety of biological methods have been developed to evaluate different end points, such as sub lethal effects, and biochemical responses. General toxicity tests are important to evaluate toxic conditions and study the behavior of living organism¹⁴. Here we discuss some of the most important and commonly used toxicity tests for assessing water quality and highlight their advantages and disadvantages.

Chemical Toxicity Testing (CTT): CTT is very beneficial for obtaining specific information about a particular chemical. Monitoring of chemicals in a CTT provides a quantitative assessment of a single contaminants in water samples but is not applicable when unknown compounds are present or if there is interaction between two or more chemicals causing changes in their toxicity¹⁵.

Direct Toxicity Testing (DTA): DTA is an often tool to assess the toxicity of mixtures such as sewage discharge, pesticides, waste water, and industrial effluent. The main aim of DTA is to ensure that waste released in aquatic environment does not affect any aquatic organism¹⁶. This method is very useful in situations where waste discharge may cause acute toxicity in the immediate receiving environment. Different dilutions of the samples are compared with the original effluent to make an initial assessment of the potential environmental risk. It is a rapid test for analyzing effluents that have the potential to cause toxicity or others that pose little or no risk¹⁷. If DTA is used in conjunction with chemical measures and biological assessment, it can provide meaningful information for maintaining high water quality. The major advantage of DTA is that it can assess unknown compounds and their behavior. DTA cannot identify the toxic components in a mixture yet it can successfully assess the toxicity of whole mixture¹⁸.

Whole Effluent Toxicity Testing (WET): WET analyzes the effect of exposure of effluents on aquatic organism. WET test is important method for detecting toxicity in water. National Pollutant Discharge Elimination System (NPDES) uses WET tests allowing authority to determine whether a facility's permit will need WET requirements. WET testing does not control the toxicity of a single chemical but assesses the effect of whole

constituents of a complex effluent. It measures the interaction of toxicants and other constituent's toxic response to within the samples.

WET tests can be Acute and Chronic. Acute tests measures how well organism survive, While chronic tests measures survival and sub-lethal effects, such as a sample's effect on organism growth production etc. Chronic WET tests are expensive and have many diverse sub-lethal endpoints¹⁹.

Water Quality Index (WQI): WQI is another method to check the quality of water. WQI determines the changes in quality of water over time and characteristics of water. This method can be used to compare quality of water supply with other water supplies from all over the world²⁰.

Divya et.al.²¹ conducted a yearlong study between 2011 and 2012, where they collected samples from Karnataka and Kerala states for three seasons' winter, summer, and monsoon. Nine parameters were assessed; namely pH, turbidity, temperature, nitrate, phosphate, dissolved oxygen, total solids, biological oxygen demand, and a biological parameter. WQI was used as an analytical tool for summarizing the data and demonstrated medium water quality.

Bioassays: Bioassay is the measurement of toxic responses upon exposure to chemical under controlled conditions in the laboratory using cultured organism. An ideal bioassay should be simple to emulate, regularly intercalibrated, sensitive to wide range of pollutants, able to utilize test organism from reliable stock, practicable, relevant and readily understood by the layman, able to yield statistically robust data²². Commonly used bioassays are in-vivo cell based bioassay and in-vitro cell based bioassay.

In-Vitro Cell Based Bioassay: In-Vitro cell based bioassays are commonly used in water and sediment quality assessment. The development of In-Vitro technologies occurred for ethical, scientific, and economical reasons. It is a valuable tool in assessing toxicity and cell viability that specifically measures adaptive stress response. In-vitro cell based assay monitors the effect of specific chemicals on cells, and can be used for high-throughput screening (HTS). This allows testing of chemicals simultaneously in a very short period of time²³. It can be used as an alternative to traditional effects based monitoring studies. A major disadvantage of most in-vitro methods is that the interactions occurring on a whole tissue or organism is not taken into account but the effects on a single (or few) cell type can be determined²⁴.

In-Vivo Cell Based Bioassay: In vivo methods are used to determine the adverse effects of chemicals on tissues or whole organs and organisms²⁵. They are often used for checking estrogenicity. In-vivo bioassays are based on the wide variety of end points, including enzyme activity and cell differentiation and require the exposure of whole organism to determine the toxicity. This type of assay is indicative of specific endpoints relevant for human or environmental health and measures the

effect of pollutants on growth, reproduction, feeding activity, and mortality, as well as effects based on specific biochemical end points²⁶. However it is not possible to use In-Vivo methods for routines or monitoring studies because of cost, time constraints, ethical problem, and requirements for big installations.

