Journal of Molecular Biomarkers & Diagnosis

Yarsan and Yipel, J Mol Biomark Diagn 2013, S1
DOI: 10.4172/2155-9929.S1-003

Review Article Open Access

The Important Terms of Marine Pollution "Biomarkers and Biomonitoring, Bioaccumulation, Bioconcentration, Biomagnification"

Ender Yarsan[1]* and Mustafa Yipel[2]

[1]*Faculty of Veterinary Medicine, Department of Pharmacology and Toxicology, Ankara University, Ankara, Turkey*
[2]*Faculty of Veterinary Medicine, Department of Pharmacology and Toxicology, Mustafa Kemal University, Hatay, Turkey*

Abstract

The numbers of chemicals which are the most important group of environmental pollution were limited to a few thousand until the beginning of this century. But nowadays, due to intensive production and the unconscious usage, the chemical pollution is increasing throughout the food chain and is damaging all living creatures. The chemical levels of the water, the sediment and the aquatic organisms are very important to determine the level of the chemical contamination of the marine environments by biological. The aquatic organisms, such as fish, crustaceans, algae, protozoa, macrophytes, bacteria and plankton are widely used as a biomarker in determining the quality of aquatic systems for the environmental contaminants. Because of this importance the description and differences of marine pollution terms are significant. In this review, the data were collected from different literatures around the World in uses terms of monitoring the aquatic organisms for chemical pollution in aquatic system.

Keywords: Marine pollution; Bioaccumulation; Bioconcentration; Biomagnifications; Biomarker; Biomonitoring

Marine Pollution and Contaminants

The various activities of human beings affect adversely all environments where the plants, the animals and the humans live [1]. The numbers of chemicals which are the most important group of environmental pollution were limited to a few thousand until the beginning of this century and the majority part of that was constituted by plants, animals and mineral origin accounted for natural ingredients. The production of the chemicals which were 7 million tons in 1950 is estimated to reach 400 million tons today. On the one hand consists of hazards, on the other hand increasing quantities of usage of requirements for the modern living that has increased the importance of the determination of threshold limits of chemicals before and after the production [2].

The marine pollution is one of the most important parts of ecotoxicology. The term 'ecotoxicology' was first introduced by the toxicologist Prof. Truhaut in the late 1960s, when it was considered a sub-discipline of medical toxicology. Since then, ecotoxicology has developed into a scientific discipline in its own right, describing not only effects of exposure to chemicals and radiation, but also the environmental fate of contaminants [3].

The marine pollution continues to increase whereas the natural resources which are economically important for seafood species have become inevitable to not to be influenced by pollution [1,2]. Marine environments are the final receiver of pollutants, due to this sustainable natural food resources are affected negatively by each passing day. The pollution is increasing throughout the food chain and is damaging all living creatures, including humans in the chain. As a result of the marine environments enormous nutritional potential and rapidly increasing world population; the scientific studies are increased in the recent years in order to benefit more from the seas. The air-based, rapidly sea vehicles-based and rapidly land-based pollutants lead to marine pollution. The marine pollution levels are increasing every day as a result of the industrial, urban and agricultural activities that fulfills the increasing demands of the rapid growth of population. The marine pollution carries a different significance, especially in terms of fisheries and tourism. The prevention of the pollution is important for sustainable use of the sources [4]. The aquatic environment with its water quality is considered the main factor controlling the state of health and disease in both man and animal. Nowadays, the increasing use of the waste chemical and agricultural drainage systems represents the most dangerous chemical pollution [5].

Fishery Products

Fish and other sea food come at the beginning of the oldest food sources of the human beings. Nowadays, more than 20,000 edible fish, shellfish and marine mammals' species live in the waters of all over the world. Approximately 250 species of them are consumed as human food [6]. Seafood industry is one of the main resources of food industry which meets the world's food requirements and is the fastest growing sector of world's food sector [7,8]. The average of the annual seafood consumption is 26 kg/year in the European countries and 17.1 kg/year in the world [7]. The fishery products with its high nutritional values have a very important place in the foodstuffs for human nutrition [9,10]. Being an important food group for nutrition, in parallel with the increasing world's population they have came out with the scientific investigations that food and eating habits plays an important role over prevention and formation of the diseases, therefore more conscious people and their nutritional requirements have been raised [9]. As a natural consequence of these conditions, the demand and the interest for seafood increase day by day [2].

