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ORGANOTIN COMPOUNDS IN THE ENVIRONMENT

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**ANALYSIS, OCCURRENCE AND FATE OF
ORGANOTIN COMPOUNDS IN THE ENVIRONMENT**

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ABSTRACT

A review is presented of the analysis, occurrence and fate of organotin compounds in the environment.

The state of the art in analytical instrumentation is generally adequate, although there are few published methods on media other than water. The main classes of organotin compounds likely to be found in the Canadian environment are methyl-, butyl-, phenyl- and cyclohexyltin compounds, and most of these species can be analyzed satisfactorily using existing methods; however, it is desirable to have a method which features continuous introduction of high pressure liquid chromatographic eluent into a suitable detector for those compounds, or conjugates, which are not volatile.

There are few data on the occurrence of organotin compounds in the environment. Some of those that have been detected are very toxic to aquatic organisms.

Persistence studies on the major classes of organotin compounds have indicated that abiotic degradation generally occurs, as does biological degradation, through mechanisms of sequential dealkylation or dearylation. Adsorption to soils and sediments appears to be strong, although subsequent mobilization by biota cannot be ruled

out. In general, photolysis appears to be the rate-limiting degradative step. Methylation of tin and organotins, although a slow process, may nevertheless be significant with regard to transport of tin in and from aquatic environments. Further information on occurrence, persistence and fate of methyl-, butyl-, phenyl- and cyclohexyltin species is required before environmental and human health risk assessments can be made.

INTRODUCTION

Tin as a metal and in its chemical compounds has a wide variety of use. Characteristically, in many of its applications, only small amounts of tin are needed to see its effect. This is generally true for the organotin compounds which, during the past thirty years, have developed into important industrial commodities. A further characteristic of tin is that it is unsurpassed by any other metal in the multiplicity of its organic applications. These involve such widely divergent fields as stabilizers for polyvinyl chloride, industrial catalysts, industrial and agricultural biocides, and wood-preserving and antifouling agents, to mention only the most important applications.

The annual world consumption of tin in all forms was about 200 million kg in 1976, and of this total about 28 million kg was in the form of organotin compounds (Zuckerman et al. 1981). The U.S. consumption of organotin compounds was about 11 million kg in that year, and an 11 to 13% annual growth was predicted for the period 1978 to 1988. Comparable Canadian figures are not available.

The increasing annual use of organotin compounds, some of which are very toxic, caused organotin compounds as a class to be placed on the Department of the Environment's Environmental

Contaminants Act Category III list, which essentially meant that further information was required on their occurrence, persistence and toxicity in order to make environmental and human health risk assessments (Canada Department of Environment and Department of National Health and Welfare 1979). Since that time, the butyl- and methylin series of compounds have been found in some Canadian waters and sediments (Maguire et al. 1982; Maguire 1984).

Acting independently of the Department of the Environment, the Subcommittee on Water of the Associate Committee on Scientific Criteria for Environmental Quality of the National Research Council of Canada has identified Organotin Compounds in the Aquatic Environment as a priority topic, and it is the intention of this committee to produce a "criteria document that will examine the critical scientific issues surrounding this topic and clarify the fundamental concepts on which criteria are based".

This review of the analytical methods for, and occurrence and fate of, organotin compounds in the environment is a contribution to the National Research Council review and it also constitutes part of an environmental risk assessment required by the Department of the Environment under the Toxic Chemicals Management Program.

This review does not cover all aspects of organotin compounds. Other aspects, including some earlier discussions on environmental chemistry, have been the subjects of several excellent reviews (Barnes and Stoner 1959; Ingham et al. 1960, Tobias 1966; Coates et al. 1967; Neumann 1970; Poller 1970; Sawyer 1971; Zuckerman 1976; Horwitz 1979; Piscator 1979; World Health Organization 1980; Negishi 1980; Davies and Smith 1980; Duncan 1980; Bock 1981; Zuckerman et al. 1981; Davies and Smith 1982).

ANALYTICAL METHODS

Table 1 describes analytical methods that have been used for inorganic tin and organotin compounds in a variety of media, with specific comments on methods where appropriate.

Compounds have generally been designated for convenience as cations since there is evidence that at least some organotin species in water exist as cations (e.g., Tobias 1966; Maguire et al. 1983a); where it is obvious that an ion is not involved (e.g., analysis of neat compound), then the relevant compound is noted. In addition, the figures in the column entitled "MDL" (minimum detectable level) should be regarded with caution since it is not yet common practice, however desirable, to distinguish "limit of detection" from "limit of

quantitation". In this regard, a good review, with guidelines, has been published (American Chemical Society Committee on Environmental Improvement and Subcommittee on Environmental Analytical Chemistry 1980).

It should be recognized that no single method will be best for all types of organotin compounds and inorganic tin. The older spectrophotometric methods have largely been supplanted by more sensitive techniques which employ chromatographic separation of different tin-containing species.

Gas chromatographic separation of organotin compounds has necessitated the preparation of suitably volatile analytes, and the preparation of hydride (R_nSnH_{4-n}) and alkyl ($R_nSnR'_{4-n}$) derivatives has predominated. Hydride derivatives are usually generated in situ, then swept into a cold trap or chromatographic column prior to elution into the detector; the advantage is that the volatile analyte can be evolved from its matrix, with attendant gains in sensitivity (e.g., Hodge et al. 1979). Alkyl derivatives are not prepared in situ and thus are usually subjected to "clean-up" steps prior to analysis. By such techniques, however, they can be greatly concentrated, facilitating analysis, and they are usually stable enough to be stored for long periods of time, unlike at least some hydrides (e.g., Soderquist and Crosby 1978). Plasma atomic emission detectors offer good

sensitivity (and of course multi-element capability); however the two most common detectors in the gas chromatographic trace analysis of organotin compounds are the flame photometric detector (FPD) and the quartz tube furnace atomic absorption spectrophotometer (AAS). The FPD offers truly outstanding sensitivity in those models which have glass internal surfaces (e.g., Aue and Flinn 1980); however the refractory combustion product SnO_2 may accumulate on internal surfaces, causing a decrease in detector sensitivity (e.g., Maguire and Tkacz 1983). The quartz tube furnace - AAS technique, introduced by Chu et al. (1972) for other purposes, has the advantages that fouled furnaces are disposable and that the technique may be used for many different volatile metals or organometals.

Liquid chromatographic separation of organotin compounds does not of course require the preparation of volatile analytes, and would in general be the method of choice for analysis of non-volatile or high molecular weight organotin compounds were it not for the fact that the development of sensitive detectors has been slower than in the field of gas chromatography. Jewett and Brinkman (1981, and references therein) have used a graphite furnace atomic absorption spectrophotometer as a detector for a high pressure liquid chromatograph (HPLC), but the connection is of necessity discontinuous, with attendant loss of sensitivity. Burns et al. (1981) have successfully coupled HPLC to a quartz tube furnace - AAS via a hydride generator, in

the analysis of lower alkyltin species; however, it remains to be seen if this technique is successful with larger organotin molecules. One technique which may have promise is the coupling of a microbore HPLC to a flame photometric detector or a quartz tube furnace AAS. The small solvent flow rate (10 to 100 $\mu\text{L}/\text{min}$) in microbore HPLC has already been shown to be compatible with direct introduction to flame photometric and alkaline flame ionization detectors in the analysis of organophosphorus pesticides (McGuffin and Novotny 1981a, 1981b).

ENVIRONMENTAL OCCURRENCE OF ORGANOTIN COMPOUNDS

Table 2 describes the environmental occurrence of tin and organotin compounds. In general, contamination of the environment by inorganic tin is only slight; however, increased concentrations in some sediments have been correlated with increasing anthropogenic activity (e.g., Hallas and Cooney 1981; Goldberg *et al.* 1981). Byrd and Andreae (1982) have estimated that waste incineration contributes more tin to the atmosphere than all other combined anthropogenic and natural sources.

There have been few studies on the environmental occurrence of organotin compounds. Methyltin compounds have been detected in a

variety of waters (Braman and Tompkins 1979; Hodge et al. 1979; Byrd and Andreae 1982; Jackson et al. 1982; Maguire et al. 1982; Tugrul et al. 1983) and in sediment and aquatic biota (Tugrul et al. 1983). The environmental occurrence of methyltin compounds may be a result of anthropogenic input, or the result of biologically-mediated methylation of inorganic tin which may or may not be of anthropogenic origin. In addition to methyltin compounds, methyltin hydrides have been detected in some areas of Chesapeake Bay (Jackson et al. 1982).

The more toxic butyltin compounds have been detected at generally higher concentrations than the methyltin compounds in some waters (Hodge et al. 1979; Jackson et al. 1982; Maguire et al. 1982) and sediments (Seidel et al. 1980; Maguire 1984). The environmental occurrence of butyltin compounds is a result of anthropogenic input primarily through the use of tri-n-butyltin compounds as antifouling agents in marine paint. In Ontario, the occurrence of butyltin compounds is largely restricted to the water and sediments of harbours, marinas and other areas of heavy boating or shipping activity. In addition to butyltin compounds, butylmethyltin compounds have been detected in the sediments of some harbours in Ontario (Maguire 1984), and are probably the result of biologically-mediated methylation of anthropogenically-derived butyltin species.

ENVIRONMENTAL TRANSFORMATION AND FATE OF ORGANOTIN COMPOUNDS

The persistence and fate of any toxic substance in any environmental "compartment" is a function of the kinetics of a variety of routes of degradation and dissipation. From the aquatic point of view, some of the more important considerations, in addition to simple water flow, are basic properties such as aqueous solubility, vapour pressure and octanol-water partition coefficient, and such processes as hydrolysis (or stability in the dark), volatilization, sunlight photolysis, adsorption to suspended matter and to sediments, microbiological degradation or transformation and uptake by aquatic biota.

Before the literature is reviewed, there are a few points worth noting.

The persistence of any organotin compound should not be defined in terms of the time required for anion exchange; this gives a false impression of degradation kinetics when what is significant is a definition in terms of loss of alkyl or aryl groups, since the toxicity of organotins to most organisms decreases with decreasing number of organic substitutents at the tin atom.

The persistence of any toxic substance in a water-sediment system should not be solely defined in terms of adsorption to sediment

since toxic residues could be mobilized again through sediment re-suspension, or could be taken up by benthic biota.

An important point to note with regard to photolysis is that although the use of Hg lamps in the laboratory yields much useful information on chemical mechanisms, the use of environmentally more relevant light sources (i.e., sunlight or appropriately filtered light of suitable intensity) will yield more reliable estimates for persistence vis-a-vis sunlight photolysis.

Some organotin species, and inorganic tin, under some conditions adsorb to Teflon and glass (Meinema et al. 1978; Maguire et al. 1983a); such adsorption may vitiate the findings of some workers.

For convenience, the discussion on the persistence and fate of tin and organotins will treat the compounds separately by class.

The Sn^{4+} oxidation state is thermodynamically more stable than Sn^{2+} and thus in most environmental compartments, with the exception of some anaerobic sediments, inorganic tin will likely be found in the Sn^{4+} state. Fanchiang and Wood (1981) have shown that the half-life for oxidation of Sn^{2+} to Sn^{4+} is about 2 d in oxygenated water at 23°C.

Several workers have shown that Sn^{4+} can be methylated in nutrient medium or natural water-sediment mixtures; MeSn^{3+} , $\text{Me}_2\text{Sn}^{2+}$, Me_3Sn^+ , Me_4Sn and a methyldtin hydride of unknown composition (but more volatile than Me_4Sn) have been variously identified as products. In only one case were yields given, and they were vanishingly small ($\leq 0.008\%$ - Chau et al. 1981); nevertheless, methylation of inorganic tin should not be discounted as a significant environmental phenomenon, since the process (i) can convert tin to more volatile forms capable of atmospheric redistribution, and (ii) can convert tin to more toxic forms. In this latter context, however, the toxicity difference between methyldtin compounds and inorganic tin is not as great as that between methylmercury and inorganic mercury.

Methyldtin species can also be further methylated in natural water-sediment systems. The process may be better described as being biologically mediated rather than solely biomethylation since, for example, Me_4Sn may result from disproportionation of lesser-methylated species (Guard et al. 1981), or of a methyldtin hydride (Jackson et al. 1982). Methyldtin compounds can also be sequentially demethylated to inorganic tin by photolysis (Blunden 1983), but an estimate of an "environmental half-life" is uncertain since light of wavelengths less than 290 nm (the lower limit for sunlight) was used. Estimated lower limits for these photolytic half-lives in water are 30 hr for Me_3Sn^+ , 300 hr for $\text{Me}_2\text{Sn}^{2+}$ and 1500 hr for MeSn^{3+} .

Neat Me_3SnOH (and the bis oxide) will react with atmospheric CO_2 to produce $(\text{Me}_3\text{Sn})_2\text{CO}_3$; however, in water, Me_3Sn^+ will probably remain as the hydrated cation in the presence of dissolved CO_2 . This comment is applicable to all those neat trialkyltin hydroxides or bis (alkyltin) oxides which react with atmospheric CO_2 to yield carbonates.

