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REVIEW ARTICLE **OPEN ACCESS**

Sources, Fates and Control of Dichloro-DiphenylTrichloroethane (DDT); a case study on the Alpine Lakes

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ABSTRACT
DDT was assumed to be diluted in oceans to negligible concentrations and was considered 'unblemished'' as pristine in high-altitude or cold mountainous environment. Banned during the Stolkholm Convention due to its hazardous impact on both human and ecosystems as it's extremely difficult to completely degrade once in the environment. The main sources were identified to be from mountain glaciers, agricultural run-off, surface and lacustrine sediments; industries leading to run-off into rivers and atmospheric emission, which is more dominant to occur in the alpine lakes due to evaporation from other warm environment. Major pathways includes Aeolian dispersion, floods/ run-off, bioaccumulation as well as biota migration the toxic effects of these compounds on biota. The toxic effects of these compounds on biota endocrine disruptor's behavioural changes and its reproductive systems. Environmental remediating of such pollution may be achieved using supercritical fluid extraction and clean up from soil, at high temperature and pressure which is highly expensive. We thus further recommend the use of environmental fate modelling of pollutants.
Keywords: *DDT, POPs, Alpine lakes*

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INTRODUCTION

DDT-*p, p'*-dichlorodiphenyltrichloroethane is a pesticide used for variety of crops classified as a Persistent organic Pollutant (POPs) perhaps the best known [1]. Although DDT was assumed to be diluted in oceans to negligible concentrations [2], it was widely used during the second war to combat insect of vector borne diseases before its ban in the 1970's by the legislation decrees during the Stockholm convention to regulate its use although no restriction was put on its production. Although, it is still been used in applications of floriculture and zootechnics [3] and in region where malaria poses major health hazard, where it's of immense benefit[1]. Its widespread, uncontrolled, intensive use has resulted in worldwide pollution.

Alpine lakes are high latitudes lakes similar to high mountains which may serve as 'cold traps' for persistent organic pollutants [4]. Cold temperatures at higher latitudes favour deposition from the atmosphere on to soil and water [5-8]. As such DDT contagion was evident in the Italian Alps as higher precipitation intensities and gradient in agreement with altitude [9.

POPs can migrate to higher latitudes in a series of relatively short jumps sometimes termed the 'grasshopper effect' [10]. Several organochlorines, including DDT, peaked in the most recent layers in the high arctic lakes. DDT is stored in all tissues with the highest accumulation in fat where repeated exposures, even at low concentrations, it accumulate resulting in a high level storage [11]. This lipophilic behaviour of DDT results in growing concern over the toxic effect on biota for instance the bioaccumulation is greater the longer an organism lives [3]. Suggesting that large predatory fish likely have the highest probability of accumulation and endangered. In this work a careful review of the sources, fate and control of DDT was achieved considering the alpine lake as a case study area.

SOURCES

There are different sources and means of transportation of this pollutant through the aquatic environment as revealed in Figure 1 in the alpine lakes. For instance, DDT pollution in Lake Maggiore in Italy since 1996 has been identified [12] and caused by industrial production and effluents, traced back to

a chemical plant [13]. The plant both produced and discharged DDT for decades before it closure on a tributary of the River Toce, one of the major affluent of the lake [3].
Analysis from the Zebra mussel specimens of Baveno Bay where River Toce flows, indicates contamination source is probably derived from the lacustrine sediments and the River Toce [3]. Similarly, flood events might lead to contaminants adsorbed to resuspended sediments, as in the case of Pallaza Bay where sediments are considered to be one of the main sources of DDT pollution [14].
Another major source of DDT in water is agricultural run-off from fields that were once heavily sprayed with DDT for pest control. Similarly, rainfall might probably be the dominant mechanism for the removal of DDT in contrast to the atmosphere that is more dominant to occur in the alpine lakes due to condensation [15]. The soil can also be major contributor to sources of DDT generated from weathering, as they bind very strongly to soil particles which makes them very slow in reaching ground water and are thus available to be easily run off, as well as evaporates from the soil and surface water into the air.
Mountain glaciers are used as natural archives for studying historical trends of pollution [4] and are acknowledged as a significant source of DDT in the alpine lakes [16-18]. Melt-water from glaciers may contribute relatively high concentrations of DDTs and HCHs to cold aquatic ecosystems of the Himalayas [4]. Less volatile POPs will partition into water, snow, ice, soil, or vegetation. Bizzotto *et al,* [19] concluded that meltwaters originating from old glacier ice could represent the main source of legacy pollutants to alpine ecosystems. As, condensed DDT might have been stored in glaciers during their volumetric growth [20] and then released into glacier-fed lakes during the recent retreat. Cold slows evaporation of POPs from water and promotes their condensation and movement, or "partitioning," from the atmosphere to the surface [10].

