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السمية البيئية لبعض الملوثات على الحيوانات المائية

إعـــــــداد

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الملخص

انتشرت في الآونة الأخيرة ظاهرة تلوث المسطحات المائية المختلفة من مصادر متعددة ، مما يهدد الأحياء المائية بالتسمم والهلاك ، وتعزى خطورة تلك الملوثات ليس فقط لسميتها العالية وإنما لطول بقائها في البيئة ، ويحدث تراكم للملوثات في أجسام الحيوانات المعرضة مباشرة من المحلول المحيط بها أو خلال سلاسل الغذاء ، كما ترجع زيادة سمية بعض الملوثات عن البعض الآخر إلى سرعة معدل اختراقها لسطح الجسم أكثر من تأثيرها على الأنسجة ، و هي قد تسبب تغيرات بيوكيميائية وفسيولوجية شديدة في الأحياء المائية الحساسة و بخاصة لمراحلها العمرية الصغيرة، ومع ذلك،تكتسب بعض الأنواع القدرة على التحمل التدريجي بفضل تعرضها المستمر لمستويات تحت مميتة من تلك الملوثات .

وبسبب تعرض الحيوانات المائية لبعض الملوثات تلفا غير منعكس للعديد من الوظائف المتراكبة كالنمو والتكاثر والسلوك ، مما يؤدي إلى فقد هائل للعشائر و الأنواع المعرضة. وزيادة على ذلك فإن العدوى الطفيلية يمكن أن تتزايد بسبب هبوط المناعة لدى العوائل المختلفة بفعل الملوثات المائية . وفي ذات الوقت تؤدي الملوثات عادة إلى تدمير العلاقات الغذائية التي تشمل التفاعل بين المفترسات و الفرائس ، و تعمل على الحد من أعداد المفترسات العليا ، فيختل التوازن البيئي بما يؤدي إلى تسارع انقراض الأنواع الحساسة ، و تهديد التنوع البيولوجي للفونه المائية في النهاية .

ECOTOXICITY OF SOME POLLUTANTS ON AQUATIC ANIMALS

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Abstract

Hazards of certain aquatic pollutants are not only due to their high toxicity but also to their longevity and persistence in the environment. Bioaccumulation of pollutants can occur from solution or through food chains. Greater toxicity of some pollutants than others can be attributed to their faster penetration rather than to their tissue affection. They may cause severe biochemical and physiological changes to sensitive organisms particularly their young stages. However, some species acquire gradual tolerance by frequent exposure to sublethal levels of these pollutants. On the other hand, parasitic infections can be enhanced due to immunity suppression of host species by the toxicity of some pollutants.

Moreover, exposure to aquatic pollutants cause irreversible damage to many integrated functions such as growth, reproduction and behavior of target animals that might eventually lead to detrimental loss of populations and species. Meanwhile, they can destroy trophic relations involving predator-prey interactions and thereby reduce top predators and impair the ecological balance. They eventually accelerate the extinction of vulnerable species with a negative impact on the biodiversity of the aquatic fauna.

Introduction

The dynamic interactions between aquatic organisms and their physico-chemical environment are crucial in maintaining the stability of their ecosystem. However, considerable variations occur usually in the aquatic fauna (density and composition) due to introduction of some pollutants that lead to devastating impacts. Once we observed an effect and related it to a particular pollutant, it is reasonable to assess its level of concentration. The hazards of certain aquatic pollutants are not only due to their high toxicity but also due to their longevity and persistence in the environment. They might cause several pathological and biochemical alterations in the aquatic organisms that can be structural and functional at the cellular and subcellular levels. However, some species can acquire gradual tolerance to the toxic effects of some pollutants by previous exposure to sublethal concentrations. Metal resistant strains of aquatic organisms have been collected from contaminated areas. Moreover, the usual exposure pattern of aquatic organisms to pollutants in the field is to oscillating rather than constant concentrations, thus allowing a chance for recovery, adaptation or avoidance of the stress, provided that the exposure concentration is not acute. Therefore, laboratory studies of continuous exposure to constant level of pollutants are seldom presented in the real life. Moreover, at subacute exposure, assessment of toxicity should be applied over the life- span to simulate variable responses of the target organisms under most environmental conditions. Furthermore, toxicants act in nature in combination with one another so that the dose response can be synergistic or antagonistic. Consequently, we should be cautious of drawing conclusions about the impact of a specific pollutant regardless of other components and ambient conditions of the environment.

