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# Existing Substances Program

*Canadian Environmental Protection Act, 1999 – CEPA 1999*



## **Draft Follow-up to the 1993 Ecological Risk Assessment of Organotin Substances on Canada's Domestic Substances List**

**June 2006**

Canada 

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Assessment of Organotin Substances on  
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## 1.0 Introduction

Between August 1994 and March 2000, the Minister of the Environment received notifications for nine organotin substances as “new” and/or “transitional” substances pursuant to Subsection 26(2) of the 1988 *Canadian Environmental Protection Act* (CEPA) or Subsection 81(1) of the *Canadian Environmental Protection Act, 1999* (CEPA 1999). These substances were proposed for importation or manufacture in Canada as stabilizers for polyvinyl chloride (PVC) products, as intermediates used in the manufacture of organotin stabilizers and as fungicides or preservatives for building material formulations.

These new and transitional substances were assessed, and it was concluded that the nine substances are entering or may enter the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. Therefore, these substances are suspected of meeting the criteria set out under Paragraph 64(a) of CEPA 1999.

Environment Canada has produced a consolidated assessment report that presents the basis for the environmental concerns with these nine substances (Environment Canada, 2006). The report, entitled *Risk assessment of new and transitional organotin substances*, is available upon request from the Director, New Substances Division, Environment Canada, at [nsn-info@ec.gc.ca](mailto:nsn-info@ec.gc.ca).

The purpose of the present document is to determine if the conclusions reached for the nine notified individual organotins would also apply to other organotin substances on Canada’s Domestic Substances List (DSL).

Organotin substances are generally represented by the formula  $R_xSnL_{4-x}$  (where  $x = 1-4$ ). For these chemicals, “R” is a typical organic group, such as methyl, octyl, butyl or phenyl, which is covalently bonded to the tin atom by a carbon–tin bond. The other anionic moieties on tin, designated “L,” may be halogens (chloride, fluoride, etc.) or other sulphur- or oxygen-based organic moieties, such as  $-SR'$ ,  $-OR'$ ,  $-OC(O)R'$ ,  $-S-$ ,  $-O-$ , etc. Organotins are designated mono-, di-, tri- or tetrasubstituted depending upon the number of carbon–tin bonds in the molecule.

There are 109 organotin substances on Canada’s DSL, 104 of which belong to nine subcategories of organotins, as outlined in Table 1. Six additional subcategories, tri- and tetramethyltins, tri- and tetraoctyltins and mono- and diphenyltins, contain no substances on the DSL. These subcategories are not considered in this ecological assessment. Tetrabutyltin is not on the DSL, but it was one of the nine organotins notified as new and/or transitional substances under CEPA 1999, and tetrabutyltin is addressed in this report. The remaining

five organotin substances on the DSL, three organotin substances<sup>1</sup> and two UVCBs<sup>2</sup> (Unknown or Variable Composition Complex Reaction Products or Biological Materials), do not belong to these subcategories, and these five substances were not addressed. Annex 1 presents the organotin substances on the DSL.

Table 1. Organotin subcategories: Number of organotin substances on the DSL

	Methyltins	Butyltins	Octyltins	Phenyltins
Mono-	13	18	2	0
Di-	15	38	8	0
Tri-	0	8	0	1
Tetra-	0	0	0	1

“Non-pesticidal organotin compounds” were assessed under the first Priority Substances List (PSL1) and were concluded not to be toxic to the environment (Government of Canada, 1993). At that time, there was insufficient information available to conclude on risk to human health. Since that time, Health Canada has completed a PSL1 follow-up report on organotins and concluded that non-pesticidal organotins do not present a danger to human life or health (Government of Canada, 2003).

The PSL1 assessment (Government of Canada, 1993) focused on mono- and dimethyltins, mono- and dibutyltins and mono- and dioctyltins and based exposure on monitoring data. Most environmental sampling was done in harbours, marinas and shipping lanes, where contamination by butyltin compounds from antifouling paints was expected. It was determined that mean concentrations of non-pesticidal organotins found in these waters were below the estimated effects thresholds for these substances.

There are renewed environmental concerns with organotins for several reasons. The quantity of organotin compounds used as PVC stabilizers has increased substantially in recent years. The PSL1 assessment (Government of Canada, 1993) estimated that 1300 tonnes were imported into Canada in 1984. In the assessment of the nine notified substances, Environment Canada (2006) estimated that up to 400 tonnes of tin stabilizers could be used annually at a

<sup>1</sup> Distannoxane, hexakis(2-methyl-2-phenylpropyl)- (CAS No. 13356-08-6)  
 Propanoic acid, 3,3-bis[[2-(isooctyloxy)-2-oxoethyl]thio]stannylene]bis-, dibutyl ester (CAS No. 63397-60-4)  
 Acetic acid, 2,2,2-[(1,1,3-tributyl-1-distannathianyl-3-ylidene)tris(thio)]tris-, triisooctyl ester (CAS No. 33703-04-7)

<sup>2</sup> 9-Octadecenoic acid (Z)-, 2-mercaptoethyl ester, reaction products with dichlorodimethylstannane, sodium sulfide (Na<sub>2</sub>S) and trichloromethylstannane (UVCB, CAS No. 68442-12-6)  
 Stannane, dibutylbis[(1-oxopentadecyl)oxy]-, branched (UVCB, CAS No. 68512-27-6)

single facility. Rinsing of shipping containers, storage tanks and associated transfer hoses was identified by Environment Canada (2006) as a potentially significant source of release of organotin substances to the environment. Further, some recent toxicity studies indicate that some organotin substances are more toxic to sensitive aquatic organisms than had previously been recognized. Finally, additional concerns have emerged regarding the potential for persistent and bioaccumulative substances to cause harm in the environment. There are limitations in using traditional short-term laboratory toxicity tests for such substances and uncertainties in applying risk quotient-based assessment methods to such substances.

This document focuses principally on the freshwater environment, because the organotin substances considered in this report have mainly non-pesticidal uses and their releases are probably primarily to fresh water. However, information from marine or estuarine environments is sometimes used — for example, in the discussion of the persistence and bioaccumulation of organotin substances.

This assessment uses a group approach, reaching a conclusion for each organotin subcategory that contains substances on the DSL and for tetrabutyltin.

## 2.0 Entry Characterization

### 2.1 Uses of Organotin Substances

Mono- and dialkyltins (i.e., methyl-, butyl- and octyltins) are used mainly as PVC stabilizers. Approximately 70% of the total annual world production of non-pesticidal organotin compounds is used in PVC stabilizers (Lytle *et al.*, 2003). Sulphur-containing organotins impart heat stability to PVC, whereas non-sulphur-containing organotins (e.g., carboxylates) provide resistance to light and weathering. Some mono- and dialkyltins (e.g., butyltin trichloride and dimethyltin dichloride) are also used in depositing clear, durable tin oxide coatings on reusable glass bottles. Certain dialkyltin compounds are used as catalysts in producing various polymers and esters. Internationally, dialkyltins are also used as stabilizers for lubricating oils, hydrogen peroxide and polyolefins (Gitlitz and Moran, 1983). Dioctyltin compounds are generally used as additives for PVC food packaging products.

Tetraalkyltin compounds are used primarily as intermediates in the synthesis of other organotin substances (Gitlitz and Moran, 1983).

Certain types of organotins have pesticidal uses. Some dialkyltins are used as anthelmintics for controlling parasitic worms in poultry (Gitlitz and Moran, 1983). Trialkyltin compounds are used mainly as biocides. It is believed that all, or almost all, of the intentional use of tributyltins in Canada is related to their pesticidal properties. As of 1999, five tributyltin substances were registered as active ingredients of pesticide formulations in Canada under the *Pest Control Products Act*. These active ingredients were formulated into antifouling agents, material preservatives, wood preservatives and slimicides (Maguire, 2000). The use of tributyltins in antifouling paints has been prohibited in Canada since January 1, 2003 (Pest Management Regulatory Agency, 2000). As of May 2005, two tributyltin substances were registered under the *Pest Control Products Act* and are found in 10 products. Formulations imported into Canada that do not make a pest control products claim and substances that are manufactured in Canada only for export are not subject to the *Pest Control Products Act* and fall under the jurisdiction of CEPA 1999.

It is recognized that triorganotins occur as contaminants in other organotin commercial products. For example, Environment Canada (2006) reported that tributyltin can be an impurity at concentrations up to about 20% in tetrabutyltin imported for use in the synthesis of organotin stabilizers. Tributyltin is also present at lower concentrations (up to about 0.5%) in dibutyltins.

## **2.2 Environmental Releases**

As discussed in section 3.1.2, methyltin compounds may be present in the environment both as a result of natural methylation of inorganic tin (Chau *et al.*, 1980, 1997; Weber and Alberts, 1990) and from industrial uses such as PVC stabilization (Chau *et al.*, 1997).