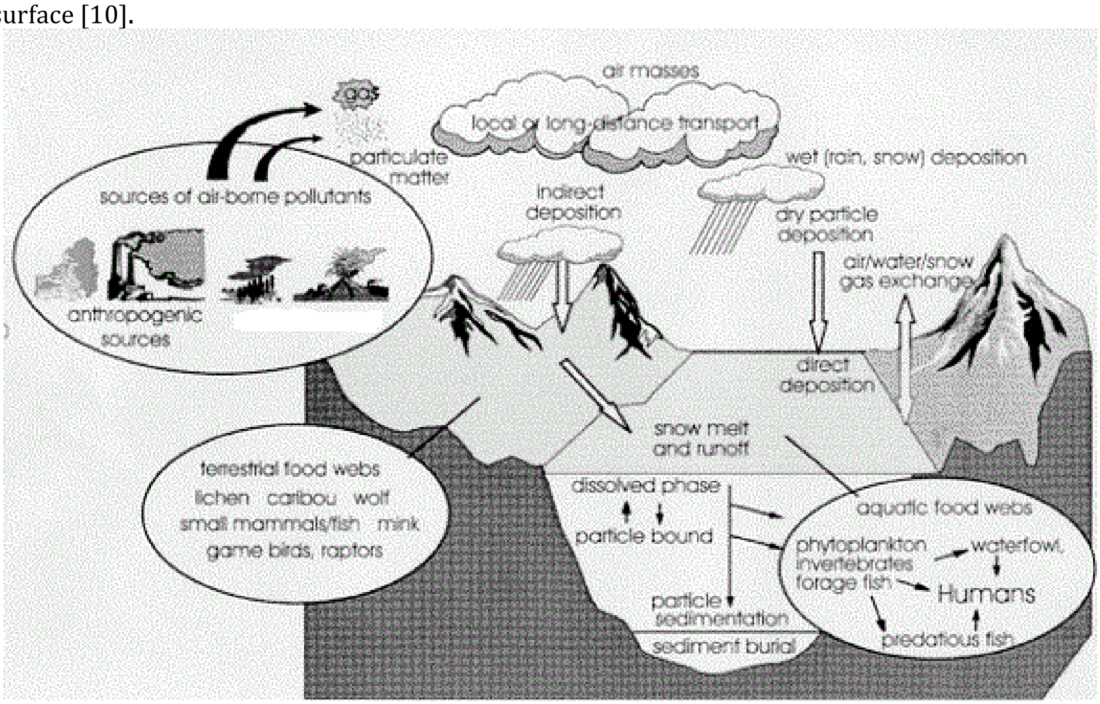

Figure 1: Sources of DDT in the Environment [21]

TRANSPORT

Generally, there are different agents that aids in the transportation of contaminants (POPs) which includes atmospheric dispersion by air/wind current, floods/ run-off as well as biota migration. Contaminants may enter alpines lakes via atmospheric deposition run off in which alpine lakes may be sensitive to airborne contaminants [22]. POPs exist in the atmosphere both as vapour-phase chemicals as gases and in condensed form adsorbed to atmospheric aerosol particles. The combination of stability and propensity to form a gas under appropriate environmental conditions means that POPs are subject to long-range atmospheric transport [23]. The combination of resistance to metabolism and lipophilicity means that POPs will accumulate in food chains through the biota [23]. They can bioaccumulate and biomagnify through the food chain thus making the organisms on the top of the chain to have the highest concentration example fish-preying bird. Binelli and Provini, [3] explained that flooding contributed to large extent on DDT transport in Lake Maggiore, North Italy. The study investigated the environmental risk associated with contaminants, histopathological markers, and bioaccumulation which shows fluctuations typical of flood events over a year period. The flow processes of DDT in the environment are as shown in Figure 1 according to Randers [24].