Patterns of Response to Pollutants

According to Sheehan *et al* (1984), there are five patterns of organismal response to toxic pollutants:

1. Acute toxicity causing death,
2. Chronic accumulating damage ultimately causing death,
3. Sublethal impairment of various aspects of physiology and morphology,
4. Sublethal behavioral effects,
5. Measurable biochemical changes.

As the concentration of the toxic pollutant increases, the response rises as shown in general concentration response model (Fig. 1), where the effect represents a curve crossing 3 zones of response: non-measurable, measurable sublethal and lethal levels.

Assessing the impact of a specific toxicant on the ecosystem requires knowledge of the threshold for acute-lethal and critical chronic effects and their interactions determining the survival and propagation of organisms in that ecosystem.

Behavior of animals exposed to toxicants also plays a critical role in determining sublethal effects. Some animals such as fish can readily avoid toxicants by escaping from contaminated areas, others such as bivalves can close their shells for days. On the contrary, sedentary animals such as catfish, clams and some gastropods as well as other less motile animals have the ability to accumulate heavy metals to levels much higher than that in their environment (Ibrahim *et al*, 1997).

Bio-accumulation of pollutants can occur from solution or through food chains. The rate at which accumulation occurs depends on the concentration of the pollutant, environmental conditions and the ability of organisms to assimilate it.

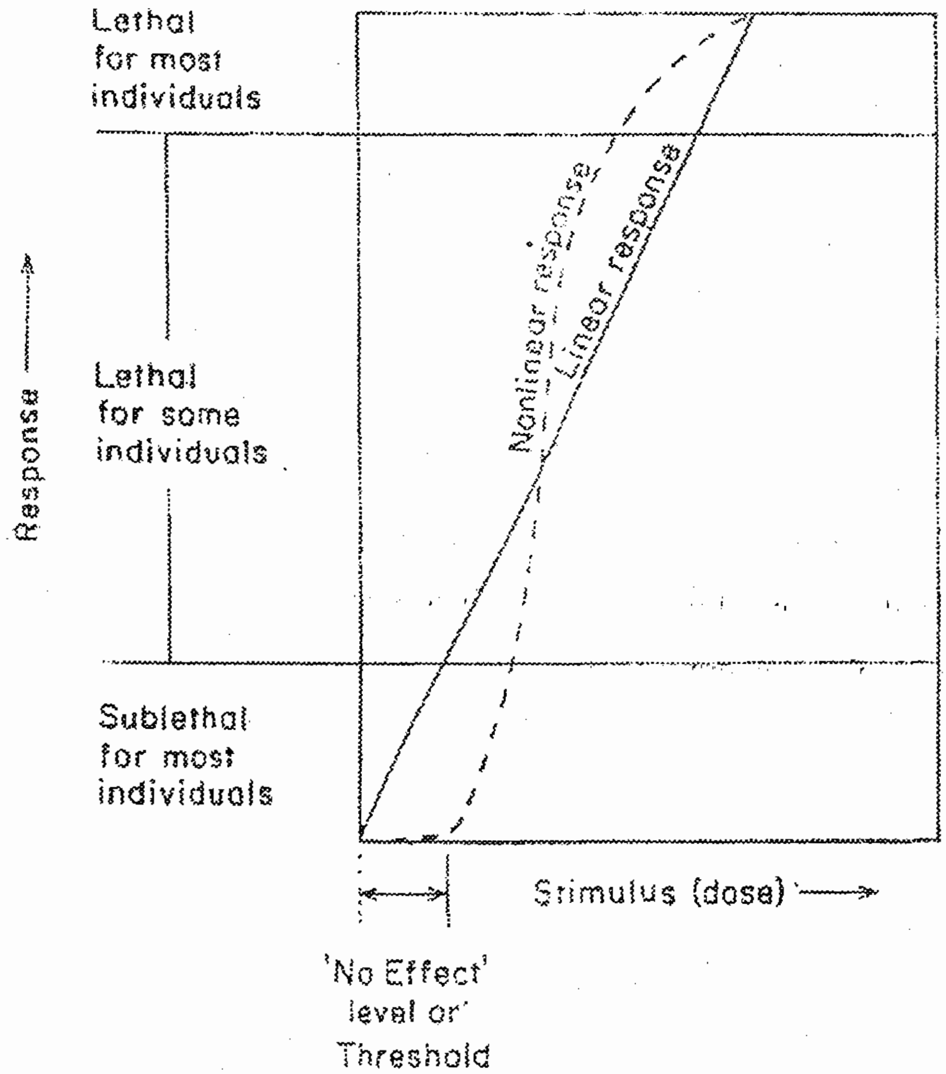

Figure 1. A generalized model of response to dose or concentration
(After Sheehan *et al*, 1984)