Terms of Pollution

Until recently, the chemical analysis of the water contaminants has

***Corresponding author:** Ender Yarsan, Faculty of Veterinary Medicine, Department of Pharmacology and Toxicology, Ankara University, Irfan Baştug Street, 06110 Diskapi/Ankara, Turkey, Tel: 0-312-3170315; Fax: 0-312-3176073; E-mail: Ender.Yarsan@veterinary.ankara.edu.tr

Received December 26, 2012; **Accepted** February 14, 2013; **Published** February 16, 2013

Citation: Yarsan E, Yipel M (2013) The Important Terms of Marine Pollution "Biomarkers and Biomonitoring, Bioaccumulation, Bioconcentration, Biomagnification". J Mol Biomark Diagn S1: 003. doi:10.4172/2155-9929.S1-003

been used as the conventional methods for monitoring water pollution. However, these methods are inadequate to determine the water pollution and do not reflect the effects of the pollutants on the aquatic organisms which live in that environment. Therefore, the aquatic organisms are used to determine the water pollution. For this purpose, the chemicals levels of the water, the sediment and the aquatic organisms are very important to determine the level of the chemical contamination of the marine and of the other aquatic environments [11,12]. The coastal, the gulf and the enclosed seas have got higher heavy metal concentration levels than the oceans [13]. Contrary to organics, the inorganic contaminants do not undergo the process of disintegration that reduce their concentrations or toxicity and accumulate in the aquatic organisms with significant levels. This accumulation is important both in terms of potential effects on the aquatic organisms and on the human health. For this reason, “biomonitoring” programs (biological monitoring) are required to determine the temporary and permanent effects of the contaminants on the coastal regions [12].

A biological approach has been used as a counterpart of a classic chemical approach for surveying marine pollution effects in many international programs. A chemical analysis solely is considered as an invaluable analysis for interpretation of the pollutant impact in marine ecosystem since it does not illustrate the harmful effects and the fate of chemical compounds on living organism through biotransformation of xenobiotic substances within living organism body. In many cases, the biotransformation may increase xenobiotic substances toxicity on organism via producing reactive metabolite compounds that are more toxic than original parent compounds. Moreover, the chemical approach is costly, usable to only a small proportion of the xenobiotic compounds in the environment, produces a little biologically meaningful data, and consequently simplifies the complexity of the ecosystem under monitoring. For those reasons, the classic chemical analysis should be accompanied by the biological approach which is so called “biomarker” that elucidates biological responses of environmental pollution. Biomarkers have been considered as sensitive and suitable tools for detecting either exposure, or effects of, pollutants since they can provide more comprehensive and biologically more relevant information on the potential impact of pollutants on the health status of organism. In respect to pollutants that has a lower stability in water such as organophosphate and carbamate pesticides, biomarkers are reliable tools for assessing the impacts of the pollutants on biota even if the existence of the pollutants in water cannot be detected. It is because biomarkers can detect persistent responses and/or effects of the pollutants in such duration of biota lifetime. Therefore, they have been used enormously in biomonitoring to assess the risk of marine ecosystem pollution [14].

“Biomarkers/Bioindicators” are the organisms which respond to the environmental pollution by changing the life functions or accumulating toxins in to their bodies. The aquatic organisms, such as fish, crustaceans, algae, protozoa, macrophytes, bacteria and plankton are used as a bioindicator in determining the quality of water. Due to feeding and living in the sea environments these organisms are heavily exposed to pollution [11,15]. Therefore relative body size, long life span, being on the top step of the food chain and the direct effects on the human health are being researched; the fish and the prawns bioindicator species in the aquatic organisms are widely used in evaluating the quality of the systems for the environmental contaminants [11,16,17].

