

Chlorpyrifos

Guideline

The maximum acceptable concentration (MAC) for chlorpyrifos in drinking water is 0.09 mg/L (90 µg/L).

Identity, Use and Sources in the Environment

Chlorpyrifos (C₉H₁₁Cl₃NO₃PS) is an organophosphorus insecticide used for the control of mosquitoes, flies, various crop pests in soil and on foliage, household pests and aquatic larvae. It is also used on sheep and cattle for the control of ectoparasites. Annual use in Canada is in the range of 100 000 to 500 000 kg.¹

The vapour pressure of chlorpyrifos is 2.49×10^{-3} Pa at 25°C, and its solubility in water is 2 mg/L at 25°C.² Reported log octanol–water partition coefficients are high, ranging from 4.82 to 5.11.³

Chlorpyrifos is tightly absorbed by soil and is not expected to leach significantly.⁴ It persists in soil for 60 to 120 days,⁵ with degradation being primarily due to microbial action.⁶ Products of degradation include 3,5,6-trichloro-2-pyridinol, which is subsequently broken down to organochlorine compounds and carbon dioxide.⁷ The rate of hydrolysis of chlorpyrifos in water increases with pH and temperature and is enhanced by the presence of copper.⁵ Between 30 and 60% of the total amount of chlorpyrifos in the aqueous phase may disappear within 24 hours through adsorption, degradation and vaporization.⁸

Exposure

Chlorpyrifos was not detected in a survey of 511 samples from municipal and private drinking water supplies encompassing Metropolitan Toronto (1971 to 1982), Manitoba (1986) and Alberta (1978 to 1985) (detection limits 0.20 and 0.04 µg/L).⁹ It was not found in 446 samples taken from surface waters of the Grand River and Thames River basins, although nearly 3000 and 7500 kg/year, respectively, had been used in these areas (detection limit 0.1 µg/L).¹⁰

Based on the residue tolerance limits set by the Food Directorate of the Department of National Health and Welfare,¹¹ the theoretical maximum daily intake of chlorpyrifos from food is 0.07 mg/d, which represents 10% of the acceptable daily intake (ADI) of 0.7 mg/d for a 70-kg adult.¹² Chlorpyrifos was detected in only 49 of 6391 domestic food samples in the United States, 94% of which had concentrations below 2.0 ppm; in imported foods, chlorpyrifos was detected in 1777 of 12 044 samples, with all but five samples containing concentrations at or below 0.5 µg/g.¹³ The average daily dietary intake of chlorpyrifos has been estimated to be 0.241 µg, based on the U.S. market basket survey.¹⁴

Analytical Methods and Treatment Technology

Organophosphorus insecticides in water may be analysed by extraction separately into hexane and dichloromethane, separation by gas chromatography and flame thermionic or flame photometric detection (detection limit 1 µg/L);¹⁵ separation may also be accomplished by gas/liquid chromatography, followed by flame photometric detection (detection limit 0.1 µg/L).¹⁶

No information was found on the effectiveness of current treatment technologies in removing chlorpyrifos from drinking water.

Health Effects

Chlorpyrifos is readily absorbed from the gastrointestinal tract and is rapidly metabolized. Metabolites are excreted principally in the urine and to a lesser extent in the faeces; the main metabolites are 3,5,6-trichloro-2-pyridylphosphate and 3,5,6-trichloro-2-pyridinol.¹⁷ Small amounts of unmetabolized chlorpyrifos have been detected in the blood, brain and liver after accidental human ingestion.¹⁸

Chlorpyrifos is a cholinesterase inhibitor. Human volunteers (four men per group) were administered oral doses of chlorpyrifos of 0.014 mg/kg bw per day for

27 days, 0.03 mg/kg bw per day for 20 days or 0.10 mg/kg bw per day for nine days.¹⁹ Red blood cell cholinesterase activity was not affected at any level.

Beagle dogs were fed diets containing chlorpyrifos at dose levels of 0, 0.01, 0.03, 0.1, 1.0 or 3.0 mg/kg bw per day for two years.²⁰ Red blood cell cholinesterase was inhibited in males and females at 1.0 and 3.0 mg/kg bw per day. In a similar study,²¹ rats were fed diets containing chlorpyrifos at concentrations of 0, 0.01, 0.03, 0.1, 1.0 and 3.0 mg/kg bw per day for two years. Brain cholinesterase activity was inhibited at 3.0 mg/kg bw per day and slightly depressed at 1.0 mg/kg bw per day. Based on these results, the no-observed-adverse-effect level (NOAEL) for red blood cell and brain cholinesterase inhibition is considered to be 0.1 mg/kg bw per day. The NOAEL in Rhesus monkeys receiving 0.08 mg/kg bw per day of chlorpyrifos by gavage for six months was similar; animals exhibited no depression in red blood cell cholinesterase activity.²²

In a carcinogenicity study in CD-1 mice, chlorpyrifos was not oncogenic when administered at dose levels up to 15 ppm (1.5 mg/kg bw per day) in food for 105 weeks.²³ Chlorpyrifos was not found to be mutagenic in five microbial assay systems.²⁴ In a CF-1 mouse teratogenicity study, chlorpyrifos was not teratogenic at doses up to 25 mg/kg bw per day, although significant reductions in plasma and erythrocyte cholinesterase levels were observed in maternal mice at 1 mg/kg bw per day or greater and in fetuses at 10 mg/kg bw per day or more.²⁵

Rationale

The ADI for chlorpyrifos has been derived by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO)¹² as follows:

$$\text{ADI} = \frac{0.1 \text{ mg/kg bw per day}}{10} = 0.01 \text{ mg/kg bw per day}$$

where:

- 0.1 mg/kg bw per day is the NOAEL derived from two-year studies in the dog and rat^{20,21} and studies with human volunteers¹⁹
- 10 is the uncertainty factor.

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

$$\text{MAC} = \frac{0.01 \text{ mg/kg bw per day} \times 70 \text{ kg} \times 0.20}{1.5 \text{ L/d}} \approx 0.09 \text{ mg/L}$$

where:

- 0.01 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 daily intake of chlorpyrifos allocated to drinking water
- 1.5 L/d is the average daily consumption of drinking water for an adult.

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