Butyltin species are not produced biologically from inorganic tin (Maguire, 1992). Mono- and dibutyltin compounds are usually present in the environment as a result of the degradation of tributyltin, as well as from non-pesticidal industrial uses such as PVC stabilization (Chau *et al.*, 1997).

Phenyltin compounds are probably present in harbours as a result of antifouling uses (Chau *et al.*, 1997).

In Canada, the largest releases of organotins to the environment from non-pesticidal uses probably occur as a result of formulation and blending processes, principally resulting from the release of liquid residues remaining in shipping containers. These point source releases could result in significant concentrations of organotins in local receiving waters and sediments. A survey of the handling practices of users of organotin stabilizers, conducted by the Vinyl Council of Canada and the Tin Stabilizers Association indicates that mainly totes (semi-bulk), tanker cars and drums are used to ship the substances, although the stabilizers can also be shipped in pails and kegs. Users either manually or automatically transfer the organotin stabilizers from shipping and storage containers to compound mixers. Transfer lines are cleaned on a monthly to infrequent basis, with rinsate being either recycled or directed to wastewater treatment facilities prior to being discharged to receiving waters.

Environment Canada (2006) estimates that in the absence of stewardship practices, up to 0.4 kg of organotin stabilizers per day could be released into the environment from a facility receiving stabilizers in drums, whereas up to 0.13 kg/day could be released from a facility receiving stabilizers by bulk or tote shipments. It was assumed that there would be no environmental releases from dry blend manufacture of powder coatings.

As noted by Environment Canada (2006), facilities using organotin stabilizers have adopted product stewardship practices that have led to a decrease in the quantity of organotins that could potentially be released to the environment. One facility practising these measures claims to have reduced its discharge of organotins to zero. The Vinyl Council of Canada and the Tin Stabilizers Association developed a guideline for the environmental management of stabilizers in Canada (Vinyl Council of Canada and the Tin Stabilizers Association, 2004). The guideline is applicable to companies that process PVC with a tin-based stabilizer. It is estimated that implementation of the practices in



the guideline substantially has substantially decreased the potential release of organotins to the environment. Environment Canada (2006) estimated that with stewardship practices in place, up to 0.0016 kg of organotin stabilizers per day could be released into the environment from a facility.

As stated above, certain alkyltins are used as catalysts and in glass coatings. It is believed that the quantities used for these applications are much less than the quantity used as PVC stabilizers, so potential environmental releases would also be much lower.

## 3.0 Exposure

### 3.1 Environmental Fate

#### 3.1.1 Environmental Partitioning

Environmental releases of organotins are expected to occur mostly to water. Organotins with a moderate to high adsorption coefficient would tend to partition to bottom sediments and to suspended particulate matter in the water column. Generally, partitioning of organotins to air is expected to be negligible. Some organotin substances that have a low water solubility and a high vapour pressure would partition to air to a greater, but still limited, extent.

#### 3.1.2 Environmental Fate and Persistence

In water, dissolution of many organotins yields the organotin cation, which is either hydrated or combined with the most prevalent anion (e.g., chloride ion in seawater). The rate of hydrolysis is uncertain. There is uncertainty regarding the hydrolytic stability of the tin–sulphur bond under environmentally relevant conditions. Studies have demonstrated the susceptibility of tin thiolates to hydrolysis when dissolved in organic solvents; however, there is still uncertainty concerning potential hydrolysis of these chemicals under natural environmental conditions and across a full spectrum of environmental pH (Environment Canada, 2006).

In general, the hydrolyzed organotins (i.e.,  $R_xSn^{(4-x)+}$  moieties) are not believed to be persistent in water, with estimated half-lives of less than a few months at 20°C and longer at lower temperatures (Government of Canada, 1993).

Tributyltins do not appear to be persistent in water, but Maguire (2000) presented evidence that these substances have half-lives in sediments ranging from 0.9 to 15 years. Viglino *et al.* (2004) estimated half-lives for tributyltin of  $8 \pm 5$  years in the surface oxic layer of sediment of the Saguenay Fjord in Québec and  $87 \pm 17$  years in the deep anoxic layer.

Triphenyltins have also been reported to have a relatively long half-life (3.1 years) in sediment (Shim *et al.*, 1999). Furthermore, high concentrations of triphenyltins in deep-sea organisms have been interpreted by Borghi and Porte (2002) to indicate that triphenyltins can persist for relatively long times in deep-sea environments.

Because organotins generally do not partition significantly to air, potential for long-range transport via air is expected to be limited.

Degradation of organotins occurs via sequential dealkylation of entire chain groups with hydroxylated intermediates, rather than systematic demethylation of the alkyl chains. For example, tributyltin degrades biologically and abiotically by sequential debutylation, yielding dibutyltin, monobutyltin and inorganic tin in water/sediment mixtures or water alone (Maguire, 1992). Tetrabutyltin and tetraphenyltin are expected to degrade in a similar stepwise manner, with tributyltin and triphenyltin compounds, respectively, being the first products of degradation.

Biological methylation of inorganic tin to mono-, di-, tri- or tetramethyltin can occur in the environment. Methylation rates are highest in sediments under anaerobic conditions. Reported yields of methyltin species are generally much less than 1%, but a total yield of 3.2% (0.03% monomethyltin, 0.08% dimethyltin, 2.86% trimethyltin and 0.19% tetramethyltin) has been reported (Rapsomanikis *et al.*, 1987). Methylated butyltin compounds have been detected in the environment infrequently and at concentrations that are low relative to concentration of the organotin substance originally released into the environment (Maguire, 1992). Butyl-, octyl and phenyltins are not formed from inorganic tin by natural processes.

**Based on this information, tributyltin and triphenyltin compounds meet the criterion for persistence in sediments (half-life  $\geq$  365 days in sediment) as specified in the Persistence and Bioaccumulation Regulations of CEPA 1999 (Government of Canada, 2000).**

### 3.1.3 Bioaccumulation

Short-chain organotin chlorides are not expected to bioaccumulate appreciably in aquatic biota. The log octanol/water partition coefficient ( $K_{ow}$ ) values for monobutyltin trichloride and dibutyltin dichloride are 0.09 and 0.05, respectively (Government of Canada, 1993). The high molecular weights of some organotin substances would hinder their bioaccumulation.

However, some organotins do have the capacity to bioaccumulate. Maguire (2000) reported bioconcentration factors (BCFs) for tributyltin ranging up to 46 000 for freshwater fish, 330 000 for freshwater algae and 900 000 for freshwater mussels and up to 10 000 for marine periwinkles and oysters, 12 000 for eelgrass, 40 000 for crabs, 50 000 for marine fish, 100 000 for dogwhelks and 500 000 for marine clams. The log  $K_{ow}$  for tributyltins is less than 5, so Maguire (2000) concluded that this high level of bioaccumulation resulted from a mechanism such as binding to metal-binding proteins in the liver and kidney, rather than simple lipophilic partitioning to fatty tissues. Hunziker *et al.* (2001) also concluded that triorganotin compounds interact with biological material by hydrophobic partitioning and complexation reactions. Maguire (2000) noted that the relatively high concentrations of tributyltin in tissue samples (up to 4  $\mu\text{g/g}$  wet weight) from a range of top predators collected worldwide are further evidence of

elevated potential for bioaccumulation of tributyltin. Limited evidence of weak biomagnification of tributyltin in marine food chains has been reported (e.g., Takahashi *et al.*, 1997; Rouleau *et al.*, 1998; Mamelona and Pelletier, 2003). Reported biomagnification factors are typically less than 10.

Huang *et al.* (1993) reported a BCF of 11 400 for triphenyltin in the alga *Scenedesmus obliquus* over a 7-day exposure, compared with a BCF of >33 200 for tributyltin. Borghi and Porte (2002) reported elevated levels of triphenyltin in livers of certain deep-sea fish (up to 4.2 µg/g wet weight) in the Mediterranean Sea, with lower concentrations of mono-, di- and tributyltins. This indicates that triphenyltin is bioaccumulative and sufficiently persistent to reach deep-sea areas. Although biomagnification of triphenyltins has not been widely studied, results reported by Borghi and Porte (2002) suggest that triphenyltins have the potential to biomagnify. These authors estimated a biomagnification factor of close to 1 for triphenyltins in one fish species from the Mediterranean Sea.

It should be noted that many of the BCFs cited above were based on field studies. Therefore, the term “bioaccumulation factor” (BAF) would be more appropriate than BCF, because the organisms would be exposed to organotins in water, food and particulate matter, not just in water. Furthermore, several of the studies reported tissue concentrations on a dry weight basis. BAFs (or BCFs) calculated on a dry weight basis would be several times higher than if reported on a wet weight basis.

