Biodegradation, an Environmental Solution to Some Toxic Organic Compounds

by

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ENVIRONMENTAL IMPACT

Highly valued for their insulating and other properties, polychlorinated biphenyls (PCBs) have, until recently, found extensive use in industry—*inter alia* as dielectric fluids in transformers, as hydraulic fluids in heavy machinery, and in formulations for paint and ink. Unfortunately, their stability increases their importance as pollutants; indeed, as they do not break down at all easily in the natural environment, high concentrations of PCBs have accumulated at various levels in the food-chains in our ecosystems. For this reason, the Monsanto Company, the sole U.S. producer of PCBs, has voluntarily restricted the sale of PCBs to those electrical industries that use them in 'closed' systems. Despite these restrictions, however, the concentrations of PCBs in foods-chains are not decreasing at all rapidly.

A search of the literature reveals that only a handful of research workers are actively studying the biodegradation of PCBs and that we still know rather little about the manner in which they are degraded in the environment.

BIODEGRADATION PROCESSES

In view of the paucity of knowledge concerning the persistence of these toxic organic compounds in the environment, and in the hope that it will stimulate additional research in this field, I would like to describe briefly the work that has been performed in the Biodegradation Laboratory of the Canada Centre for Inland Waters on the biodegradation of PCBs. Theoretically, all organic compounds are subject to biodegradation, regardless of whether they occur naturally or have been chemically synthesized. In order for a compound to be biodegraded, the right microorganisms must be present at the right time and under the right conditions.

Two distinct types of biodegradation occur in the environment in terms of the relative solubility of the compounds concerned; these are referred to as the homogeneous and heterogeneous biodegradation processes, respectively. In the former process, the substance to be tested is easily soluble in water and its concentration in the aqueous phase is well above those concentrations which could limit microbial growth. In the latter process, the substance to be tested is virtually insoluble in water and its solubility in the aqueous phase is thus the limiting factor. Unfortunately, most of the persistent toxic organic compounds, such as PCBs and DDT, fall into this second category, thus enhancing their persistence in the natural environment. For example, PCB Aroclor 1254 has a solubility of 0.1 μg l^{-1} (Schoor, 1975). The ability of Bacteria to use the soluble portion of PCBs in the aqueous phase is therefore remote. Our recent studies in this Laboratory have indicated that the rate of heterogeneous biodegradation can be greatly increased if the substance to be tested is suspended as a fine stable emulsion in an aqueous phase.

COMPLEXITY OF BIODEGRADATION

Another problem encountered in the study of the biodegradation of persistent toxic organic substances is the high oxygen demand of the degrading microorganisms. These persistent substances differ from the more common pollutants which are already partially oxidized—for example, protein and carbohydrates—in that they contain little or no oxygen. Thus the need for the cell to produce the same essentials, regardless of the carbon source, requires that the degrading microorganisms have a ready access to an adequate supply of oxygen. Caution must be used, however, in employing theoretical mathematical models to predict the very complicated biodegradation processes. For example, theoretical calculations have indicated that three times as much oxygen is required for petroleum degradation processes as for carbohydrate degradation (Humphrey, 1967). In practice, however, it was found that active degradation of petroleum hydrocarbons could be carried out with less than 0.5 ppm dissolved oxygen in the growth medium

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(Hepple, 1971). This occurred because hydrocarbon dispersion rather than the oxygen-dissolution rate was the factor limiting microbial growth in the petroleum degradation process (Blakebrough *et al.*, 1967). The high mixing-energy required for the treatment of industrial waste-water is more likely to create a larger substance–water interface for the microorganisms.

MECHANISM OF BIODEGRADATION

By using a specific strain of PCB-degrading Bacteria, which had been isolated from sewage sludge and examined with both light and scanning electron microscopes, it has been possible to show that the primary site of PCB-biodegradation is actually the PCB–water interface. This initial PCB–water interfacial area is the true microbial growth-limiting factor which governs the subsequent rate of PCB degradation. In order to accelerate the rate of PCB biodegradation, sufficient PCB–water interfacial area must be provided at an early stage in the microbial growth-medium to supply sufficient accessible substrate to the microorganisms. This is accomplished by using ultrasonification to make a fine emulsion of PCBs and then having the emulsion stabilized by addition of lignin derivatives, such as lignin sulphonate. By using this new technique, a highly chorinated biphenyl, such as Aroclor 1254, can be reduced in one week from concentrations of 300,000 ppb to little more than 20 ppb. The presence of other nutrient organic compounds, such as glucose and sodium acetate, did not interfere with the rate of PCB degradation by these substrate-specific Bacteria. Moreover, these Bacteria could oxidize PCBs over a wide range of temperature (4° to 35°C).

This discovery is likely to be most applicable in the treatment of industrial wastes containing PCBs. Although it may not answer the problem of PCBs that are already dispersed in the environment, the new technique may have some application in the treatment of various other toxic organic compounds. I hope this short paper will serve to open up a possible new approach to our understanding of the mechanism of the biodegradation of persistent toxic organic substances in the environment.

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SUMMARY

The failure of conventional waste-treatment methods to solve problems associated with complex industrial wastes, suggests that we must re-examine our approach to this problem. Two distinct types of biodegradation, homogeneous and heterogeneous, have been recognized to occur in the environment and are distinguished according to the solubility or insolubility, respectively, of the compound involved. Unfortunately, many of the most persistent toxic compounds fall into the second or insoluble category, and conventional treatment processes are inefficient in dealing with them.

Our studies have shown that the primary site of the biodegradation of these persistent compounds is at the substance–water interface and that the rate of such biodegradation can be greatly increased if the tested compound can be suspended in an aqueous phase as a fine stable emulsion. Our recent work on PCB biodegradation exemplifies the benefit of a multidisciplinary approach in solving environmental problems, and supports the need to continue fundamental research in such areas of applied environmental science.

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Seychelles Asked to Continue Marine Turtle Protection

The Seychelles Government has been asked not to yield to pressure to relax protection of the endangered Green Turtle (*Chelonia mydas*). The World Wildlife Fund (WWF) and the International Union for Conservation of Nature and Natural Resources (IUCN), in a joint cable to the Hon. James R. M. Mancham, Chief Minister of Seychelles, referred to reports of strong pressure to drop protection. They said an extensive survey was needed before any such steps were taken and accordingly promised their aid.

The Green Turtle is among the most widely distributed of the seven existing species of marine turtles, all of which are in danger of extinction because of excessive exploitation of females and their eggs, which they lay on tropical beaches.

The Green Turtle is especially relished for its meat and for making soup, while the eggs are considered a delicacy. It has long been exploited by indigenous peoples, who are now threatened with the loss of a legitimate natural resource if over-exploitation is not curbed. WWF and IUCN have channeled considerable funds into scientific research and conservation measures for the marine turtles, including support for an international group of specialists to coordinate the work.*

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* To our great regret and deep sense of loss, the Chairman of this 'Marine Turtle Group' of IUCN, our old friend Dato Tom Harrisson, and his delightful wife Christine, were both killed in a traffic accident recently in Bangkok, Thailand.—Ed.

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