Toxic pollutants often cause characteristic responses in the affected organism, commonly known as ‘biomarkers’. A biochemical, (genetic) cellular, physiological or behavioral variation that can be measured in tissue or body fluid samples or at the level of the whole organism (either individuals or populations), that provides evidence of exposure and/or effects of one or more chemical pollutants (and/or radiation) defined as biomarker [18]. Biomarkers are powerful tools for detecting the impact of exposure to sublethal concentrations of a given substance or complex chemical mixtures, enabling the evaluation of less obvious effects on organisms.

In aquatic ecotoxicology the use of biomarkers has traditionally been applied to the exposure of sentinel organisms or *in vitro* test systems to pollutants in aqueous solutions or suspensions. These approaches have been instrumental in providing guidelines for legislative measures aimed at reducing the impact of anthropogenic activity on marine and freshwater environments. In recent years, however, the relative improvement of water quality in many areas and the recognition that those sediments may serve as sinks and secondary sources for many persistent chemicals [19] has shifted the focus of ecotoxicological studies towards sediments and the potential deleterious effects that persistent pollutants have on benthic ecosystems [20].

The evaluation of impacts of pollution on the marine ecosystem is based on two types of scientific findings:

a) Indicators of change of composition and/or stress of the ecosystem of the marines;

b) Analysis of trend of levels of bioaccumulation of chemical contaminants in the ecosystem elements which are considered as indirect indicators of impact on the ecosystem [21].

“Biomonitoring” is a scientific technique for assessing the environment including human exposures to natural and synthetic chemicals, based on sampling and analysis of an individual organism’s (biomarkers/bioindicators) tissues and fluids [17,22]. Some organisms are used as an indicator for monitoring the contaminants uptake, bioavailability, excretion and the determination of the toxic effects. This provides information about the level of the environmental pollution [12]. The Bioindicator groups (biological indicator organisms) are used for monitoring and investigations of the environmental quality.

In recent years, institutes, health and environmental agencies have been moving towards the increased use of biomonitoring measures (in human, aquatic organisms and other aquatic materials) in order to better understand the relationship between exposure to environmental pollutants and human health [23,24].

The aquatic organisms and the other members of the food chain accumulate the contaminants into their tissues and organs [12].

The process of the increase in concentration of a substance in an organism’s tissues or organs which it exposes to the surrounding environment is called “Bioaccumulation”. Bioaccumulation of substances taken in by the organism from water is only called “Bioconcentration” (Figure 1) [1,22,25].

Bioconcentration in fish involves the uptake of chemical by absorption from the water only (usually underlaboratory conditions), which can occur via the respiratory surface and/or the skin, and results in the chemical concentration in an aquatic organism being greater than that in water. The bioconcentration factor (BCF) is defined as the ratio of the chemical concentration in an organism C_B, to the total chemical concentration in the water C_{WT}, or to C_{WD}, the freely dissolved chemical concentration in water and is expressed as follows:

$$BCF=C_B=C_{WT} \text{ or } C_B=C_{WD}$$

The use of C_{WD} is preferred because it only takes into account the fraction of the chemical in the water that is biologically available for uptake [26].

Bioaccumulation is the process which causes an increased chemical concentration in an aquatic organism compared to that in water, due to uptake by all exposure routes including dietary absorption, transport across respiratory surfaces and dermal absorption. Bioaccumulation can thus be viewed as a combination of bioconcentration and food uptake. The bioaccumulation factor (BAF) in fish is the ratio of the concentration of the chemical in the organism C_B to that in the water, similarly to that of BCF.

$BAF=C_B=C_{WT}$ or $C_B=C_{WD}$ [26]

The increase in concentration of a substance in a food chain (not an organism) is called as "Biomagnification" (Figure 2) [1,22,25,27-30]. The water environments contain more than one metal; therefore, an organism is exposed to several metals. The levels of the contaminants in the aquatic organisms can be changed by depending on the lifestyle, dietary habits, age, duration of exposure, and the concentration of the metals in the environment and body. There are also differences between the levels of tissues and organs (Figure 2) [13].

