Journal of Advances in Science and Technology

Vol. VIII, Issue No. XVI, February-2015, ISSN 2230-9659

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AN INTERNATIONALLY INDEXED PEER REVIEWED & REFEREED JOURNAL

Journal of Advances in Science and Technology
Vol. VIII, Issue No. XVI, February-2015, ISSN 2230-9659

A Study on the Concept of Bio-magnification

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Abstract – Bio-magnification also known as bio-amplification or biological magnification occurs when the concentration of a substance, such as DDT or mercury, in an organism exceeds the background concentration of the substance in its diet. This increase can occur as a result of:

- ***Persistence – where the substance can't be broken down by environmental processes.***
- ***Food chain energetics – where the substance concentration increases progressively as it moves up a food chain.***
- ***Low or non-existent rate of internal degradation or excretion of the substance – often due to water-insolubility.***

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INTRODUCTION

Biological magnification often refers to the process whereby certain substances such as pesticides or heavy metals move up the food chain, work their way into rivers or lakes and are eaten by aquatic organisms such as fish, which in turn are eaten by large birds, animals or humans. The substances become concentrated in tissues or internal organs as they move up the chain. Bio-accumulants are substances that increase in concentration in living organisms as they take in contaminated air, water, or food because the substances are very slowly metabolized or excreted.

The following is an example showing how bio-magnification takes place in nature: An anchovy eats zoo-plankton that has tiny amounts of mercury that the zoo-plankton has picked up from the water throughout the anchovies lifespan. A tuna eats many of these anchovies over its life, accumulating the mercury in each of those anchovies into its body. If the mercury stunts the growth of the anchovies, that tuna is required to eat more little fish to stay alive. Because there are more little fish being eaten, the mercury content is magnified.

Although sometimes used interchangeably with "bioaccumulation", an important distinction is drawn between the two, and with bio-concentration.

- Bioaccumulation occurs within a trophic level, and is the increase in concentration of a substance in certain tissues of organisms' bodies due to absorption from food and the environment.
- Bioconcentration is defined as occurring when uptake from the water is greater than excretion.

Thus, bio-concentration and bioaccumulation occur within an organism, and bio-magnification occurs across trophic (food chain) levels.

Biodilution is also a process that occurs to all trophic levels in an aquatic environment; it is the opposite of bio-magnification, thus a pollutant gets smaller in concentration as it progresses up a food web.

Lipid (lipophilic) or fat soluble substances cannot be diluted, broken down, or excreted inurine, a water-based medium, and so accumulate in fatty tissues of an organism if the organism lacks enzymes to degrade them. When eaten by another organism, fats are absorbed in the gut, carrying the substance, which then accumulates in the fats of the predator. Since at each level of the food chain there is a lot of energy loss, a predator must consume many prey, including all of their lipophilic substances.

For example, though mercury is only present in small amounts in seawater, it is absorbed by algae (generally as methylmercury). It is efficiently absorbed, but only very slowly excreted by organisms. Bioaccumulation and bio-concentration result in buildup in the adipose tissue of successive trophic levels: zooplankton, small nekton, larger fish, etc. Anything which eats these fish also consumes the higher level of mercury the fish have accumulated. This process explains why predatory fish such as swordfish and sharks or birds like osprey and eagles have higher concentrations of mercury in their tissue than could be accounted for by direct exposure alone. For example, herring contains mercury at approximately 0.01 parts per million (ppm) and shark contains mercury at greater than 1 ppm.

REVIEW OF LITERATURE

In a review of a large number of studies, Suedel et al. concluded that although bio-magnification is probably more limited in occurrence than previously thought, there is good evidence that DDT, DDE, PCBs, toxaphene and the organic forms of mercury and arsenic do bio-magnify in nature. For other contaminants, bio-concentration and bioaccumulation account for their high concentrations in organism tissues. More recently, Gray reached a similar substances remaining in the organisms and not being diluted to non-threatening concentrations. The success of top predatory-bird recovery (bald eagles, peregrine falcons) in North America following the ban on DDT use in agriculture is testament to the importance of bio-magnification.

