Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health

DDT (TOTAL) 1999

This fact sheet provides Canadian soil quality guidelines for total DDT for the protection of environmental health (Table 1). A supporting scientific document is also available (Environment Canada 1998). The CCME recognizes that persistent, bioaccumulative substances such as DDT should be virtually eliminated from the environment. Nevertheless, the CCME also recognizes the need for remediation guidelines as interim management objectives for persistent, bioaccumulative substances in soils.

Background Information

The term DDT is commonly applied to 1,1,1- trichloro-2,2-bis(*p*-chlorophenyl)ethane (*p,p'*-DDT, CAS 50-29-3) and to its isomeric forms, including *o,p'*-DDT and *m,p'*-DDT (USEPA 1980; WHO 1989). The term is also applied to a variety of commercial pesticide formulations that contain *p,p'*-DDT and *o,p'*- DDT as primary active ingredients (WHO 1989). In the environment, these active ingredients are transformed into a number of compounds

Table 1. Soil quality guidelines for DDT (total) (mg·kg^{-1}).

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline	**0.7**[a]	**0.7**[a]	**12**[a, b]	**12**[a, b]
SQG_{HH}	NC[c]	NC[c]	NC[c]	NC[c]
Limiting pathway for SQG_{HH}	ND	ND	ND	ND
Provisional SQG_{HH}	NC[d]	NC[d]	NC[d]	NC[d]
Limiting pathway for provisional SQG_{HH}	ND	ND	ND	ND
SQG_E	0.7[e]	0.7[e]	12[e]	12[e]
Limiting pathway for SQG_E	Soil and food ingestion	Soil and food ingestion	Soil contact	Soil contact
Provisional SQG_E	NC[f]	NC[f]	NC[f]	NC[f]
Limiting pathway for provisional SQG_E	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	—	—	—	—

Notes: NC = not calculated; ND = not determined; SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health.

[a]Data are sufficient and adequate to calculate only an SQG_E. An interim soil quality criterion (CCME 1991) has not been established for this land use, therefore, the SQG_E becomes the soil quality guideline.

[b]In site-specific situations where the size and/or the location of commercial and industrial land uses may impact primary, secondary or tertiary consumers, the soil and food ingestion guideline is recommended as the SQG_E.

[c]There is no SQG_{HH} for this land use at this time.

[d]There is no provisional SQG_{HH} for this land use at this time.

[e]The environmental groundwater check (aquatic life) value has not been applied in the determination of the soil quality guideline. The applicability of the groundwater check (aquatic life) should be determined on a site-specific basis.

[f]Because data are sufficient and adequate to calculate an SQG_E for this land use, a provisional SQG_E is not calculated.

with similar chemical structures. Of these, *o,p'*-DDE and *p,p'*-DDE (1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene, CAS 72-55-9) tend to be the most abundant and persistent in the environment. The two DDD isomers, *o,p'*-DDD and *p,p'*-DDD (1,1-dichloro-2,2-bis(*p*-chlorophenyl) ethane, CAS 72-54-8), are also formed when DDT is degraded or metabolized.

Technical grade DDT (TG-DDT) is made up of 77.1% *p,p'*-DDT, 14.9% *o,p'*-DDT, 4.0% *p,p'*-DDE, 0.1% *o,p'*-DDE, 0.3% *p,p'*-DDD, 0.1% *o,p'*-DDD, and a number of unidentified compounds (3.5%) (USEPA 1980). Technical grade DDT is a nonflammable, tasteless, and almost odourless white crystalline or waxy solid at room temperature (WHO 1989; Worthing and Hance 1991). At standard temperature and pressure, the *p,p'*-DDT and *o,p'*-DDT isomers form colourless crystals that are sparingly soluble in water ($3\ \mu g \cdot L^{-1}$), strongly hydrophobic (log K_{OW}: 6.0), and highly soluble in organic solvents such as ethanol ($20\ g \cdot L^{-1}$) or acetone ($580\ g \cdot L^{-1}$) (Suntio et al. 1988; Budavari et al. 1989). All of the DDE and DDD isomers have notably higher vapour pressures and water solubilities than the DDT isomers.

In this fact sheet, the term total DDT (tDDT) refers to the sum of the concentrations of *p,p'*-DDT, *o,p'*-DDT, *p,p'*-DDE, *o,p'*-DDE, *p,p'*-DDD, and *o,p'*-DDD. The more general term, DDT, refers to any or all of the six substances identified above, as well as the metabolites and degradation products of these six compounds.

The extensive use of DDT resulted both from its efficacy as an insecticide and from its low cost of manufacturing. DDT was commonly sold as an emulsifiable concentrate, a wettable powder, or a dustable powder. It was also sold for household use in granules, aerosols, smoke candles, lotions, and charges for vaporizers. Agricultural products containing DDT were first sold in 1941 by Ciba-Geigy in Switzerland under the trade name Gesarol. DDT products were later patented and produced in Germany, Great Britain, and the United States (USEPA 1980). DDT became available to the Canadian public in 1945 (Twinn 1947).

In the United States, approximately 1.5 million t were produced between 1945 and 1983. The production of DDT in Europe has never been fully reported, but is likely to be on the order of 0.7–0.8 million t (Environment Canada 1995). DDT was never manufactured in Canada, but was imported from the United States until 1985.

DDT has been used extensively for the control of vector-transmitted diseases (e.g., as a delousing agent to control typhus and as a mosquito control agent against malaria) and for the control of insects in forests and on agricultural crops. DDT was used primarily in Canada to combat agricultural and forest pests. The bulk of DDT use occurred from the mid-1940s to the late 1960s (Nigam 1975) and was applied in Canada using both aerial and land-based spraying operations. After the early 1970s, only two DDT products, Sanex Rodentrak and Poulin's Bat and Mouse Doom Powder, were registered for use in Canada.

Kelthane, an acaricide containing the active ingredient dicofol, is still mainly used on fruit crops, but is also registered for use on vegetables, ornamental and flowering plants, deciduous trees, coniferous trees, soil, and dwellings. Kelthane has been found to contain DDT impurities in the formulation (Riseborough et al. 1986) and may, therefore, be a contributing source of DDT and DDE to wildlife residing near orchards. Kelthane is registered for use in Canada until 1999 (Agriculture and Agri-Food Canada 1996).

Current Status of DDT in Canada and Other Countries

Pesticides are regulated in Canada under the Pest Control Products Act and Regulations. As a result of environmental and human health concerns, registration of all uses of DDT were suspended in 1985. Use of existing stocks was permitted until December 31, 1990, after which any use was in violation of the Pest Control Products Act (PMRA 1995).

DDT is included on the Tier 1 Substance List with a management target of zero discharge under the Canada–Ontario Agreement Respecting the Great Lakes Basin Ecosystem. Pursuant to the Great Lakes Water Quality Agreement between the governments of Canada and of the United States, the International Joint Commission has included DDT on its critical pollutants list of substances to be virtually eliminated from the Great Lakes Basin.