Biomagnification can be regarded as a special case of bioaccumulation in which the chemical concentration in the organism exceeds that in the organism's diet due to dietary absorption. A biomagnification factor (BMF) can be defined as the ratio of the concentration of chemical in the organism CB to that in the organisms diet C_A and can be expressed as:

$BMF=C_B=C_A$

It is probably more meaningful to express both concentrations on a lipid normalized basis. A problem obviously arises when defining BMFs when an organism has several food sources with different concentrations. Chemicals that bioaccumulate do not necessarily biomagnify [26].

The contaminants uptake mechanisms of the fish, by gills, directly go through the skin from the water and then absorption of the contaminated food or suspended particles in the water go to the digestive system. The contaminants are taken up mostly by the gills. The amount that is received through the skin is insignificant [31]. The toxic effects vary according to the characteristics of each contaminant and accumulated tissue. However, in general, they affect the multiple organs and systems. Two mechanisms are available on contaminants toxicity: enzyme inhibition and replacement with essential elements [2,13].

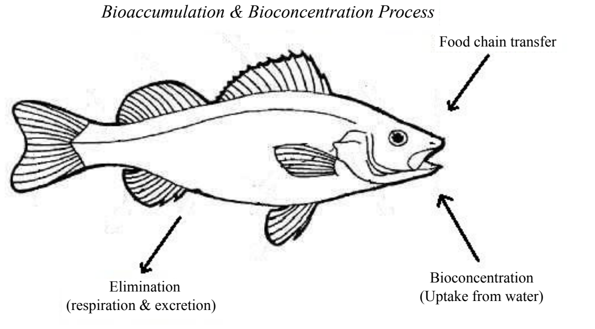

Figure 1: Illustration of Bioconcentration and Bioaccumulation [1,22,25].

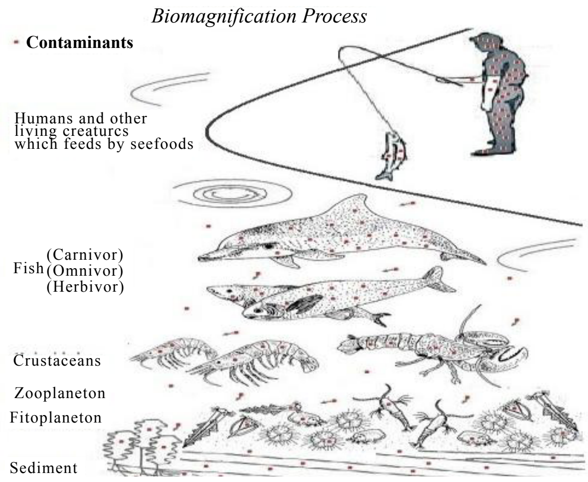

Figure 2: Illustration of Biomagnification [13].

The bioaccumulation and bioconcentration process are initiated with species (benthic, demersal, pelajic), feed habitat, age of bioindicators, exposure time to contaminants, the concentration and chemical characteristic of other contaminants. Also there is significant differences between tissues and organs accumulation or concentration [1,13].

The factors that led to contamination of environments like marine and disrupt the natural balance between organisms in ecosystem and must be monitored by markers can be classified as follows [32]:

- Metals (Al, As, Cd, Co, Cu, Fe, Hg, Ni, Pb, Se, Zn, etc.)
- Pesticides (organophosphorus, etc.)
- Halogenated compounds (chloral, brome, aromatic compounds, etc.);
- Halomethanes (chloroform, bromoform)
- Dioxins (TCDD, PCDD, HCDD, OCDD)
- Furans (TCDF, PCDF, HCDF, OCDF)
- Polychlorobiphenyls (PCB)
- Polybromobiphenyls (PBBs)
- Chlorophenols (PCP)
- Chlorinated naphthalenes (tetracloronaphthalen, etc.)
- Polyaromatic Hydrocarbons (PAHs)
- Nitrile compounds (acetonitrile, glyconitrile, etc.)
- N-Nitroso compounds (nitrosamines, etc.).