Ethyltin species are dealkylated in mammals, but little reliable information is available on environmental persistence or fate; these comments are also applicable to propyl-, pentyl-, hexyl-, octyl- and mixed cyclohexylphenyltin compounds. These six classes of organotin compounds are either little-used or are not very toxic to most organisms.

The literature on butyltin compounds is, by contrast, fairly extensive. Butyltin species are sequentially dealkylated by mammals, sheepshead minnows, one algal species and some fungal and bacterial cultures, although an attempt at degrading Bu_3Sn^+ by tin-tolerant bacteria from Chesapeake Bay was unsuccessful (Blair *et al.* 1982). The mechanism of dealkylation in mammals appears to involve carbon-hydroxylated intermediates. The maximum observed bioconcentration factor for Bu_3Sn^+ in whole sheepshead minnow was 2.6×10^3 , and the depuration "first half-life" was 7 d.

The tributyltin species does not lose butyl groups in the dark, and does not volatilize, over a period of at least two months. There is equivocal evidence for its strong binding to soils and sediments; experimental complications include the formation of unextractable residues and microbial dealkylation. Soil-bound Bu_3Sn^+ should not be thought of as biologically unavailable; Gile *et al.* (1982) have presented some equivocal evidence for its uptake by earthworms. Estimates of the sunlight photolytic half-life of Bu_3Sn^+ vary from 18 to 89 d; indeed, statements on the aquatic environmental persistence of Bu_3Sn^+ rest on this difference in half-life of what is probably the rate limiting degradative process. Recoveries of products of Bu_3Sn^+ photolysis are generally poor. One reason for this, by analogy with phenyltin compounds, may be that water-soluble polymeric di- and monobutyltin compounds are formed. There has been a report of the occurrence of methylated derivatives of tri- and dibutyltin species which suggests that methylation may be a significant pathway of transformation of Bu_3Sn^+ in sediment-water systems.

There are fewer data on Bu_2Sn^{2+} and $BuSn^{3+}$; photolytic half-lives are generally of the same order as those for Bu_3Sn^+ .

Tricyclohexyltin degrades in vivo (mammals) through sequential loss of cyclohexyl groups; carbon-hydroxylated intermediates are involved. Photolysis on surfaces proceeds with an estimated "sunlight

"half-life" of 8 d, and appears to proceed through sequential dealkylation. Volatilization from water is at least ten times slower. There is some evidence for strong binding to soil and dealkylation by soil microbes. Photolysis in water produces cyclohexane and cyclohexanol, indicating dealkylation, but half-lives are not available. The above statements are generally applicable to Cy_2Sn^{2+} and $CySn^{3+}$.

The triphenyltin species suffers sequential dearylation by mammals and bacteria. It appears to bind strongly to soil as evidenced by a 50% decrease in extractability over 40 d (Barnes *et al.* 1973). Sunlight photolysis on surfaces ($t_{\frac{1}{2}} \sim 14$ d) and in water ($t_{\frac{1}{2}}$ 14 to 21 d) appears to proceed through sequential dearylation, although there is evidence for formation of water-soluble polymeric di- and monophenyltin species. The Ph_3Sn^+ species is stable in water in the dark for over a month, and is slowly degraded ($t_{\frac{1}{2}} \sim 140$ d) by microbes in soil. At low concentrations, Ph_2Sn^{2+} and $PhSn^{3+}$ are much less stable in water ($t_{\frac{1}{2}}$ is several minutes for $PhSn^{3+}$ and 3 d for Ph_2Sn^{2+}), and there is evidence for formation of water-soluble polymeric tin species.

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TABLE 1: Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
1	Sn^{2+}	water	Iodometric titration in absence of air asv	125 $\mu\text{g/L}$	Sn^{2+} in a chloride solution In MeOH is only 1% converted to Sn^{4+} in 10 hr	Kolthoff and Sandell (1952)
2	Sn^{2+}	water	carbon filament aas	100 pg	Linear range up to 8 ng; 224.6 mm	Fano and Zanotti (1973)
3	Sn^{2+}	water	carbon filament aas	70 pg	286.3 mm, with edta; linear range up to 10 ng	Everett et al. (1974)
4	Sn^{2+}	water	carbon filament aas	150 pg	286.3 mm; linear range up to 20 ng	Everett et al. (1974)
5	Sn^{2+}	xylene	carbon filament aas	180 pg	286.3 mm; linear range up to 6 ng	Everett et al. (1974)
6	Sn^{2+}	SAE 10 oil	carbon filament aas	36 ng/L	this reaction interferes with Brinckman et al. (1983)	Everett et al. (1974)
7	Sn^{2+}	water	hydride derivatization; SnH_4 detected by gc-fpd	microgram quantities	the hydride derivatization method for Sn^{4+}	Luke (1956)
8	Sn^{4+}	In lead and in 1% antimony-lead alloys	spectrophotometric determination of phenyl-fluorone complex	0.1 $\mu\text{g/mL}$	33% dimethylformamide preferred for solvent	Coyle and White (1957)
9	Sn^{4+}	water	determination of flavonol complex	20 $\mu\text{g/L}$	a modification of method No. 8	Bennett and Smith (1959)
10	Sn^{4+}	water	spectrophotometric determination of phenyl fluorone complex	240 $\mu\text{g/L}$	Zr, Ti, Bi, Sb, Ga and Mb interfere, but Sn^{2+} does not	Ross and White (1961a)
11	Sn^{4+}	water	spectrophotometric determination of pyrocatechol violet complex			

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
12	Sn^{4+}	EtOH	extracted from acidic solution with tris (2-ethylhexyl) phosphine oxide, diluted with EtOH , followed by method No. 11	10 $\mu\text{g/L}$	method used in Pb , Zn , Cu , Fe and Zr -based alloys	Ross and White (1961b)
13	Sn^{4+}	sea water, rocks, clays, marine animals	acid digestion (if necessary), conversion to SnO_2 and ras		exhaustive purification steps required	Haneguchi <i>et al.</i> (1964)
14	Sn^{4+}	etherreal	Grignard conversion to Me_4Sn , then gc-tcd			Steinmeyer <i>et al.</i> (1965)
15	Sn^{4+}	standards	Grignard conversion to Pr_4Sn or Pb_4Sn , then gc-tcd			Jitsu <i>et al.</i> (1969)
16	Sn^{4+}	acidic aqueous	(a) distillation of SnBr_4 with $\text{HBr}-\text{HCl}$ mixture, or (b) extraction of SnBr_4 into hexane, then spectrophotometric determination of dithiol complex	0.2 mg Sn		Corbin (1970)
17	Sn^{4+}	acidic solution, either of sea water or tissue digest	extraction of SnI_4 into dilute NaOH , then spectrophotometric determination of phenyl-fluorone complex	0.1 μg Sn		Smith (1970)
18	Sn^{4+}	water	asv	40 $\mu\text{g/L}$		Hoggon <i>et al.</i> (1972)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
19	Sn^{4+}	acidic aqueous solution	see method No. 11	1 μg	cetyltrimethylammonium bromide sensitizes the reaction	Corbin (1973)
20	Sn^{4+}	acidic solution (steel digest)	see method No. 11		sensitization with surfactants and basic dyes; metal interferences were shown, as well as ways to remove the interferences	Ashton et al. (1973)
21	Sn^{4+}	fresh water or freeze-dried plants, sediment and fish	naa			Schramel et al. (1973)
22	Sn^{4+}	water (pH4)	extraction with diethyl-dithiocarbamate in CHCl_3 , then spectrophotometric determinations of dithiol complexes			Freitag and Bock (1974a)
23	Sn^{4+}	on sugar beet plants and in rats	radioactive ^{113}Sn determination after extraction as per method No. 22			Freitag and Bock (1974b)
24	Sn^{4+}	water	generation of SnH_4 , then gas with Ar/H_2 flame	1 ng		Schmidt et al. (1975)
25	Sn^{4+}	water	gas		response increased by (a) addition of Cd^{2+} , and (b) addition of propane, ethylene, acetylene or methane to purge gas, which results in deposition of pyrolytic graphite; the two effects are not additive	Thompson et al. (1975)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
26	Sn^{4+}	suspended particulate matter in air	Sn dissolved from Hi-Vol filter, then SnH_4 generated on and aes with a quartz tube furnace	0.1 $\mu\text{g}/\text{L}$	response linear to 40 $\mu\text{g}/\text{L}$; $\lambda=286.5$ nm (sensitivity 66% higher at 224.6 nm, but considerable baseline drift); analyses also done on beverages	ViJen and Chen (1976)
27	Sn^{4+}	municipal sewage sludges	naa			Fuhr et al. (1976)
28	Sn^{4+}	tlc plates	$^{119}\text{Sn}^{4+}$ located with dithizone, then analyzed in scintillation counter			Smith et al. (1976)
29	Sn^{4+}	water		50-120 $\mu\text{g}/\text{L}$		Winge et al. (1977)
30	Sn^{4+}	tlc plates	icp-aes chromatogenic reagents: either pyrocatechol violet or 8-hydroxy-5-quinoinesulfonic acid	1-10 $\mu\text{g}/\text{spot}$		Kimmeil et al. (1977)
31	Sn^{4+}	water	SnH_4 generation, then plasma aes	40 ng	linear range 0.1-10 μg ; hydride generator coupled to spectrometer via a condensation tube and Chromosorb 102 column to separate SnH_4 from H_2	Fricke et al. (1978)
32	Sn^{4+}	water	extraction with 0.05% tropolone in C_6H_6 or CHCl_3 , Grignard derivatization to Bu_4Sn , then gc-ms		80-90% recovery at 1 mg/L level; strong tendency noted for Sn to adsorb to glass	Melinema et al. (1978)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins^a

Number	Compound	Medium	Method	MDL	Comments	Reference
33	Sn^{4+}	water, sediment suspended solids	after digestion (if necessary), SnH_4 generation, then <i>aas</i> with quartz tube furnace	1 $\mu\text{g/L}$ or 0.1 $\mu\text{g/g}$	a refinement of method No. 26	Pyen and Fishman (1979)
34	Sn^{4+}	fresh, estuarine, sea, tap and rain water, and urine	SnH_4 generation, then flame emission detection (610 nm)	0.3 ng/L for 100 mL samples	H_2 -rich flame; NaBH_4 reagent frequently contaminated with Sn	Brennan and Tompkins (1979)
35	Sn^{4+}	shells (miscellaneous)	SnH_4 generation, then flame emission detection (610 nm)	0.05 ng/g	method of digestion of (or extraction from) shells not stated	Brennan and Tompkins (1979)
36	Sn^{4+}	fresh and sea water, marine algae, sediment	SnH_4 generation from digests (if necessary), then <i>aas</i> with quartz tube furnace	0.4 ng	Hodge <i>et al.</i> (1979)	
37	Sn^{4+}	Juices	<i>aas</i> with Mb micro-tube furnace	9 pg	addition of H_2 to Ar purge gas improves efficiency of Sn atomization; phosphoric acid lowers atomization temperature and depresses some interferences	Ohta and Suzuki (1979)
38	Sn^{4+}	food	digestion, SnH_4 generation, then <i>aas</i> with quartz tube furnace	0.2 mg/kg	good statistical evaluation of results; furnace heated only by flame	Evans <i>et al.</i> (1979)
39	Sn^{4+}	flour and whole blood	digestion, SnH_4 generation, then microwave-induced Ar-He plasma <i>aes</i>	2 $\mu\text{g/L}$ for 20 mL aqueous standard	Robbins <i>et al.</i> (1979)	

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
40	Sn^{4+}	pure and tap water	asv	1 $\mu\text{g/L}$	can be determined in the presence of five-fold excess of Pb^{2+} and Cd^{2+} ; effects of diphenols and oxalic acid demonstrated	Głodowski and Kublik (1980)
41	Sn^{4+}	artificial sea water	dpass	8 $\mu\text{g/L}$		Macchi and Pettine (1980)
42	Sn^{4+}	rocks, In presence of other metals and metalloids	MIBX extraction, then selective back-extraction and flame aas			Clark and Viets (1980)
43	Sn^{4+}	dialkylbenzene sulfonate salt In toluene	size exclusion chromatography with Icp-aes	4.1 $\mu\text{g/L}$	100-Angstrom μ -Styragel column	Hausler and Taylor (1981a)
44	Sn^{4+}	"petroleum-based organic matrix"	size exclusion chromatography with Icp-aes	220 $\mu\text{g/L}$	pyridine solvent	Hausler and Taylor (1981b)
45	Sn^{4+}	coal fly ash	digestion, substoichiometric isotope dilution analysis by complexation in benzene with salicylideneamino-2-thiophenol extraction with iodide, then method No. 45	1 μg		Imura and Suzuki (1981a)
46	Sn^{4+}	as contaminant in organotin compounds			butylltin compounds in 5×10^3 -fold excess amounts do not interfere	Imura and Suzuki (1981b)
47	Sn^{4+}	aqueous standards	greases		Zr-coated furnaces increased atomization efficiency by 2-3 X	Vickrey <i>et al.</i> (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins^a

