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Phorate

Guideline

The maximum acceptable concentration (MAC) for phorate in drinking water is 0.002 mg/L (2 μg/L).

Identity, Use and Sources in the Environment

Phorate ($C_7H_{17}O_2PS_3$) is an organophosphorous insecticide and acaricide used for the control of sucking and biting insects, mites and certain nematodes on root and feed crops, cotton, brassicas and coffee. Between 50 000 and 100 000 kg are used annually in Canada.[1] Phorate has a vapour pressure of 0.11 Pa at 20°C; its solubility in water at 25°C is 50 mg/L.[2] Reported log octanol–water partition coefficients range from 2.92 to 4.26.[3]

Phorate released to the soil is rapidly oxidized to the sulphoxide and sulphone forms and their phosphorothioate analogues, which are then hydrolysed.[4] Phorate sulphoxide and sulphone are generally more persistent than the parent compound.[5] Phorate has some potential to leach through the soil to groundwater.[5] Its half-life in aqueous solution at pH 8 and 70°C is two hours.[6]

Exposure

Phorate was not detected in 24 samples of municipal and private drinking water supplies in two cities (Harrow, 1985, and Toronto, 1971 to 1982) in Ontario (detection limit 0.02 μg/L). It was found in one of seven samples from Prince Edward Island at a level of 150 μg/L (date and detection limit not reported).[7] It was not detected in 949 stream water samples from 11 agricultural watersheds in southern Ontario from 1975 to 1977 (detection limit not reported)[8] or in 446 samples from three Ontario river basins surveyed from 1981 to 1985 in which more than 1200 kg of phorate were applied annually (detection limit 0.1 μg/L).[9]

Based on the residue tolerance limits established by the Food Directorate of the Department of National Health and Welfare,[10] the theoretical maximum daily intake of phorate from food is 0.026 mg. The actual average daily intake for a 70-kg adult is estimated to be 0.21 μg, based on a U.S. market basket survey.[11]

Analytical Methods and Treatment Technology

The content of phorate in water may be determined by extracting into dichloromethane, drying the extract and redissolving it in hexane and analysing by gas–liquid chromatography with flame photometric detection (detection limit 0.1 μg/L).[9]

No information on the effectiveness of current treatment technology in removing phorate from drinking water was identified.

Health Effects

Phorate is readily absorbed from the gastrointestinal tract. It is metabolized in animals to phorate sulphoxide and sulphone and their phosphorothioate analogues, followed by hydrolysis to dithio-, thio- and orthophosphoric acids.[4] Thirty-five percent of an orally administered dose of 2 mg/kg bw of radioactively labelled phorate was eliminated in the urine and 3.5% in the faeces of rats within six days.[12] Metabolites found in the urine of phorate formulators include diethyl phosphate, diethyl phosphorothioate and diethyl thiophosphate.[13]

Phorate is reported to be one of the more toxic cholinesterase-inhibiting organophosphorous insecticides.[5] In occupationally exposed workers, there was a significant depression in the level of plasma cholinesterase activity to 46 and 29% of normal levels after one and two weeks of exposure, respectively. Recovery of up to 79% of normal activity was reported 10 days after exposure was ceased. Whole blood cholinesterase levels were depressed to 90 and 86% of normal after one and two weeks of exposure. Neurological (headache, giddiness, fatigue) effects, gastrointestinal (nausea, vomiting, stomachache) effects, skin and eye irritation and lowering of heart rate were among the symptoms reported.[14]

Groups of three dogs (two females and one male) were administered phorate in encapsulated corn oil in doses of 0, 0.01, 0.05, 0.25 or 1.25 mg/kg bw per day six days per week for 15 weeks. In animals receiving 0.05 mg/kg bw per day, there was a significant decrease in plasma cholinesterase activity; higher exposure levels produced significant depressions in both plasma and red cell cholinesterase activity. The no-observed-adverse-effect level (NOAEL) was considered to be 0.01 mg/kg bw per day, although a slight decrease in plasma cholinesterase was observed at this level.[15]

Groups of 50 male and 50 female CRL:COBS CD(SD)BR rats were fed diets containing phorate at levels of 0, 1, 3 or 6 ppm (approximately equivalent to doses of 0, 0.05, 0.15 and 0.30 mg/kg bw per day, respectively) for two years. A significant decrease in plasma cholinesterase activity was observed in males exposed to 0.30 mg/kg bw per day at 12 months, in males of all dose groups at 24 months and in females consuming 0.15 and 0.30 mg/kg bw per day at 3, 6, 12 and 24 months. Erythrocyte cholinesterase activity was not significantly depressed. Brain cholinesterase activity was significantly depressed in males at 0.30 mg/kg bw per day and in females at 0.15 mg/kg bw per day and above. There was no significant difference in the incidence, type and time of detection of tumours between the control group and the treated animals. The NOAEL for rats for plasma and brain cholinesterase inhibition in this study was considered by the authors to be 0.05 mg/kg bw per day.[16]

Teratological studies were conducted on groups of 25 mated female rats (CRL:COBS CD(SD)BR strain) administered doses of phorate of 0, 0.125, 0.25 or 0.50 mg/kg bw per day by intubation on gestation days 6 through 15. There was an increased incidence of enlarged hearts in foetuses whose dams had been exposed to 0.5 mg/kg bw per day. No other significant differences between the exposed and control groups were noted. The NOAEL for teratogenic effects was considered by the researchers to be 0.25 mg/kg bw per day.[17]

Phorate was not found to be mutagenic in bacterial systems,[18] nor did it produce any dominant lethal mutations in mice.[19]

Rationale

The acceptable daily intake (ADI) of phorate has been established by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO)[20] as 0.0002 mg/kg bw per day, based on the NOAELs of 0.01 mg/kg bw per day in dogs[15] and 0.05 mg/kg bw per day in rats.[16]

The maximum acceptable concentration (MAC) for phorate in drinking water is therefore derived as follows:

$$\text{MAC} = \frac{0.0002 \text{ mg/kg bw per day} \times 70 \text{ kg bw} \times 0.20}{1.5 \text{ L/d}} \approx 0.002 \text{ mg/L}$$

where:

- 0.0002 mg/kg bw per day is the ADI established by the FAO/WHO
- 70 kg bw is the average body weight of an adult
- 0.20 is the proportion of daily intake of phorate allocated to drinking water
- 1.5 L/d is the average daily consumption of drinking water by an adult.

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