Table-1
Comparison of Routinely Used Toxicity Tests

Methods	Country	Advantages	Disadvantages
WQI	India	WQI can determine the changes and characteristics of water ²⁰	The actual specification of chemicals is hard to be known ²⁶
WET	USA	Simple, Inexpensive ²⁷	Less sensitive, No direct treatment, no direct human health protection ²⁸
DTA	Australia and New Zealand	DTA can assess the unknown compound ²⁹	Toxic components of mixture is hard to identify ²⁹
In-Vivo cell based Bioassay	India	Measure the effect on parameters like growth, feeding activity, mortality etc ²⁵	Expensive, Time consuming, Ethically Questionable
In-Vitro Cell Based Bioassay	India	Chemicals can be tested in a short period of time, low ethical cost, Rapid response ²³	It can only identify a single cell type ³⁰

Discussion

Water is the basic need of all living beings. So the removal of toxicants from water and correct assessment of water quality is very important. Water quality models are useful to assess the quality of water and to predict the changes in surface water quality.

Routinely used tests to evaluate water quality include CTT, DTA, WET, WQI and bioassays. These methods provide useful information regarding the quality of water.

WQI compares the quality of water supplies with one another and it can also detect the characteristics of water and changes over time.

WET method is less sensitive and inexpensive. During the performance of WET toxic substances may get degraded or absorbed. WET tests are conducted for specific chemical analysis to protect aquatic life or aquatic organism.

DTA has gained more acceptances over the recent years. It measures direct biological effect of effluents or contaminants on an organism. This method can also assess the effect of unknown toxic compounds in water. However, DTA cannot identify the toxic compounds in a mixture of samples. It is the most widely used and accepted technique for assessing water quality all over the world due to speed, lower cost and lack of ethical issues.

Bioassays which evaluate effect of toxic chemicals on environment give rapid response, easy interpretation and are cost effective. Bioassays can also be used to check the estrogenicity or endocrine disruption. In-vitro bioassay cannot determine the effect of chemicals on whole tissue or organism but in-vivo bioassays are able to do so. However in-vivo bioassays are used less frequently due to expense, time, and ethical issues.

Conclusion

Toxicity testing methods reveal the activity of specific determinants or toxicants but do not reveal the impact of these chemical on specific biological function such as hormone action.

Aquatic organism forms an important link in the food chain. Any impairment in their biological activities is likely to have a major impact on other aquatic and land ecosystem. Thus polluted water can not only have an immediate impact on organism exposed to it rather it may have a long term negative impact on many other ecosystems.

Assays need to be developed to understand and visualize the impact of these chemicals on endocrine system and other biological systems critical for survival of an organism.

References

1. Sonika S. and Chhipa RC, Interpretation of ground water quality parameter for selected area of jaipur using regression and correlation, *Journal scientific and industrial research*, **72**, 781-783 (2013)
2. Baroni L, Cenci L, Tettamanti M and Berati M., Evaluating the environmental impact of various dietary patterns combined with different food production systems., *European Journal of Clinical Nutrition*, **61(2)**, 279-286 (2007)
3. Olaniran N.S., Environment and health: an introduction on olaniran N.S.et.al, (ED) Environmental and health, Micmillan Nig.Pub.Co for NCF, 34-151 (1995)
4. Escher B.I, Van D, Dutt C, Tang M, J.Y.M and Altenburg R, Most oxidative stress response in water samples comes from unknown chemical: the need for

