An Overview of Organotin in the Marine Environment

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ABSTRACT

A very adaptable class of organometallic compounds the organotin are employed in both industrial and agricultural settings. The aquatic environment is contaminated by leaching and discharge from the increased usage of substances like agricultural pesticides that contain organotin. The detection of organotin compounds in environmental sample points to a significant rise in the usage of items containing organotin, which has an adverse effect on all aspects of ecosystems and has resulted in a worldwide ban on its use. Many studies have been conducted on the presence of organotin compounds in environmental sample data. The origin, health risks and speciation of organotin chemicals to humans are covered in this publication. Numerous types of organotin compounds have been detected in a range of environmental samples, despite the primary theory regarding the sources being the use of these compounds as biocides in antifouling paints. The use of organotin compounds as fungicides, glass coatings, catalysts and PVC thermos-stabilizers are the primary sources of these pollutants. People may be exposed to organotin compounds through the accumulation of these compounds in sea sediment or marine life, such as fish, shells and squid. The predominance of parent chemicals (tributyltin and triphenyltin) in sediment, biota and seawater samples may be a sign of recent imports and their slow breakdown. Organotin compounds such as triphenyltin, tributyltin, dibutyltin and methyl butyltin are less prevalent in developed countries than in developing ones because the health risks related to their use are managed. Therefore, it is imperative to monitor for organotin contamination from large shipping vessels.

KEYWORDS: Organotin, Bioaccumulation, Bioremediation.

INTRODUCTION

The industrial use of organotins such as butyltins (BTs) and phenyltins (PTs), has increased dramatically over the last 20 years. The production of poly-vinyl chloride (PVC) has extensively employed synthetic, multifunctional compounds, referred to as BTs and PTs, as stabilisers (Blunden et al., 1984; Hoch, 2001, Jonny beyer et al.,2022 and zhakovskaya et al., 2024). Organotins (OTs), particularly paints containing tributyltin (TBT) and triphenyltin (TPT), are highly efficient antifouling chemicals that shield ship hulls from fouling for nearly three to five years (Hoch, 2001). However, because TBT disrupts hormones, it is extremely toxic and can lead to high larval mortality, shell deformation, cell growth retardation, imposex and other problems in oysters, gastropods, and other invertebrates (Fent, 1996). Oysters, clams, fish and other higher organisms bioaccumulate organic pollutants. At concentrations of up to 100 ngL1, TBT can fatally affect fish immune systems and impair the normal functioning of the immune system in mammals (Kannan et al., 1995). When inhaled, OTs can cause headaches, vomiting and irritation of the skin and respiratory tract, among other effects on people. The survival of thymocytes which are vital components of human immunity against tumours and virally-infected cells in human bodies and natural killer cells (NK cells) are lymphocytes produced by the endocrine gland thymus are known to be impacted by OTs, especially BTs (Kannan et al., 1995 and Hoch, 2001).

SECTION SNIPPETS

ORGANOTIN

Tin is an element found in a wide variety of inorganic and organometallic compounds. Organometallic tin compounds or organotins are characterised by the presence of at least one covalent carbon-tin bond. Tetravalent structures are found in almost all organotins even though tin can exist in the Sn 2+ or Sn 4+ oxidation states. The number of organic moieties in the mono-, di-, tri- and tetraorganotin compounds determine their classification. Methyl, butyl, octyl and phenyl groups are the organic substituents in compounds of industrial importance; the anion is usually one of the following: hydroxide, carboxylate, thiolate, fluoride, oxide or chloride. All of the alkyltin compounds that are covered in this article consist of unbranched saturated hydrocarbons (n-alkyltins) in their side chains (N. J. SNOEIJ, et al. 1987).