Root of Uptake:

A. From Solution

Movement of certain pollutants which are attributable to active transport systems have been largely observed in some protozoans, worms and echinoderms. In higher animals, movement of heavy metals can be mediated by carrier systems used primarily for Ca or Mg.

c

Absorption from solution by most animals seems to involve passive diffusion of the pollutant as a soluble complex down gradients created by adsorption at the surface (cuticle, tegument, epithelial covering etc..) and binding by constituents of the surface cells, body fluids and internal organs. This pattern holds for Zn, Mn, Cd, Cr in fish eggs, fish, many crustaceans, bivalves and polychaetes. The rate of metal absorption is directly proportional to the outer concentration, provided that permeability could not be controlled.

The greater toxicity of some pollutants than others can be attributed to their faster rate of penetration rather than their higher toxicity to tissues such as the more lipid soluble alkyl-mercury compounds that readily penetrate the epidermal cell membranes. Other factors such as levels of water salinity, hardness, pH, temperature, presence of complexing agents, status of target organisms (stage, vitality, starvation, etc..) play crucial role in the severity of toxicity of pollutants.

B. From Food

Most of the toxic pollutants are taken from food sources and become transported through trophic levels to be accumulated at the highest consumers. Variation among various aquatic animals in metal concentration could be attributed to their difference in feeding habits, where higher levels occur in detritus feeders and benthic inhabitants.

Uptake of some metals in the gut of some annelids, crustaceans, and fish was carried out readily without change. However, the ultimate level of accumulation depends on the internal processes of detoxification, excretion and storage. Some fish can regulate Zn and Cu levels in muscle and can metabolize aromatic hydrocarbons, while bivalve molluscs can not metabolize them and so their lipid contents are enormous. However, there seems to be an upper limit to the amount of excreted pollutants so their concentration increases with animal's size and age. How regulation is achieved is not clear, though there is enough evidence that the gills and kidneys partake in it. In contaminated lakes, the concentration grows linearly with size, suggesting an upper limit for excretion. The ability of many marine fish to excrete Hg is limited and its levels in tissues rise with age and size. This is the reason for highest levels of Hg in large specimens of tuna, sword fish and some sharks.

Detoxification And Storage

Temporary protection can be achieved by the binding capacity of compounds such as amino acids and polysaccharides. In some annelids and crustaceans, Zn, Cu, Fe granules were bound by amino acids and stored in the digestive gland or in the epidermal cells. In molluscs, wandering leukocytes play an important role in translocation and detoxification of metals. In oysters, accumulation of Cu by leucocytes gives the animal a greenish color.

On the other hand, Hg in sediment can be transformed into methyl mercury (by some bacteria) which is much more toxic than the metal to many freshwater organisms. However, demethylation was reported in some fish predators to an inorganic form. When the gut is the main route of excretion as in some crustaceans, metal contamination was largely removed when the animal was fed.

Increased metal concentration in liver of many fish may represent a storage site, where detoxification occurs mainly due to metallothionin formation. (Hamza *et al*, 1996).

Development Of Tolerance

In some aquatic animals, increased tolerance to the toxic effects of some pollutants can be acquired by previous exposure to sublethal concentrations. Moreover, metal resistant strains of aquatic species have been collected from contaminated areas. Tolerance of some forms have been observed to many pollutants though development for each element may arise separately or in coexistance. Organismal tolerance and adaptability to pollutants was found to be genetically determined. However, many tolerant organisms contain manifold the normal concentrations of various pollutants and these may be transmitted to non-adapted predators including man causing serious disorders.

Biological Impacts

Most pollutants exert toxic effects at a functional level by reacting with enzymes or metabolites or by binding and interacting with membrane structures or subcellular components. Such interactions may induce a series of alterations that can eventually impair vital functions such as nerve and muscle interaction, circulation, respiration, immune defense or gamete formation. Such changes can extend to many integrated functions such as behavior, growth and survival of target organisms which eventually can lead to detrimental loss of populations and the community.

Young developmental stages of organisms are regarded as being too sensitive to toxic effects and so can affect the reproductive capacity of the species. The use of eggs or larval forms for evaluating the toxicity of chemicals and effluents is therefore considered ecologically sound. The impact of an oil spill on some soft bottom crustaceans led to abnormal eggs and deformed embryos.