As a result of its high persistence, bioaccumulation, toxicity, and long-range transport, DDT has been identified as a candidate for the United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution Possible Protocol for Persistent Organic Pollutants (UNECE 1994). DDT has been banned or severely restricted in several foreign jurisdictions, including Austria, Finland, Switzerland, the United Kingdom, the United States, and the European Union (IRPTC 1990). Various jurisdictions in Canada and around the world have set guidelines/criteria for DDT and its isomers.

In spite of severe restrictions or bans, DDT is still being produced, exported, and used in many countries around the world (e.g., the former USSR, India, the Netherlands, Italy, China, Mexico, Indonesia, Japan, South Korea,

Central America, and South America) (ATSDR 1994; Environment Canada 1995). It has been suggested that DDT consumption worldwide will likely double in the future as a result of its use in agriculture and public health applications in China, the former USSR, India, and other countries (Ostromogil'skii et al. 1987).

Levels in the Canadian Environment

Hebert et al. (1994) reported concentrations of DDT, DDE, and DDD ranging from 1.7 to 131.7 $mg \cdot kg^{-1}$, 4.0 to 342.6 $mg \cdot kg^{-1}$, and not detectable to 11.7 $mg \cdot kg^{-1}$, respectively, in soil samples from the Niagara Peninsula, Ontario. The Ontario Ministry of Environment and Energy (OMEE 1993a) reported a background concentration of 170 $\mu g \cdot kg^{-1}$ for *o,p'*-DDT and of 1300 $\mu g \cdot kg^{-1}$ for *p,p'*-DDT in Ontario old urban parkland. The background concentrations in rural parklands were reported as 5.4 and 75 $\mu g \cdot kg^{-1}$ for *o,p'*-DDT and *p,p'*-DDT, respectively.

DDT is distributed throughout the tissues of mammals, but accumulates preferentially in tissues with high lipid content. Of the tissues commonly sampled, muscle typically has the lowest concentrations of DDT (Bowes and Jonkel 1975; Ronald et al. 1984). In the same way, avian tissues with the highest lipid content are likely to have the highest DDT levels. Consequently, tDDT residues were roughly 40 times higher in the fat of northern fulmars than they were in breast muscle (Thomas and Hamilton 1988).

Among terrestrial mammals, the highest levels of DDT have been observed in species that include fish and other aquatic organisms in their diet. Mink collected in 1991 and 1992 from three sites in Alberta had levels of DDE residues in their livers ranging from <2 to 14 $\mu g \cdot kg^{-1}$ ww (Wayland 1995). Conversely, terrestrial herbivores, such as caribou *(Rangifer tarandus)*, tend to have low levels of tDDT in their tissues. For example, Elkin and Bethke (1995) reported levels of total DDT ranging from 0.36 to 1.49 $\mu g \cdot kg^{-1}$ ww in the fat of caribou. Similarly, concentrations ranging from below the detection limit to 2.6 μg DDT$\cdot kg^{-1}$ ww in the fat, liver, and muscle of caribou were reported in Indian and Northern Affairs Canada (1997).

Avian predators at the highest trophic level of the aquatic food web tend to have the most highly contaminated tissues, as illustrated by the elevated levels of SUM DDE in the muscle of peregrine falcons collected from the Northwest Territories (up to 1695 $\mu g \cdot kg^{-1}$ ww) (Johnstone et al. 1994). Similarly, grazers, dabblers, and divers, such as Canada geese *(Branta canadenis)*, lesser snow geese *(Chen caerulescens)*, mallards *(Anas platyrhychos)*, king eiders *(Somateria spectabilis)*, and common eiders *(Somateria mollissima)*, collected from 1988 to 1992 in the Arctic, generally had relatively low levels of tDDT in breast muscle tissues (≤40.5 $\mu g \cdot kg^{-1}$ ww) (Braune 1993). By comparison, the fish-eating birds from the Arctic generally had much higher concentrations of DDT, with the highest tDDT concentrations measured in surf scoters *(Melanitta perspiliiata)* (up to 126 $\mu g \cdot kg^{-1}$ ww), lesser scaups *(Aythya affinis)* (up to 92 $\mu g \cdot kg^{-1}$ ww), and thick-billed murres *(Uria lomvia)* (up to 237 $\mu g \cdot kg^{-1}$ ww in chick whole body) (Braune 1993; Braune et al. 1994). Differences in DDT residues among the various bird species are also reflected in other tissues, such as liver and eggs.

Terrestrial birds, particularly raptors at the top of terrestrial food chains, are also susceptible to bioaccumulation of DDTs (Elliot and Martin 1994). Several studies have examined the levels of DDT and its metabolites in the eggs of terrestrial birds in the Okanogan Valley, British Columbia, and the Niagara Peninsula, Ontario (Noble and Elliott 1990; Elliott and Martin 1994; Elliott et al. 1994; Hebert et al. 1994). For example, mean DDE concentrations of 22.0, 11.0, and 1.2 $mg \cdot kg^{-1}$ ww were measured in eggs of American robins, black-billed magpies, and California quail, respectively, from central British Columbia (Elliot et al. 1994). These birds were though to obtain DDE burdens locally, since they were either occasional migrants or year-round residents. In top predators, mean DDE levels of 7.23, 4.48, and 0.90 $mg \cdot kg^{-1}$ ww were reported for eggs of sharp-shinned hawks, Cooper's hawks, and goshawks, respectively, in south-central Ontario from 1986 to 1989 (Elliot and Martin 1994). It should be noted in the above data that differences in average concentrations of DDE levels between top predators and lower-level consumers may be due to differences in sites examined, rather than food chain effects.

The two CCME-recommended analytical methods for the detection of tDDT in soils are "Organochlorine Pesticides and Polychlorinated Biphenyls by Gas Chromatography" (USEPA Method 8080B, Revision 2, November 1990) and "Semivolatile Organic Compounds by Gas Chromatography/ Mass Spectrometry (GC/MS): Capillary Column Technique" (USEPA Method 8270B, Revision 2, November 1990) (CCME 1993). Details of these methods can be found in CCME (1993). Following corrections for a 30-g soil sample digested with final extract being brought to 10 mL, a detection limit of 4×10^{6} mg DDT$\cdot kg^{-1}$ ww soil for USEPA method 8080B is calculated.

Environmental Fate and Behaviour

DDT enters the atmosphere during spraying operations and through volatilization from water, plants, and soils. Under simulated atmospheric conditions, both DDT and

DDD were subject to photooxidation, with potential decomposition to carbon dioxide and hydrochloric acid with an estimated half-life of 2 d. However, the presence of DDT residues throughout the atmosphere suggests that this reaction may occur more slowly under environmental conditions (WHO 1979; ATSDR 1994). Hence, precipitation (including both wet and dry deposition) and dustfall probably represent the most important environmental fate processes for DDT released into the atmosphere (Woodwell et al. 1971).