Number	Compound	Medium	Method	MDL	Comments	Reference
48	Sn^{4+}	pure and fresh water	extraction with tropolone in C_6H_6 , Grignard derivatization to Pb_4Sn , then gc-modified-fpd	60 pg	> 94% recovery at 10 mg/L level	Maguire and Huneault (1981)
49	Sn^{4+}	"artificial tap water"	see method No. 36 extracts of new PVC and CPVC pipe	0.5 ng	Linear range over 0.05-1 $\mu\text{g}/\text{L}$ for 100 mL sample	Boettner <u>et al.</u> (1981)
50	Sn^{4+}	"artificial tap water"	extraction with tropolone in C_6H_6 , Grignard derivatization to Pb_4Sn , then gc-fid	1.5-3 $\mu\text{g}/\text{L}$	(1 L sample)	Boettner <u>et al.</u> (1981)
51	Sn^{4+}	water and sediment	(a) sediment leached with acid; (b) water extracted with MIBK after addition of ammonium pyrrolidine dithiocarbonate; gfaas	100 pg Sn	Hallas and Cooney (1981)	
52	Sn^{4+}	pure and fresh water	saturation with NaCl, extraction with tropolone in C_6H_6 , Grignard derivatization to $n\text{-Bu}_4\text{Sn}$, then gc-aas with quartz tube furnace gfaas	100 pg Sn	Chau <u>et al.</u> (1982)	
53	Sn^{4+}	aqueous standard			addition of 10% H_2 to purge gas increases sensitivity	Rayson and Holcombe (1982)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
54	Sn^{4+}	estuarine water	SnH_4 generation to purge and trap sampler, then gc-modified-fpd	0.03 $\mu\text{g/L}$ with 10 mL samples		Jackson <i>et al.</i> (1982)
55	Sn^{4+}	sea water, marine algae, sediment	SnH_4 generation from digest (if necessary), then aas with quartz tube furnace	5 ng/L in sea water		Ishii (1982)
56	Sn^{4+}	with $\text{Bu}_3\text{Sn}^{3+}$, $\text{Bu}_2\text{Sn}^{2+}$ and Bu_3Sn^+ in benzene	separation of species with selective halide extraction, then analysis by method No. 44	5 $\mu\text{g/kg}$ with 1 g samples	this work also dealt with Bu_3MeSn and $\text{Bu}_2\text{Me}_2\text{Sn}$ in sediment	Imura and Suzuki (1983)
57	Sn^{4+} sediment		dry sediment extracted with tropolone in C_6H_6 , then analysis by method No. 44	5 $\mu\text{g/kg}$ with 1 g samples	sensitivity of the two detectors roughly the same, but quartz furnace more stable	Maguire (1984)
58	Sn^{4+}	water	extraction according to method No. 48, with analysis either by gc-modified-fpd or gc-aas with quartz tube furnace	~60 pg	sensitivity of the two detectors roughly the same, but quartz furnace more stable	Maguire and Tkacz (1983)
59	Sn^{4+}	water	SnH_4 generation then swept into (a) aas with quartz tube furnace, or (b) fpd	(a) 90 pg (b) 10 pg	to avoid adsorption of hydride to internal surfaces of detection apparatus, all inner surfaces deactivated with silicating agent	Andreas (1983)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins^a

Number	Compound	Medium	Method	MDL	Comments	Reference
60	SnCl_4	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		discontinuous method since only part of effluent is sampled, giving nongraphic presentation of results; Zr-treated furnaces reduced species-dependent sensitivity	Vickrey <i>et al.</i> (1980a)
61	SnCl_4	MeOH	gfaas	13-19 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey <i>et al.</i> (1980b)
62	SnO_2	precipitated from water during degradation of Ph_3Sn^+	fusion with KHSO_4 at 300-350°; solubilized Sn^{4+} then analyzed by method No. 19			Soderquist and Crosby (1978)
63	"total Sn"	solvent extracts from PVC films	gfaas	0.1 ng	linear range to 0.75 ng; no species-dependent sensitivity even without Zr-coating of furnace	Trachman <i>et al.</i> (1977)
64	"total Sn"	beef tissues	digestion with a quarter-normal ammonium hydroxide dissolved in toluene, then gfaas	0.1 ng	apparently no lipid interferences	Trachman <i>et al.</i> (1977)
65	"total Sn"	water	preconcentration by coprecipitation with 1,10-phenanthroline and Ph_4B , then gfaas	0.1 ng	linear range 0.4-14 ng	Dogan and Hacerli (1980)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
66	"Total Sn"	plants, plankton, fish organic component of sediment water	digestion with quaternary ammonium hydroxide in 1-propanol, then gfaas	0.1 ng	apparently no lipid interferences	Dogen and Haerdi (1980)
67	"Total Sn"		extracted with hexane, oxidized with H ₂ SO ₄ , then spectrophotometric determination of phenyl-fluorone complex	yield not stated		Sherman and Carlson (1980)
68	"Total Sn"	soil	extracted with hexane, oxidized with H ₂ SO ₄ , then spectrophotometric determination of phenyl-fluorone complex	yield not stated		Sherman and Carlson (1980)
69	"Total Sn"	plants, fish	dissolved in H ₂ SO ₄ , then method No. 67	yield not stated		Sherman and Carlson (1980)
70	"Total Sn"	marine algae, fish, molluscs	acid digestion, SnH ₄ generation, then eas with silica tube furnace	0.9 µg/L of analyte		Mather (1982)
71	MeSn ³⁺	MeSnCl ₃ in E ₂ O	Grignard derivatization to MeBu ₃ Sn or MeOct ₃ Sn, then gc with fcd or hot wire detector			Neubert and Wirth (1975)
72	MeSn ³⁺	water	270 MHz nuclear magnetic resonance			Dizikes et al. (1978)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins^a

Number	Compound	Medium	Method	MDL	Comments	Reference
73	MeSn ³⁺	fresh, estuarine, sea, tap and rain water, and urine	MeSnH ₃ ⁺ generation and detection by method No. 34	0.01-0.02 ng/L for 100 mL samples		Brennan and Tompkins (1979)
74	MeSn ³⁺	shells (miscellaneous)	MeSnH ₃ ⁺ generation and detection by method No. 34	0.01 ng/g	method of extraction from shells not stated	Brennan and Tompkins (1979)
75	MeSn ³⁺	fresh and sea water	MeSnH ₃ ⁺ generation, then method No. 36 hplc-rid	0.5 ng		Hodge <i>et al.</i> (1979)
76	MeSn ³⁺	MeSnCl ₃ in organic solvents			various column packing materials tested	Jessen <i>et al.</i> (1979)
77	MeSn ³⁺	MeSnCl ₃ in organic solvents	(a) gc-hot wire detector, (a) could not be determined or (b) hplc-rid		(a) redistribution reaction occurs if Me ₄ Sn were present In presence of Me ₄ Sn (b) 100 µg	Burns <i>et al.</i> (1980)
78	MeSn ³⁺	MeOH/water (97.5/2.5, v/v)	hplc-gfaas	see method No. 60		Vickrey <i>et al.</i> (1980a)
79	MeSn ³⁺	MeSnCl ₃ standards	hplc-rid		acetone-pentane solvent	Glockling (1980)
80	MeSn ³⁺	MeSnCl ₃ standards	hplc, then MeSnH ₃ ⁺ generation, then electrothermal aas	1 ng	no detail given on detector; this method failed for mixtures of butyl or phenyl- tin halides, owing to the lower volatility of the resulting hydrides	Glockling (1980)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins^a

Number	Compound	Medium	Method	MDL	Comments	Reference
81	MeSn ³⁺	MeSnCl ₃ standards	hplc-flame aas	19 ng	N ₂ O-C ₂ H ₂ flame	Burns et al. (1981)
82	MeSn ³⁺	MeSnCl ₃ standards	gc-aas with quartz tube furnace	1.1 ng	redistribution reaction occurs if Me ₄ Sn is present	Burns et al. (1981)
83	MeSn ³⁺	MeSnCl ₃ standards	hplc, then MeSnH ₃ generation, then aas with quartz tube furnace	5.4 pg		Burns et al. (1981)
84	MeSn ³⁺	"artificial-tap water"	see method No. 75	0.5 ng	Linear range over 0.05-1 µg/L for mL sample	Boettner et al. (1981)
85	MeSn ³⁺	extracts of new PVC and CPVC pipe	method No. 52 with MeBu ₂ Sn species	0.04 µg/L, with 5L sample		Chau et al. (1982)
86	MeSn ³⁺	MeSnH ₃	gc-ecd			Hallas et al. (1982)
87	MeSn ³⁺	estuarine water	method No. 54 with MeSnH ₃ species	0.05 µg/L with 10 mL samples		Jackson et al. (1982)
88	MeSn ³⁺	marine algae	homogenized, and resulting supernatant			Ishii (1982)
89	MeSn ³⁺	MeSnCl ₃ standards	analyzed by method No. 55 for MeSnH ₃ gc-fid	0.1 µg		Tan et al. (1983)
90	MeSn ³⁺	MeSnCl ₃ in CCl ₄ or water	¹ H nuclear magnetic resonance spectroscopy			Blunden (1983)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
91	$\text{Me}_3\text{Sn}^{3+}$	water	MeSnH_3 generation, then swept into (a) aas with quartz tube furnace, or (b) fpd	(a) 90 pg (b) 10 pg	see method No. 58	Andreas (1983)
92	$\text{Me}_2\text{Sn}^{2+}$	atmosphere above culture media	ms			Huey et al. (1974)
93	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 in E+O	method No. 71 with $\text{Me}_2\text{Bu}_2\text{Sn}$ or $\text{Me}_2\text{Oct}_2\text{Sn}$			Neubert and Wirth (1975)
94	$\text{Me}_2\text{Sn}^{2+}$	fresh, estuarine, sea, tap and rain water, and urine	Me_2SnH_2 generation and detection by method No. 34	0.01-0.02 ng/L for 100 mL samples		Braman and Tompkins (1979)
95	$\text{Me}_2\text{Sn}^{2+}$	shells (miscellaneous)	Me_2SnH_2 generation and detection by method No. 34	0.01 ng/g	method of extraction from shell is not stated	Braman and Tompkins (1979)
96	$\text{Me}_2\text{Sn}^{2+}$	fresh and sea water	Me_2SnH_2 generation, then method No. 36	0.5 ng		Hodge et al. (1979)
97	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 standards	hplc-rid		various column packing materials tested	Jessen et al. (1979)
98	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2	see method No. 77, (a) and (b) gfaes	(a) 8 µg (b) 90 µg 9-22 pg	see method No. 77	Burns et al. (1980)
99	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 in MeOH	hplc-rid		Zr-treated furnaces	Vickrey et al. (1980b)
100	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 standards	acetone-pentane solvent			Glockling (1980)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
101	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 standards	hplc, then Me_2SnH_2 generation, then electro-thermal aas	1 ng	see method No. 80	Glockling (1980)
102	$\text{Me}_2\text{Sn}^{2+}$	water	spectrophotometric determination of 3-hydroxy-flavone complex	$\epsilon_{385} = 4.7 \times 10^4 \text{ L mole}^{-1} \text{ cm}^{-1}$		Aldridge and Street (1981)
103	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 standards	hplc-flame aas	17 ng	$\text{N}_2\text{O-C}_2\text{H}_2$ flame	Burns et al. (1981)
104	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 standards	gc-aas with quartz tube furnace	1 ng		Burns et al. (1981)
105	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 standards	hplc, then Me_2SnH_2 generation, then aas with quartz tube furnace	8.6 pg		Burns et al. (1981)
106	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 standards	gc, then Me_2SnH_2 generation and aas with quartz tube furnace	1.5 pg		Burns et al. (1981)
107	$\text{Me}_2\text{Sn}^{2+}$	"artificial tap water"	see method No. 96	0.5 ng	linear range over 0.05 to 1 $\mu\text{g/L}$ for 100 mL sample	Boettner et al. (1981)
		extracts of new PVC and CPVC pipe				
108	$\text{Me}_2\text{Sn}^{2+}$	water	method No. 52 with $\text{Me}_2\text{Bu}_2\text{Sn}$ species	0.04 $\mu\text{g/L}$, 5 L sample		Chau et al. (1982)
109	$\text{Me}_2\text{Sn}^{2+}$	atmosphere above cultures	Me_2SnH_2 derivative analyzed by gc-ecd and gc-ms			Hollas et al. (1982)
110	$\text{Me}_2\text{Sn}^{2+}$	estuarine water	method No. 54 with Me_2SnH_2 species	0.01 $\mu\text{g/L}$ with 10 mL samples		Jackson et al. (1982)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
111	$\text{Me}_2\text{Sn}^{2+}$	marine algae	method No. 88 for Me_2SnH_2 species			Ishii (1982)
112	$\text{Me}_2\text{Sn}^{2+}$	spiked rat tissues	homogenization, extraction with EtOAc, partitioning into hexane, then hplc with fluorescence detection of 21,3, 4',5,7-pentahydroxy-flavone complex	0.1 to 1 ng	91% recovery from tissues spiked at 5 mmole level	Yu and Arakawa (1983)
113	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 standards	gc-fid	0.1 μg		Tan et al. (1983)
114	$\text{Me}_2\text{Sn}^{2+}$	Me_2SnCl_2 in CCl_4 or water	^1H nuclear magnetic resonance spectroscopy			Blunden (1983)
115	$\text{Me}_2\text{Sn}^{2+}$	water	Me_2SnH_2 generation, then swept into (a) aas with quartz tube furnace, or (b) fpd	(a) 90 pg (b) 10 pg	see method No. 58	Andreas (1983)
116	Me_3Sn^+	Me_3SnCl standard	gc-fpd	10 ng	Linear response to 10 ⁴ ng	Aue and Hill (1972a)
117	Me_3Sn^+	Me_3SnCl in Et_2O	method No. 71 with Me_3BuSn or Me_3OctSn			Neubert and Wirth (1975)
118	Me_3Sn^+	fresh, estuarine, sea, tap and rain water and urine	Me_3SnH generation and detection by method No. 34	0.01 to 0.02 ng/L for 100 mL samples		Braman and Tompkins (1979)
119	Me_3Sn^+	Me_3SnCl standards	Me_3SnH generation, then method No. 36	0.4 ng		Hodge et al. (1979)
120	Me_3Sn^+	Me_3SnCl standards	hplc-rid		various column packing materials tested	Jessen et al. (1979)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	NDL	Comments	Reference
121	Me_3Sn^+	Me_3SnCl standards	see method No. 77, (a) and (b) hplc-gfaas	(a) 8 μg (b) 80 μg	see method No. 77	Burns et al. (1980)
122	Me_3Sn^+	MeOH/water (97.5/2.5, v/v)	gfaas		see method No. 60	Vickrey et al. (1980a)
123	Me_3Sn^+	Me_3SnCl standards	gfaas	26 to 51 pg	Zr-treated furnaces	Vickrey et al. (1980b)
124	Me_3Sn^+	Me_3SnCl standards	hplc-rfd		acetone-pentane solvent	Glockling (1980)
125	Me_3Sn^+	Me_3SnCl standards	hplc, then Me_3SnH generation, then electrothermal aas	1 ng	see method No. 80	Glockling (1980)
126	Me_3Sn^+	MeOH	ion exchange hplc-gfaas		possible volatilization during dry and ash cycles	Jewett and Brinckman (1981)
127	Me_3Sn^+	MeOH	hplc-dppd			MacCrahan (1981)
128	Me_3Sn^+	water	spectrophotometric determination of 3-hydroxyflavone complex	82 ng		Aldridge and Street (1981)
129	Me_3Sn^+	Me_3SnCl standards	hplc-flame aas	16 ng	$\text{N}_2\text{O}-\text{C}_2\text{H}_2$ flame	Burns et al. (1981)
130	Me_3Sn^+	Me_3SnCl standards	gc-aas with quartz tube furnace	1.2 ng		Burns et al. (1981)
131	Me_3Sn^+	Me_3SnCl standards	hplc, then Me_3SnH generation, then aas with quartz tube furnace	9.5 pg		Burns et al. (1981)
132	Me_3Sn^+	Me_3SnCl standards	gc, then Me_3SnH generation, then aas with quartz tube furnace	2 pg		Burns et al. (1981)
133	Me_3Sn^+	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 119	0.5 ng	linear range over 0.05 to 1 $\mu\text{g/L}$ for 100 mL samples	Boettner et al. (1981)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins^a

