Time perspectives of organochlorine contamination in the global environment

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Organochlorine compounds such as PCBs, DDTs, and HCHs are ubiquitous environmental pollutants in the global ecosystem. Because of their chemical inertness most of these chemicals have proved useful in many industrial, agricultural and public health operations. During the first half of the 20th century these chemicals were produced and utilized extensively throughout the world; subsequently, decline of seabird and marine mammal populations and the evidences from laboratory experiments showing deleterious effects on organisms exposed to organochlorines, led many countries in the northern hemisphere to ban or strictly regulate the use of such compounds in 1970s. Nevertheless, considering the history of usage and persistent, bioaccumulative characteristics of these compounds, the residues would remain in the environment and biota for several years in the future and continue to pose problems for humans and wildlife (Tanabe, 1988; Goldberg, 1991). Time trend monitoring studies are valuable tools in determining the history of contamination and future implications of toxic chemicals in the environment.

Temporal trend studies on the residues of persistent chemicals have been carried out extensively using fish and other biological samples from the Japanese environment (Loganathan et al., 1989a,b 1990), Western North Pacific ecosystem (Tanabe et al., 1984), Great Lakes and North America (D'Itri, 1988; Novak et al., 1988; Elliott et al., 1988), Northwest Atlantic (Pearce et al., 1989), Northwestern hemisphere (Olsson & Reutergardh, 1986; Andersson et al., 1988; Greve & van Zoonen, 1990; Kannan et al., 1991) and Arctic marine ecosystem (Norstrom et al. 1988). Most of these investigations were performed with the objective of understanding the existing status of pollutant concentrations when compared to those in the past. The various factors that determine trends of contaminant levels in the environment are not clearly explained.

A systematic investigation carried out using biological samples collected in and around Japan describes the factors determining long-term contamination, behaviour and fate of organochlorines such as PCBs, DDTs, and HCHs (for sample details and results refer to Loganathan et al., 1989a,b, 1990, 1991). Fish, human adipose tissue and striped dolphin samples represent point source, non-point source and remote areas of contamination, respectively. Fish samples were collected during 1968–1986 from the River Nargarawa, Japan, which had a history of serious environmental problems due to the discharges of industrial and agricultural wastes. Human adipose tissue samples of Japanese males were collected in 1928–1985 from various hospitals in Japan. Blubber samples of striped dolphin caught off Taiji, on the Pacific coast of central Japan during the period 1978–79 and 1986 were used for analysis. The information is summarized in schematic figures (Figs 1a, b, c) and interpretations were made from spatial, biological, and chemical characteristic viewpoints. These representations are based mainly on the results obtained in the present investigation, in addition to some reasonable speculations.

Spatial viewpoint

In the point source area, namely the River
Nagaragawa, an increase in residue levels of PCBs, HCHs, and DDTs was noticed during the period of usage and then a rapid decline was observed after restriction. In the non-point source contamination sites (terrestrial environment), organochlorines showed an upward trend in concentrations from the beginning to the end of usage of these chemicals. Following the ban, a steady state or a gradual decrease was observed until recent years. In the remote areas (open ocean environment) these contaminants showed a very slight decline or a stable condition in the residual concentrations even after several years of banning the chemicals (Fig. 1a).

Based on the results of spatial viewpoint, it may be concluded that in the point source areas, particularly in the riverine environment, the organochlorine concentration increases during their usage and declines at a rapid rate when the restrictions are imposed. Contaminant levels in biota from the terrestrial environment and in the remote areas gradually rises with usage and after imposing restrictions on their use a slower rate of decline could be discerned. Remote areas such as the open ocean environment reveal slower clearance rates of contamination, therefore it takes a long-time to see the effectiveness of restriction on the use of persistent chemicals (Fig. 1a). Similar trends were also observed in point source, non-point source and open ocean from different parts of the world (Novak et al., 1988; Robinson et al., 1990; Boer, 1989; Greve & van Zoonen, 1990).

**Biological viewpoint**

Fish samples collected from point-source areas exhibited elevated levels of organochlorines during the period of usage. Residue levels declined when the production and consumption of these chemicals were stopped. In contrast, concentrations of organochlorines in human adipose tissue gradually increased until the ban on man-made organics. A steady state or a slower rate was observed after the ban. Interestingly, organochlorine levels in striped dolphins depicted that the contamination of PCBs and DDTs remain unchanged in the open ocean environment (Fig. 1b).

Therefore, animals having short life-span and less metabolic capacity to degrade organochlorines, such as fishes, get contaminated rapidly. The clearance rate is faster for these animals when the restrictions are imposed on the use of these chemicals. Whereas, in organisms with long life-spans and high metabolic capacities, such as humans, both the contamination and the clearance rate are slower. Similarly, animals of long life-span but least capable of metabolizing xenobiotics recorded extremely slow clearance rates. Hence, it can be delineated that the animals which have long life-spans and low metabolic capacities (e.g., marine mammals) are subjected to long-term accumulation and greater toxic threat to persistent man-made chemicals. This viewpoint is true on the global scale, since similar trends were also discernible from published reports from other parts of the world (Tanabe et al., 1988; Norstrom et al., 1988; Elliott et al., 1988; Andersson et al., 1988). Further, it is worth indicating that the animals having a
relatively higher content of fat in their body show slower clearance of organochlorines (Skäre et al., 1985; Kannan et al., 1991).

Chemical characteristics viewpoint

Residues of relatively less lipophilic and unstable compounds, namely HCHs, showed declining trend after withdrawal from production and use in all the biological samples of different ecosystems. On the other hand, highly lipophilic and stable contaminants (PCBs and DDTs) continued to exhibit higher residue levels even after restrictions on production and use (Fig. 1c).

It has been elucidated from our results that the less lipophilic and comparatively unstable compounds (e.g. HCH) contaminate the environment gradually and get cleared rapidly upon restriction. Highly lipophilic and stable compounds contaminate the environment quickly and the clearance rate is very slow. Hence, highly lipophilic and more stable compounds impose long-term effects on humans and wildlife. These results can be projected for the whole of the global environment and supported by the results obtained by various authors (Olsson & Reutergrårdh, 1986; Robinson et al., 1990; Pearce et al., 1989; Kannan et al., 1991).

Future implications

Until recently, long-term trend studies of persistent chemicals performed by most of the researchers were confined to tracing the history and present status of contamination. One of the main objectives of temporal trend studies is to predict the future levels of contamination. These studies could be of further use while making appropriate legislative actions and policy decisions by the local governments to combat pollution in the environment. Nevertheless, no particular emphasis has been placed on using time trend data to predict the future trends of organochlorine contamination in fishes and related biota. This is primarily due to the lack of suitable mathematical models to fit the time trend data for assessing the future trends of contaminant levels. Very recently, few statistical equations have been developed for future data collection using trend studies (Nicholson et al., 1991; Thomann et al., 1991). Application and development of such models is necessary to understand the future course of pollutant behaviour in various ecosystems. Influences of different variables determining the pollutant characteristics should also be taken into account in those models. Since chemodynamics of any chemical depends on various abiotic and biotic factors, ecosystem development of models must be site specific and representative of the prevailing conditions.