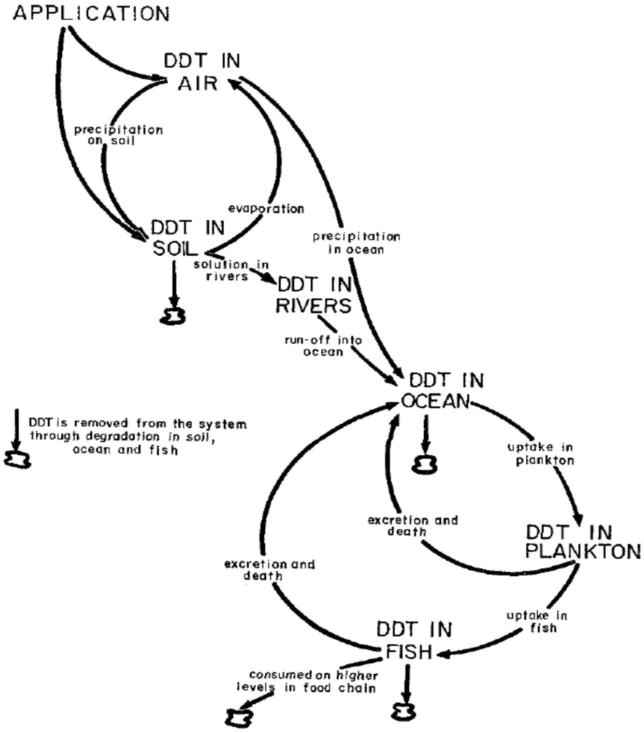

Figure 1 the flow of DDT in the environment. [24]

FATE IN THE ENVIRONMENT

DDT is a very persistent substance and is extremely difficult to degrade once it is present in the environment [25]. DDT residues (DDTr) still persist in the environment are predominantly in the form of DDT, 1,1-dichloro- 2,2-bis(p-chlorophenyl)ethylene (DDE), 1,1- dichloro-2,2-bis(p-chlorophenyl)ethane (DDD), and 1,1,1 -trichloro-2-(o-chlorophenyl)-2-(p chlorophenyl) ethane (o,p'-DDT) [26]. Boul [27] described that both DDD and DDE are transformation products of DDT. DDD is formed by dechlorination of DDT under reducing conditions [28-32], either microbial mediated [33] or as the result of chemical reactions [34-38] some of which are mediated by biomolecules [39]. DDE is formed from DDT through photochemical reactions in the presence of sunlight [40] and through dehydrochlorination in bacteria [41] and animals [42]. Heberer and Dunnbier [43] proposed that DDA is formed by the biodegradation of DDD, as shown in the figure (2) below.

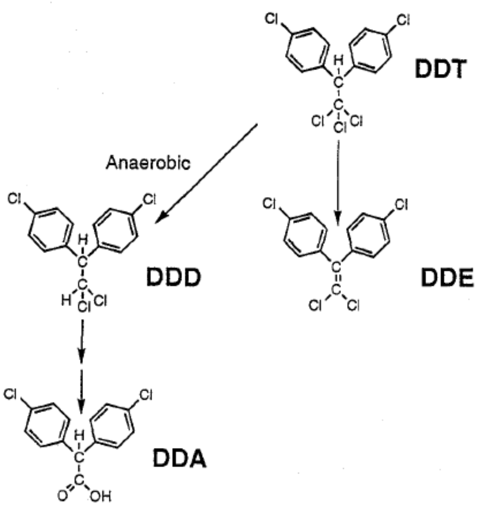

Figure 2: Proposed bacterial degradation pathways for DDT
Adopted from Heberer and Dunnbier [43].

EFFECTS ON BIOTA

The endocrine-disrupting properties of DDT on biota has been extensively discussed [44, 45] and the problem of endocrine disruptors is one of the five priority research areas established by the Committee on the Environment and Natural Resources of the United States [46]. There is a growing concern over the toxic effects of these compounds on biota, particularly on higher species resulting from food chain due to bioaccumulations as presented in figure (3), even at extremely low environmental levels [3]. Some of these chemicals are endocrine disruptors and thus give rise to various dangerous effects such as eggshell thinning, behavioural changes, impaired male reproductive ability and estrogenic activity interfering with sex hormones have been confirmed [47]. It is well documented that such effects does occurs virtually in all types of organisms ranging from mollusks to predators at different stages of food web [48-50].
Zebra mussels from Lake Maggiore were evaluated for DDT contamination and it was identified that in the ovaries of the most highly polluted mussels, histological analyses showed a delay in oocyte maturation and a high incidence of pathological pictures mainly referable to oocyte degeneration and haemocytic infiltration [51]. Histological studies carried out in 1997 [52] showed that a significant percentage of specimens sampled inside the Baveno Bay had a marked oocyte degeneration and released gametes earlier than those sampled at a nearby reference station outside the bay, suggesting a possible endocrine-disrupting effect of DDTs [23,3, 53, 54]. It is well known that pp0DDE is an antiadrogenic compound while op0DDT was found to determine pseudo-estrogenic effects on several organisms [47].