Number	Compound	Medium	Method	MDL	Comments	Reference
134	Me_3Sn^+	water	method No. 52 with Me_3BuSn species	0.04 $\mu\text{g}/\text{L}$, 5 L sample		Chau <u>et al.</u> (1982)
135	Me_3Sn^+	atmosphere above cultures	Me_3SnH derivative analyzed by GC-TCD and GC-MS			Hallas <u>et al.</u> (1982)
136	Me_3Sn^+	estuarine water	method No. 54 with Me_3SnH species	~0.01 $\mu\text{g}/\text{L}$, for 10 mL samples		Jackson <u>et al.</u> (1982)
137	Me_3Sn^+	marine algae	method No. 88 for Me_3SnH species			Ishii (1982)
138	Me_3Sn^+	Me_3SnCl standards	gc-tid	10 ng		Tan <u>et al.</u> (1983)
139	Me_3Sn^+	Me_3SnCl in CCl_4 or water	^1H nuclear magnetic resonance spectroscopy			Blunden (1983)
140	Me_3Sn^+	water	Me_3SnH generation, then swept into (a) aas with quartz tube furnace, or (b) fpd	(a) 90 pg (b) 10 pg	see method No. 58	Andreas (1983)
141	Me_4Sn	standards	gc with (a) tcd, (b) fid, and (c) gas density balance detectors	relative sensitivities are (a) 1, (b) 1.7 and (c) 10	determined retention times on 3 stationary phases	Pollard <u>et al.</u> (1964)
142	Me_4Sn	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965a)
143	Me_4Sn	standards	gc-tcd		linear response to 10^4 ng	Putnam and Pu (1965b)
144	Me_4Sn	standards	gc-fpd	10 ng	transfer line maintained at	Aue and Hill (1972a)
145	Me_4Sn	standards	gc-gfaas	12 ng Sn	100°C; graphite furnace run continuously at 1800°C; H_2 added to Ar carrier gas	Parris <u>et al.</u> (1977)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
146	Me_4Sn	standards	hplc-rid			Jessen et al. (1979)
147	Me_4Sn	standards	see method No. 77, (a) and (b) hplc-rid	(a) 8 μg (b) 50 μg	various column packings materials tested see method No. 77	Burns et al. (1980)
148	Me_4Sn	standards	hplc-electrothermal aas	1 ng	acetone-pentane solvent	Glockling (1980)
149	Me_4Sn	standards	hp lc-flame aas	1 ng	see method No. 80	Glockling (1980)
150	Me_4Sn	standards	hp lc-flame aas	11 ng	$\text{N}_2\text{-O-C}_2\text{H}_2$ flame	Burns et al. (1981)
151	Me_4Sn	standards	gc-aas with quartz tube furnace	1 ng		Burns et al. (1981)
152	Me_4Sn	standards	hplc-purge-aas with quartz tube furnace	9.6 pg		Burns et al. (1981)
153	Me_4Sn	atmosphere above sediment culture	gc-fid	~18 μg	mdl estimated	Guard et al. (1981)
154	Me_4Sn	standards	gc-ecd and gc-ms			Hallas et al. (1982)
155	Me_4Sn	estuarine water	purged and trapped, then swept into gc-modified fpd	0.02 $\mu\text{g/L}$ for 10 mL samples		Jackson et al. (1982)
156	Me_4Sn	standards	gc-fid	10 ng		Tam et al. (1983)
157	EtSn^{3+}	EtSnCl_3	see method No. 77, (a) and (b) hplc-rid	(a) 16 μg (b) 100 μg	acetone-pentane solvent	Burns et al. (1980)
158	EtSn^{3+}	EtSnCl_3				Glockling (1980)
159	EtSn^{3+}	EtSnCl_3	hplc, then EtSnH_3 generation, then electro- thermal aas	1 ng	see method No. 80	Glockling (1980)
160	EtSn^{3+}	EtSnCl_3	hplc-flame aas	19 ng		Burns et al. (1981)
161	EtSn^{3+}	EtSnCl_3	gc-aas with quartz tube furnace	1 ng		Burns et al. (1981)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotin Ins*

Number	Compound	Medium	Method	MDL	Comments	Reference
162	EtSn^{3+}	EtSnCl_3 standards	hplc, then EtSnH_3 generation, then aas with quartz tube furnace	10 pg		Burns et al. (1981)
163	EtSn^{3+}	EtSnCl_3 standards	gc, then EtSnH_3 generation, then aas with quartz tube furnace	2.2 pg		Burns et al. (1981)
164	$\text{Et}_2\text{Sn}^{2+}$	microsomal metabolite of Et_3Sn^+	tic separation and spot identification with 8-hydroxyquinoline-sulfonic acid spray		qualitative	Kimmel et al. (1977)
165	$\text{Et}_2\text{Sn}^{2+}$	Et_2SnCl_2 standards	Et_2SnH_2 generation, then method No. 36	0.6 ng		Hodge et al. (1979)
166	$\text{Et}_2\text{Sn}^{2+}$	Et_2SnCl_2 standards	see method No. 77, (a) and (b)	(a) 12 μg (b) 90 μg	see method No. 77	Burns et al. (1980)
167	$\text{Et}_2\text{Sn}^{2+}$	Et_2SnCl_2 standards	hplc-rid		acetone-pentane solvent	Glockling (1980)
168	$\text{Et}_2\text{Sn}^{2+}$	Et_2SnCl_2 standards	hplc, then Et_2SnH_2 generation, then electro-thermal aas	1 ng	see method No. 80	Glockling (1980)
169	$\text{Et}_2\text{Sn}^{2+}$	water	spectrophotometric determination of 3-hydroxyflavone complex		$\epsilon_{385} = 4.1 \times 10^4 \text{ L mole}^{-1} \text{ cm}^{-1}$	Aldridge and Street (1981)
170	$\text{Et}_2\text{Sn}^{2+}$	Et_2SnCl_2 standards	hplc-flame aas	17 ng		Burns et al. (1981)
171	$\text{Et}_2\text{Sn}^{2+}$	Et_2SnCl_2 standards	gc-aas with quartz tube furnace	1.1 ng		Burns et al. (1981)
172	$\text{Et}_2\text{Sn}^{2+}$	Et_2SnCl_2 standards	hplc, then Et_2SnH_2 generation, then aas with quartz tube furnace	12 pg		Burns et al. (1981)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
173	$\text{Et}_2\text{Sn}^{2+}$	Et_2SnCl_2 standards	gc, then Et_2SnH_2 generation, then aas with quartz tube furnace	4.6 pg		Burns <i>et al.</i> (1981)
174	$\text{Et}_2\text{Sn}^{2+}$	spiked rat tissues	see method No. 112	0.1-1 ng	92% recovery from tissues spiked at 5 nmole level qualitative	Yu and Arakawa (1983)
175	Et_3Sn^+	microsome preparations	tic separation and spot identification with dilute zone spray			Kimmei <i>et al.</i> (1977)
176	Et_3Sn^+	Et_3SnCl standard	Et_3SnH generation, then method No. 36	0.7 ng		Hodge <i>et al.</i> (1979)
177	Et_3Sn^+	Et_3SnCl standard	see method No. 77, (a) and (b) hplc-rid	(a) 8 µg (b) 80 µg	see method No. 77	Burns <i>et al.</i> (1980)
178	Et_3Sn^+	Et_3SnCl standard	hplc, then Et_3SnH generation, then electrothermal aas	1 ng	acetone-pentane solvent	Glockling (1980)
179	Et_3Sn^+	Et_3SnCl standard	ion exchange hplc-gfaas		see method No. 80	Glockling (1980)
180	Et_3Sn^+	MeOH	possible volatilization during dry and ash cycles			Jewett and Brinckman (1981)
181	Et_3Sn^+	MeOH	hplc-dppd			MacCrehan (1981)
182	Et_3Sn^+	water	spectrophotometric determination of 3-hydroxyflavone complex			Adridge and Street (1981)
183	Et_3Sn^+	Et_3SnCl standard	hplc-flame aas	16 ng		Burns <i>et al.</i> (1981)
184	Et_3Sn^+	Et_3SnCl standard	gc-aas with quartz tube furnace	1.2 ng		Burns <i>et al.</i> (1981)
185	Et_3Sn^+	Et_3SnCl standard	hplc, then Et_3SnH generation, then aas with quartz tube furnace	13.5 pg		Burns <i>et al.</i> (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
186	Et_3Sn^+	Et_3SnCl standard	gc, then Et_3SnH generation, then aas quartz tube furnace	5.3 pg		Burns <u>et al.</u> (1981)
187	Et_3Sn^+	spiked rabbit tissues	homogenization, extraction as Et_3SnCl into EtOAc, partitioning into hexane, then gc-ecd	~1 pg	> 98% recovery at 50 pmole level	Arikawa <u>et al.</u> (1981a)
188	Et_4Sn	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)
189	Et_4Sn	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965b)
190	Et_4Sn	standards	gc-aafid			Dressler <u>et al.</u> (1971)
191	Et_4Sn	standards	gc-fid	20 pg	hydrogen-rich flame; linear response over $10^3 \times$	Aue and Hill (1972b)
192	Et_4Sn	standards	gc-fpd	10 ng	linear response to 10^4 ng	Aue and Hill (1972a)
193	Et_4Sn	standards	(a) gc-fpd (air-rich) (b) gc-fpd (hydrogen-rich) (c) gc-fid (hydrogen-rich)	5 ng 5 ng 10 pg		Aue and Hill (1973)
194	Et_4Sn	standards	gc-modified-fpd	30 pg	filterless	Aue and Hastings (1973)
195	Et_4Sn	standards	see method No. 77, (a) and (b)	(a) 8 μg (b) 50 μg	see method No. 77	Burns <u>et al.</u> (1980)
196	Et_4Sn	standards	gc-modified-fpd	< 50 pg	610 nm optical filter; electronic filter enhanced sensitivity by ~4x	Kapilla and Vogt (1980)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
197	Et ₄ Sn	standards	hplc-rfd		Glockling (1980)	
198	Et ₄ Sn	standards	hplc-electrothermal aas	1 ng	see method No. 80	Glockling (1980)
199	Et ₄ Sn	standards	gc-plasma aas			Estes et al. (1980)
200	Et ₄ Sn	rabbit tissues	homogenization, extraction with hexane, gc-fid	10 ng	100% recovery from tissues spiked at 85 nmole level	
201	Et ₄ Sn	standards	hplc-flame aas	11 ng		Arakawa et al. (1981b)
202	Et ₄ Sn	standards	gc-aas with quartz tube furnace	1.4 ng		Burns et al. (1981)
203	Et ₄ Sn	standards	hplc-purge-aas with quartz tube furnace	14 pg		Burns et al. (1981)
204	Et ₄ Sn	standards	capillary gc-plasma aas	6 pg	linear range 10 ³	Estes et al. (1982)
205	Pr ₂ Sn ²⁺	microsonic metabolite of Pr ₃ Sn ⁺	tic separation and spot identification with 8-hydroxyquinolinous fonic acid spray		qualitative	Kimmerl et al. (1977)
206	Pr ₂ Sn ²⁺	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		see method No. 60	Vickrey et al. (1980a)
207	Pr ₂ Sn ²⁺	MeOH	gfaas	12-21 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
208	Pr ₂ Sn ²⁺	water	spectrophotometric determination of 3-hydroxyflavone complex		$\varepsilon_{385} = 4.2 \times 10^4 \text{ Lmole}^{-1} \text{ cm}^{-1}$	Aldridge and Street (1981)
209	Pr ₂ Sn ²⁺	spiked rat tissues	see method No. 112	0.1-1 ng	95% recovery from tissues spiked at 5 nmole level	Yu and Arakawa (1983)
210	Pr ₃ Sn ⁺	MeOH	hplc-gfaas			Brinckman et al. (1977)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins^a