In water, adsorption to suspended particulates and subsequent deposition to aquatic sediments represents the most important fate process for DDT (Picer et al. 1977; Zayed et al. 1994). However, considerable losses of DDT from water may occur through volatilization (Edwards 1975). The potential importance of this process is emphasized by the reported volatilization half-life of DDT in water, which ranges from several hours to approximately 50 h (HSDB 1988). In addition, laboratory studies suggest that DDE is likely to volatilize 10–20 times faster from seawater than from freshwater (Atlas et al. 1982). In contrast, the transformation of DDT in surface waters is very slow. For instance, the estimated half-life for DDT hydrolysis, dark hydrolysis, direct photolysis, and photooxidation is 22 years, 8 years, 150 years, and 7–350 d, respectively (Zepp et al. 1976; Wolfe et al. 1977; USEPA 1979; Howard et al. 1991).

The cold condensation hypothesis suggests that sequential volatilization and condensation of certain organic pollutants results in transport toward the poles. This hypothesis is generally supported by data on DDT concentrations collected in surficial sediments from eight Canadian Arctic lakes between 1988 and 1991. DDT concentrations ranged from 0.11 to 9.96 $\mu g \cdot kg^{-1}$ dw, with significant declines in concentrations as latitude increases (Muir et al. 1995). While contemporary data (1985–1998) are somewhat limited regarding levels of DDT in sediments from temperate freshwater environments, mean concentrations of tDDT were generally below 15 $\mu g \cdot kg^{-1}$ dw (Jaagumagi et al. 1988; Jaagumagi et al. 1989). The Detroit and Niagara rivers had among the highest recent levels of tDDT in their sediments, with mean concentrations of 140 and 40.7 $\mu g \cdot kg^{-1}$ dw, respectively, observed in 1985 (Jaagumagi et al. 1988; Jaagumagi et al. 1989).

DDT forms strong associations with sediment particles (ATSDR 1989). Photooxidation has the potential to transform sediment-associated DDT; however, it is likely to be significant only in sediments that are periodically dewatered (Coulston 1985). Furthermore, hydrolysis of sediment-associated DDT has not been reported (Lichtenstein and Schultz 1959). Thus, biodegradation is probably the most important transformation process. Under aerobic conditions, dehydrochlorination is the dominant reaction that facilitates the degradation of DDT primarily to DDE (ATSDR 1994). Biodegradation occurs more rapidly under anaerobic than aerobic conditions, and results primarily in the formation of DDD through reductive dechlorination (Albone et al. 1972; ATSDR 1994). Oliver et al. (1989) used sediment cores from Lake Ontario to estimate the half-life of DDT in sediments at 14–21 years.

The majority of the historical and current global production of DDT has been used for application to soil (Bevenue 1976). DDT is usually very stable in soil since it is readily adsorbed, particularly to soil with high organic matter content. Half-life measurements under field conditions for the aerobic degradation of DDT in soil range from 2 years (Lichenstein and Shulz 1959) to more than 15 years (Keller 1970; Stewart and Chisholm 1971). In flooded soil or under anaerobic conditions, biodegradation is faster, with half-lives estimated from 16 to 100 d (Castro and Yoshida 1971). DDD is highly persistent in soils, with a half-life estimated to be 190 years (OMEE 1993b). DDT from contaminated soils migrates to other environmental compartments (i.e., sediment, water, atmosphere, and biota) through volatilization, erosion of soil particles, groundwater or surface water transport, and bioconcentration/bioaccumulation in biota.

Bell and Failey (1991) found that movement of DDT through the vapour phase was the dominant pathway of DDT contamination in plants. Concentrations of environmental contaminants in plants are much higher than concentrations in water and resemble those in soil and sediment (Trapp 1993).

Beyer and Gish (1980) examined the transfer and persistence of tDDT between soil and earthworms and the potential hazards this accumulation posed to birds. DDE was found to be the most persistent metabolite, with constant concentrations of 0.4 $mg \cdot kg^{-1}$ in soil and approximately 7 $mg \cdot kg^{-1}$ in earthworms when test plots were treated with 9 $kg \cdot ha^{-1}$ TG-DDT. Fries (1991) reported soil-to-earthworm BCFs from the scientific literature ranging from 2.5 to 16. Menzie et al. (1992) determined that the BCF would be highly dependent on the lipid content of the organism and the organic carbon content of the soil.

Birds and mammals accumulate DDT by ingesting contaminated foods, often resulting in high BAFs (BAF = DDT in bird or mammal tissues/DDT in diet). For example, BAFs of 12–29 were observed in mice fed DDT for up to 27 weeks (Laug et al. 1950). Lower BAFs (i.e., <1) were observed in rats that were administered DDE for 16 weeks in their diet (Wrenn et al. 1970). In hens,

10 mg·kg^{-1} of DDT in food for 2 months resulted in 117 mg·kg^{-1} residue in fat and 5 mg·kg^{-1} in egg yolk (Smith et al. 1970). Field-collected data show that the highest bioaccumulation levels are generally observed in terrestrial predators that feed primarily on other birds or aquatic predators that feed largely on fish (WHO 1989). For instance, species such as peregrine falcons *(Falco peregrinus anatum)*, kestrels *(Falconidae)*, and bald eagles *(Haliaeetus leucocephalus)* tend to have higher DDT residues compared to species such as golden eagles *(Aquila chrysaetos)* and buzzards *(Cathartes aura)*, which feed primarily on rodents and reptiles (WHO 1989). Carnivorous species tend to have higher DDT BAFs than herbivorous species. Based on a field study, Forsythe and Peterle (1984) reported BAFs ranging from 0.90 to 0.91 (ww food : ww whole body) for voles (herbivores) and from 1.31 to 1.77 (ww food : ww whole body) for shrews (carnivores).

Behaviour and Effects in Biota

Soil Microbial Processes

Microorganisms are an important part of terrestrial ecosystems. Thus, changes to the structure and function of microorganism populations could have adverse effects on the functioning of the ecosystem. For instance, Bollen et al. (1954) reported slight reductions in mould counts in Chehalis silty clay loam and Melbourne clay loam at soil concentrations of 5 and 10 mg·kg^{-1} DDT, respectively. Jones (1952) added DDT to a fertile black loam, high in organic matter, and to a sandy loam, low in organic matter. In both soils, 1250 mg·kg^{-1} of DDT reduced ammonification by 12%, whereas, 1000 mg·kg^{-1} of DDT reduced nitrification by 36% compared to control levels. Eno and Everett (1958) reported a 31% reduction in nitrate production after 16 months of exposure following the addition of 12.5 mg·kg^{-1} DDT to an Arredondo loamy fine sand. A 24% and a 22% reduction in nitrate production were also reported after 16 months of exposure to 50 and 100 mg·kg^{-1}, respectively.

