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Malathion

Guideline

The maximum acceptable concentration (MAC) for malathion in drinking water is 0.19 mg/L (190 μg/L).

Identity, Use and Sources in the Environment

Malathion ($C_{10}H_{19}O_6PS_2$) is an organophosphorus insecticide and acaricide used for the control of a variety of insects and mites on a wide range of agricultural and horticultural crops, as well as for the control of mosquitoes, flies, household insects, animal ectoparasites and human head and body lice. Between 100 000 and 500 000 kg are used annually in Canada.[1]

Malathion has a low vapour pressure of 5×10^{-3} Pa at 30°C; its solubility in water is quite high (145 mg/L at 25°C).[2] Reported log octanol–water partition coefficients range from 2.36 to 2.89;[3] malathion is, therefore, not expected to bioaccumulate in human or animal tissues.

Malathion binds moderately to soil and is biodegraded and hydrolysed significantly; it is not expected to leach to groundwater.[4] The rate of disappearance from soil has been reported to be 75 to 100% in one week.[5] In aquatic systems, the rate of hydrolysis is dependent on pH; reported half-lives range from 0.2 weeks at pH 8.0 to 21 weeks at pH 6.0.[4] Biodegradation is important in the removal of malathion from natural waters.[4] Malathion tends to be degraded more rapidly in water than other organophosphorus insecticides.[6]

Exposure

Malathion was not detected in 179 samples from municipal and private water supplies from Prince Edward Island (1986), Nova Scotia (1986), Ontario (1971 to 1982, 1985) and Manitoba (1986) (detection limits ranged from 0.001 to 0.3 μg/L).[7] It was not found in approximately 100 surface water samples from the Prairies analysed from 1973 to 1974 (detection limit not reported)[7] and was present in the range of 0.24 to 1.8 μg/L in only four of 949 stream water samples in 11 southern Ontario agricultural watersheds from 1975 to 1977 (detection limit 0.1 μg/L).[8] Malathion was detected only once (0.99 μg/L) in 446 samples from three Ontario river basins (detection limit 0.1 μg/L).[9]

Based on the residue tolerance limits set by the Food Directorate of the Department of National Health and Welfare,[10] the theoretical maximum daily intake of malathion from food is 3.4 mg. For an adult Canadian, the actual average daily intake has been estimated to be 0.84 μg/d, or 0.012 μg/kg bw per day, based on residue data from a market basket survey carried out in 1978.[11] In the United States, the average daily intake from food has been estimated to be 5.1 μg for an adult, based on residue data from a market basket survey carried out in 1982 to 1984.[12] This is about one-third of the daily intake estimated from a survey conducted in 1980 to 1982.[13] Malathion and its oxygen analogue were detected in 120 of 6391 U.S. domestic food samples surveyed from 1981 to 1986; 92% contained 2.0 ppm or less (detection limit not reported).[14]

Analytical Methods and Treatment Technology

The malathion content of water may be determined by extracting into dichloromethane, drying the extract, redissolving it in hexane and analysing by gas/liquid chromatography, phosphorus mode (detection limit 0.1 μg/L).[8,9]

Little information has been found on the effectiveness of current treatment technologies in removing malathion from drinking water. Coagulation does not appear to be effective in removing malathion from water; it is only moderately adsorbed (up to 50% removal) at low concentrations (in the range of 0.05 to 0.1 μg/L) by granular activated carbon.[15]

Health Effects

Malathion is rapidly absorbed from the gastrointestinal tract. It is degraded by liver microsomal enzymes to the active metabolite, malaoxon. Malathion and malaoxon are detoxified rapidly by hydrolysis by carboxylesterases.[16] In rats, excretion is mainly via the

urine, with almost 92% of an oral dose of 25 mg of ^{14}C-labelled malathion being eliminated within 24 hours.[17]

Malathion is of low acute toxicity in humans. Its principal toxic action is inhibition of acetylcholinesterase, causing disruption of nerve transmission in the parasympathetic and sympathetic nervous systems, as well as some blockage in the central nervous system.[18] In one study, human volunteers were administered oral doses of 8, 16 or 24 mg malathion for up to 56 days. Dosages up to 16 mg/d caused no significant reduction of plasma or red cell cholinesterase activity. Persons receiving 24 mg/d for 56 days had up to 25% reduction in plasma cholinesterase activity three weeks after dosing was terminated,[19] which indicates rather slow reversibility of the binding of malathion to the acetylcholinesterase binding site. The no-observed-adverse-effect level (NOAEL) from this study, therefore, is 16 mg/d, or 0.23 mg/kg bw per day.