Number	Compound	Medium	Method	MDL	Comments	Reference
211	Pr ₃ Sn ⁺	microsome preparations	tic separation and spot identification with dithizone spray ion exchange hplc-gfaas	qualitative	Kimmel et al. (1977)	
212	Pr ₃ Sn ⁺	MeOH			Jewett and Brinckman (1981)	
213	Pr ₃ Sn ⁺	water	spectrophotometric determination of 3-hydroxyflavone complex homogenization, extraction as Pr ₃ SnCl into EtOAc, partitioning into hexane, then gc-tcd	~ 1 pg	during dry and ash cycles $\epsilon_{385} = 1.2 \times 10^4$ Lmole ⁻¹ cm ⁻¹	Aldridge and Street (1981)
214	Pr ₃ Sn ⁺	spiked rabbit tissues		> 96% recovery at 50 pmole level	Arakawa et al. (1981a)	
215	Pr ₄ Sn	standards	gc-tcd	determined retention times on 3 stationary phases	Putnam and Pu (1965a)	
216	Pr ₄ Sn	standards	gc-tcd	extended previous work to temperature programming filterless; linear range 10 ³	Putnam and Pu (1965b)	
217	Pr ₄ Sn	standards	gc-modified fpd	0.2 pg	Aue and Flinn (1977)	
218	Pr ₄ Sn	standards	gc-modified fpd	< 50 pg	610 nm optical filter; electronic filter enhanced sensitivity by ~4 times	Kapila and Vogt (1980)
219	Pr ₄ Sn	MeOH	gfaas	35-76 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
220	Pr ₄ Sn	standards	gc-modified fpd	0.04 pg	similar to method No. 204, but with quartz wool plug positioned above flame; linear range > 10 ³	Aue and Flinn (1980)
221	Pr ₄ Sn	standards	gc-plasma aes		Estes et al. (1980)	
222	Pr ₄ Sn	rabbit tissues	homogenization, extraction with hexane, gc-fid	10 ng	100% recovery from tissues spiked at 85 nmole level	Arakawa et al. (1980)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
223	Pr ₄ Sn	standards	capillary gc-plasma aes	6 pg	linear range 10 ³	Estes <i>et al.</i> (1982)
224	i-Pr ₄ Sn	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)
225	i-Pr ₄ Sn	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965b)
226	BuSn ³⁺	BuSnBr ₃ in Et ₂ O	Grignard conversion to BuMe ₃ Sn, then gc-tcd			Steinmeyer <i>et al.</i> (1965)
227	BuSn ³⁺	standards	Grignard conversion to BuPr ₃ Sn, then gc-tcd		qualitative	Jitsu <i>et al.</i> (1969)
228	BuSn ³⁺	microsomal metabolite of Bu ₃ Sn ⁺	tic separation and spot identification with 8- hydroxyquinoliniumsulfonic acid spray		qualitative	Kimmel <i>et al.</i> (1977)
229	BuSn ³⁺	water	extraction with 0.05% tropolone in C ₆ H ₆ or CHCl ₃ , Grignard derivation to BuMe ₃ Sn, then gc-ms		70-90% recovery at 1 mg/L level; BuSn ³⁺ in water probably adsorbs to glass	Melinema <i>et al.</i> (1978)
230	BuSn ³⁺	fresh water	BuSnH ₃ generation, then method No. 36	0.9 ng		Hodge <i>et al.</i> (1979)
231	BuSn ³⁺	pure and fresh water	extraction with tropolone in C ₆ H ₆ , Grignard derivation to BuPe ₃ Sn, then gc- modified-fpd	100 pg	95-100% recovery from water at 10 mg/L level	Maguire and Huneault (1981)
232	BuSn ³⁺	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 230	0.5 ng	linear range over 0.05- 1 µg/L for 100 mL sample	Boettner <i>et al.</i> (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
233	BuSn ³⁺	"Artificial tap water" extracts of new PVC and CPVC pipe bacterial and fungal cultures estuarine water	extraction with tropone in C ₆ H ₆ , Grignard derivatization to BuP ₃ Sn, then gc-tcd see method No. 229	1.5-3 µg/L (1 L samples)		Boettner et al. (1981)
234	BuSn ³⁺					Barug (1981)
235	BuSn ³⁺					Jackson et al. (1982)
236	BuSn ³⁺	marine algae	method No. 54 with BuSnH ₃ species	0.02 µg/L with 10 mL sample		Ishii (1982)
237	BuSn ³⁺	benzene	method No. 88 for BuSnH ₃ species method No. 56			Imura and Suzuki (1983)
238	BuSn ³⁺	sediment	see method No. 57 with BuPe ₂ Sn species	5 µ/kg with 1 g samples	see method No. 57	Maguire (1984)
239	BuSn ³⁺	water	see method No. 58 with BuPe ₂ Sn species	~110 pg	see method No. 58	Maguire and Tkacz (1983)
240	Bu ₂ Sn ²⁺	CHCl ₃	spectrophotometric determination of diphenylcarbazone complex	3 µg	can be determined in presence of BuSn ³⁺ , Bu ₃ Sn ⁺ and Bu ₄ Sn	Skeel and Bricker (1961)
241	Bu ₂ Sn ²⁺	Bu ₂ SnBr ₂ in Et ₂ O	Grignard conversion to Bu ₂ Me ₂ Sn, then gc-tcd			Steinmeyer et al. (1965)
242	Bu ₂ Sn ²⁺	standards	Grignard conversion to Bu ₂ Pr ₂ Sn, then gc-tcd i.r. spectra			Jitsu et al. (1969)
243	Bu ₂ Sn ²⁺	standards	extracted with CHCl ₃ , transferred to MeOH, then flame aas	qualitative	quantitative recovery at 0.02% concentration	Udris (1971)
244	Bu ₂ Sn ²⁺	dibutyltin diaurate in poultry feeds	analyte to be aspirated			George et al. (1973)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
245	Bu ₂ Sn ²⁺	sea water	extraction with CCl ₄ , oxidation to Sn ⁴⁺ , then spectrophotometric determination of phenylfluorone complex	0.01 mg/L		Mor <u>et al.</u> (1973)
246	Bu ₂ Sn ²⁺	microsomal metabolite of Bu ₃ Sn ⁺	identification with 8-hydroxyquinoilinesulfonic acid spray	qualitative		Klimm <u>et al.</u> (1977)
247	Bu ₂ Sn ²⁺	water	extraction with 0.05% tropolone in C ₆ H ₆ or CHCl ₃ , Grignard derivatization to Bu ₂ Me ₂ Sn, then gc-ms	70-90% recovery at 1mg/L level		Meinema <u>et al.</u> (1978)
248	Bu ₂ Sn ²⁺	fresh water	Bu ₂ SnH ₂ generation then method No. 36	1.0 ng		Hodge <u>et al.</u> (1979)
249	Bu ₂ Sn ²⁺	textiles	extracted with MeOH/0.05% HCl, diluted with H ₂ O, extracted with 4-(2-pyridylazo) resorcinol in CH ₂ Cl ₂ , then oxidized, then gfaas			Kojima (1979)
250	Bu ₂ Sn ²⁺	MeOH/water (97.5/2.5, v/v)	hplc-gfaas	see method No. 60		Vickrey <u>et al.</u> (1980a)
251	Bu ₂ Sn ²⁺	MeOH	gfaas	13-22 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey <u>et al.</u> (1980b)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
252	Bu ₂ Sn ²⁺	soil	extraction with wet Et ₂ O / formic acid (98/2, v/v), tlc and scintilla-ion counting	70% recovery		Barug and Vank (1980)
253	Bu ₂ Sn ²⁺	MeOH				Jewett and Brinckman (1981)
254	Bu ₂ Sn ²⁺	water	spectrophotometric ion-exchange hplc-gfaas	0.2 mg/L		Aldridge and Street (1981)
255	Bu ₂ Sn ²⁺	pure and fresh water	determination of 3-hydroxyflavone complex method No. 231 with Bu ₂ Pb ₂ Sn	120 pg	$\epsilon_{385} = 4.0 \times 10^4 \text{ L mole}^{-1} \text{ cm}^{-1}$	Maguire and Huneault (1981)
256	Bu ₂ Sn ²⁺	"artificial tap water"	"artificial tap water" extracts with Bu ₂ SnH ₂ generation of new PVC and CPVC pipe	0.5 ng	> 95% recovery at 10 mg/L level linear range 0.05-1 $\mu\text{g/L}$ for 100 mL sample	Boettner <i>et al.</i> (1981)
257	Bu ₂ Sn ²⁺	"artificial tap water"	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 233 with Bu ₂ Pb ₂ Sn species	1.5-3 $\mu\text{g/L}$ (1 L sample)	Boettner <i>et al.</i> (1981)
258	Bu ₂ Sn ²⁺	bacterial and fungal cultures	see method No. 229			Jackson <i>et al.</i> (1982)
259	Bu ₂ Sn ²⁺	estuarine water	see method No. 54 with Bu ₂ SnH ₂ species	0.04 $\mu\text{g/L}$ with 10 mL samples		
260	Bu ₂ Sn ²⁺	PVC	119mSn Mossbauer spectroscopy			Brooks <i>et al.</i> (1982)
261	Bu ₂ Sn ²⁺	fishling nets	dppd	14 $\mu\text{g/L}$		Hasebe <i>et al.</i> (1982)
262	Bu ₂ Sn ²⁺	spiked rat tissue	see method No. 112	0.1-1 ng	98% recovery from tissues spiked at 5 nmole level	Yu and Arakawa (1983)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
263	Bu ₂ Sn ²⁺	benzene	see method No. 56			Imura and Suzuki (1983)
264	Bu ₂ Sn ²⁺	sediment	see method No. 57 with Bu ₂ P ₂ Sn species	5 µg/kg with 1 g samples	see method No. 57	Maguire (1984)
265	Bu ₂ Sn ²⁺	water	see method No. 58 with Bu ₂ P ₂ Sn species	120–140 pg		Maguire and Tkacz (1983)
266	Bu ₃ Sn ⁺	Bu ₃ SnBr /n Et ₂ O standards	Grignard conversion to Bu ₃ MeSn, then gc-tcd			Steinmeyer et al. (1965)
267	Bu ₃ Sn ⁺		Grignard conversion to Bu ₃ PrSn, then gc-tcd			Jitsu et al. (1969)
268	Bu ₃ Sn ⁺	sea water	method No. 245 dppd	0.01 mg/L 29 µg/L		Nor et al. (1973)
269	Bu ₃ Sn ⁺	50% (v/v) EtOH				Fleet and Fouzder (1975)
270	Bu ₃ Sn ⁺	acidic aqueous solution	asv after dealkylation under UV light	0.01 mg/L		Woggon and Jehle (1975)
271	Bu ₃ Sn ⁺	MeOH	hplc-gfaas			Br-Inckman et al. (1977)
272	Bu ₃ Sn ⁺	Bu ₃ SnH standards	gc-modified tpd	1 pg	see method No. 217	Aue and Flinn (1977)
273	Bu ₃ Sn ⁺	microsome preparations	tic separation and spot identification with 8- hydroxyquinoline spray extraction with 0.05% trapolone in C ₆ H ₆ or CHCl ₃ . Grignard derivatization to Bu ₃ MeSn, then gc-ms		qualitative	Kimmel et al. (1977)
274	Bu ₃ Sn ⁺	water			70–90% recovery at 1 mg/L level	Meinema et al. (1978)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotin⁺

