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The status of pesticide pollution in surface waters (rivers and lakes) of Greece. Part I. Review on occurrence and levels

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Information on pesticide pollution of surface waters in Greece is reviewed.

Abstract

This review evaluates and summarizes the results of long-term research projects, monitoring programs and published papers concerning the pollution of surface waters (rivers and lakes) of Greece by pesticides. Pesticide classes mostly detected involve herbicides used extensively in corn, cotton and rice production, organophosphorus insecticides as well as the banned organochlorines insecticides due to their persistence in the aquatic environment. The compounds most frequently detected were atrazine, simazine, alachlor, metolachlor and trifluralin of the herbicides, diazinon, parathion methyl of the insecticides and lindane, endosulfan and aldrin of the organochlorine pesticides. Rivers were found to be more polluted than lakes. The detected concentrations of most pesticides follow a seasonal variation, with maximum values occurring during the late spring and summer period followed by a decrease during winter. Nationwide, in many cases the reported concentrations ranged in low ppb levels. However, elevated concentrations were recorded in areas of high pesticide use and intense agricultural practices. Generally, similar trends and levels of pesticides were found in Greek rivers compared to pesticide contamination in other European rivers. Monitoring of the Greek water resources for pesticide residues must continue, especially in agricultural regions, because the nationwide patterns of pesticide use are constantly changing. Moreover, emphasis should be placed on degradation products not sufficiently studied so far.

Keywords: Occurrence; Pesticide residues; Freshwaters; Greece

1. Introduction

Worldwide pesticide usage has increased dramatically during the last two decades, coinciding with changes in farming practices and the increasingly intensive agriculture. This widespread use of pesticides for agricultural and non-agricultural purposes has resulted in the presence of their residues in various environmental matrices. Pesticide contamination of surface waters has been well documented worldwide and constitute a major issue that gives rise to concerns at local, regional, national and global scales (Planas et al., 1997; USGS, 1999; Huber et al., 2000; Cerejeira et al., 2003).

Pesticide residues reach the aquatic environment through direct run-off, leaching, careless disposal of empty containers, equipment washing, etc. Although significant advances have been made in controlling point-source pollution, little progress has been accomplished in the area of nonpoint-source pollution of surface waters. This is because of the seasonality, inherent variability and multiplicity of origins of nonpoint-source pollution (Albanis et al., 1998; Pereira and Hostettler, 1993).

Pesticides are primarily moved from agricultural fields to surface waters in surface run-off (Richards and Baker, 1993). The amount lost from fields and transported to surface waters depends on several factors, including soil

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characteristics, topography, weather, agricultural practices, and chemical and environmental properties of individual pesticides (Wagenet, 1987; Leonard, 1990). The combined effect of these factors on the temporal and spatial magnitude of pesticide concentrations and fluxes in large integrating river systems is largely unknown (Larson et al., 1995). Chemical reactions and physical displacements influence the persistence of the chemicals in the soil, but with different environmental implications. Chemicals, which are sufficiently resistant to degradation and are adequately soluble to be transported in water, may reach the water bodies in significant amounts (Wauchope, 1978; Wagenet, 1987).

The trends in pesticide consumption used in Greece during the period 1986–1998 are given in Fig. 1A (FAO, 2004). The relative contribution of the various chemical families to the total pesticide use is given in Fig. 1B. Organophosphorus compounds, triazines and dithiocarbamates represent the main chemical categories of pesticides used in Greece. Other categories such as dinitroanilines, carbamates and amides follow with percentages less than 5% of the total used pesticides. Organochlorine insecticides such us DDT, endrin, dieldrin, aldrin, heptachlor, heptachlor epoxide and technical mixtures of