DDT is thought to bio-magnify and bio-magnification is one of the most significant reasons it was deemed harmful to the environment by the EPA and other organizations. DDT is stored in the fat of animals and takes many years to break down, and as the fat is consumed by predators, the amounts of DDT bio-magnify. DDT is now a banned substance in many parts of the world

There are two main groups of substances that bio-magnify. Both are lipophilic and not easily degraded. Novel organic substances are not easily degraded because organisms lack previous exposure and have thus not evolved specific detoxification and excretion mechanisms, as there has been no selection pressure from them. These substances are consequently known as "persistent organic pollutants" or POPs.

Metals are not degradable because they are elements. Organisms, particularly those subject to naturally high levels of exposure to metals, have mechanisms to sequester and excrete metals. Problems arise when organisms are exposed to higher concentrations than usual, which they cannot excrete rapidly enough to prevent damage. Some persistent heavy metals are especially harmful to the organism's reproductive system.

BIOMAGNIFICATION AND FOOD-WEB ACCUMULATION

Organisms are exposed to a myriad of chemicals in their environment. Some of these chemicals occur in trace concentrations in the environment, and yet they may be selectively accumulated by organisms to much larger concentrations that can cause toxicity. This tendency represents bio-magnification.

Some of the biomagnified chemicals are elements such as selenium, mercury, nickel, or organic derivatives such as methylmercury. Others are in the class of chemicals known as chlorinated hydrocarbons (or organo-chlorines). These are extremely insoluble in water, but are freely soluble in organic solvents, including animal fats and plant oils (these are collectively known as lipids). Many of the chlorinated hydrocarbons are also very persistent in the environment, because they are not easily broken down to simpler chemicals through the metabolism of microorganisms, or by ultraviolet radiation or other inorganic processes. Common examples of bio-accumulating chlorinated hydrocarbons are the insecticides DDT and dieldrin and a class of industrial chemicals abbreviated as PCBs.

Food-web accumulation is a special case of bio-magnification, in which certain chemicals occur in their largest ecological concentration in predators at the top of the food web. An ecological food web is a complex of species that are linked through their trophic interactions, that is, their feeding relationships. In terms of energy flow, food webs are supported by inputs of solar energy, which is fixed by green plants through photosynthesis. Some of this fixed energy is used by the plants in their own respiration, and the rest, as plant biomass, is available to be passed along to animals, which are incapable of metabolizing any other type of energy. Within the food web, animals that eat plants are known as herbivores. These are eaten by carnivores, which in turn may be eaten by other carnivores. Top predators (examples include wolves, bears, and seals) occur at the summit of the food web. In general, food webs have a pyramidal structure, with plant productivity being much greater than that of herbivores, and these being more productive than their predators. Top predators are usually quite uncommon. Within food webs, biomagnifying chemicals such as DDT, dieldrin and PCBs have their largest concentrations, and cause the greatest damage, in top predators.

All of the naturally occurring elements occur in the environment. Some occur at very low concentration, while others are more abundant. This contamination is always detectable, as long as the analytical chemistry method of detection is sensitive enough to detect even trace amounts of the target chemical. About 25 of the elements are required by plants and/or animals, including the micronutrients copper, iron, molybdenum, zinc, and rarely, aluminum, nickel, and selenium. However, under certain ecological conditions these micronutrients can bio-magnify to very large concentrations, and even cause toxicity to organisms.

One example is serpentine soil and the vegetation that grows in it. Serpentine minerals contain relatively large concentrations of nickel, cobalt, chromium, and iron. Soils derived from this mineral can be toxic to plants. However, some plants grown on serpentine soils are physiologically tolerant of these metals, and can bio-accumulate them to very large concentrations. For example, the normal concentration of nickel in plants is about 1-5 ppm (parts per million, a concentration equivalent to mg/kg). However, on sites with serpentine soils much larger concentrations of nickel occur in plant foliage and other tissues. Nickel concentrations as large as 16% occur in tissues of a plant in the mustard family, *Streptanthus polygaloides,* in California and 11-25% nickel occurs in the blue-colored latex of *Sebertia acuminata* on the island of New Caledonia in the Pacific Ocean. It is common for plants growing on serpentine soils to have nickel concentrations of thousands of parts per million, which is usually considerably larger than the concentration in soil.