**Based on this information, tributyltin and triphenyltin compounds meet the criteria for problematic bioaccumulation (BCF values  $\geq 5000$  or  $\log K_{ow} \geq 5$ ) as specified in the Persistence and Bioaccumulation Regulations of CEPA 1999 (Government of Canada, 2000).**

### **3.2 Environmental Concentrations**

#### 3.2.1 Estimated Concentrations<sup>3</sup>

Predicted Environmental Concentrations (PECs) for mono- and dialkyltins and for tributyltins and tetrabutyltin released from shipping containers, storage tanks and transfer lines were calculated to range from  $4.1 \times 10^{-4}$  to  $2.0 \mu\text{g/L}$  for average and low flow rate Canadian river systems, assuming instantaneous dilution (Environment Canada, 2006).

With appropriate industry-wide stewardship practices in place, PECs would be reduced to  $8 \times 10^{-8}$  to  $8.1 \times 10^{-3} \mu\text{g/L}$  for average and low flow rate Canadian river systems (Environment Canada, 2006).

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<sup>3</sup> Estimated concentrations are expressed on a whole-molecule basis, including the anionic moiety.

Environment Canada (2006) estimated a sediment PEC of 7.8 mg/kg dry weight for tributyltins, using an equilibrium partitioning approach based on the highest estimated concentration of tributyltin in overlying waters.

### 3.2.2 Measured Concentrations<sup>4</sup>

Chau *et al.* (1997) presented the results of a survey of organotin substances in water and sediment (freshwater and marine) from across Canada carried out in 1994. Samples were collected at various locations, including marinas, harbours and shipping lanes, as well as some areas less likely to be receiving substantial input from pesticidal (antifouling) uses of organotins. A summary of the results of this survey is presented in Table 2 (concentrations in Canadian fresh waters) and Table 3 (concentrations in Canadian freshwater sediments). Organotins were detected in surface waters and sediments throughout Canada, with the highest concentrations of the various organotin substances almost always being in harbours and marinas. It is thought that butyltin substances found in these areas resulted mainly from the degradation of tributyltin substances used in antifouling paints. As stated above, organotins may also enter the environment from other sources. The highest organotin concentration in water, 0.0593 µg dimethyltin/L, was found in the Welland River, Ontario, downstream from a PVC manufacturing plant (Chau *et al.*, 1997).

Table 2. Concentrations of various organotin substances in Canadian fresh water, 1994 survey (Chau *et al.*, 1997)

Substance	Frequency of detection	Concentration range (µg/L) <sup>a</sup>
Monomethyltin	0/89	<0.0006
Dimethyltin	10/89	<0.0006–0.0593
Monobutyltin	6/89	<0.0007–0.0220
Dibutyltin	5/89	<0.001–0.0182
Tributyltin	12/89	<0.0012–0.0434
Monooctyltin	0/89	<0.001
Diocetyl tin	0/89	<0.0014
Triphenyltin	0/89	<0.0015

<sup>a</sup> Detection limits and concentrations were originally reported as µg Sn/L.

<sup>4</sup> Measured concentrations are expressed on a hydrolyzed basis (e.g., monobutyltin), not including the anionic moiety.

Table 3. Concentrations of various organotin substances in Canadian freshwater sediments, 1994 survey (Chau *et al.*, 1997)

Substance	Frequency of detection	Concentration range ( $\mu\text{g/g}$ dry weight) <sup>a</sup>
Monomethyltin	24/80	<0.0006–0.331
Dimethyltin	1/80	<0.0006–0.0068
Monobutyltin	33/80	<0.0007–0.484
Dibutyltin	43/80	<0.001–0.766
Tributyltin	42/80	<0.0012–2.38
Monooctyltin	7/80	<0.001–0.0142
Diocyltin	6/80	<0.0014–0.0626
Triphenyltin	3/80	<0.0015–0.0576

<sup>a</sup> Detection limits and concentrations were originally reported as  $\mu\text{g Sn/g}$  dry weight.

Restrictions were placed on tributyltins in antifouling paints under Canada's *Pest Control Products Act* in 1989. Surveys carried out in 1982–1985, before these restrictions were put in place, show that organotins were generally detected more frequently and at higher concentrations in water during that period than in 1994, as shown in Table 4 and Table 5.

Table 4. Concentrations of various organotin substances in Canadian fresh water, 1982–1985 surveys (Chau *et al.*, 1997; octyltin data from Government of Canada, 1993)

Substance	Frequency of detection	Concentration range ( $\mu\text{g/L}$ ) <sup>a</sup>
Monomethyltin	32/216	<0.003–1.22
Dimethyltin	27/216	<0.004–0.4
Monobutyltin	65/253	<0.003–8.481
Dibutyltin	67/253	<0.004–7.3
Tributyltin	64/253	<0.005–5.703
Monooctyltin	0/275	<0.02
Diocyltin	0/275	<0.03

<sup>a</sup> Detection limits and concentrations were originally reported as  $\mu\text{g Sn/L}$ .

Table 5. Concentrations of various organotin substances in Canadian freshwater sediments, 1982–1985 surveys (Chau *et al.*, 1997)

Substance	Frequency of detection	Concentration range ( $\mu\text{g/g}$ dry weight) <sup>a</sup>
Monomethyltin	3/163	<0.003–0.146
Dimethyltin	1/163	<0.004–0.213
Monobutyltin	43/219	<0.001–7.0
Dibutyltin	49/219	<0.002–1.136
Tributyltin	63/219	<0.002–3.119

<sup>a</sup> Detection limits and concentrations were originally reported as  $\mu\text{g Sn/g}$  dry weight.

## 4.0 Effects

The toxicity of organotins to aquatic organisms is generally understood to result from exposure to the  $R_xSn^{(4-x)+}$  moiety and to be largely independent of the anionic moiety (Maguire, 1992). There are a few exceptions to this generality, as highlighted in Table 6. For acute toxicity to red killifish, *Oryzias latipes*, dibutyltin maleate is less toxic than dibutyltin oxide, diacetate and dilaurate. In the bioassays with the diatoms *Skeletonema costatum* and *Thalassiosira pseudonana*, there is a decrease in toxicity in the order dibutyltin diacetate, dichloride and difluoride.

Toxicity data for selected organotin substances were presented in Government of Canada (1993) and Maguire (1992). A search of the ECOTOX database was conducted in January 2003 for aquatic toxicity data for the organotin substances on Canada's DSL. Table 7 presents the most sensitive aquatic toxicity results for a number of subcategories of organotins.

Toxicity data presented in Table 7 are not necessarily the same as those used in the assessment of the nine new and/or transitional organotins. Environment Canada (2006) considered toxicity data for substances that are most closely related to the nine specific substances they assessed, whereas the data presented in Table 7 represent the worst-case toxicity of subcategories of organotins.



Table 6. Aquatic toxicity of some organotin substances with different anionic moieties

Substance	Organisms	Endpoint	Value (µg/L) <sup>a</sup>	Reference
Dibutyltin oxide	Red killifish	48-h LC <sub>50</sub>	1000	Nagase <i>et al.</i> , 1991
Dibutyltin diacetate	Red killifish	48-h LC <sub>50</sub>	2000	Nagase <i>et al.</i> , 1991
Dibutyltin dilaurate	Red killifish	48-h LC <sub>50</sub>	2000	Nagase <i>et al.</i> , 1991
Dibutyltin dichloride	Red killifish	48-h LC <sub>50</sub>	4700	Nagase <i>et al.</i> , 1991
Dibutyltin maleate	Red killifish	48-h LC <sub>50</sub>	8000	Nagase <i>et al.</i> , 1991
Dibutyltin diacetate	<i>Skeletonema costatum</i> (diatom)	72-h EC <sub>50</sub> (growth)	20	Walsh <i>et al.</i> , 1985
Dibutyltin dichloride	<i>Skeletonema costatum</i> (diatom)	72-h EC <sub>50</sub> (growth)	40	Walsh <i>et al.</i> , 1985
Dibutyltin difluoride	<i>Skeletonema costatum</i> (diatom)	72-h EC <sub>50</sub> (growth)	60	Walsh <i>et al.</i> , 1985
Dibutyltin diacetate	<i>Thalassiosira pseudonana</i> (diatom)	72-h EC <sub>50</sub> (growth)	80	Walsh <i>et al.</i> , 1985
Dibutyltin dichloride	<i>Thalassiosira pseudonana</i> (diatom)	72-h EC <sub>50</sub> (growth)	160	Walsh <i>et al.</i> , 1985
Dibutyltin difluoride	<i>Thalassiosira pseudonana</i> (diatom)	72-h EC <sub>50</sub> (growth)	240	Walsh <i>et al.</i> , 1985

<sup>a</sup> Concentration expressed as µg dibutyltin/L.