Terrestrial Plants

DDT is known to be phytotoxic to a number of agricultural crops (Tomlin 1994). Moreover, technical grade DDT (5% impurities) was reported to be more toxic to plants than purified DDT (Thurston 1953; Boswell et al. 1955). According to the available literature, the Blakemore strawberry plant is the crop species most sensitive to the presence of DDT in soil. As reported by Goldsworthy and Dunegan (1948), 3 mg DDT·kg^{-1} soil are sufficient to inhibit root development in this species, while 6 mg DDT·kg^{-1} soil can reduce the number of plants produced by 21%. Boswell et al. (1955) conducted an extensive experimental field study on the long-term effects (4 years) of single applications of technical and purified DDT on a wide range of crop plants in various North American locations having different soil types. They reported that harmful and persistent effects of DDT were more pronounced in fine sandy loam having low organic matter and relatively low mineral colloids than any other soils. The most sensitive crop in this study, stringless black valentine beans, suffered reduced pod and vine yields of 34 and 36%, respectively, 1 year after the single application of 12 mg DDT·kg^{-1} soil.

Terrestrial Invertebrates

Hoy (1955) conducted field experiments in which significant earthworm mortality (66 and 74%) occurred at 15 and 30 mg DDT·kg^{-1} soil, respectively, 23 weeks after pesticide application. Cook et al. (1980) observed reductions and complete elimination of earthworm surface casting activity in DDT-treated plots and laboratory trials in southern Nigeria. The lowest observed concentration of DDT, which resulted in 35–45% casting reductions in laboratory trials, was 25 mg DDT·kg^{-1} soil. Furthermore, surface casting completely disappeared for two earthworms species at 125 mg DDT·kg^{-1} soil. However, the density or biomass of earthworms did not differ significantly between treated and untreated plots, regardless of the reductions in casting activity. The authors suggest that the worms may have inhabited deeper soils to avoid contact with high concentrations of DDT and continued casting in the subsurface. Perfect et al. (1981) determined that soil DDT concentrations of 25 mg DDT·kg^{-1} resulted in the mortality of 50% of Cryptostigmatid mites *(Archegoztes magna)* after 24 h.

Birds and Mammals

DDT is known to reduce longevity in mammals and to alter cellular metabolism, neural activity, and liver function (USEPA 1980). Furthermore, adverse effects on reproduction, growth, and immunocompetence have been observed in both mammalian and avian species exposed to DDT. Mutagenic and carcinogenic effects are known to occur in various species as a result of long-term dietary exposures (ATSDR 1994). A variety of neurotoxic effects, including tremors, convulsions, hyperexcitability, hyperthermia, and tachycardia (rapid heartbeat), have been reported following acute exposures to DDT (WHO 1989; ATSDR 1994). Studies have confirmed that DDT effectively mimics the reproductive hormone estrogen. Thus, elevated levels of DDT can result in reduced

fertility, gestation period, fecundity, and fetal weight (Wrenn et al. 1970; Hart et al. 1971). DDT can also influence reproductive success in males by reducing testes weight and seminiferous tubule diameter (Krause et al. 1975; ATSDR 1994). In birds, the estrogenic effects of DDT are expressed by changes in mating behaviour and thinning of eggshells (WHO 1989).

The results of controlled acute toxicity studies have demonstrated that TG-DDT is only moderately toxic to mammals, while longer-term studies have demonstrated that these substances cause a range of chronic effects in both birds and mammals. Of the species tested, dogs appear to be the most sensitive, with acute oral LD_{50}s ranging from 60 to 75 mg·kg^{-1} (USEPA 1980). Mice are also relatively sensitive to TG-DDT, with LD_{50}s ranging from 80 to 95 mg·kg^{-1} (Terracini et al. 1973). Similarly, long-term exposure to TG-DDT has been demonstrated to affect survival in rodents (Fitzhugh and Nelson 1947). Daily doses of 29.3 mg·kg^{-1} bw per day greatly reduced the longevity of male mice from more than 80 weeks to fewer than 50 weeks (Terracini et al. 1973).

Data from many studies confirm that DDT is carcinogenic in certain laboratory animals (ATSDR 1994). Terracini et al. (1973) conducted a multigenerational study to evaluate the carcinogenic effects of TG-DDT on weanling BALBc mice. In female mice, 29.3 mg TG-DDT·kg^{-1} bw per day in the diet for up to 980 d significantly increased the incidence of liver-cell tumours in both parental (44.4%) and first generation (74.1%) mice. A significant increase (up to 13%) in the incidence of liver tumours was observed in female CF-1 mice administered 5.84 mg·kg^{-1} bw per day of TG-DDT for an average of 707 d (Turusov et al. 1973). In a multigenerational study, Tarjan and Kemeny (1969) investigated the effects of *p,p'*-DDT on both male and female BALBc mice. Incidence of leukemia and malignant tumours was increased by long-term exposure to daily doses as low as 0.7 mg *p,p'*-DDT·kg^{-1} bw per day. These effects were significant in the F_2 and F_3 generations and continued to increase in each succeeding generation. At somewhat higher doses (5.5 and 11 mg·kg^{-1} bw per day), increased liver tumour incidence was reported in CF-1 mice during 630- to 730-d exposures (Walker et al. 1972; Thorpe and Walker 1973).

DDT and its metabolites, DDE and DDD, generally have moderate to low toxicities to birds when administered as acute oral doses or in the diet (WHO 1989). Five-day LC_{50}s of DDT were 611 mg·kg^{-1} diet in adult bobwhite quail *(Colinus virginianus)*, 568 mg·kg^{-1} diet in Japanese quail, and 1869 mg·kg^{-1} diet in mallard ducks (Hill et al. 1971). Pheasants had a more sensitive response with a 5-d LC_{50} of 311 mg DDT·kg^{-1} diet (Hill et al. 1971). Sensitivity to DDT differs significantly depending on the life stage of the species under consideration. For example, a 10-d LD_{45} of 23 mg·kg^{-1} bw per day was reported by Gish and Chura (1970) for 3-month-old quails. Long-term exposure (120 d) to TG-DDT was associated with increased thyroid weight in Japanese quail at levels of 45 mg TG-DDT·kg^{-1} bw per day (Hurst et al. 1974). However, growth rates, as indicated by final body weight, were not affected in this study. American kestrels *(Falco sparverius)* were among the most sensitive species tested, as yearling and 5-year-old males died when administered 0.84 mg·kg^{-1} bw per day of *p,p'*-DDE for 420–480 d (Porter and Wiemeyer 1972). Van Velzen et al. (1972) emphasized the potential for lethal mobilization of DDT residues stored in fat during periods of stress, such as reproduction, cold weather, disease, injury, limited food supply, or migration.