Another case of bio-magnification occurs on some sites in semiarid regions in which the soil is contaminated by selenium, which may then be hyper-accumulated (i.e., extremely accumulated) by specialized species of plants. These plants are poisonous to grazing livestock and other large animals, causing a toxic reaction called "blind staggers." The most important selenium-accumulating plants in North America are milk vetches in the genus *Astragalus,* in the legume family. There are 500 species of *Astragalus* in North America, of which 25 are accumulators of selenium. The foliage of these plants can contain thousands of parts per million (ppm; equivalent to 1 milligram per liter) of selenium, to a maximum of about 15,000 ppm, much larger than the concentration in soil. Sometimes, accumulator and non-accumulator *Astragalus* species grow together, as in the case of a place in Nebraska with 5 ppm selenium in soil, and 5,560 ppm in *Astragalus bisulcatus* but only 25 ppm in *A. missouriensis.*

Mercury can also be biomagnified from trace concentrations in the environment. In this case, trace concentrations of mercury in water can result in large contaminations of fish and other predators. For example, fish species known to bioaccumulate mercury in offshore waters of North America include Atlantic swordfish, Pacific blue marlin, tunas, and halibut, among others. These fish can accumulate mercury from trace concentrations in seawater (less than 0.1 ppm) to concentrations in flesh that commonly exceed 0.5 ppm of the fresh weight of the fish, the maximum acceptable concentration in fish for human consumption. The contamination of oceanic fish by mercury is probably natural, and is not only a modern phenomenon. Studies have found no difference in mercury contaminations of modern tuna and museum specimens collected before 1909, or concentrations in feathers of pre-1930 and post-1980 seabirds collected from islands in the northeast Atlantic Ocean. In this phenomenon of mercury bio-magnification, there is a tendency for larger, older fish to have relatively large concentrations. In a study of Atlantic swordfish, for example, the average mercury concentration of animals smaller than 51 lb (23 kg) was 0.55 ppm, compared with 0.86 ppm for those 51-99 lb (23-45 kg) in weight, and 1.1 ppm for those heavier than 45 kg. Large concentrations of mercury also occur in fish-eating marine mammals and birds that are predators at or near the top of the marine food web.

REFERENCES

- Jorgensen SE and Fath B (2008) Encyclopedia of Ecology Volume 1, Newnes. ISBN 9780080914565. Page 442.
- Landrum, PF and SW Fisher, 1999. Influence of lipids on the bioaccumulation and trophic transfer of organic contaminants in aquatic organisms. Chapter 9 in MT Arts and BC Wainman. Lipids in fresh water ecosystems. Springer Verlag, New York.
- Croteau, M., S. N. Luoma, and A. R Stewart. 2005. Trophic transfer of metals along freshwater food webs: Evidence of cadmium biomagnification in nature. Limnol. Oceanogr. 50 (5): 1511-1519.
- EPA (U.S. Environmental Protection Agency). 1997. Mercury Study Report to Congress. Vol. IV: An Assessment of Exposure to Mercury in the United States . EPA-452/R-97-006. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Research and Development.
- http://www2.epa.gov/aboutepa/ddt-ban-takes-effect
- Suedel, B.C., Boraczek, J.A., Peddicord, R.K., Clifford, P.A. and Dillon, T.M., 1994. Trophic transfer and biomagnification potential of contaminants in aquatic ecosystems. Reviews of Environmental Contamination and Toxicology 136: 21–89.
- Gray, J.S., 2002. Biomagnification in marine systems: the perspective of an ecologist. Mar. Pollut. Bull. 45: 46–52.