SOURCE OF ORGANOTIN IN THE MARINE ENVIRONMENT

Organotin compounds (OTCs) are metal–organic compounds of tin combined with carbon and are thought to be among the most hazardous substances that humans have released into the marine environment (Champ, 2000, Shu et al., 2023 and Bajt et al., 2024). In the 1970s, environmental agencies worldwide started to take an interest in the increasing use of organotin compounds and the resulting contamination of the aquatic environment. Sewage sludge, municipal and industrial wastewater and antifouling paints are the primary source of organotin compounds in the marine environment according to Fent and Muller (1991). Because aquatic organisms are extremely sensitive to these compounds and because they are used as antifouling agents that come into direct contact with aquatic environments, triphenyltin (TPI) and butyltin (TBT) compounds are the most dangerous of the many organotin currently in use (Bock, 1981; Farm Chemicals Handbook, 1987). For instance, these compounds can be found in fungicides and insecticides used in agriculture, industrial impregnation of textiles, and most importantly—biocides used in antifouling paints on seagoing ships' hulls and fish cages in mariculture sites (Hoch, 2001). OTs are discharged from partially treated sewage effluents, runoff from agricultural fields, and direct leaching from antifouling paints into the marine environment. These pollutants are subsequently exposed to the organisms residing in these environments (Fent, 1996 and Sham et al., 2020).

THE IDEA BEHIND BIOREMEDIATION

Recently, there has been a rise in interest in the microbial biotransformation/biodegradation of pollutants as a means of identifying sustainable solutions for cleaning up contaminated environments. Bioremediation and biotransformation techniques utilise the diversity of microbial catabolism to break down, change, or accumulate a wide range of substances, including hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), xenobiotics, etc (Alexander 1999). Recent significant advances in methodology have made it possible to conduct in-depth analyses of native microorganisms, which have shed light on important biotransformation pathways and the capacity of organisms to adapt to shifting environmental conditions (Shah and Dahanukar 2011).

ORGANOTIN BIOREMEDIATION

Tolerating OTs, bacteria have evolved a variety of highly effective mechanisms (Trevors et al. 1985). Normal toxic levels of OT frequently have no effect on these tolerant organisms' ability to grow cells. The following explanations (Cruz et al. 2007) may account for the mechanisms underlying bacteria's tolerance to OT:

1) Transformation of OTs to less toxic compounds.
2) Exclusion of OTs from cell mediated by a multidrug efflux pump.
3) Degradation/ utilization as a carbon source.
4) Bioaccumulation into cell without breaking down.

POTENTIAL OF BIOREMEDIATION OF ORGANOTIN

According to Suzuki et al. (1992), nearly 90% of the bacterial flora in naturally occurring seawater is resistant to TBT-CI and is primarily composed of Vibrio species. It was discovered that *Alteromonas sp*., one of the cultures, was tolerant to 250 nm TBT-CI (Suzuki et al. 1992). Most reports state that chromosomal genes give bacteria their OT resistance (Suzuki et al. 1994, Suzuki and Fukagawa 1995). The existence of operon TbtABM homologus to RND multidrug efflux pump was responsible for the *Pseudomonas stutzeri* 5MP1 isolate's resistance to 1000 mg L'1 of TBT in the sediments of Arcachon Harbour (Jude et al. 2004). According to Cruz et al. (2007), *Aeromonas veronii* isolated from a Portuguese estuarine environment was resistant to 3 mM TBT (Miller et al.1995), however, demonstrated that plasmid-mediated OT resistance in bacteria is possible.

DIFFICULTIES WITH BIOREMEDIATION

When it comes to naturally heterotrophic populations, OT compounds are toxic. According to a study by Pettibone and Cooney (1986), plate counts and the incorporation of 3H-thymidine indicate that Me2SnCI2 was toxic to microbial populations in sediments from Boston Harbour. TPT-CI at 0.84 pM concentration killed pure cultures of *Streptococcus faecalis*. It is noted that both bacteria and OT molecules can be concentrated on suspended particles and on sediments, which would expose bacteria to higher concentrations of OTs, even though these concentrations are higher than those reported in environmental samples. Furthermore, in the aquatic environment, stress brought on by OTs may interact with other stressors (Pettibone and Cooney 1986).

CONCLUSION

Native microorganisms in contaminated environments frequently lack the capacity to break down harmful substances and xenobiotics with highly substituted or particularly unique chemical structures (Pipke et al. 1992). The bioremediation of organotin-contaminated sites mediated by microbes is far from a real large-scale commercial process, despite the fact that microorganisms have been shown to bioremediate heavy metal and aromatic hydrocarbon of polluted sites. This is because very little research has been done to explore the exact biochemical mechanism of organotin biodegradation and genes involved in the process. Thus, using molecular biological and genetic techniques, intensive research is needed to clarify the mechanism of TBTC bioaccumulation, biodegradation, and bioremediation in TBTC-resistant marine bacteria (Sambrook et al. 1989).

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