Lincer (1975) fed captive American kestrels diets containing 3 mg DDE·kg^{-1} food, which resulted in a 15.1% thinning of eggshells. The effects of dietary DDE on eggshell thinning in raptors have been confirmed in other laboratory studies on kestrels and screech owls *(Otus asio)* (Wiemeyer and Porter 1970; McLane and Hall 1972; Peakall et al. 1973). Waterfowl species also appear to be very sensitive to DDT. Eggshell index was significantly reduced when mallard ducks were given 1 mg·kg^{-1} bw per day of *p,p'*-DDT for 30 d (Kolaja 1977). Similar results were obtained when mallard ducks were administered 1 mg *p,p'*-DDE·kg^{-1} bw per day for 105 d (Vangilder and Peterle 1980). On the other hand, galliform species seem very resistant to eggshell thinning. Administration of daily doses of TG-DDT as high as 5.7 mg·kg^{-1} bw to leghorn chickens and Japanese quail for 70 d had no effect on the breaking strength of eggs (Scott et al. 1975). Field observations reported that a 20% reduction in eggshell thickness was associated with population decline in seven out of eight bird species (Anderson and Hickey 1972).

Guideline Derivation

Canadian soil quality guidelines are derived for different land uses following the process outlined in CCME (1996a) using different receptors and exposure scenarios for each land use (Table 1). Detailed derivations for DDT soil quality guidelines are provided in Environment Canada (1998).

Soil Quality Guidelines for Environmental Health

Environmental soil quality guidelines (SQG_Es) are usually based on soil contact using data from toxicity studies on plants and invertebrates. In the case of agricultural land, soil and food ingestion toxicity data for mammalian and avian species are also included. However, since DDTs are

persistent substances that are subject to long-range transport and have a strong tendency to bioaccumulate and biomagnify in the food chain, particularly in third-level predators, the concept of land uses as envisioned in CCME (1996a) does not provide adequate protection for ecological receptors. Therefore, soil quality guidelines for residential/ parkland and agricultural land uses are based on models designed to protect primary, secondary, and tertiary consumers from ingestion of contaminated soil and food. To provide a broader scope of protection, a soil nutrient and energy cycling check is also calculated.

For all land uses, the preliminary soil contact value (also called threshold effects concentration [TEC] or effects concentration low [ECL], depending on the land use) is compared to the nutrient and energy cycling check. If the nutrient and energy cycling check is lower, the geometric mean of the preliminary soil contact value and the nutrient and energy cycling check is calculated as the soil quality guideline for soil contact. If the nutrient and energy cycling check is greater than the preliminary soil contact value, the preliminary soil contact value becomes the soil quality guideline for soil contact.

For residential/parkland and agricultural land uses, the lower of the soil quality guideline for soil contact and the soil and food ingestion guideline is recommended as the SQG_E. The soil and food ingestion guideline is based on the lowest of three values: the protection of primary consumers value, the protection of secondary consumers value, and the protection of tertiary consumers value. The primary consumer value is modeled using a soil → plant → herbivore pathway; the secondary consumer model uses a soil → plant → herbivore → predator pathway; and the tertiary consumer model uses a soil → invertebrate → secondary consumer → predator pathway. All exposure scenarios incorporate bioconcentration and bioavailability factors of DDTs through the food chains to estimate the soil concentrations, which should not be exceeded in order to prevent adverse toxicological effects to ecological receptors.

For commercial and industrial land uses, the soil quality guideline for soil contact is recommended as the SQG_E. However, in site-specific situations where the size and/or the location of these land uses may impact primary, secondary, or tertiary consumers, the soil and food ingestion guideline is recommended as the SQG_E.

Acceptable toxicological data were available for a variety of DDT isomers and commercial mixtures. As many combinations of DDT isomers and metabolites (including DDE and DDD) may be present in the soil environment, the guideline derived from these data should be regarded as a guideline for total DDTs present in the soil.

Soil Quality Guidelines for Human Health

There are no human health guidelines or check values available at this time (Table 2).

Soil Quality Guidelines for DDT

The soil quality guidelines are usually the lower of the SQG_E and the interim soil quality criteria (CCME 1991). However, since no interim soil quality criteria were established for DDT, the SQG_Es are the soil quality guidelines for all land uses. (Table 1).

CCME (1996b) provides guidance on potential modifications to the recommended soil quality guideline when setting site-specific objectives.

References

Agriculture and Agri-Food Canada. 1996. Regulatory information on pesticide products. Agriculture and Agri-Food Canada and Canadian Centre for Occupational Health and Safety, Ottawa.

Albone, E.S., G. Eglinton, N.C. Evans, et al. 1972. Fate of DDT in seven estuary sediments. Environ. Sci. Technol. 6:914–919. (Cited in ATSDR 1994.)

Anderson, D.W., and J.J. Hickey. 1972. Eggshell changes in certain North American birds. Proc. Int. Ornithol. Congr. 15:514–540.

Atlas, E., R. Foster, and C. Glam. 1982. Air–sea exchange of high molecular weight organic pollutants: Laboratory studies. Environ. Sci. Technol. 16:283–286. (Cited in ATSDR 1994.)

ATSDR (Agency for Toxic Substances and Disease Registry). 1989. Toxicological profile for DDT, DDE, and DDD. U.S. Public Health Service, Agency for Toxic Substances and Disease Registry, Atlanta, GA.

———. 1994. Toxicological profile for DDT, DDE, and DDD (update). U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, Atlanta, GA.

Bell, R.M., and R.A. Failey. 1991. Plant uptake of organic pollutants. In: Organic contaminants in the environment, K.C. Jones, ed.. Elsevier Science Publishers Ltd., London.

Bevenue, A. 1976. The "bioconcentration" aspects of DDT in the environment. Residue Rev. 61:37.

Beyer, W.N., and C.D. Gish. 1980. Persistence in earthworms and potential hazards to birds of soil applied DDT, dieldrin and heptachlor. J. Appl. Ecol. 17:295–307.

Bollen, W.B., H.E. Morrison, and H.H. Crowell. 1954. Effect of field and laboratory treatments with BHC and DDT on nitrogen transformations and soil respiration. J. Econ. Entomol. 47(2):307–312.

Boswell, V.R, W.J. Clore, B.B Pepper, C.B. Taylor, P.M. Gilmer, and R.L. Carter. 1955. Effects of certain insecticides in soil on crop plants. U.S. Department of Agriculture Technical Bulletin No. 1121, Washington, DC.

Bowes, G.W., and C.J. Jonkel. 1975. Presence and distribution of polychlorinated biphenyls (PCB) in Arctic and sub-Arctic marine food chains. J. Fish. Res. Board Can. 32:2111–2123. (Cited in Muir et al. 1992.)

Braune, B.M. 1993. Trends and effects of environmental contaminants in arctic seabirds, waterfowl and other wildlife. Study I., Contaminants in waterfowl: Native harvest in Labrador. In:

Table 2. Soil quality guidelines and check values for DDT (total) (mg·kg^{-1}).