Conclusion

Chemical analysis provides baseline information on the occurrence of potentially toxic pollutants in the environment, but fails to predict synergistic, additive or antagonistic effects, that may give an important measure of potential biological effects. Biomarkers on the other hand can detect direct and indirect effects of sublethal concentrations of toxic pollutants and offer additional biologically and ecologically relevant information – a valuable tool for the establishment of guide lines for effective environmental management [33]. Biomarkers should therefore ideally be employed as part of an integrated programme of pollution monitoring, involving general measurements of biological damage and animal health in a variety of taxa as well as analysis of chemical contaminants in the biota and environment. The terms details and differences must be well known for successful monitoring of marine pollution by biologically.

References

1. Kaya S, Pirincci I, Bilgili A (2002) Toxicology in Veterinary Medicine (2ndedn), Medisan, Ankara.
2. Utku GÜNER (2008) Heavy metal effects on P, Ca, Mg, and total protein contents in embryonic pleopodal eggs and stage-1 juveniles of freshwater crayfish Astacus leptodactylus (Eschscholtz, 1823). Turk J Biol 34: 405-412.
3. Hartl MGJ (2002) Benthic fish as sentinel organisms of estuarine sediment toxicity. In: The Vienna School of Marine Biology: A Tribute to Jörg Ott. 89-100. Facultas Universitätsverlag, Wien.
4. Barwick M, Maher W (2003) Biotransference and biomagnification of selenium copper, cadmium, zinc, arsenic and lead in a temperate seagrass ecosystem from Lake Macquarie Estuary, NSW, Australia. Mar Environ Res 56: 471-502.
5. Rashed MN (2002) Biomarkers as indicator for water pollution with heavy metals in rivers, seas and oceans. South Valley University, Egypt.
6. Besler T (2005) Fish Consumption and Interaction of Health. Danone Institute Foundation of Turkey Research Bulletin 9: 5-8.
7. Eurostat (2009) Total Fishery Production. European Commission Eurostat.
8. FAO (2010) The State Of World Fisheries And Aquaculture.
9. Ozalp B (2008) Determination Of The Composition And Various Technological Properties Of Some Seafood Products. Selçuk University, Graduate School of Natural and Applied Sciences, Konya (Turkey).
10. Turan H, Kaya Y, Sonmez G (2006) Position in human health and food value of fish meat. JFAS (Electronic Journal) 23: 505-5087.
11. Bascinar NS (2009) Benthics creatures and bioindicator species. Central Fisheries Research Institute.
12. Taylan ZS, Ozkoc HB (2007) Bioavailibility of aquatic organisms in determination of potential heavy metal pollution. Journal of BAU FBE. 9: 17-33.
13. Vural N (2005) Toxicology. Publications of Ankara University Pharmacy Dep. No: 73.
14. Yaqin K, Lay BW, Riani E, Masud ZA, Hansen PD (2011) Hot spot biomonitoring of marine pollution effects using cholinergic and immunity biomarkers of tropical green mussel (Perna viridis) of the Indonesian waters. J Toxicol Environ Health Sci 3: 356-366.
15. Kazanci N, Girgin S (1998) Three Main Biological Approaches to Evaluation and Monitoring of Environmental Quality of Aquatic Ecosystems. Eastern Anatolia Region 3. Symposium of Aquaculture.
16. Köck G, Triendl MR, Hofer R (1996) Seasonal Patterns of Metal Accumulation in Arctic Char (Salvelinus alpinus) From An Oligotrophic Alpine Lake Related To Temperature. Can J Fish Aquat Sci 53: 780-786.
17. Zhou Q, Zhang J, Fu J, Shi J, Jiang G (2008) Biomonitoring: an appealing tool for assessment of metal pollution in the aquatic ecosystem. Anal Chim Acta 606: 135-150.