Table 7. Summary of the toxicity of various organotin substances to the most sensitive freshwater organisms

	Methyltins (µg/L)	Butyltins (µg/L)	Octyltins (µg/L)	Phenyltins (µg/L)
Mono-	178	16	>234	Not applicable
Di-	756	13	4.1	Not applicable
Tri-	Not applicable	0.01	Not applicable	0.209
Tetra-	Not applicable	45	Not applicable	398

For monomethyltins, the most sensitive freshwater organism is the green alga, *Scenedesmus obliquus*, with a 96-h EC<sub>50</sub> (growth) of 178 µg/L (from trichloromethylstannane) (Huang *et al.*, 1996).

For dimethyltins, the most sensitive freshwater organism is *Scenedesmus obliquus*, with a 96-h EC<sub>50</sub> (growth) of 756 µg/L (from dichlorodimethylstannane) (Huang *et al.*, 1993).

For monobutyltins, the most sensitive freshwater organism is the water flea, *Daphnia magna*, with a chronic Maximum Acceptable Toxicant Concentration (MATC) of 16 µg/L (from butyltin tris(2-ethylhexylmercaptoacetate)) (Organotin Environmental Programme sponsored study, cited in Environment Canada, 2006).

For dibutyltins, the most sensitive freshwater organism is *Daphnia magna*, with a 48-h EC<sub>50</sub> of 13 µg/L (from dibutyltin bis(2-ethylhexylmercaptoacetate)) (IUCLID, 2002a). A 21-day No-Observed-Effect Concentration (NOEC) of 8 µg/L (from dibutyltin dichloride) was reported for *Daphnia magna* (Analytical Bio-Chemistry Laboratories, 1990).

It should be noted that tributyltin can be present as an impurity in commercial and probably laboratory dibutyltin formulations and can contribute significantly to the toxicity of these formulations. For example, Lytle *et al.* (2003) noted that a tributyltin impurity as low as 0.1% may have a significant influence on the perceived toxicity of dibutyltins. The authors expressed the opinion that it may not be possible to reduce levels of impurities in dibutyltins much below 0.1%.

For tributyltins, the most sensitive freshwater organism is the guppy, *Poecilia reticulata*, with a 90-day NOEC of 0.01 µg/L (from hexabutyldistannoxane) (Becker, 1992; data presented in ECOTOX). The 110-day Lowest-Observed-Effect Concentration (LOEC) for rainbow trout, *Oncorhynchus mykiss*, yolk sac fry was 0.173 µg/L (from tributyltin chloride), based on increased mortality and decreased resistance to *Aeromonas* (de Vries *et al.*, 1991). Induction of “imposex” (the imposition of male sexual characteristics on females) has been reported for dogwhelks, *Nucella lapillus*, a marine gastropod, at tributyltin concentrations of 0.001 µg/L, whereas sterilization of females is initiated at

0.007–0.012 µg/L (Bryan *et al.*, 1988; Gibbs *et al.*, 1988). Shimasaki *et al.* (2003) reported that tributyltin oxide induced sex reversal of genetic female Japanese flounders, *Paralichthys olivaceus*, into phenotypic males when they were exposed to the substance in food at concentrations of 0.1 µg/g (25.7% sex reversal) and 1.0 µg/g (31.1% sex reversal). In sediments, the 21-day IC<sub>50</sub>, for the mayfly, *Hexagenia* spp., based on growth, was 1.5 µg/g dry weight (from tributyltin chloride) (Day *et al.*, 1998). This is consistent with the observation of Meador (2000) that chronic effects on benthos may occur at tributyltin concentrations in the range 0.1–1 µg/g dry weight of sediment. According to Meador (2000), tributyltin toxicity may result from several specific modes of action, including endocrine disruption, as well as alterations in energy production, the P-450 enzyme system and heme metabolism.

For tetrabutyltin, the most sensitive freshwater organism is the fathead minnow, *Pimephales promelas*, with a 96-hour LC<sub>50</sub> of 45 µg/L (Geiger *et al.*, 1990; data presented in ECOTOX).

For monoocetylins, a 48-hour LC<sub>50</sub> for *Daphnia magna* of >234 µg/L (from monoocetyltrin trichloride) was the only study result identified (Schering AG, 1998).

For dioctyltins, the most sensitive freshwater organism is *Daphnia magna*, with a 48-hour LC<sub>50</sub> of 4.1 µg/L (from dioctyltin dichloride) (Steinhauser *et al.*, 1985).

For triphenyltins, the most sensitive freshwater organisms were rainbow trout yolk sac fry, with a 110-day LOEC of 0.209 µg/L (from triphenyltin chloride, based on increased mortality, liver glycogen depletion and decreased resistance to *Aeromonas*) (de Vries *et al.*, 1991). The Canadian Water Quality Guideline for the Protection of Freshwater Aquatic Life is 0.022 µg/L (CCME, 1999).

For tetraphenyltin, a 48-hour LC<sub>50</sub> for the Japanese medaka, *Oryzias latipes*, of 398 µg/L was the only study result identified (Nagase *et al.*, 1991).

## 5.0 Risk Characterization

In the environmental assessments of organotin substances notified between August 1994 and March 2000, Environment Canada used conservative estimates of rates of release to water and assessment factors to calculate estimated concentrations of concern. It was concluded that concentrations of these substances in water and sediments would be high enough to potentially harm organisms. Therefore, the notified substances are suspected to be toxic under Paragraph 64(a) of CEPA 1999 (Environment Canada, 2006).

Environment Canada (2006) noted that with effective stewardship practices in effect at facilities using organotin stabilizers, releases of these substances would be minimized to levels that are not of concern to the environment.

Because of the unique concerns relating to persistent and bioaccumulative substances, the potential for tributyltin and triphenyltin compounds to cause environmental harm has been evaluated separately. The potential for tetrabutyltin and tetraphenyltin to cause environmental harm is also evaluated separately, because of their status as precursors to tributyltin and triphenyltin compounds, respectively.

### ***5.1 Organotins Other than Tributyltins, Triphenyltins and Their Precursors***

Table 8 presents ratios of PEC to Predicted No-Effect Concentration (PNEC) calculated using the toxicity data for pelagic organisms presented in section 4 of this report and the PEC based on the highest concentration predicted in the assessments of new and/or transitional organotins (section 3.2.1). Use was assumed to be as PVC stabilizers. The quantities of organotins used as catalysts and in glass coatings are believed to be much less than the quantity used as PVC stabilizers, so PECs and PEC/PNEC ratios resulting from these uses would be substantially lower than the values presented in Table 8. In Table 8 and subsequent tables, the toxicity values are termed Critical Toxicity Values, or CTVs. In general, PNECs are calculated by dividing the CTVs by assessment factors (100 for lethal acute endpoints and 10 for algal EC<sub>50</sub> and chronic endpoints). Mono- and dibutyltins and dioctyltins have PEC/PNEC ratios greater than 1 using this approach which indicates a potential to cause harm.

Table 8. PEC/PNEC ratios for various organotin substances, based on the highest environmental concentrations predicted for new and/or transitional organotins<sup>a</sup>

	PEC (µg/L)	CTV (µg/L)	PNEC (µg/L)	PEC/PNEC
Monomethyltins	2.0	178	18	0.1
Dimethyltins	2.0	756	76	0.03
Monobutyltins	2.0	16	1.6	<b>1.3</b>
Dibutyltins	2.0	13	0.13	<b>15</b>
Monooctyltins	2.0	>234	>2.34	<0.9
Diocetylins	2.0	4.1	0.04	<b>50</b>

<sup>a</sup> In this table, CTVs and PNECs are expressed on a hydrolyzed basis, which does not include the anionic moieties, whereas PECs are expressed on a whole-molecule basis, which does include the anionic moieties. PECs expressed on a hydrolyzed basis would be smaller, and therefore the PEC/PNEC ratios would also be smaller.

With industry-wide stewardship practices related to use as PVC stabilizers in place, the PEC is lower (section 3.2.1), and therefore the PEC/PNEC ratios are reduced to below 1, as shown in Table 9. Similar results are obtained if PECs are based on the maximum measured concentrations in Canadian surface waters reported in Table 2.