	Land use			
	Agricultural	**Residential/ parkland**	**Commercial**	**Industrial**
Guideline	**0.7**[a]	**0.7**[a]	**12**[a, b]	**12**[a, b]
Human health guidelines/check values[c]				
SQG_{HH}	NC	NC	NC	NC
Soil ingestion guideline	NC	NC	NC	NC
Inhalation of indoor air check	NC	NC	NC	NC
Off-site migration check	—	—	—	NC
Groundwater check (drinking water)	NC	NC	NC	NC
Produce, meat, and milk check	NC	NC	—	—
Provisional SQG_{HH}	NC	NC	NC	NC
Limiting pathway for provisional SQG_{HH}	ND	ND	ND	ND
Environmental health guidelines/check values				
SQG_E	0.7[d]	0.7[d]	12[b, e]	12[b, e]
Soil contact guideline	12	12	12	12
Soil and food ingestion guideline:				
Primary consumer	1.5	1.5	—	—
Secondary consumer (mammal)	2	2	—	—
Secondary consumer (bird)	0.7	0.7		
Tertiary consumer	1	1		
Nutrient and energy cycling check	547	547	547	547
Off-site migration check	—	—	—	ND
Groundwater check (aquatic life)	0.1[f]	0.1[f]	0.1[f]	0.1[f]
Provisional SQG_E	NC[g]	NC[g]	NC[g]	NC[g]
Limiting pathway for provisional SQG_E	ND	ND	ND	ND
Interim soil quality criterion (CCME 1991)	—	—	—	—

Notes: NC = not calculated; ND = not determined; SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health. The dash indicates guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.

[a]Data are sufficient and adequate to calculate only an SQG_E. The interim soil quality criterion (CCME 1991) has not been established for this land use, therefore, the SQG_E becomes the soil quality guideline.

[b]In site-specific situations where the size and/or the location of commercial and industrial land uses may impact primary, secondary, or tertiary consumers, the soil and food ingestion guideline is recommended as the SQG_E.

[c]There are no values for the human health guidelines/check values at this time.

[d]Based on the lowest of the soil and food ingestion guideline values, which are based on primary, secondary, or tertiary consumer receptors.

[e]Based on the soil contact guideline value.

[f]The environmental groundwater check (aquatic life) value has not been applied in the determination of the soil quality guideline. The applicability of the groundwater check (aquatic life) should be determined on a site-specific basis.

[g]Because data are sufficient and adequate to calculate an SQG_E for this land use, a provisional SQG_E is not calculated.

Synopsis of research conducted under the 1992/93 Northern Contaminants Program, J.L. Murray and R.G. Shearer, eds. Environmental Studies #70. ISBN 0-662-21037-9. Indian Affairs and Northern Development Canada, Northern Affairs Program, Ottawa.

Braune, B.M., B. Wakeford, A. Gaston, A. Scheuhammer, D. Nettleship, and K. McCormick. 1994. Trends and effects of environmental contaminants in arctic seabirds, waterfowl and other wildlife. Study II, Contaminants in arctic seabirds. In: Synopsis of research conducted under the 1993/94 Northern Contaminants Program, J.L. Murray and R.G. Shearer, eds. Environmental Studies #72. ISBN 0-662-22692-5. Indian Affairs and Northern Development Canada, Northern Affairs Program, Ottawa.

Budavari, S., M.J. O'Neil, A. Smith, and P.E. Heckelman. 1989. The Merck index: An encyclopedia of chemicals, drugs and biologicals. Merck and Company, Inc., Rahway, NJ.

Castro, T.F., and T. Yoshida. 1971. Degradation of organochlorine insecticides in flooded soils in the Philippines. J. Agric. Food Chem. 19:168–170.

CCME (Canadian Council of Ministers of the Environment). 1991. Interim Canadian environmental quality criteria for contaminated sites. CCME, Winnipeg.

———. 1993. Guidance manual on sampling, analysis, and data management for contaminated sites. Vol. II, Analytical method summaries. CCME, Winnipeg.

———. 1996a. A protocol for the derivation of environmental and human health soil quality guidelines. CCME, Winnipeg. [A summary of the protocol appears in Canadian environmental quality guidelines, Chapter 7, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]

———. 1996b. Guidance manual for developing site-specific soil quality remediation objectives for contaminated sites in Canada. CCME, Winnipeg. [Reprinted in Canadian environmental quality guidelines, Chapter 7, Canadian Council of Ministers of the Environment, 1999, Winnipeg.]

CCREM (Canadian Council of Resource and Environment Ministers). 1987. Canadian water quality guidelines. Prepared by the Task Force on Water Quality Guidelines.

Cook, A.G., B.R. Critchley, U. Critchley, T.J. Perfect, and R. Yeadon. 1980. Effects of cultivation and DDT on earthworm activity in a forest soil in the sub-humid tropics. J. Appl. Ecol. 17:21–29.

Coulston, F. 1985. Reconsideration of the dilemma of DDT for the establishment of an acceptable daily intake. Regul. Toxicol. Pharmacol. 5:332–383. (Cited in ATSDR 1994.)

Edwards, C.A. 1975. Persistent pesticides in the environment. 2d ed. CRC Press, Cleveland, OH. (Cited in Zayed et al. 1994.)

Elkin B.T., and R.W. Bethke. 1995. Environmental contaminants in caribou in the Northwest Territories, Canada. Sci. Total Environ. 160–161:307–321.

Elliott, J.E., and P.A. Martin. 1994. Chlorinated hydrocarbons and shell thinning in eggs of *(Accipiter)* hawks in Ontario, 1986–1989. Environ. Pollut. 86:189–200.

Elliott, J.E., P.A. Martin, T.W. Arnold, and P.H. Sinclair. 1994. Organochlorines and reproductive success of birds in orchard and non-orchard areas of central British Columbia, Canada, 1990–91. Arch. Environ. Contam. Toxicol. 26:435–443.

Eno, C.F., and P.H. Everett. 1958. Effects of soil applications of 10 chlorinated hydrocarbon insecticides on soil microorganisms and the growth of stringless black valentine beans. Soil Sci. Soc. Am. Proc. 22:235–238.

Environment Canada. 1995. Substance profile for DDT, DDE and DDD. In: Supporting documentation for the International Experts Meeting on Persistent Organic Pollutants (POPs): Towards Global Action. Canadian Planning Committee. Hull, Quebec.

———. 1998. Canadian soil quality guidelines for DDT: Environmental. Supporting document — Final draft. October 1998. Environmental Conservation Service, Environmental Quality Branch, Guidelines and Standards Division, Ottawa.

Fitzhugh, O.G., and A.A. Nelson. 1947. The chronic oral toxicity of DDT (2,2-bis-*p*-chlorophenyl-1,1,1-trichloroethane). J. Pharmacol. 89:18-30.

Forsythe, D.J., and T.J. Peterle. 1984. Species and age differences in accumulation of ^{36}Cl-DDT by voles and shrews in the field. Environ. Pollut. (Series A) 33:327–340.

Fries, G.F. 1991. Organic contaminants in terrestrial food chains. In: Organic contaminants in the environment, K.C. Jones, ed. Elsevier Science Publishers Ltd., London.

Gish, C.D., and N.J. Chura. 1970. Toxicity of DDT to Japanese quail as influenced by body weight, breeding condition and sex. Toxicol. Appl. Pharmacol. 17:740–751.