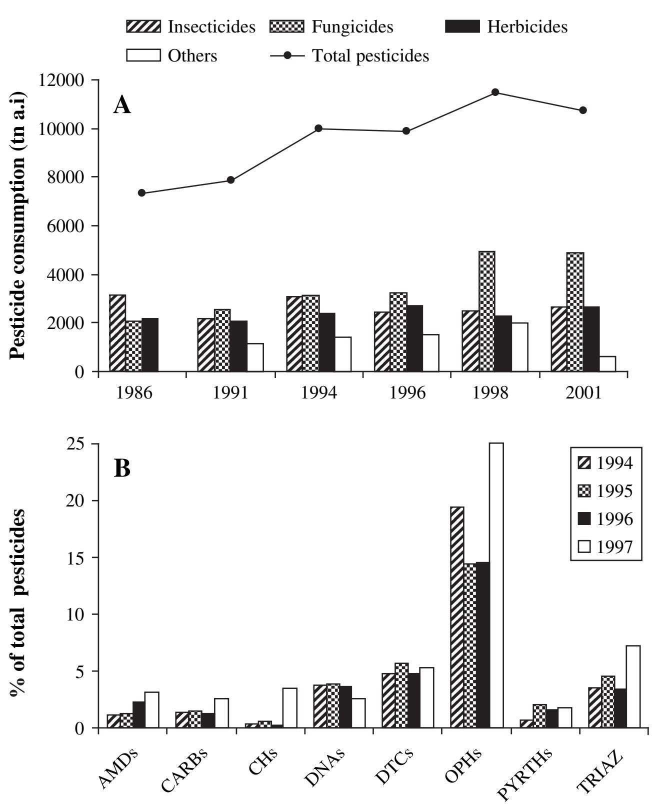

Fig. 1. The trends in the consumption of pesticides in Greece (FAO, 2004). (A) During the period 1986–2001. Insecticides: acaricides, molluscicides, nematocides and mineral oils; fungicides: bactericides and seed treatments; herbicides: defoliants and dessicants. Total pesticides may include other pesticides such as growth regulators and rodenticides. (B) The relative contribution of the different chemical families to the total pesticides used. AMDs, amides; CARBs, carbamates; CHs, chlorinated hydrocarbons; DNAs, dinitroanilines; DTCs, dithiocarbamates; OPHs, organophosphates; PYRTHs, pyrethroids; TRIAZ, triazines.

BHCs and HCHs were extensively used in Greece until their ban in 1972 (Albanis et al., 1994) and still persist in the aquatic environment (Albanis et al., 1998).

Although the physicochemical properties and the pollution pattern by nutrients and metals of the Greek lakes and rivers have already been reviewed (Skoulikidis et al., 1998), the contamination of surface waters by pesticides has not been performed so far. The aim of the present review is to compile all available data on pesticide pollution of Greek surface freshwaters, to discuss the seasonal patterns and their occurrence and finally to compare them with pesticide levels in other European surface waters.

2. Occurrence and environmental levels

It should be noted that the literature available data reviewed herein concerning river water pollution by pesticides, include several principal rivers of Greece that drain major agricultural areas; however, there is a lack of data for some other important rivers mainly in central and Southern Greece (e.g. Sperheios). In addition, though the existing data cover the last two decades only few concern annual monitoring surveys that include all the categories of pesticides. The rivers that were monitored in a systematic way are Aliakmon, Axios, Loudias, Louros, Arachthos and Kalamas. The above river deltas are regions protected by international conventions as they constitute important aquatic ecosystems.

The water bodies of Greece that have been monitored for pesticide residues are shown in Fig. 2. Generally the pesticides that are most commonly detected are those that are widely applied, have low K_{oc} values and high environmental persistence. Table 1 lists selected commonly occurring pesticides in surface waters of Greece as well as their use, physicochemical properties and run-off indices. We can distinguish two main groups of pesticides according to their occurrence and the concentration range detected. The first group consists of pesticides that were occasionally seen in surface waters of Greece. The compounds in this group have one or more of the following characteristics: low application rates (metribuzin, azinphos-methyl), use only in limited geographical areas (molinate, propanil), short soil lifetimes (malathion, parathion, EPTC, propanil), short aquatic lifetimes (malathion, propanil), lower run-off hazard (propanil, malathion, EPTC). The second group includes those compounds that are usually found in Greek surface waters and exhibit seasonally elevated concentrations (atrazine, simazine, alachlor, metolachlor, diazinon, trifluralin, parathion methyl, lindane). The compounds of this group have higher application rates and widespread use and (or) higher run-off hazard, with little loss within the riverine network or the lake (longer aquatic half-lives).

Another way to separate the detected pesticides is by type and application method, i.e. surface-applied herbicides, incorporated herbicides, and insecticides. As is shown in Table 1, surface-applied herbicides such as atrazine, simazine, alachlor and metolachlor have greater load as percent of use (LAPU) mean values compared to the incorporated herbicides and