Pathological Changes

Water pollutants can cause or enhance several pathological changes in the aquatic fauna other than skin erosion such as ulceration, atrophy, hyperplasia as well as cellular and tissue aberrations commonly reported in contaminated fish. Tissue analysis of fish with fin erosion indicated an association between DDT and PCB levels and the disease. Moreover, benthic fish recovered from lakes contaminated with coal combustion wastes showed severe skin erosion (Hopkins *et al*, 2003). Crustaceans grown in polluted habitats, exhibit a syndrome known as "shell disease" and can serve as bio-indicator of a degrading environment. Affected animals suffer from a dark erosion on the exoskeleton that can cover most of the body.

Acute sensitivity to specific toxicants differs more among different species than among individuals of the same species, but it varies greatly among different life stages. Chronic lesions may be either progressive or regressive, depending on toxicant level and exposure. Even when an appropriate species is chosen for any bioassay study, it's acute or chronic responses to pollutants vary according to several factors including salinity, temperature, pH, oxygen content, genetic status, resistance and synergism among toxicants.

Pollutants And Parasitism

Pollutants may have an indirect effect on the prevalence and intensity of parasitic infections without directly affecting the host. Some helminth infections become greatly reduced in polluted water, while others increase as the susceptibility of the host becomes affected. Therefore, pollutants can act as an irritant to the host fish, reducing their resistance to infestations. Such process occurs commonly in the local aquatic fauna, that are suffering from suppression of immunological competence and host resistance to most of the infective organisms (Overstreet,1988).

Population impact

Indices which best reflect individual performance and are most related to population fitness are growth and reproductive success. Recent studies have reported reduced growth rates in macro-invertebrates at sublethal levels (Ibrahim *et al*,1998). On the other hand, the long-term impact of pollutants on any exposed population can be revealed on a series of embryonic and growth processes. The failure or inability of an organism to pass successfully over the above processes would lead to its population decline.

Populations exposed to grossly polluted discharges became sexually sterile the next reproductive season. Oil industry wastes can suppress sperm motility and interfere with fertilization in some animals. Sublethal levels of some heavy metals are toxic to gemetes and fertilization of fish eggs. Moreover, toxic pollutants can impair the normal function of a species, alter its trophic relations regarding the predator-prey interactions and thereby affect the organization of the ecosystem. They can lead to drastic reduction of predator populations resulting in much prey abundance. The reduction of zooplankton grazing pressure caused by toxic pollutants is usually followed by phytoplankton blooms.

Community Dynamics

The dynamics of community structure into a larger framework of integrated eco-toxicological assessment is shown in figure 2. Reduction in biomass, abundance, taxonomic and trophic diversity indices indicates a disruption in the community structure due to toxic pollutants. A time series of changes in these structural indices after introduction of a pollutant reflect trends in reorganization (Sheehan *et al*, 1984).

In lakes, the great influx of organic pollutant initially produces prolific growth of algae leading to artificial eutrophication of ecosystem. This creates a decaying habitat with greater number of bacteria that help deplete water oxygen, causing massive death of fish and other biota, where the ecosystem becomes lifeless. A nearly similar situation was reached in Lake Manzala in the 1980's, where some sensitive fish disappeared while other tolerant species took over.

The continuous reduction of stressed populations can accelerate species extinction and decline the biodiversity. The loss of fish populations has profound impacts on the lake ecosystem, since top consumers contribute to the regulation of energy and nutrient turn over, as well as to the maintenance of the community composition of zooplankton and benthic invertebrates.

