Deltamethrin in sediment samples of the Okavango Delta, Botswana

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Abstract

Deltamethrin concentrations were determined in 35 sediment samples collected from three different habitats: channel, lagoon and pool sites from Xakanaxa in the Okavango Delta, NW Botswana. The samples were Soxhlet-extracted in acetone to extract deltamethrin residues and subsequently cleaned-up with silica gel 60. The final determination was carried out with a gas chromatograph equipped with an electron capture detector (GC-ECD). The sample work-up and determination gave deltamethrin recoveries of 54 to 97%, and detection limits of 0.004 mg/kg dw. The concentration of deltamethrin residues in the sediment samples collected from the three sprayed areas in the Okavango delta ranged between 0.013 and 0.291 mg/kg dw, with the highest concentrations observed in samples obtained from the pool sites. Analysis of samples for organic matter content showed percentage total organic carbon (% TOC) ranging between 0.19% and 8.21%, with samples collected from the pool having the highest total organic carbon. The concentrations of deltamethrin residues and the % TOC in sediment samples showed a similar trend with the highest levels recorded in the pool samples. These data confirmed that a simple method based on GC-ECD, after Soxhlet extraction, was robust enough to enable quantification of deltamethrin in the sediments, because comparable results were obtained with a more sophisticated system consisting of a GC coupled to a mass spectrometer with a time of flight (TOF) analyser.

Keywords: Okavango Delta, chromatography, sediments, deltamethrin

Introduction

The Okavango Delta, situated in north-western Botswana, is a large alluvial fan with a wetland located in a semi-arid environment (Fig. 1). The wetland has a rich biodiversity that has attracted national and international concern over its preservation. The near pristine aquatic ecosystem was listed in 1996 as a RAMSAR site, a wetland of international importance (Ramberg, 1997). The designated area (65 000 km^2) of the site makes it the largest designated RAMSAR site in the world (Ashton and Neal, 2003; RAMSAR, 1971). Nevertheless, some parts of the delta are experiencing rapid changes such as drying which may be linked to both natural (i.e. tectonics and channel blockages) and anthropogenic causes. The environmental impact of pesticide application to control tsetse fly populations in the Okavango Delta is not well quantified.

Pesticide use in the Okavango Delta has varied in the past. Dieldrex was used in 1964; this was followed by dichlorodiphenyltrichloroethane (DDT) during 1967 to 1970. From 1972 to 1991, endosulfan was initially used alone, and then a mixture of endosulfan and deltamethrin was used, starting in the 1980s (Kgori, 2001). Since 2001, deltamethrin [(S)-alpha-cyano-3-phenoxybenzyl (1R)-cis-3-(2, 2-dibromovinyl)-2, 2-dimethylcyclopropane-carboxylate], a synthetic pyrethroid insecticide (Pham et al., 1984) has been used in controlling tsetse fly populations. Deltamethrin is widely used in agriculture (such as in Mexico) due to its persistence, residual activity and low toxicity to mammals (Laskowski, 2002). However, deltamethrin has been found to be very toxic to terrestrial invertebrates, fish and other aquatic organisms (Amweg et al., 2005; Pawlisz et al., 1998).

Once a compound such as deltamethrin enters the environment, it will partition into various components of that environment, based on the physical and chemical properties of the compound and the prevalent environmental conditions (Pawlisz et al., 1998). Deltamethrin has a vapour pressure of 0.002 mPa, and a water solubility of less than 2 µg/ℓ. The log octanol-water partition coefficient (Log_{kow}) is 5.4 (Kidd and James, 1991), which results in deltamethrin being highly lipophilic. This has a significant impact on the partitioning of deltamethrin into biota. Given the Log_{kow} of deltamethrin, the compound would most likely partition into sediments (both suspended and bed-load), biota and vegetation. A few studies have been conducted on the environmental fate, persistence and degradation of deltamethrin (Yanez et al., 2002; Ernsfed, 1999; Maguire et al., 1989, Muir et al., 1985,) and these have confirmed that sediments act as a sink for deltamethrin, and some losses, especially in pond environments, were due to volatilisation. Additionally, it has a very short half life in water (ranging between 8 to 48 h) and degrades to decamethrinic acid, as well as to its less active isomers. Additionally, deltamethrin bioconcentrates in aquatic animals but does not biomagnify up the food web. A study conducted in the Okavango Delta in 2001 (Huntsman-Mapila et al., 2002) found that peat samples become enriched with deltamethrin, but that there is a high degree of variation in results from sediment samples collected within 1 m^2, suggesting that deltamethrin is not uniformly distributed, possibly due to heterogeneity in the sediments, leading to differing degradation rates. The variable rate of degradation would therefore affect its degree of accumulation.

The heterogeneity of the sediment also makes the detection and quantification of low concentrations of insecticide residues a difficult task. For example, due to interferences from other organic substances in the sample, extensive sample preparation

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