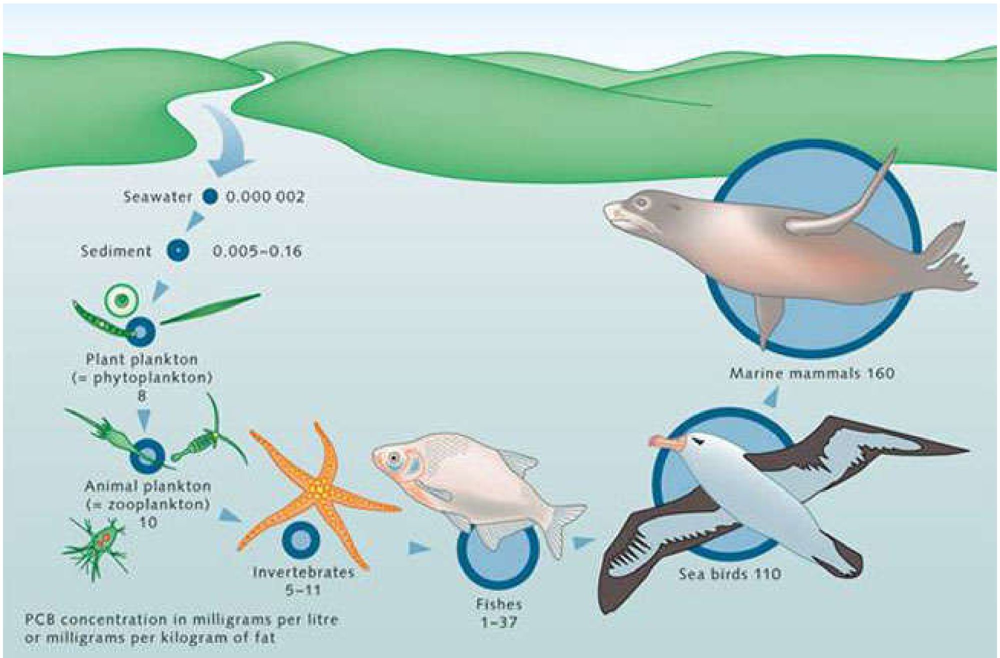

Figure 3: Showing the principle of Bioaccumulation of DDT [57]

HOW THE POLLUTANT CAN BE MEASURED

De la Cal *et al.,* [55] analysed Total Organic carbon of sediments samples for DDT contaminations as well as fish tissues were also analysed. The analyses obtained from the fish tissues can be termed as the fish uptake. The values obtained in the contaminated area are always compared to the values of fishes or sediments from uncontaminated lakes. The sediments are analysed because POPs are known to bind well to soil and sediments. Among the biomarkers used to study the effects of animal exposure to environmental contaminants, histological changes are particularly effective for their morphological responses affect all levels of biological organization [56]. A single toxicity test can be carried out such as that of the Zebra mussels in Lake Maggiore in which the reproductive biology of Zebra Mussels are known to be altered by DDT [51].

CONTROLS

According to UNEP [1] during the Stockholm convention, not much can be done with the traces of chemicals that are literally everywhere, from the industrial region of the Northern hemisphere to the Antarctica except to let time do it work. Various measures against the use of DDT in European countries has been highlighted by UNEP, [58]. There are different policy recommendations highlighted in the work of [8]. These includes a global restriction on the release of these compounds, reduction or elimination of emissions, discharges and where appropriate a ban on manufacture and use of persistent organic pollutants. Likewise, production of unintentional POPs should be extremely controlled by taking various measures such as development of action plans and preventative actions to reduce the release into environment. Such as banning of open burning and precautionary measure to reduce the scale of forest fires.

Environmental fate modelling of pollutants can help to reducing uncertainties and also give a clearer insight to the behaviour of this pollutant in the environment. [59]. Developed countries will have to provide funds and technical assistance to less developed nations, so that the latter can take effective measures [60]. Establishment of agreements between countries such as Commission for Environmental Cooperation (CEC) which list steps to reduce and eliminate the pollution of certain chemicals [61]. Which may help in regulating the use of DDT in all countries to be seize, by initiating more generating a more effective and efficient methods to fight Malaria and none or less toxic insecticide [45]. We thus recommend that more concentration should be given into generation of better modelling of such environmental pollutants which will increase the area coverage and hence a better understanding of other remediation ways.

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