Table 9. PEC/PNEC ratios for various organotin substances, based on the highest environmental concentrations predicted for new and/or transitional organotins under industry-wide stewardship practices<sup>a</sup>

	PEC (µg/L)	CTV (µg/L)	PNEC (µg/L)	PEC/PNEC
Monomethyltins	0.008	178	18	0.0004
Dimethyltins	0.008	756	76	0.0001
Monobutyltins	0.008	16	1.6	0.005
Dibutyltins	0.008	13	0.13	0.06
Monooctyltins	0.008	>234	>2.34	<0.003
Diocetylins	0.008	4.1	0.04	0.2

<sup>a</sup> In this table, CTVs and PNECs are expressed on a hydrolyzed basis, which does not include the anionic moieties, whereas PECs are expressed on a whole-molecule basis, which does include the anionic moieties. PECs expressed on a hydrolyzed basis would be smaller, and therefore the PEC/PNEC ratios would also be smaller.

## 5.2 Tributyltin and Triphenyltin Compounds

Tributyltin and triphenyltin compounds meet both persistence and bioaccumulation criteria specified in the Persistence and Bioaccumulation Regulations of CEPA 1999 (Government of Canada, 2000).

There are special concerns with such highly persistent and bioaccumulative substances. Although current science is unable to accurately predict the long-term ecological effects of these substances, they are generally acknowledged to

have the potential to cause serious and possibly irreversible impacts. Assessments of such substances must therefore be performed using a preventative, proactive approach, to ensure that such harm does not occur.

Evidence that a substance is persistent and bioaccumulative may itself be a significant indication of its potential to cause environmental harm. Persistent substances remain in the environment for long periods of time, increasing the probability and the duration of exposure. Persistent substances that are subject to long-range transport are of particular concern because they can result in low-level, regional contamination. Releases of extremely small amounts of persistent and bioaccumulative substances may lead to relatively high concentrations in organisms over wide areas. Very bioaccumulative and persistent substances may also biomagnify through the food chain, resulting in especially high internal exposures for top predators. Because they are widespread, several different persistent and bioaccumulative substances may be present simultaneously in the tissues of organisms, increasing the likelihood and potential severity of harm.

Other factors can increase concerns regarding the potential for persistent and bioaccumulative substances to cause environmental harm. For example, there is a particular concern for substances that have the potential to harm organisms at relatively low concentrations and/or that have specific modes of toxic action (in addition to narcosis). Evidence that a substance does not occur in the environment naturally may also indicate an elevated potential to cause harm, since organisms will not have had very long to develop specific strategies for mitigating the effects of exposures. Evidence from monitoring studies indicating that a substance is widespread in the environment and/or that concentrations have been increasing over time is an indicator of elevated exposure potential. Evidence that a substance is used in Canada in moderate to large quantities (e.g., greater than 1000 kg/year) in a variety of locations and/or that use quantities are increasing may also be taken as an indicator of significant potential for exposure.

Each of the lines of evidence mentioned above is reviewed for tributyltin and triphenyltin compounds in Table 10.

Table 10. Evaluation of indicators of potential for tributyltins and triphenyltins to cause environmental harm

Indicator	Evaluation	
	Tributyltins	Triphenyltins
Persistence (as defined in CEPA 1999 Regulations)	Tributyltins are persistent in sediment ( $t_{1/2}$ = 0.9–15 years). However, potential for long-range transport is limited, because they are not persistent in water and do not partition to air.	Triphenyltins are persistent in sediment ( $t_{1/2}$ = 3.1 years). However, potential for long-range transport is limited, because they are not persistent in water and do not partition to air.
Bioaccumulation (as defined in CEPA 1999 Regulations)	Tributyltins are highly bioaccumulative, with reported BAFs of up to 900 000. Concentrations in tissues of top predators are also high (up to 4 µg/g wet weight). Limited evidence of weak biomagnification has been reported for some marine food chains.	Triphenyltins are highly bioaccumulative, with reported BCFs of up to 11 400. Concentrations in the tissues of deep-sea fish are also high (up to 4.2 µg/g wet weight). Although data are very sparse, triphenyltins may have limited potential to biomagnify.
Inherent toxicity	Tributyltins are toxic at low concentrations. For example, the NOEC for the guppy is reported to be 0.01 µg/L. Furthermore, several specific modes of toxic action are possible, including endocrine disruption.	Triphenyltins are toxic at low concentrations. For example, the LOEC (mortality) for rainbow trout yolk sac fry is reported to be 0.209 µg/L.
Natural occurrence	Tributyltins are not naturally occurring substances.	Triphenyltins are not naturally occurring substances.
Use quantities	There are eight tributyltin compounds on the DSL. One transitional tributyltin is reported to be manufactured in moderate quantities (150 000 kg/year) for export at one Canadian facility.	There is one triphenyltin compound on the DSL. It is believed that this substance is no longer used in Canadian commerce.
Widespread occurrence	Tributyltins have been detected in surface waters and sediments throughout Canada, although levels have decreased since restrictions were placed on use of tributyltins in antifouling paints in Canada in 1989.	Triphenyltins have not been detected in Canadian surface waters but have been detected in sediment samples from British Columbia, Ontario and Nova Scotia.

Although risk quotients may also be used to indicate potential to cause environmental harm for persistent and bioaccumulative substances, risks are likely to be underestimated using this approach. For example, if steady state has not been achieved in the environment and concentrations are continually increasing, measured PECs will be too low. In addition, PNECs may be too high because of the long time needed to achieve steady state and the lack of exposure through food consumption in typical short-term laboratory toxicity tests. Consequently, risk quotients for persistent and bioaccumulative substances are often estimated more conservatively, using, for example, an additional assessment factor of 10 applied to the PNEC.

Nevertheless, risk quotients for tributyltins were calculated for comparison purposes. PEC/PNEC ratios for tributyltin compounds, based on both modelled and measured PECs in water and sediment, are shown in Table 11. The Canadian Water Quality Guideline for the Protection of Freshwater Aquatic Life of 0.008 µg/L (CCME, 1999) was used as the PNEC for tributyltins in water. The most sensitive benthic organism reported was the mayfly, *Hexagenia* spp., with a 21-day IC<sub>50</sub> (growth) of 1.5 mg tributyltin/kg dry weight. Dividing this toxicity value by an assessment factor of 100 (10 to extrapolate from an acute to a chronic no-effect level, and 10 to account for extrapolation from laboratory to field conditions and for inter- and intraspecies variability) gives a chronic PNEC of 0.015 mg/kg dry weight for tributyltins in sediment. Although an extra assessment factor of 10 was not used to derive these PNECs, all risk quotients in Table 11 are significantly greater than 1.

Table 11. PEC/PNEC ratios for tributyltin substances

	PEC	CTV	PNEC	PEC/PNEC
Water: modelled PEC <sup>a</sup>	0.22 µg/L	–	0.008 µg/L	<b>28</b>
Water: measured PEC <sup>b</sup>	0.043 µg/L	–	0.008 µg/L	<b>5.4</b>
Sediment: modelled PEC <sup>a</sup>	7.8 mg/kg dry weight	1.5 mg/kg dry weight	0.015 mg/kg dry weight	<b>520</b>
Sediment: measured PEC <sup>b</sup>	2.4 mg/kg dry weight	1.5 mg/kg dry weight	0.015 mg/kg dry weight	<b>160</b>

<sup>a</sup> Highest environmental concentrations predicted for new and/or transitional tributyltins associated with chemical manufacturing, expressed as hydrolyzed tributyltin.

<sup>b</sup> Highest concentrations measured in Canada (Tables 2 and 3).

Based on the various lines of evidence presented above, it is concluded that both tributyltin and triphenyltin compounds have the potential to cause environmental harm. However, it is believed that triphenyltins are not currently in use in Canada.

### **5.3 Tetrabutyltin and Tetraphenyltin**

As noted in section 3.1.2, like most other organotins, tetrabutyltin and tetraphenyltin are not believed to be persistent in the environment. Tetrabutyltin is expected to degrade by removal of one of the alkyl groups attached to the tin atom, producing tributyltins. Tetraphenyltin is expected to degrade to triphenyltin compounds in a similar manner. As precursors to persistent and bioaccumulative compounds that have the potential to cause environmental harm, tetrabutyltin and tetraphenyltin are themselves considered to have the potential to cause harm.

Data are also available to evaluate risks to pelagic organisms from direct exposure to tetrabutyltin using a quotient method. A PEC of 1.2 µg/L may be established based on the highest concentration of tetrabutyltin predicted in the assessments of new and/or transitional organotins associated with use as a



chemical intermediate (Environment Canada, 2006). A PNEC of 0.45 µg/L may be derived by dividing the acute CTV of 45 µg tetrabutyltin/L (see Table 7) by an assessment factor of 100. Based on these data, the PEC/PNEC ratio is 2.7, suggesting some potential to cause harm to pelagic organisms.

Considering the above lines of evidence, it is concluded that both tetrabutyltin and tetraphenyltin have the potential to cause environmental harm. However, it is believed that tetraphenyltin is not currently in use in Canada.