- effect based quality trigger value, *Environmental Science and Technology*, **47(13)**, 7002-7011 (2013)
5. Wasi S, Tabrez and Ahmed M., Toxicology effects of major environmental pollutants: An overview: Environmental monitoring and Assessment, **185(3)**, 2585-2593 (2013)
 6. Schwarzenbach RP, Escher B.I., Fenner K, Hostetter T.B., Johnson C.A., Von Gunten U and wehrli B., The challenge of micropollutants in aquatic system, *Science*, **313(5790)** 1072-1077 (2006)
 7. Sushismita Das and Abhik Gupta., Acute toxicity studies on Indian flying barb, *Esomus Dancricus* (Hamilton-buchanan), in relation to exposure of heavy metals, cadmium and copper, *Journal Environmental Research and Development*, **4(3)** (2010)
 8. Klaassen CD and Watkins J.B, Casarett and Doull's essentials of Toxicology, McGraw-Hill, **1** (2003)
 9. Van Leeuwen C.J. and Vermeire T.G, Risk Assessment of Chemicals, 2nd ed. Springer, (2007)
 10. Soto AM, Sonnenschein C, Chung KL, Fernandez M F, Olea n and Serrano F O., The E-Screen assay as a tool to identify estrogens: an update on estrogenic environmental pollutants, *Environmental Health Perspect*, **103**, 113-122 (1995)
 11. Jobling S, Reynolds T, White R, Parker MG and Sumpter JP, A variety of environmentally persistent chemicals, including some phthalate plasticizers, are weakly estrogenic, *Environmental Health Persistant*, **103**, 582-587 (1995)
 12. Brian A, Patricia N, Kristine G, Rosamaria K, John H and Bryn P., Overview of Freshwater and Marine Toxicity Test, (2004)
 13. Xiaowei Z, Steve W and John G., *Toxicology of Water*, (2012)
 14. Marinella F. and Damia B., Biosensors for Aquatic Toxicology Evaluation, *Hdb Env Chem*, **5**, 115-160 (2008)
 15. Malik GM, Raval H, Viral and Ahmad Khalil HK, Toxic effects of effluent on mortality and behaviour changes on fresh water fish *poecilia reticulata*, *Journal of environmental research and development*, **7(2a)** (2012)
 16. Rand GM., Fundamentals of Aquatic Toxicology, *Taylor and Francis, Bristol, PA.*, 2 Edition (1995)
 17. Hart WB, Doudoroff P and Greenbank J, The evaluation of the toxicity of industrial wastes, chemicals and other substances to fresh-water fishes, Atlantic Refining Co. Philadelphia, (1994)
 18. Dean L, Peter S and Luke S, Direct toxicity assessment of mixtures in effluents:- current UK experience, WCa Environment Ltd, http://www.wca-environment.com/wp-content/uploads/2011/05/wca_SETAC2011_DTA-effluents_WE310_May-2011_A0.pdf, (2015)
 19. Jop KM, Kendall TZ, Askew AM and Foster RB, Use of fractionation procedures and extensive chemicals analysis for toxicity identification of a chemical plant effluent, *Environ Toxicol Chem*, **10**, 981-990 (1991)
 20. Randall M., Laboratory Guidance and Whole Effluent Toxicity Test Review Criteria, Department of ecology state of Washington, (2008)
 21. American public health association, Standard method for examination of water and waste water, Washington DC, **17**, (1989)
 22. Divya KS and Mahadeva M., Study of water quality assessment using water quality index (WQI) in few water samples of Karnataka and Kerala states, Department of Microbiology, **4(3)**, 267-270 (2013)
 23. Marinella F., CSIC Spain, Ecotoxicity in waste waters and natural waters, Ankara University, Turkey, 8-11 (2007)
 24. Dellarco V, Henry T, Sayre P, Seed J and Bradbury S., meeting the common needs of more effective and efficient testing and assessment paradigm for chemical risk management, *Journal of Toxicology and Environmental Health, Part B. Critical reviews*, **13(2-4)**, 347-360 (2010)
 25. Farre M and Barcelo D., Toxicity testing of waste water and sewage sludge by biosensors, *Bioassays and Chemical Analysis*, TRAC- Trends in Analytical Chemistry, **22(5)**, 299-310 (2003)
 26. Cornelia K, Robert K, Inge W., In-Vitro and In-Vivo Bioassays for the Performance Review in the Project, Strategy Micropoll, (2011)
 27. Chowdhary RM, Muntasir SY and Hossain MM, water Quality Index of water bodies along Faridpur-Barisal Road in Bangladesh *Global Eng. Technol*, **2**, 1-8 (2012)
 28. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to fresh water organisms, United States Environmental Protection Agency, October 4th Edt. (2002)
 29. Christopher JN, Whole effluent toxicity basics, NJDEP, Office of Quality Assurance, (2013)
 30. RA Van Dam and Chapman JC, Direct Toxicity Assessment (DTA) for water quality Guidelines in Australia and New Zealand, *Australian Journal of Ecotoxicology*, **7**, 175-198 (2001)
 31. Jeffrey M., Improving water and sediment quality assessment using adaptive stress response assays and implementing more efficient methodologies, Utrecht University, Institute for Risk Assessment Sciences, (2013)