18. Depledge M, Amaral-Mendes JJ, Daniel B, Halbrook RS, Loepper-Sams P, et al. (1993) The conceptual basis of the biomarker approach. Biomarkers: Research and Application in the assessment of Environmental Health, NATO ASI Series H: Cell Biology. Springer Verlag, Berlin 68: 15-29.
19. Harris JRW, Cleary JJ, Valkirs AO (1996) Particle-water partitioning and the role of sediments as a sink and secondary source of TBT. In: Champ MA, Seligman PF (Eds.)., Organotin. Environmental fate and effects. Chapman & Hall, London: 459-474.
20. Anderson BS, Hunt JW, Hester M, Phillips BM (1996) Assessment of sediment toxicity at the sediment-water interface. In: Ostrander GK (Ed.)., Techniques in Aquatic Toxicology. CRC Lewis Publishers, Boca Raton: 609-624.
21. Abausamra F, Baric A, Civilli SF (2005) Transboundary Diagnostic Analysis for the Mediterranean Sea. UNEP. Mediterranean Action Plan. Med Pol, Global Environmental Facility.
22. Cincinnati Breast Canser and The Enviroment Research Center (2012) Glossary of Scientific and Medical Terms. University of Cincinnati.
23. Demers RY, Garabrandt D, Kamrin MA, Novak R, Richardson RJ (2003) Critical Review of a Proposed List of Toxic Substances to Biomonitor in Michigan Residents. Michigan Environmental Science Board Biomonitoring Investigation Panel.
24. Tugrul S, Kucuksezgin F, Yemenicioglu S, Uysal Z (2009) Med Pol Phase IV. Long-term Biomonitoring Trend and Compliance Monitoring Program in Aegean, Northern Mediterranean and Uetrofication Monitoring in Mersin Bay. Final report. Institute of Marine Sciences. Middle East Technical University.
25. Türe C, Candan M, Böcük H, Yücel H, Ketenoglu O, et al. (2009) Ecology (2ndedn), Anatolian University.
26. Mackay D, Fraser A (2000) Kenneth Mellanby Review Award. Bioaccumulation of persistent organic chemicals: mechanisms and models. Environ Pollut 110: 375-391.
27. EPA (2010) U.S. Environmental Protection Agency.
28. Macdonald DD, Ingersoll CG (2002) A Guidance Manual To Support The Assessment Of Contaminated Sediments in Freshwater Ecosystems. Volume I-An Ecosystem-Based Framework for Assessing And Managing Contaminated Sediments.
29. Nowell LH, Capel PD, Dileanis PD (1999) Pesticides in Stream Sediment and Aquatic Biota. Water Resources of the United States.
30. Yarsan E, Bilgili A, Sagmanligil H, Cetinkaya N (1995) The natural quality of Van Lake and the levels of some heavy metals in grey mullet (Chalcalburus tariehi, Pallas 1811) samples taken from this lake. Veterinary Journal of Ankara University 42: 445-450.
31. van der Oost R, Beyer J, Vermeulen NP (2003) Fish bioaccumulation and biomarkers in environmental risk assessment: a review. Environ Toxicol Pharmacol 13: 57-149.
32. Yipel M (2012) Determination of Some Heavy Metal Levels of Red Mullet (Mullus barbatus, Linnaeus, 1758), Grey Mullet (Mugil cephalus, Linnaeus, 1758) and Green Tiger Prawn (Panaeus semisulcatus, De Haan, 1844) Species Caught in the Gulf of Antalya Mediterranean Sea. Ankara University Institute of Health Sciences PhD Thesis.
33. Long E, MacDonald DD, Severn CG, Hong CB (2000) Classifying probabilities of acute toxicity in marine sediments with empirically derived sediment quality guidelines. Environ Toxicol Chem 19: 2598-2601.

This article was originally published in a special issue, **Biomarkers: Toxicology** handled by Editor(s). Dr. James V. Rogers, Wright State University, USA; Dr. Jagjit S. Yadav, University of Cincinnati, USA; Dr. Huixiao Hong, National Center for Toxicological Research, USA