## 6.0 Sources of Uncertainty

Predicted concentrations of organotins in water and sediments, based on estimated usage, release rates and treatment efficiency, are considerably higher than those reported in the 1994 survey. It must be recognized, however, that the survey focused on harbours, marinas and shipping lanes, and it is quite possible that sampling was not done in the areas of highest industrial releases of organotins.

Experimental  $K_{ow}$  values are lacking for most organotins, making estimates of bioaccumulation and partitioning to sediments uncertain.  $K_{ow}$  values can be extremely difficult or impossible to determine for organotin substances that are practically insoluble in water, because the presence of even a small amount of a more water-soluble impurity (i.e.,  $\ll 1\%$ ) significantly increases the amount of tin in the water phase (IUCLID, 2002b). Estimations of  $K_{ow}$  may not be accurate for organotin substances that hydrolyze quickly, and the hydrolysis of organotins is controversial (Environment Canada, 2006).

Several subcategories of organotins have been detected in sediments, but sediment toxicity studies have been carried out only with tributyltin.

## 7.0 Conclusions

### ***7.1 Subcategories that Meet the Criteria Set out under Section 64 of CEPA 1999***

**Tributyltins** are harmful to many aquatic organisms at low concentrations. They are present in the environment primarily from human activity. They have been shown to impose male sexual characteristics on females of some marine gastropods and appear to have the potential to induce sex reversal in some marine fish. Estimated and measured concentrations of tributyltins in some locations in Canada are high enough to cause adverse effects in sensitive organisms. Furthermore, tributyltins meet the criteria for persistence and bioaccumulation according to the Persistence and Bioaccumulation Regulations of CEPA 1999. Tributyltins are present as a contaminant in commercial tetrabutyltin formulations and probably at much lower levels in dibutyltin formulations.

**Tetrabutyltin** can be harmful to sensitive aquatic organisms at low concentrations. There is further concern for this substance because it can break down to tributyltin by dealkylation and because commercial formulations of tetrabutyltin contain substantial amounts of tributyltin.

### ***7.2 Subcategories that Do Not Meet the Criteria Set out under Section 64 of CEPA 1999***

**Monomethyltins, dimethyltins, monobutyltins, dibutyltins, monoctyltins and dioctyltins** have the potential to harm aquatic organisms, and commercial formulations of monobutyltin and dibutyltin may contain tributyltin as a contaminant. However, it is believed that harmful concentrations of these substances would not be reached with industry-wide stewardship practices in place to limit their environmental releases. Releases from other uses of these substances as catalysts or in glass coatings are not expected to be significant, based on the much smaller quantities currently used in these industries.

### ***7.3 Subcategories that are believed of no longer being in use in Canada***

**Triphenyltins** can be harmful to sensitive aquatic organisms at low concentrations, and they meet the criteria for persistence and bioaccumulation according to the Persistence and Bioaccumulation Regulations of CEPA 1999 (Government of Canada, 2000). They are present in the environment primarily from human activity. It is believed that these substances are no longer in use in Canada.

**Tetraphenyltin** has the potential to break down to the more hazardous triphenyltins. Commercial formulations of tetraphenyltin likely contain triphenyltin as a contaminant. It is believed that this substance is no longer in use in Canada.

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## Annex 1. Organotin Substances on the Domestic Substances List

Chemical name	Molecular formula	CAS No.
<b>Monomethyltin compounds</b>		
Stannane, trichloromethyl-	CH <sub>3</sub> Cl <sub>3</sub> Sn	993-16-8
Distannathiane, dimethyldithio-	C <sub>2</sub> H <sub>6</sub> S <sub>3</sub> Sn <sub>2</sub>	33397-79-4
Stannane, tris(dodecylthio)methyl-	C <sub>37</sub> H <sub>78</sub> S <sub>3</sub> Sn	52165-03-4
Propanoic acid, 3,3,3-[(methylstannylidyne)tris(thio)]tris-, triisooctyl ester	C <sub>34</sub> H <sub>66</sub> O <sub>6</sub> S <sub>3</sub> Sn	53040-42-9
Acetic acid, 2,2,2-[(methylstannylidyne)tris(thio)]tris-, triisooctyl ester	C <sub>31</sub> H <sub>60</sub> O <sub>6</sub> S <sub>3</sub> Sn	54849-38-6
8-Oxa-3,5-dithia-4-stannatetradecanoic acid, 10-ethyl-4-[[2-[(2-ethylhexyl)oxy]-2-oxoethyl]thio]-4-methyl-7-oxo-, 2-ethylhexyl ester	C <sub>31</sub> H <sub>60</sub> O <sub>6</sub> S <sub>3</sub> Sn	57583-34-3
Octanoic acid, (methylstannylidyne)tris(thio-2,1-ethanediyl)ester	C <sub>31</sub> H <sub>60</sub> O <sub>6</sub> S <sub>3</sub> Sn	57813-62-4
9-Octadecenoic acid (Z)-, (methylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>61</sub> H <sub>114</sub> O <sub>6</sub> S <sub>3</sub> Sn	59118-79-5
Dodecanoic acid, (methylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>43</sub> H <sub>84</sub> O <sub>6</sub> S <sub>3</sub> Sn	67859-62-5
Tetradecanoic acid, (methylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>49</sub> H <sub>96</sub> O <sub>6</sub> S <sub>3</sub> Sn	68928-38-1
9,12-Octadecadienoic acid (Z,Z)-, (methylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>61</sub> H <sub>108</sub> O <sub>6</sub> S <sub>3</sub> Sn	68928-40-5
Hexadecanoic acid, (methylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>55</sub> H <sub>108</sub> O <sub>6</sub> S <sub>3</sub> Sn	68928-41-6
Decanoic acid, (methylstannylidyne)tris(thio-2,1-ethanediyl)ester	C <sub>37</sub> H <sub>72</sub> O <sub>6</sub> S <sub>3</sub> Sn	68928-50-7
<b>Dimethyltin compounds</b>		
Stannane, dichlorodimethyl-	C <sub>2</sub> H <sub>6</sub> Cl <sub>2</sub> Sn	753-73-1
Stannane, dimethylthio-	C <sub>2</sub> H <sub>6</sub> SSn	13269-74-4
Acetic acid, 2,2-[(dimethylstannylene)bis(thio)]bis-, diisooctyl ester	C <sub>22</sub> H <sub>44</sub> O <sub>4</sub> S <sub>2</sub> Sn	26636-01-1
Propanoic acid, 3,3-[(dimethylstannylene)bis(thio)]bis-, diisooctyl ester	C <sub>24</sub> H <sub>48</sub> O <sub>4</sub> S <sub>2</sub> Sn	42378-34-7
Distannoxane, 1,1,3,3-tetramethyl-1,3-bis[(1-oxo-9-octadecenyl)oxy]-, (Z,Z)-	C <sub>40</sub> H <sub>78</sub> O <sub>5</sub> Sn <sub>2</sub>	43136-18-1
Stannane, bis(dodecylthio)dimethyl-	C <sub>26</sub> H <sub>56</sub> S <sub>2</sub> Sn	51287-84-4
10-Oxa-4,6-dithia-5-stannahexadecanoic acid, 12-ethyl-5,5-dimethyl-9-oxo-, 2-ethylhexyl ester	C <sub>24</sub> H <sub>48</sub> O <sub>4</sub> S <sub>2</sub> Sn	57057-50-8
8-Oxa-3,5-dithia-4-stannatetradecanoic acid, 10-ethyl-4,4-dimethyl-7-oxo-, 2-ethylhexyl ester	C <sub>22</sub> H <sub>44</sub> O <sub>4</sub> S <sub>2</sub> Sn	57583-35-4