Number	Compound	Medium	Method	MDL	Comments	Reference
275	Bu ₃ Sn ⁺	soil	radio labelled compound extracted with acetic acid, partitioned into hexane, then tic and scintillation counting		% recovery not stated	Sheldon (1978)
276	Bu ₃ Sn ⁺	standards	Bu ₃ SnH generation, then method No. 36 see method No. 249	2.0 ng		Hodge <i>et al.</i> (1979)
277	Bu ₃ Sn ⁺	textiles	radio labelled compound detected by scintillation counting after			Kojima (1979)
278	Bu ₃ Sn ⁺	mouse tissues	radio labelled compound digested with HClQ ₄ -H ₂ O ₂ , extracted with hexane, oxidized with H ₂ SO ₄ -H ₂ O ₂ then spectrophotometric determination of phenyl-fluorone complex	1.5 ng	% recovery not stated	Evans <i>et al.</i> (1979)
279	Bu ₃ Sn ⁺	water (spiked)		0.1 µg	linear response to 4 µg	Sherman and Carlson (1980)
280	Bu ₃ Sn ⁺	MeOH	see method No. 252	8-22 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey <i>et al.</i> (1980b)
281	Bu ₃ Sn ⁺	soil			% recovery not stated	Berug and Vonk (1980)
282	Bu ₃ Sn ⁺	MeOH	ion exchange hplc-gfaas	0.16 mg/L		Jewett and Brinckman (1981)
283	Bu ₃ Sn ⁺	MeOH	hplc-dppd			MacCrehan (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
284	Bu ₃ Sn ⁺	water	spectrophotometric determination of 3-hydroxyflavone complex	$\epsilon_{385}=1.2 \times 10^4 \text{ Lmole}^{-1} \text{cm}^{-1}$		Aldridge and Street (1981)
285	Bu ₃ Sn ⁺	spiked rabbit tissues	homogenization, extractions as Bu ₃ SnCl into EtOAc, partitioning into hexane, then gc-ecd	~1 pg	> 96% recovery at 10 mg/L level	Arakawa et al. (1981a)
286	Bu ₃ Sn ⁺	pure and fresh water	method No. 231 with Bu ₃ Pesn	150 pg	> 96% recovery at 10 mg/L level	Maguire and Huneault (1981)
287	Bu ₃ Sn ⁺	"artificial tap water" extracts	see method No. 230 with Bu ₃ SnH generation of new PVC and CPVC pipe	0.5 ng	Linear range 0.01-1 $\mu\text{g/L}$ for 100 mL sample	Boettner et al. (1981)
288	Bu ₃ Sn ⁺	"artificial tap water" extracts	see method No. 233 with Bu ₃ Pesn species of new PVC and CPVC pipe	1.5-3 $\mu\text{g/L}$ (1 L samples)		Boettner et al. (1981)
289	Bu ₃ Sn ⁺	bacterial and fungal cultures	see method No. 229			Barug (1981)
290	Bu ₃ Sn ⁺	fishling nets	dppd	64 $\mu\text{g/L}$		Hasebe et al. (1982)
291	Bu ₃ Sn ⁺	estuarine bacterial cultures	cells collected by centrifugation, then HNO ₃ oxidation, then gfaas			Blair et al. (1982)
292	Bu ₃ Sn ⁺	bound to bacterial cells	cells centrifuged, extracted with MeOH, then ion exchange hplc-gfaas			Blair et al. (1982)
293	Bu ₃ Sn ⁺	sea water	dpasv	5 μL		Kenis and Zirino (1983)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
294	Bu ₃ Sn ⁺	benzene	see method No. 56			Imura and Suzuki (1983)
295	Bu ₃ Sn ⁺	sediment	see method No. 57 with Bu ₃ PeSn species	5 µg/kg with 1 g samples	see method No. 57	Maguire (1984)
296	Bu ₃ Sn ⁺	water	see method No. 58 with Bu ₃ PeSn species	150 pg		Maguire and Tkacz (1983)
297	TBT0	air	glass fibre filters extracted with MIBK, then flame-aas			Jeltes (1969)
298	Bu ₄ Sn	standards	gc-tcd			Steinmeyer et al. (1965)
299	Bu ₄ Sn	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)
300	Bu ₄ Sn	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965b)
301	Bu ₄ Sn	standards	gc-tcd		linear response to 10 ⁴ ng	Jitsu et al. (1969)
302	Bu ₄ Sn	standards	gc-fpd	10 ng	filter less; linear range 10 ³	Aue and Hill (1972a)
303	Bu ₄ Sn	standards	gc-modified fpd	1 pg	see method No. 205	Aue and Flinn (1977)
304	Bu ₄ Sn	standards	gc-modified fpd	<50 pg		Kapila and Vogt (1980)
305	Bu ₄ Sn	MeOH	gf-aas	15-23 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
306	Bu ₄ Sn	rabbit tissues	homogenization, extraction with hexane, then gc-fid	10 ng	> 96% recovery of tissues spiked at 85 nmole level	Arakawa et al. (1981b)
307	I-Bu ₄ Sn	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
308	$i\text{-Bu}_4\text{Sn}$ standards	gc-tcd			extended previous work to temperature programming; this work and method No. 307 also dealt with Me_3EtSn , Me_3PrSn , $\text{Me}_3i\text{-PrSn}$, $\text{Me}_3t\text{-BuSn}$, Me_3CySn , Me_3ViSn , Me_2PhSn and Vi_4Sn qualitative	Putnam and Pu (1965b)
309	Pe_3Sn^+ microsome preparations		tic separation and spot identification with 8-hydroxyquinoline spray			Kimmel et al. (1977)
310	Hex_3Sn^+ microsome preparations		tic separation and spot identification with 8-hydroxyquinoline spray			Kimmel et al. (1977)
311	OctSn^{3+} standards		Grignard conversion to OctPe_3Sn , then gc-tcd			Jitsu et al. (1969)
312	OctSn^{3+} standards		Grignard conversion to OctMe_3Sn , then gc with tcd or hot wire detector			Neubert and Wirth (1975)
313	OctSn^{3+} standards		Grignard conversion to OctEt_3Sn , then gc-tcd			Filge et al. (1977)
314	$\text{Oct}_2\text{Sn}^{2+}$ standards		Grignard conversion to $\text{Oct}_2\text{Pe}_2\text{Sn}$, then gc-tcd i.r. spectra			Jitsu et al. (1969)
315	$\text{Oct}_2\text{Sn}^{2+}$ standards		Grignard conversion to $\text{Oct}_2\text{Me}_2\text{Sn}$, then gc with tcd or hot wire detector			Udris (1971)
316	$\text{Oct}_2\text{Sn}^{2+}$ standards		Grignard conversion to $\text{Oct}_2\text{Et}_2\text{Sn}$, then gc-tcd			Neubert and Wirth (1975)
317	$\text{Oct}_2\text{Sn}^{2+}$ standards					Filge et al. (1977)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
318	Oct ₂ Sn ²⁺ as bis-maleate In EtOH, HOAc and heptane	glass		10 µg/L		Varnes and Taylor (1978)
319	Oct ₂ Sn ²⁺ spiked rat tissues	see method No. 112		0.1-1 ng	> 96% recovery from tissues spiked at 5 nmole level	Yu and Arakawa (1983)
320	Oct ₃ Sn ⁺ standards	Grignard conversion to Oct ₃ Pesn, then gc-tcd				Jitsu et al. (1969)
321	Oct ₃ Sn ⁺ standards	Grignard conversion to Oct ₃ Mesn, then gc with tcd or hot wire detector				Neubert and Wirth (1975)
322	Oct ₃ Sn ⁺ standards	Grignard conversion to Oct ₃ Etsn, then gc-tcd				Filge et al. (1977)
323	CySn ³⁺ residues on apples and pears	fruit extracted with HOAc/hexane solution, which was in turn extracted with HCl and back-extracted with hexane; CySn ³⁺ in the HCl phase was oxidized to Sn ⁴⁺ and determined spec- trophotometrically as dithiol complex				Getzendaner and Corbin (1972)
324	CySn ³⁺ CySnBr ₃ standards	gc-cd	on-column degradation			Gauer et al. (1974)
325	CySn ³⁺	on glass slides and wax-coated glass slides	tlc with spot identifi- cation by diphenylthio- carbazone and quantita- tion by scintillation counting of the radio- labelled spike			Smith et al. (1976)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
326	Cy ₂ Sn ²⁺	residues on apples and pears	start with method No. 323; Cy ₂ Sn ²⁺ in back-extracted hexane solution transferred to KOH solution, back extracted with hexane and analyzed as in method No. 323	80-90% recovery from fruit at 0.1-1 mg/L level; 94% recovery from water at 1 mg/L; on-column degradation or adsorption noted	Gauer <i>et al.</i> (1974)	Getzendaner and Corbin (1972)
327	Cy ₂ Sn ²⁺	residues on strawberries, apples and grapes, and in water	extracted with C ₆ H ₆ , converted by HBr to Cy ₂ SnBr ₂ , cleaned up and analyzed by gc-cd	see method No. 325	Smith <i>et al.</i> (1976)	Klimm <i>et al.</i> (1977)
328	Cy ₂ Sn ²⁺	on glass slides and wax-coated glass slides	see method No. 325	qualitative	Vickrey <i>et al.</i> (1980a)	Vickrey <i>et al.</i> (1980b)
329	Cy ₂ Sn ²⁺	microsome I	tic separation and spot identification with 8-hydroxyquinoline spray	see method No. 60	Zr-treated furnaces reduced species-dependent sensitivity	Corbin (1970)
330	Cy ₂ Sn ²⁺	metabolite of Cy ₃ Sn ⁺ in MeOH/water (97.5/2.5, v/v)	hplc-gfaas	13-24 pg	cont'd...../	
331	Cy ₂ Sn ²⁺	MeOH	gfaas			
332	Cy ₃ Sn ⁺	residues on fruit	wet oxidation to Sn ⁴⁺ , then method No. 16	0.2 mgSn		

TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
333	Cy ₃ Sn ⁺	residues on apples and pears	start with method No. 326; Cy ₃ Sn ⁺ in the hexane solution after KOH extraction is oxidized to Sn ⁴⁺ and analyzed by method No. 323 extracted with C ₆ H ₆ , converted by HBr to Cy ₃ SnBr, cleaned up and analyzed by gc-cd		78-95% recovery from fruit at 0.1-1 mg/L level; 99% recovery from water at 1 mg/L; on-column degradation or adsorption noted	Gauer et al. (1974)
334	Cy ₃ Sn ⁺	residues on strawberries, apples and grapes, and In water	rat urine, scintillation counting			Blair (1975)
335	Cy ₃ Sn ⁺	feces, organs, fat and blood	see method No. 325			Smith et al. (1976)
336	Cy ₃ Sn ⁺	on glass slides and wax-coated glass slides	see method No. 325			
337	Cy ₃ Sn ⁺	in microsome preparations	tic		qualitative	Kimmel et al. (1977)
338	Cy ₃ Sn ⁺	standards	Grignard conversion to Cy ₃ PhSn, then gc-fid			Esposito et al. (1978)
339	Cy ₃ Sn ⁺	standards	Grignard conversion to Cy ₃ EtSn, then gc-ms			Stewart and Cannizzaro (1980)
340	Cy ₃ Sn ⁺	MeOH	ion exchange-hplc-gfae			Jewett and Brinckman (1981)
341	Cy ₃ Sn ⁺	as Cy ₃ SnOH in air	filter samples wet ashed, then Sn ⁴⁺ determined by gfaes			Hoek and Beaulieu (1981)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
342	PhSn ³⁺	standards	Grignard conversion to PhP ₃ Sn, then gc-tcd detection by tlc with catechol violet spray;		Jitsu et al. (1969)	
343	PhSn ³⁺	on glass plate (after photolysis)	quantitation by oxidation to Sn ⁴⁺ followed by spectrophotometric determination of phenyl-fluorone complex		Chapman and Price (1972)	
344	PhSn ³⁺	on glass plate (after photolysis)	tlc with uv-fluorescence		Barnes et al. (1973)	
345	PhSn ³⁺	standards	fluorescence determination of 3-hydroxyflavone complex	$\lambda_{ex} = 470 \text{ nm } \lambda_{em} = 490 \text{ nm}$	Vernon (1974)	
346	PhSn ³⁺	water	extracted with tropolone in CHCl ₃ , determined spectrophotometrically with a number of complexing agents, or by gc-fid as PhSnCl ₃		Freitag and Bock (1974a)	
347	PhSn ³⁺	on sugar beet leaves and in rats (radio-labelled Ph ₃ Sn ⁺ spike)	see method No. 346 with scintillation counting		Freitag and Bock (1974b)	
348	PhSn ³⁺	standards	fluorescence determination of 3-hydroxyflavone complex		Blunden and Chapman (1978)	
					complex is unstable under laboratory light; $\lambda_{ex} = 415 \text{ nm}; \lambda_{em} = 450 \text{ nm}$	