Goldsworthy, M.C., and J.C. Dunegan. 1948. The effect of incorporating technical DDT in soil on the growth of Blakemore strawberry plants. Plant Dis. Rep. 32(4):139–143.

Hart, M.M., R.H. Adamson, and S. Fabro. 1971. Prematurity and intrauterine retardation induced by DDT in the rabbit. Arch. Int. Pharmacodyn. Ther. 192:286.

Hebert, C.E., D.V. Weseloh, L. Kot, and V. Glooschenko. 1994. Organochlorine contaminants in a terrestrial food web on the Niagara Peninsula, Ontario, Canada 1987–89. Arch. Environ. Contam. Toxicol. 26:356–366.

Hill, E.F., W.E. Dale, and J.W. Miles. 1971. DDT intoxication in birds: Sub-chronic effects and brain residues. Toxicol. Appl. Pharmacol. 20:502–514.

Howard, P.H., R.S. Boethling, W.F. Jarvis, W.M. Meylan, and E.M. Michalenko. 1991. Handbook of environmental degradation rates. Lewis Publishers, Chelsea, MI.

Hoy, J.M. 1955. Toxicity of some hydrocarbon insecticides to earthworms. N. Z. J. Sci. Technol. 37:367–372.

HSDB (Hazardous Substances Data Bank). 1988. National Library of Medicine, National Toxicology Information Program, Bethesda, Maryland. November 11, 1988. (Cited in ATSDR 1994.)

Hurst, J.G., W.S. Newcomer, and J.A. Morrison. 1974. Some effects of DDT, toxaphene and polychlorinated biphenyl on thyroid function in bobwhite quail. Poult. Sci. 53(1):125–133.

Indian and Northern Affairs Canada. 1997. Canadian Arctic contaminants assessment report. Department of Indian Affairs and Northern Development, Ottawa.

IRPTC (International Register of Potentially Toxic Chemicals) 1990. IRPTC databases on-line. Government of Canada, Bureau of Chemical Hazards, Ottawa.

Jaagumagi, R., D. Persaud, and T. Lomas. 1988. The in-place pollutants program: Vol. V, Part B, Benthic invertebrates studies results. ISBN 0-7729-5435-6. Prepared for the Ontario Ministry of the Environment, Water Resources Branch, Toronto.

———. 1989. The in-place pollutants program: Vol. V, Part A, A synthesis of benthic invertebrate studies. Ontario Ministry of the Environment, Water Resources Branch, Aquatic Biology Section, Toronto.

Johnstone, R.M., G.S. Court, D.M. Bradley, J.D. MacNeil, A.C. Fesser, and L.W. Oliphant. 1994. Temporal trends in contaminant levels of the peregrine falcon and its prey in the Keewatin District of the Northwest Territories. In: Synopsis of research conducted under the 1993/94 Northern Contaminants Program, J.L. Murray and R.G. Shearer, eds. Environmental Studies #72. ISBN 0-662-22692-5. Northern Affairs Program. Indian Affairs and Northern Development Canada, Ottawa.

Jones, L.W. 1952. Stability of DDT and its effect on microbial activities of soil. Soil Sci. 73:237–241.

Keller, E. 1970. The DDT story. Chemistry 43:8–12. (Cited in CCREM 1987).

Kolaja, G.J. 1977. The effects of DDT, DDE and their sulfonated derivatives on eggshell formation in the mallard duck. Bull. Environ. Contam. Toxicol. 17(6):697–701.

Krause, W., K. Hamm, and J. Weissmüller. 1975. The effect of DDT on spermatogenesis of the juvenile rat. Bull. Environ. Contam. Toxicol. 14:171–179.

Laug, E.P., A.A. Nelson, O.G. Fitzhugh, and F.M. Kunze. 1950. Liver cell alteration and DDT storage in the fat of the rat induced by dietary levels of 1 to 50 ppm DDT. J. Pharmacol. Exp. Ther. 98:268.

Lichtenstein, E., and K. Schulz. 1959. Persistence of some chlorinated hydrocarbon insecticides as influenced by soil types, rate of application and temperature. J. Econ. Entomol. 52:124–131. (Cited in ATSDR 1994.)

Lincer, J.L. 1975. DDE-induced eggshell-thinning in the American kestrel: A comparison of the field situation and laboratory results. J. Appl. Ecol. 12:781–793.

McLane, M.A.R., and L.C. Hall. 1972. DDE thins screech owl eggshells. Bull. Environ. Contam. Toxicol. 8(2):65–68.

Menzie, C.A., D.E. Burmaster, J.S. Freshman, and C.A. Callahan. 1992. Assessment of methods for estimating ecological risk in the terrestrial component: A case study at the Baird and McGuire Superfund site in Holbrook, Massachusetts. Environ. Toxicol. Chem. 11:245–260.

Muir, D.C., R, Wagemann, B.T. Hargrave, D.J. Thomas, D.B. Peakall, and R. J. Norstrom. 1992. Arctic marine ecosystem contamination Sci. Total Environ. 122:75–134.

———. 1995. Spatial trends and historical profiles of organochlorine pesticides in Arctic lake sediments. Sci. Total Environ. 160/161:447–457.

Nigam, P.C. 1975. Chemical insecticides. In: Aerial control of forest insects in Canada, M.L. Prebble, ed. Department of the Environment, Ottawa.

Noble, D.G., and J.E. Elliott. 1990. Levels of contaminants in Canadian raptors, 1966 to 1988: Effects and temporal trends. Can. Field-Nat. 104(2):222–243.

Oliver, B.G., M.N. Charlton, and R.W. Durham. 1989. Distribution, redistribution and geochronology of PCB congeners and other chlorinated hydrocarbons in Lake Ontario sediments. Environ. Sci. Technol. 23:200–208.

OMEE (Ontario Ministry of Environment and Energy). 1993a. Ontario typical range of chemical parameters in soil, vegetation, moss bags and snow. Version 1.0a. PIBS 2792. Standards Development Branch, Phytotoxicology Section, Toronto.

———. 1993b. Candidate substances for bans, phase-outs or reductions. Multimedia revision. Report. Toronto.

Ostromogil'skii, A.K., A.O. Kokorin, and M.I. Afanas'ev. 1987. Modeling the global DDT cycle. Sov. Meteorol. Hydrol. 2:28–35.

Peakall, D.B., J.L. Lincer, R.W. Risebrough, J.G. Pritchard, and W.B. Kinter. 1973. DDE-induced egg-shell thinning: Structural and physiological effects in three species. Comp. Gen. Pharmacol. 4:305–313.

Perfect, T.J., A.G. Cook, B.R. Critchley, and A. Russel–Smith. 1981. The effect of crop protection with DDT on the microarthropod population of a cultivated forest soil in the sub-humid tropics. Pedobiologia 21:7–18.