Chemical name	Molecular formula	CAS No.
Octanoic acid, (dimethylstannylene)bis(thio-2,1-ethanediyl)ester	C <sub>22</sub> H <sub>44</sub> O <sub>4</sub> S <sub>2</sub> Sn	57813-60-2
9-Octadecenoic acid (Z)-, (dimethylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>42</sub> H <sub>80</sub> O <sub>4</sub> S <sub>2</sub> Sn	67859-63-6
9,12-Octadecadienoic acid (Z,Z)-, (dimethylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>42</sub> H <sub>76</sub> O <sub>4</sub> S <sub>2</sub> Sn	67859-64-7
Decanoic acid, (dimethylstannylene)bis(thio-2,1-ethanediyl)ester	C <sub>26</sub> H <sub>52</sub> O <sub>4</sub> S <sub>2</sub> Sn	67874-41-3
Dodecanoic acid, (dimethylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>30</sub> H <sub>60</sub> O <sub>4</sub> S <sub>2</sub> Sn	68928-42-7
Tetradecanoic acid, (dimethylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>34</sub> H <sub>68</sub> O <sub>4</sub> S <sub>2</sub> Sn	68928-48-3
Stannane, dimethylbis[(1-oxoneodecyl)oxy]-	C <sub>22</sub> H <sub>44</sub> O <sub>4</sub> Sn	68928-76-7
<b>Monobutyltin compounds</b>		
Stannane, butyltrichloro-	C <sub>4</sub> H <sub>9</sub> Cl <sub>3</sub> Sn	1118-46-3
Stannane, butylhydroxyoxo-	C <sub>4</sub> H <sub>10</sub> O <sub>2</sub> Sn	2273-43-0
Stannane, butylchlorodihydroxy-	C <sub>4</sub> H <sub>11</sub> ClO <sub>2</sub> Sn	13355-96-9
Distannathiane, dibutyldithioxo-	C <sub>8</sub> H <sub>18</sub> S <sub>3</sub> Sn <sub>2</sub>	15666-29-2
Stannane, butyltris[(2-ethyl-1-oxohexyl)oxy]-	C <sub>28</sub> H <sub>54</sub> O <sub>6</sub> Sn	23850-94-4
Acetic acid, 2,2,2-[(butylstannylidyne)tris(thio)]tris-, triisooctyl ester	C <sub>34</sub> H <sub>66</sub> O <sub>6</sub> S <sub>3</sub> Sn	25852-70-4
Stannane, butylmercaptooxo-	C <sub>4</sub> H <sub>10</sub> OSSn	26410-42-4
Acetic acid, [(butylthioxostannyl)thio]-, 2-ethylhexyl ester	C <sub>14</sub> H <sub>28</sub> O <sub>2</sub> S <sub>2</sub> Sn	26821-65-8
8-Oxa-3,5-dithia-4-stannatetradecanoic acid, 4-butyl-10-ethyl-4-[[2-[(2-ethylhexyl)oxy]-2-oxoethyl]thio]-7-oxo-, 2-ethylhexyl ester	C <sub>34</sub> H <sub>66</sub> O <sub>6</sub> S <sub>3</sub> Sn	26864-37-9
Propanoic acid, 3,3,3-[(butylstannylidyne)tris(thio)]tris-, triisooctyl ester	C <sub>37</sub> H <sub>72</sub> O <sub>6</sub> S <sub>3</sub> Sn	36118-60-2
Octanoic acid, (butylstannylidyne)tris(thio-2,1-ethanediyl)ester	C <sub>34</sub> H <sub>66</sub> O <sub>6</sub> S <sub>3</sub> Sn	59118-80-8
9-Octadecenoic acid (Z)-, (butylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>64</sub> H <sub>120</sub> O <sub>6</sub> S <sub>3</sub> Sn	67361-76-6
Decanoic acid, (butylstannylidyne)tris(thio-2,1-ethanediyl)ester	C <sub>40</sub> H <sub>78</sub> O <sub>6</sub> S <sub>3</sub> Sn	67874-51-5
Tetradecanoic acid, (butylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>52</sub> H <sub>102</sub> O <sub>6</sub> S <sub>3</sub> Sn	68928-34-7
9,12-Octadecadienoic acid (Z,Z)-, (butylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>64</sub> H <sub>114</sub> O <sub>6</sub> S <sub>3</sub> Sn	68928-37-0
Hexadecanoic acid, (butylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>58</sub> H <sub>114</sub> O <sub>6</sub> S <sub>3</sub> Sn	68928-39-2
Dodecanoic acid, (butylstannylidyne)tris(thio-2,1-ethanediyl) ester	C <sub>46</sub> H <sub>90</sub> O <sub>6</sub> S <sub>3</sub> Sn	68928-52-9
Ethanol, 2,2,2-[(butylstannylidyne)tris(thio)]tris-	C <sub>10</sub> H <sub>24</sub> O <sub>3</sub> S <sub>3</sub> Sn	70729-71-4

Chemical name	Molecular formula	CAS No.
<b>Dibutyltin compounds</b>		
Stannane, dibutylbis[(1-oxododecyl)oxy]-	C <sub>32</sub> H <sub>64</sub> O <sub>4</sub> Sn	77-58-7
1,3,2-Dioxastannepin-4,7-dione, 2,2-dibutyl-	C <sub>12</sub> H <sub>20</sub> O <sub>4</sub> Sn	78-04-6
6H-1,3,2-Oxathiastannin-6-one, 2,2-dibutyldihydro-	C <sub>11</sub> H <sub>22</sub> O <sub>2</sub> SSn	78-06-8
Stannane, dibutyldichloro-	C <sub>8</sub> H <sub>18</sub> Cl <sub>2</sub> Sn	683-18-1
Stannane, dibutyloxo-	C <sub>8</sub> H <sub>18</sub> OSn	818-08-6
Stannane, bis(acetyloxy)dibutyl-	C <sub>12</sub> H <sub>24</sub> O <sub>4</sub> Sn	1067-33-0
Stannane, dibutylbis(dodecylthio)-	C <sub>32</sub> H <sub>68</sub> S <sub>2</sub> Sn	1185-81-5
Stannane, dibutylbis[(2-ethyl-1-oxohexyl)oxy]-	C <sub>24</sub> H <sub>48</sub> O <sub>4</sub> Sn	2781-10-4
Distannoxane, 1,1,3,3-tetrabutyl-1,3-bis[(1-oxododecyl)oxy]-	C <sub>40</sub> H <sub>82</sub> O <sub>5</sub> Sn <sub>2</sub>	3669-02-1
Stannane, dibutylthioxo-	C <sub>8</sub> H <sub>18</sub> SSn	4253-22-9
Stannane, dibutylbis[(1-oxooctadecyl)oxy]-	C <sub>44</sub> H <sub>88</sub> O <sub>4</sub> Sn	5847-55-2
8-Oxa-3,5-dithia-4-stannatetradecanoic acid, 4,4-dibutyl-10-ethyl-7-oxo-, 2-ethylhexyl ester	C <sub>28</sub> H <sub>56</sub> O <sub>4</sub> S <sub>2</sub> Sn	10584-98-2
Stannane, dibutylbis[(1-oxo-9-octadecenyl)oxy]-, (Z,Z)-	C <sub>44</sub> H <sub>84</sub> O <sub>4</sub> Sn	13323-62-1
Stannane, butoxydibutylchloro-	C <sub>12</sub> H <sub>27</sub> ClOSn	14254-22-9
2,7,9-Trioxa-8-stannatrideca-4,11-dien-13-oic acid, 8,8-dibutyl-3,6,10-trioxo-, methyl ester, (Z,Z)-	C <sub>18</sub> H <sub>28</sub> O <sub>8</sub> Sn	15546-11-9
5,7,12-Trioxa-6-stannaoctadeca-2,9-dienoic acid, 6,6-dibutyl-14-ethyl-4,8,11-trioxo-, 2-ethylhexyl ester	C <sub>32</sub> H <sub>56</sub> O <sub>8</sub> Sn	15546-12-0
5,7,12-Trioxa-6-stannahexadeca-2,9-dienoic acid, 6,6-dibutyl-4,8,11-trioxo-, butyl ester, (Z,Z)-	C <sub>24</sub> H <sub>40</sub> O <sub>8</sub> Sn	15546-16-4
Tin, dibutylbis(2,4-pentanedionato-o,o)-, (oc-6-11)-	C <sub>18</sub> H <sub>32</sub> O <sub>4</sub> Sn	22673-19-4
2-Butenoic acid, 4,4-[(dibutylstannylene)bis(oxy)]bis[4-oxo-, diisooctyl ester, (Z,Z)-	C <sub>32</sub> H <sub>56</sub> O <sub>8</sub> Sn	25168-21-2
Stannane, dibutylbis[(1-oxoneodecyl)oxy]-	C <sub>28</sub> H <sub>56</sub> O <sub>4</sub> Sn	25168-22-3
Acetic acid, 2,2-[(dibutylstannylene)bis(thio)]bis-, diisooctyl ester	C <sub>28</sub> H <sub>56</sub> O <sub>4</sub> S <sub>2</sub> Sn	25168-24-5
Propanoic acid, 3,3-[(dibutylstannylene)bis(thio)]bis-, diisooctyl ester	C <sub>30</sub> H <sub>60</sub> O <sub>4</sub> S <sub>2</sub> Sn	26761-46-6
Dodecanoic acid, (dibutylstannylene)bis(thio-2,1-ethanediyl)ester	C <sub>36</sub> H <sub>72</sub> O <sub>4</sub> S <sub>2</sub> Sn	28570-24-3
5,7,12-Trioxa-6-stannatetracos-2,9-dienoic acid, 6,6-dibutyl-4,8,11-trioxo-, dodecyl ester, (Z,Z)-	C <sub>40</sub> H <sub>72</sub> O <sub>8</sub> Sn	33466-31-8
Distannoxane, 1,1,3,3-tetrabutyl-1,3-bis[(2-ethyl-1-oxohexyl)oxy]-	C <sub>32</sub> H <sub>66</sub> O <sub>5</sub> Sn <sub>2</sub>	45314-70-3
10-Oxa-4,6-dithia-5-stannahexadecanoic acid, 5,5-dibutyl-12-ethyl-9-oxo-, 2-ethylhexyl ester	C <sub>30</sub> H <sub>60</sub> O <sub>4</sub> S <sub>2</sub> Sn	53202-61-2
5,7,12-Trioxa-6-stannahexacos-2,9-dienoic acid, 6,6-dibutyl-4,8,11-trioxo-, tetradecyl ester, (Z,Z)-	C <sub>44</sub> H <sub>80</sub> O <sub>8</sub> Sn	60659-60-1
5,7,12-Trioxa-6-stannatriaconta-2,9-dienoic acid, 6,6-dibutyl-4,8,11-trioxo-, octadecyl ester, (Z,Z)-	C <sub>52</sub> H <sub>96</sub> O <sub>8</sub> Sn	61813-52-3