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TABLE I (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
349	PhSn ³⁺	water	extracted with CH ₂ Cl ₂ , transferred to hexane, PhSnH ₃ generated and analyzed by gc-ecd		poor recoveries	Soderquist and Crosby (1978)
350	PhSn ³⁺	standards	PhSnH ₃ generation, then method No. 36	1.0 ng		Hodge et al. (1979)
351	PhSn ³⁺	standards	Grignard conversion to PhMe ₃ Sn, then gc-tcd			Wright et al. (1979)
352	PhSn ³⁺	spiked in estuarine water	method No. 54 with PhSnH ₃ species	0.02 µg/L with 10 mL samples	"nearly quantitative" conversion; no optical filter	Jackson et al. (1982)
353	Ph ₂ Sn ²⁺	standards	Grignard conversion to Ph ₂ Pc ₂ Sn, then gc-tcd			Jitsu et al. (1969)
354	Ph ₂ Sn ²⁺	on glass plate (after photolysis)	see method No. 343			Chapman and Price (1972)
355	Ph ₂ Sn ²⁺	on glass plate (after photolysis)	see method No. 344		qualitative	Barnes et al. (1973)
356	Ph ₂ Sn ²⁺	standards	fluorescence determination of 3-hydroxyflavone complex	$\lambda_{ex}=465$ nm, $\lambda_{em}=495$ nm		Vernon (1974)
357	Ph ₂ Sn ²⁺	water	extracted with a number of complexing agents in different organic solvents and determined spectrophotometrically with a number of complexing agents, or by gc-tid as Ph ₂ SnCl ₂		low yield implied for conversion to Ph ₂ SnCl ₂	Freltag and Bock (1974a)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
358	$\text{Ph}_2\text{Sn}^{2+}$	on sugar beet leaves and in rats (radio-labelled Ph_3Sn^+ spike)	see method No. 357 with scintillation counting			Freitag and Bock (1974b)
359	$\text{Ph}_2\text{Sn}^{2+}$	standards	fluorescence determination of 3-hydroxy-flavone complex	see method No. 348		Blunden and Chapman (1978)
360	$\text{Ph}_2\text{Sn}^{2+}$	water	see method No. 349 with Ph_2SnH_2		poor recoveries	Soderquist and Crosby (1978)
361	$\text{Ph}_2\text{Sn}^{2+}$	standards	Grignard conversion to $\text{Ph}_2\text{Me}_2\text{Sn}$, then gc-fpd		"nearly quantitative" conversion; no optical filter	Wright et al. (1979)
362	Ph_3Sn^+	standards	Grignard conversion to Ph_3PbSn , then gc-tcd extraction with MeCN, then asv			Jitsu et al. (1969)
363	Ph_3Sn^+	potatoes	3.5 $\mu\text{g}/\text{L}$ for pure standards			Booth and Fleet (1970)
364	Ph_3Sn^+	on glass plates	see method No. 343			Chapman and Price (1972)
365	Ph_3Sn^+	sea water	see method No. 245			Mor et al. (1973)
366	Ph_3Sn^+	soil (radio-labelled spike)	extracted with hot organic solvents, then scintillation counting		recoveries diminished with soil-contact time	Barnes et al. (1973)
367	Ph_3Sn^+	standards	fluorescence determination of 3-hydroxyflavone complex	0.16 $\mu\text{g Sn}$	$\lambda_{\text{ex}}=415 \text{ nm}, \lambda_{\text{em}}=497 \text{ nm}$	Vernon (1974)
368	Ph_3Sn^+	water	extracted with CHCl_3 or CH_2Cl_2 with spectrophotometric determination of dithizone complex, or by gc-fid as Ph_3SnCl			Freitag and Bock (1974a)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
369	Ph_3Sn^+	on sugar beet leaves in rats (radiolabelled spike)	see method No. 368 with scintillation counting			Freitag and Bock (1974b)
370	Ph_3Sn^+	50% (v/v) EtOH	dppd	35 $\mu\text{g/L}$		Fleet and Fouzder (1975)
371	Ph_3Sn^+	acidic aqueous solution	asv after dealkylation under uv light	0.01 mg/L		Woggon and Jehle (1975)
372	Ph_3Sn^+	MeOH	hpic-gfaas			Brockman et al. (1977)
373	Ph_3Sn^+	standards	Grignard conversion to Ph_4Sn , then gc-fid			Esposto et al. (1978)
374	Ph_3Sn^+	technical material and formulations	extracted into acetone, cleaned up with alumina, then titrated potentiometrically			Grignard reaction catalyzed by CuCl ; yield >95%; linear response from 0.05 to 3 μg
375	Ph_3Sn^+		Interlaboratory comparison study			Interlaboratory comparison study
376	Ph_3Sn^+	toluene	distilled, tap, canal and synthetic sea water (spiked)			$\lambda_{\text{ex}} = 415 \text{ nm}$, $\lambda_{\text{em}} = 495 \text{ nm}$; recoveries varied from 94% at 2 mg/L to 75% at 4 $\mu\text{g/L}$

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
377	Ph ₃ Sn ⁺	water	see method No. 349 with Ph ₃ SnH	quantitative recovery at 50 µg/L	Soderquist and Crosby (1978)	
378	Ph ₃ Sn ⁺	soil	radiolabelled compound extracted with acetic acid, partitioned into hexane, then tic and scintillation counting	#recovery not stated	Sheldon (1978)	
379	Ph ₃ Sn ⁺	standards	Grignard conversion to Ph ₃ MeSn, then gc-fpd	10 pg	linear response to 100 ng; "nearly quantitative"	Wright et al. (1979)
380	Ph ₃ Sn ⁺	seaweeds	seaweed digested with a radiolabelled spike	seaweed digested with a quaternary ammonium hydroxide in toluene, then scintillation counting	Callow et al. (1979)	
381	Ph ₃ Sn ⁺	Daphnia magna	dissolved Daphnia in HNO ₃ , neutralized, then radiolabelled Ph ₃ Sn ⁺	then scintillation counting	Filenko and Isakova (1979)	
382	Ph ₃ Sn ⁺	MeOH/water	hplc-gfaas	see method No. 60	Vickrey et al. (1980a)	
383	Ph ₃ Sn ⁺	MeOH	gfaas	13-19 pg	Vickrey et al. (1980b)	
384	Ph ₃ Sn ⁺	standards	Grignard conversion to Ph ₃ MeSn or Ph ₃ EtSn, then gc-ms	Stewart and Cannizzaro (1980)		
385	Ph ₃ Sn ⁺	soil	extraction as Ph ₃ SnCl with CH ₂ Cl ₂ , transfer to acetone, then gc-ms	Kuwahara et al. (1980)		

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
386	Ph_3Sn^+	MeOH	Ion exchange-hplc-gfaa			Jewett and Brinckman (1981)
387	Ph_3Sn^+	MeOH	hplc-dppd			MacCrehan (1981)
388	Ph_3Sn^+	water	spectrophotometric determination of 3-hydroxyflavone complex	Linear response from 0.35-35 mg/L $\epsilon_{385} = 1.5 \times 10^4 \text{ L mole}^{-1} \text{ cm}^{-1}$		Aldridge and Street (1981)
389	Ph_3Sn^+	Ph_3SnCl standards	air/ H_2 flame; comparisons made with other flames and atomic emission			Marr and Anwar (1982)
390	Ph_4Sn	standards	gc-fpd	1 pg		Aue and Flinn (1977)
391	Ph_4Sn	standards	gc-fpd	$\sim 10^4$		Wright et al. (1979)
392	Ph_4Sn	MeOH/water (97.5/2.5, v/v)	hplc-gfaas	10 pg	no optical filter see method No. 60	Vickrey et al. (1980a)
393	Ph_4Sn	MeOH	gfaas	8-18 pg		Vickrey et al. (1980b)
394	Ph_4Sn	toluene	size exclusion chromatography with icp-aes			Hausler and Taylor (1981a)
395	Ph_4Sn	standards	flame aas			Marr and Anwar (1982)
						method also used for Vl_4Sn and two phenyl organotins containing acetylenic bonds
						air/ H_2 flame; comparisons made with other flames and atomic emission; method also used for Vl_4Sn , hexaphenyl-ditin and a number of uncommon organotin compounds with Sn-S-phenyl linkages

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TABLE I (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
396	hexakis (2-methyl-2-phenylpropyl) distannoxane	apples, oranges and tea leaves	homogenize, extract with Et ₂ O/HOAc, clean up on silica gel column, then gas	5 ng	can also determine two degradation products, tetrakis (2-methyl-2-phenylpropyl) distannoxane and 2-methyl-2-phenylpropyl stannolic acid	Sano et al. (1979)
397	(Vandex)	hexakis standards (2-methyl-2-phenylpropyl) tin, then phenylpropyl distannoxane (Vandex)	Grignard conversion to methyltri-(2-methyl-2-phenylpropyl) tin, then gc-ms			Stewart and Cannizzaro (1980)
398	12, 12-dimethyl-12-stanna-hexadecanoic acid	membranes	scanning electron microscope		compound prepared and added to culture of <u>Acholeplasma laidlawii</u> to examine its potential as an ultra-structural probe for the lipid organization of biomembranes	Andrews et al. (1978)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotin^a

Number	Compound	Medium	Method	MDL	Comments	Reference
399	oxidation products of t-butyl esters of tin-substituted peroxy-carboxylic acids	standards	Ic-uv			Makarenko and Yashin (1983)
400	methacrylate polymers containing $\text{Bu}_3\text{Sn-}$ and $\text{Pr}_3\text{Sn-}$ ester linkages; and $\text{Cy}_3\text{Sn-}$ ethyl ortho-penta-silicate	mineral spirits (Stoddard contain-solvent)	size-exclusion hplc-gfaas for polymers; rbp-gfaas for silicate		Parks et al. (1979) and Parks et al. (1983)	

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* Abbreviations

aas	atomic absorption spectrophotometry
aes	atomic emission spectroscopy
afid	alkaline flame ionization detector
Ar	argon
asu	anodic stripping voltammetry
Bu	n-butyl
C ₂ H ₂	acetylene
C ₆ H ₆	benzene
CH ₂ Cl ₂	dichloromethane
CHCl ₃	chloroform
CCl ₄	carbon tetrachloride
cd	Coulson conductivity detector
CPVC	chlorinated polyvinyl chloride
Cy	cyclohexyl
dpaev	differential pulse anodic stripping voltammetry
dppd	diifferential pulse polarographic detector
ecd	electron capture detector
edi	electrodeless discharge lamp
Et	ethyl
EtOH	ethyl alcohol
EtOAc	ethyl acetate
Et ₂ O	diethyl ether
f id	flame ionization detector
f pd	flame photometric detector
gc	gas chromatography
gc-ms	gas chromatography-mass spectrometry
grfaas	graphite furnace atomic absorption spectrophotometry

hydrogen	H ₂
nitric acid	HNO ₃
acetic acid	HOAc
high pressure liquid chromatography	hplc
iso-	i
inductively-coupled plasma-atomic emission spectroscopy	icp-aes
infrared	ir
minimum detectable level	mdl
methyl	Me
acetone	MeCN
methanol	MeOH
megahertz	MHz
methylisobutylketone	MIBK
mass spectrometry	ms
nitrous oxide	N ₂ O
sodium hydroxide	NaOH
n-octyl	Oct
n-pentyl	Pe
phenyl	Ph
n-propyl	Pr
polyvinyl chloride	PVC
reverse bonded phase	rbp
refractive index detector	rid
thermal conductivity detector	tcd
bis (tri-n-butyltin) oxide	TBT0
thin layer chromatography	tic
ultraviolet	uv
viny	vi