The National Cancer Institute conducted carcinogenicity bioassays in which malathion was administered orally to Charles River $B6C3F_1$ mice for 80 weeks, Osborne-Mendel rats for 80 weeks, and Fischer-344 rats for 103 weeks. These studies have been reviewed by the International Agency for Research on Cancer (IARC).[16] The only significant increase in tumour incidence was for the combination of thyroid follicular cell adenomas and follicular cell carcinomas in female Osborne-Mendel rats. The incidence of adrenal pheochromocytomas was increased in the low-dose group of Fischer-344 rats, but no significant increase was observed in the high-dose group. The IARC concluded that no evidence of carcinogenicity was demonstrated for malathion or its metabolite, malaoxon; the overall evaluation placed malathion in Group 3 (not classifiable as to its carcinogenicity to humans).[20]

Malathion was not mutagenic in most bacterial studies, in two studies in yeast or in *Drosophila melanogaster*.[16] Increased incidence of chromosomal aberrations in primary spermatocytes of CFW mice was reported after oral administration of a 0.3% solution of a product containing 30% malathion (equivalent to 900 mg/L) for 50 or 100 days.[21] Malathion has also been reported to induce a slight increase in the incidence of chromosomal aberrations in bone marrow cells of rats exposed *in vivo*.[22] Malathion caused a significant increase in sister chromatid exchange in human foetal lung fibroblasts (after a single dose of 40 µg/mL or double doses of 20 µg/mL),[23] Chinese hamster V79 cells (after doses of 40 µg/mL)[24] and Chinese hamster ovary cells (exposed to 0.03 mM [10 µg/mL] malathion).[25] In another study, however, no increase in sister chromatid exchanges in human foetal fibroblasts was observed.[22] No increase in unscheduled DNA synthesis was noted in WI-38 human fibroblasts treated with malathion, with or without mouse liver microsomal preparation.[26] The IARC concluded that the evidence for mutagenicity of malathion was limited.[16]

The average litter size of male and female rats exposed to malathion at 240 mg/kg bw per day for five months was smaller than that of the controls, and the number of pups that survived after seven and 21 days was approximately half the number surviving in the control litters.[26] Deformities have been observed in chicken embryos after dietary intake of up to 600 ppm malathion for three weeks by laying hens. Reduced hatchability of eggs laid by hens fed 1.0 ppm or more malathion has been reported.[17] Malathion has, however, been reported to be non-teratogenic in studies in which pregnant rats were treated intraperitoneally with 900 mg/kg on day 11 after insemination.[6]

Rationale

The acceptable daily intake (ADI) for malathion has been derived by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO)[27] as follows:

$$\text{ADI} = \frac{0.23 \text{ mg/kg bw per day}}{10} \approx 0.02 \text{ mg/kg bw per day}$$

where:

- 0.23 mg/kg bw per day is the NOAEL from studies in human volunteers[19]
- 10 is the uncertainty factor.

The maximum acceptable concentration (MAC) for malathion in drinking water is derived from the ADI as follows:

$$\text{MAC} = \frac{0.02 \text{ mg/kg bw per day} \times 70 \text{ kg} \times 0.20}{1.5 \text{ L/d}} \approx 0.19 \text{ mg/L}$$

where:

- 0.02 mg/kg bw per day is the ADI established by the FAO/WHO
- 70 kg is the average body weight of an adult
- 0.20 is the proportion of total daily intake of malathion allocated to drinking water (actual daily intake is estimated to be 0.06% of the ADI)
- 1.5 L/d is the average daily consumption of drinking water for an adult.

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