Chemical name	Molecular formula	CAS No.
9-Octadecenoic acid (Z)-, (dibutylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>48</sub> H <sub>92</sub> O <sub>4</sub> S <sub>2</sub> Sn	67361-77-7
9,12-Octadecadienoic acid (Z,Z)-, (dibutylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>48</sub> H <sub>88</sub> O <sub>4</sub> S <sub>2</sub> Sn	67859-61-4
Tetradecanoic acid, (dibutylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>40</sub> H <sub>80</sub> O <sub>4</sub> S <sub>2</sub> Sn	67859-65-8
Tin, dibutyl[N-(carboxymethyl)-N-(2-hydroxyethyl)glycinato(2-)]-	C <sub>14</sub> H <sub>27</sub> NO <sub>5</sub> Sn	68239-46-3
Hexadecanoic acid, (dibutylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>44</sub> H <sub>88</sub> O <sub>4</sub> S <sub>2</sub> Sn	68298-42-0
2-Butenoic acid, 4,4-[(dibutylstannylene)bis(oxy)]bis[4-oxo-, diisopentadecyl ester, (Z)-	C <sub>46</sub> H <sub>84</sub> O <sub>8</sub> Sn	68299-23-0
Decanoic acid, (dibutylstannylene)bis(thio-2,1-ethanediyl) ester	C <sub>32</sub> H <sub>64</sub> O <sub>4</sub> S <sub>2</sub> Sn	68928-47-2
Propanoic acid, 3,3-[(dibutylstannylene)bis(thio)]bis-, diisotridecyl ester	C <sub>40</sub> H <sub>80</sub> O <sub>4</sub> S <sub>2</sub> Sn	84896-44-6
3,5,7,9-Tetraoxa-4,8-disila-6-stannaundecane, 6,6-dibutyl-4,4,8,8-tetraethoxy-	C <sub>210</sub> H <sub>48</sub> O <sub>8</sub> Si <sub>2</sub> Sn	87735-26-0
Dibutyltin bis(stearyl maleate)		166432-49-1
<b>Tributyltin compounds</b>		
Distannoxane, hexabutyl-	C <sub>24</sub> H <sub>54</sub> O <sub>2</sub> Sn <sub>2</sub>	56-35-9
Stannane, tributyl-	C <sub>12</sub> H <sub>28</sub> Sn	688-73-3
Stannane, tributylchloro-	C <sub>12</sub> H <sub>27</sub> ClSn	1461-22-9
Stannane, tributylfluoro-	C <sub>12</sub> H <sub>27</sub> F <sub>3</sub> Sn	1983-10-4
Stannane, tributyl[(2-methyl-1-oxo-2-propenyl)oxy]-	C <sub>16</sub> H <sub>32</sub> O <sub>2</sub> Sn	2155-70-6
2-Butenoic acid, 4-oxo-4-[(tributylstannyl)oxy]-, (2Z)-	C <sub>16</sub> H <sub>30</sub> O <sub>4</sub> Sn	4027-18-3
Phenol, 2-[[[(tributylstannyl)oxy]carbonyl]-	C <sub>19</sub> H <sub>32</sub> O <sub>3</sub> Sn	4342-30-7
Stannane, [(2-octyl-1,4-dioxo-1,4-butanediyl)bis(oxy)]bis[tributyl-	C <sub>36</sub> H <sub>74</sub> O <sub>4</sub> Sn <sub>2</sub>	67701-37-5
<b>Monooctyltin compounds</b>		
Acetic acid, 2,2,2-[(octylstannylidyne)tris(thio)]tris-, triisooctyl ester	C <sub>38</sub> H <sub>74</sub> O <sub>6</sub> S <sub>3</sub> Sn	26401-86-5
8-Oxa-3,5-dithia-4-stannatetradecanoic acid, 10-ethyl-4-[[2-[(2-ethylhexyl)oxy]-2-oxoethyl]thio]-4-octyl-7-oxo-, 2-ethylhexyl ester	C <sub>38</sub> H <sub>74</sub> O <sub>6</sub> S <sub>3</sub> Sn	27107-89-7
<b>Diocetyl tin compounds</b>		
Stannane, dioctylbis[(1-oxododecyl)oxy]-	C <sub>40</sub> H <sub>80</sub> O <sub>4</sub> Sn	3648-18-8
5,7,12-Trioxa-6-stannaoctadeca-2,9-dienoic acid, 14-ethyl-6,6-dioctyl-4,8,11-trioxo-, 2-ethylhexyl ester	C <sub>40</sub> H <sub>72</sub> O <sub>8</sub> Sn	10039-33-5
8-Oxa-3,5-dithia-4-stannatetradecanoic acid, 10-ethyl-4,4-dioctyl-7-oxo-, 2-ethylhexyl ester	C <sub>36</sub> H <sub>72</sub> O <sub>4</sub> S <sub>2</sub> Sn	15571-58-1
1,3,2-Dioxastannepin-4,7-dione, 2,2-dioctyl-	C <sub>20</sub> H <sub>36</sub> O <sub>4</sub> Sn	16091-18-2
Stannane, bis(dodecylthio)dioctyl-	C <sub>40</sub> H <sub>84</sub> S <sub>2</sub> Sn	22205-30-7

Chemical name	Molecular formula	CAS No.
Acetic acid, 2,2-[(dioctylstannylene)bis(thio)]bis-, diisooctyl ester	C <sub>36</sub> H <sub>72</sub> O <sub>4</sub> S <sub>2</sub> Sn	26401-97-8
Stannane, dioctylbis[(1-oxoneodecyl)oxy]-	C <sub>36</sub> H <sub>72</sub> O <sub>4</sub> Sn	68299-15-0
5,7,12-Trioxa-6-stannaicoso-2,9-dienoic acid, 13-methyl-6,6-dioctyl-4,8,11-trioxo-, 1-methyloctyl ester, (Z,Z)-	C <sub>42</sub> H <sub>76</sub> O <sub>8</sub> Sn	108537-06-0
<b>Triphenyltin compounds</b>		
Stannane, fluorotriphenyl-	C <sub>18</sub> H <sub>15</sub> F <sub>3</sub> Sn	379-52-2
<b>Tetraphenyltin compounds</b>		
Stannane, tetraphenyl-	C <sub>24</sub> H <sub>20</sub> Sn	595-90-4
<b>Other organotin compounds</b>		
Distannoxane, hexakis(2-methyl-2-phenylpropyl)-	C <sub>60</sub> H <sub>78</sub> OSn <sub>2</sub>	13356-08-6
Acetic acid, 2,2,2-[(1,1,3-tributyl-1-distannathianyl-3-ylidene)tris(thio)]tris-, triisooctyl ester	C <sub>42</sub> H <sub>84</sub> O <sub>6</sub> S <sub>4</sub> Sn <sub>2</sub>	33703-04-7
Propanoic acid, 3,3-[bis[[2-(isooctyloxy)-2-oxoethyl]thio]stannylene]bis-, dibutyl ester	C <sub>34</sub> H <sub>64</sub> O <sub>8</sub> S <sub>2</sub> Sn	63397-60-4
9-Octadecenoic acid (Z)-, 2-mercaptoethyl ester, reaction products with dichlorodimethylstannane, sodium sulfide (Na <sub>2</sub> S) and trichloromethylstannane		68442-12-6
Stannane, dibutylbis[(1-oxopentadecyl)oxy]-, branched		68512-27-6