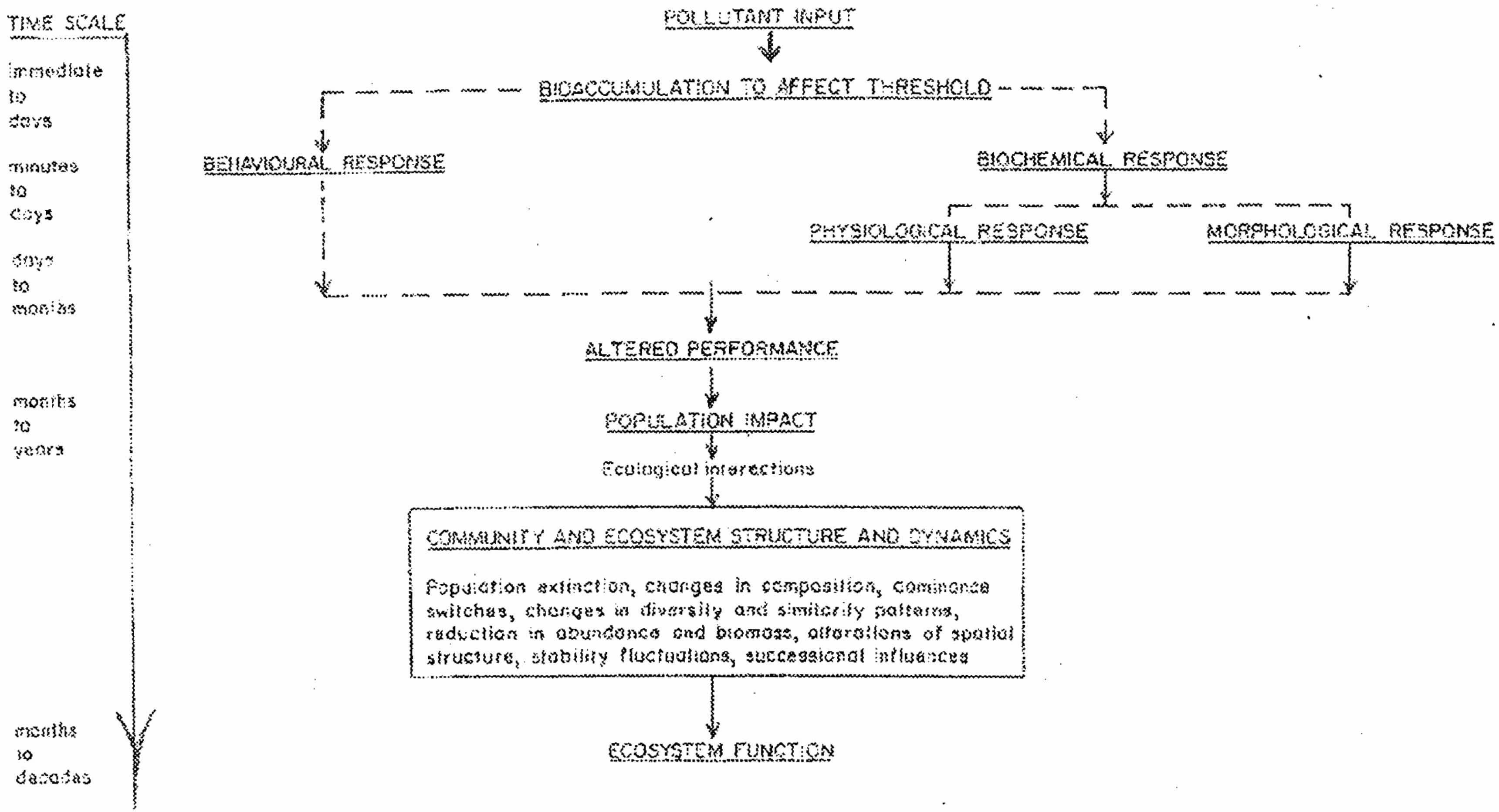

Figure 2. A conceptual chronology of induced effects following exposure to toxic pollutants, emphasizing changes in community and ecosystem structure and dynamics. (After Sheehan *et al*, 1984)

Biodiversity Response

The idea of the adverse impact of pollution on biodiversity is receiving a wider support (Howell, 1990;Khalil, 1995;Nilsson and Grelsson, 1995and Tilman, 1996)

The indices of pollutant effects on biodiversity include species richness (number of species) and evenness (distribution of all individuals among species. However, the former index is a more reliable measure to pollutant concentration and has a significant relation with the structural integrity of the ecosystem, while the latter (species richness) has a limited value in defining the severity of pollutant stress.

Many reports have documented considerable reduction in species richness in response to long and short-term exposure to toxic pollutants. Such reduction may involve key species, which support other related species and so combined extinction can eventually occur.

In conclusion, most of the local aquatic ecosystems are suffering at present from the growing concentration of toxic pollutants that arise from various sources. This involves an ever-increasing stress over the entire living organisms especially in lakes. It can lead to a continuous reduction of biodiversity, where the lake species are particularly vulnerable to extinction, because of their limited populations and restricted habitats, where migration, replacement and recovery are almost impossible. In order to help minimize the overwhelming pollution impact in our inland and coastal waters and to save their invaluable fauna, proper drainage water management should be established. (Ibrahim *et al*, 1999).

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