Picer, N., M. Picer, and P. Strohal. 1977. The interaction of DDT with suspended particles in sea water. Water Air Soil Pollut. 8(4):429–440.

PMRA (Pest Management Regulatory Agency). 1995. Database enquiry service. Health Canada, Ottawa.

Porter R.D., and S.N. Wiemeyer. 1972. DDE at low dietary levels kills captive American kestrels. Bull. Environ. Contam. Toxicol. 8(4):193–199.

Risebrough, R.W., W.M. Jarman, A.M. Springer, W. Walker, II, and W.G. Hunt. 1986. A metabolic derivation of DDE from Kelthane. Environ. Toxicol. Chem. 5:13–19.

Ronald, K., R.J. Frank, J.L. Dougan, R. Frank, and H.E. Braun. 1984. Pollutants in harp seals *(Phoca groenlandica)*: I, Organochlorines. Sci. Total Environ. 38:133–152.

Scott, M.L., J.R. Zimmermann, S. Marinsky, P.A. Mullenhoff, G.L. Rumsey, and R.W. Rice. 1975. Effects of PCBs, DDT and mercury compounds upon egg production, hatchability and shell quality in chickens and Japanese quail. Poult. Sci. 54(2):350–368.

Smith, S.I., C.W. Weber, and B.L. Reid. 1970. Dietary pesticides and contamination of yolks and abdominal fat of laying hens. Poult. Sci. 49:233–237.

Stewart, D., and D. Chisholm. 1971. Long-term persistence of BHC, DDT and chlordane in sandy loam soil. Can. J. Soil Sci. 51:379–383.

Suntio, L.R., W.Y. Shiu, D. Mackay, J.N. Seiber, and D. Glotfelty. 1988. Critical review of Henry's law constants for pesticides. Rev. Environ. Contam. Toxicol. 103:1–59.

Tarjan, R., and T. Kemeny. 1969. Multigeneration studies on DDT in mice. Food Cosmet. Toxicol. 7:215.

Terracini, B., M.C. Testa, J.R. Cabral, and N. Day. 1973. The effects of long–term feeding of DDT to BALB/C mice. Int. J. Cancer 11:747.

Thomas, D.J., and M.C. Hamilton. 1988. Organochlorine residues in biota of the Baffin Island region. SeaKem Oceanography Ltd., Sidney, BC. Report prepared for Indian and Northern Affairs Canada, Ottawa. (Cited in Muir et al. 1992.)

Thorpe, E., and A.I. Walker. 1973. The toxicology of dieldrin (HEOD): II, Comparative long–term oral toxicity studies in mice with dieldrin, DDT, Phenobarbitione, B–BHC and A–BHC. Food Cosmet. Toxicol. 11:433.

Thurston, R. 1953. The effects of some soil characteristics on DDT phytotoxicity. J. Econ. Entomol. 46(4):545–550.

Tomlin, C. (ed.) 1994. The pesticide manual: A world compendium (incorporating the Agrochemicals handbook). 10th ed. British Crop Protection Council, Farnham, Surrey, UK.

Trapp, S. 1993. Modeling the uptake of organic compounds into plants. In: Fate and prediction of environmental chemicals in soils, plants and aquatic systems, M. Mansour, ed. Lewis Publishers, Boca Raton, FL.

Turusov, V.S., N.E. Day, L. Tomatis, E. Gati, and R.T. Charles. 1973. Tumors in CF-1 mice exposed for six consecutive generations to DDT. J. Natl. Cancer Inst. 51:983.

Twinn, C.R. 1947. The newer insecticides, repellents and rodenticides of values in the field of public health. Sci. Agric. [Ottawa] 27:97–104.

UNECE (United Nations Economic Commission for Europe). 1994. Descriptions of substances identified in the UNECE LRTAP Convention: Task Force on Organic Pollutants.

USEPA (U.S. Environmental Protection Agency). 1979. Water-related environmental fate of 129 priority pollutants. EPA 440/4/79/029a. U.S. Environmental Protection Agency, Washington, DC.

———. 1980. Ambient water quality criteria for DDTs. EPA 440/5/80/038. U.S. Environmental Protection Agency, Criteria and Standards Division, Office of Water Regulations and Standards, Washington, DC.

Vangilder, L.D., and T.J. Peterle. 1980. South Louisiana crude oil and DDE in the diet of mallard hens: Effects on reproduction and duckling survival. Bull. Environ. Contam. Toxicol.25:23–28.

van Velzen, A.C., W.B. Stiles, and L.F. Stickel. 1972. Lethal mobilization of DDT by cowbirds. J. Wildl. Manag. 36(3):733–739.

Walker, A.I., E. Thorpe, and D.E. Stevenson. 1972. The toxicology of dieldrin (HEOD): I, Long-term oral toxicity studies in mice. Food Cosmet. Toxicol. 11:415.

Wayland, M. 1995. Environmental contaminants in mink: Peace and Athabasca rivers. Northern River Basins Study Project Report No. 47. Edmonton.

WHO (World Health Organization). 1979. DDT and its derivatives. Environmental Health Criteria 9. Geneva. (Cited in ATSDR 1994.)

———. 1989. DDT and its derivatives: Environmental aspects. Environmental Health Criteria 83. Geneva.

Wiemeyer, S.N., and R.D. Porter. 1970. DDE thins eggshells of captive American kestrels. Nature 227:737–738.

Wolfe, N.L., R.G. Zepp, D.F. Paris, G.L. Baughman, and R.C. Hollis. 1977. Methoxychlor and DDT degradation in water: Rates and products. Environ. Sci. Technol. 11(12):1077–1081.

Woodwell, G., P. Craig, and H. Johnson. 1971. DDT in the biosphere: Where does it go? Science 74:1101–1107. (Cited in ATSDR 1994.)

Worthing, C.R., and R.J. Hance (eds.). 1991. The pesticide manual: A world compendium. 9th ed. British Crop Protection Council, Farnham, Surrey, UK.

Wrenn, T.R., J.R. Wood, G.F. Fries, and J. Bitman. 1970. Tests of estrogenicity in rats fed low levels of *o,p'*-DDT. Bull. Environ. Contam.Toxicol. 5(1):61–66.

Zayed, S.M., A.E. El-Arab, and S.M. Soliman. 1994. Dissipation of DDT in natural water under field conditions. J. Environ. Sci. Health Part B B29(1):185–188.

Zepp, R.G., N.L. Wolfe, J.A. Gordon, and R.C. Fincher. 1976. Light induced transformations of methoxychlor in aquatic systems. J. Agric. Food Chem. 24:727–733. (Cited in CCREM 1987.)

Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian soil quality guidelines for the protection of environmental and human health: DDT (total) (1999). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

For further scientific information, contact:

Environment Canada
Guidelines and Standards Division
351 St. Joseph Blvd.
Hull, QC K1A 0H3
Phone: (819) 953-1550
Facsimile: (819) 953-0461
E-mail: ceqg-rcqe@ec.gc.ca
Internet: http://www.ec.gc.ca

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