TABLE 2: Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
total Sn	silicic rocks "intermediate" rocks	3.6 mg/kg average 1.5 mg/kg average	Japan	Hamaguchi et al. (1964)
	mafic rocks	0.9 mg/kg average	Japan	Hamaguchi et al. (1964)
	ultramafic rocks	0.25 mg/kg average	Japan	Hamaguchi et al. (1964)
	red clays	4.9 mg/kg average	Pacific Ocean near Japan	Hamaguchi et al. (1964)
	globigerina ooze	1.5 mg/kg average	Pacific Ocean near Japan	Hamaguchi et al. (1964)
	volcanic muds	1.4 mg/kg average	Pacific Ocean near Japan	Hamaguchi et al. (1964)
	seawater	0.81 µg/L	Pacific Ocean	Hamaguchi et al. (1964)
	marine animals	1.7 mg/kg average	Tokyo Bay (<i>Metapenaeus Joyneri</i> , <i>Watsonia scintillans</i> and <i>Meretrix meretrix coustonia</i>)	Hamaguchi et al. (1964)
	estuarine water	0.02-0.04 µg/kg	general	Smith and Burton (1972)
	shelf water	0.02-0.04 µg/kg	general	Smith and Burton (1972)
	surface Atlantic water	0.009 µg/kg	general	Smith and Burton (1972)
	ultramafic rocks	0.8 mg/kg	general	Smith and Burton (1972)
	basalts	1.7 mg/kg	general	Smith and Burton (1972)
	silicic rocks	2.5 mg/kg	general	Smith and Burton (1972)
	red clays	3.4 mg/kg	general	Smith and Burton (1972)
	amphibolites	1.2 mg/kg	general	Smith and Burton (1972)
	air	n.d. - 0.3 µg/m ³ up to 5 µg/m ³	general vicinity of industrial emissions	World Health Organization (1980)
	soil	<200 mg/kg up to 1000 mg/kg	general regions of tin - containing minerals	World Health Organization (1980)
	igneous rocks	1.7 mg/kg	average	Iverson and Brinkman (1978)
	shales	6 mg/kg	average	Iverson and Brinkman (1978)
	food	~1 mg/kg	diet of fresh meat, cereals vegetables	World Health Organization (1980)
	drinking water	n.d. - 30 µg/L 0.005-0.013 µg/L	general	World Health Organization (1980) Braman and Tompkins (1979)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
total Sn	fresh water	n.d.-0.73 µg/L 30-90 µg/L 30-90 µg/L $\leq 1-17 \mu\text{g}/\text{L}$ $4 \times 10^{-3} \mu\text{g}/\text{L}$	Florida N.O. polder - Netherlands Delft, Netherlands Malaysia general	Braman and Tompkins (1979) Leeuwangh et al. (1976) Leeuwangh et al. (1976) Peterson et al. (1976)
	estuarine water	$0.01-0.58 \mu\text{g}/\text{L}$ $\leq 2 \mu\text{g}/\text{L}$ 0.2-20 µg/L 2.2-3.9 µg/L $9 \times 10^{-3} \mu\text{g}/\text{L}$	Florida Chesapeake Bay, U.S.A. Baltimore Harbor, U.S.A. Malaysia North Atlantic Ocean (average)	Iverson and Brinckman (1978) Braman and Tompkins (1979) Hallas and Cooney (1981) Jackson et al. (1982) Peterson et al. (1976)
	sea water	2.5 µg/L 3 µg/L 0.002-0.085 µg/L	Malaysia general around Florida	Peterson et al. (1976) World Health Organization (1980)
	rain water	0.004-0.045 µg/L	Florida	Braman and Tompkins (1979)
	human urine	0.56-1.6 µg/L	Florida	Braman and Tompkins (1979)
	sewage treatment plant outfall sediment	152 µg/L 1-20 mg/kg dry weight n.d.-100 mg/kg dry weight	Chesapeake Bay, U.S.A. Narragansett Bay, U.S.A. Lake Leman, Switzerland	Hallas and Cooney (1981) Hodge et al. (1979) Dogan and Haerdli (1980)
		1-4 mg/kg 2 mg/kg 240 mg/kg 0.8-7.9 mg/kg 8-450 mg/kg 5-14 mg/kg dry weight	N.O. polder, Netherlands Delft, Netherlands Baltimore Harbor Chesapeake Bay Germany Savannah River estuary, U.S.A.	Leeuwangh et al. (1976) Leeuwangh et al. (1976) Hallas and Cooney (1981) Hallas and Cooney (1981) Schramek et al. (1973) Seidel et al. (1980)
		1-25 mg/kg dry weight 8-29 mg/kg dry weight	Lake Michigan Palace moat, Tokyo	Seidel et al. (1980) Seidel et al. (1980)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
total Sn	sediment	2 mg/kg at 55 cm core depth, roughly constant to 20 cm, then increasing to 26 mg/kg at 4 cm depth	Lake Michigan	Goldberg et al. (1981)
municipal sewage sludges		111-492 mg/kg dry weight	U.S.A.	Fuhr et al. (1976)
coal fly ash		4.3×10^{-3} mg/kg	Japan	Imura and Suzuki (1981)
thallophyta (primarily algae and "plankton")		3-5 mg/kg dry weight	Lake Leman, Switzerland	Dogan and Haerdi (1980)
embryophyta (largely terrestrial plants and macrophytes)		0.5-1.1 mg/kg dry weight	St. Vincent's Gulf, Australia	Maher (1982)
cocconterata pelecypoda (molluscs, oysters)		0.03-1.1 mg/kg dry weight	California	Hodge et al. (1979)
		1.5-3.2 mg/kg 4-12.8 mg/kg dry weight	Gulf of Naples, Italy Lake Leman, Switzerland	Smith (1970) Dogan and Haerdi (1980)
		0.2-1.5 mg/kg dry weight	Germany	Schramek et al. (1973)
		1.5-32 mg/kg dry weight	Malaysia	Peterson et al. (1976)
		8.4-2165 mg/kg dry weight	Malaysia (near Sn smelter)	Peterson et al. (1976)
		1.2 mg/kg 0.03-1.25 mg/kg dry weight	Gulf of Naples, Italy St. Vincent's Gulf, Australia	Smith (1970) Maher (1982)
		< 0.15-0.95 mg/kg wet weight	France	Aizieu et al. (1980)
		0.85-110 mg/kg < 0.03-1.6 mg/kg	France	Aizieu et al. (1982)
			Gulf of Naples, Italy	Smith (1970)

TABLE 2 (Cont'd.): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
gastropoda		0.02-0.13 mg/kg	N.O. polder, Netherlands	Leeuwangh <u>et al.</u> (1976)
crustacea		0.06-3.0 mg/kg	Gulf of Naples, Italy	Smith (1970)
Insecta		0.04 mg/kg	N.O. polder, Netherlands	Leeuwangh <u>et al.</u> (1976)
echinodermata		<0.03-0.96 mg/kg	Gulf of Naples, Italy	Smith (1970)
tunicata		0.5-15 mg/kg	Gulf of Naples, Italy	Smith (1970)
osteichthyes (fish)		<0.01-0.02 mg/kg dry weight	St. Vincent's Gulf, Australia Maher (1982)	
		0.4-8.4 mg/kg dry weight	Lake Leman, Switzerland	Dogan and Haerd (1980)
		190-630 mg/kg	N.O. polder, Netherlands	Leeuwangh <u>et al.</u> (1976)
		23-51 mg/kg	Deift, Netherlands	Leeuwangh <u>et al.</u> (1976)
		n.d.-0.6 mg/kg dry weight	Germany	Schramel <u>et al.</u> (1973)
Inorganic Sn	drinking water fresh water	<0.03 mg/kg	Gulf of Naples, Italy	Smith (1970)
		0.002 µg/L	Florida	Braman and Tompkins (1979)
		<0.0003-0.73 µg/L	Florida	Braman and Tompkins (1979)
		0.084-0.490 µg/L	Lake Michigan, U.S.A.	Hodge <u>et al.</u> (1979)
		n.d.-0.12 µg/L	rivers in southeastern U.S.A.	Byrd and Andreas (1982)
		0.02 µg/L	Rhine River, Germany	Byrd and Andreas (1982)
		0.001 µg/L	Main River, Germany	Byrd and Andreas (1982)
		n.d.-50 µg/L	rivers and lakes in Ontario, Canada	Maguire <u>et al.</u> (1982)
	fresh water surface microlayer	n.d.-633 µg/L	rivers and lakes in Ontario, Canada	Maguire <u>et al.</u> (1982)
	estuarine water	<0.0003-0.567 µg/L	Florida	Braman and Tompkins (1979)
	sea water	<0.0003-0.62 µg/L	Florida	Braman and Tompkins (1979)
		0.0003-0.38 µg/L	California	Hodge <u>et al.</u> (1979)
		3-7770 ng/L	La Jolla, U.S.A.	Tugrul <u>et al.</u> (1983)
	rain water	0.003-0.041 µg/L	Florida	Braman and Tompkins (1979)
	human urine	0.4-1.1 µg/L	Florida	Trugrul <u>et al.</u> (1983)
	rain water	1-3 ng/L	La Jolla, U.S.A.	Trugrul <u>et al.</u> (1983)
		5 ng/L	La Jolla, U.S.A.	Maguire (1984)
	sediment	0.08-5.13 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
Inorganic Sn	sediment	n.d.-11 mg/kg dry weight	California coast	Seldei et al. (1980)
	shell samples	<0.00005-0.0029 mg/kg	Florida	Braman and Tompkins (1979)
	invertebrates	0.014-0.052 mg/kg dry weight	San Diego Bay, California	Seldei et al. (1980)
	algae	n.d.-1.28 mg/kg dry weight	San Diego Bay, California	Seldei et al. (1980)
		0.016-0.117 mg/kg dry weight	San Francisco Bay	Seldei et al. (1980)
		0.0004-0.002 mg/kg wet weight	Mission Bay, California	Ishii (1982)
		0.001-0.015 mg/kg wet weight	San Diego Bay	Ishii (1982)
MeSn ³⁺	drinking water	0.0005-0.0081 µg/L	Florida	Braman and Tompkins (1979)
	fresh water	<0.00001-0.012 µg/L	Florida	Braman and Tompkins (1979)
		0.006-0.018 µg/L	Lake Michigan	Hodge et al. (1979)
		n.d.-0.0016 µg/L	rivers in southeastern U.S.A.	Byrd and Andreas (1982)
		0.079 µg/L	Rhine River, Germany	Byrd and Andreas (1982)
		0.06-1.2 µg/L	rivers and lakes in Ontario	Maguire et al. (1982)
	estuarine water	<0.00001-0.0085 µg/L	Florida	Braman and Tompkins (1979)
	sea water	<0.00001-0.015 µg/L	Florida	Braman and Tompkins (1979)
		n.d.-0.008 µg/L	California	Hodge et al. (1979)
		10 ng/L	La Jolla, U.S.A.	Tugrul et al. (1983)
	rain water	n.d.-42 ng/L	La Jolla, U.S.A.	Tugrul et al. (1983)
	sea water	n.d.-10.6 µg/kg dry weight	general	Tugrul et al. (1983)
	sediment			
	fish (<i>U. moluccensis</i>)	27 µg/kg dry weight	general	Tugrul et al. (1983)
	limpet (<i>Patella caerulea</i>)	0.4-4.8 µg/kg dry weight	general	Tugrul et al. (1983)
	seaweed	16.8 µg/kg dry weight	general	Tugrul et al. (1983)
	rain water	0.0006-0.0022 µg/L	Florida	Braman and Tompkins (1979)
	human urine	<0.02-0.32 µg/L	Florida	Braman and Tompkins (1979)
	shell samples	<0.0001-0.00045 mg/kg	Florida	Braman and Tompkins (1979)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
MeSn ³⁺	algae	n.d.-0.004 mg/kg wet weight	Mission Bay, California	Ishii (1982)
		n.d.-0.0012 mg/kg wet weight	San Diego Bay, California	Ishii (1982)
Me ₂ Sn ²⁺	drinking water	0.0004-0.0022 µg/L	Florida	Braman and Tompkins (1979)
	fresh water	< 0.00001-0.0075 µg/L	Florida	Braman and Tompkins (1979)
		n.d.-0.063 µg/L	Lake Michigan	Hodge et al. (1979)
		n.d.-0.0039 µg/L	rivers in southeastern U.S.A.	Byrd and Andreas (1982)
		0.26 µg/L	Rhine River, Germany	Byrd and Andreas (1982)
		0.00051 µg/L	Main River, Germany	Byrd and Andreas (1982)
		n.d.-0.4 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
		0.0007-0.0046 µg/L	Florida	Braman and Tompkins (1979)
		< 0.005-0.05 µg/L	Baltimore Harbor	Jackson et al. (1982)
	sea water	0.0006-0.007 µg/L	Florida	Braman and Tompkins (1979)
		n.d.-0.045 µg/L	California	Hodge et al. (1979)
		< 0.00001-0.0074 µg/L	Florida	Braman and Tompkins (1979)
	rain water	< 0.02-0.17 µg/L	Florida	Braman and Tompkins (1979)
	human urine	< 0.00001-0.00021 mg/kg	Florida	Braman and Tompkins (1979)
	shell samples	n.d.-0.0022 mg/kg dry weight	San Diego Bay, California	Seldel et al. (1980)
	algae	n.d.-0.0002 mg/kg wet weight	Mission Bay, California	Ishii (1982)
		0.0004-0.0022 mg/kg wet weight	San Diego Bay, California	Ishii (1982)
	sea water	n.d.-45 ng/L	La Jolla, U.S.A.	Tugrul et al. (1983)
	sediment	n.d.-13.4 µg/kg dry weight	general	Tugrul et al. (1983)
		~2.75 µg/kg dry weight	general	Tugrul et al. (1983)
	fish (<i>U. moluccensis</i> and <i>M. barbatus</i>)	~2.75 µg/kg dry weight	general	Tugrul et al. (1983)
	limpet (<i>Fatella caerulea</i>)	0.2-18 µg/kg dry weight	general	Tugrul et al. (1983)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
$\text{Me}_2\text{Sn}^{2+}$	brown macroalgae chlorophyta seaweed	0.5 µg/kg dry weight 12 µg/kg dry weight 37 µg/kg dry weight	general general general	Tugrul et al. (1983) Tugrul et al. (1983) Tugrul et al. (1983)
	drinking water	0.0005-0.0024 µg/L	Florida	Braman and Tompkins (1979)
	fresh water	< 0.00001-0.0076 µg/L	Florida	Braman and Tompkins (1979)
	n.d.-0.05 µg/L			
	n.d.-0.0023 µg/L			
	0.0022 µg/L			
	0.00041 µg/L			
	< 0.00001-0.004 µg/L			
	0.005-0.02 µg/L			
	< 0.00001-0.00098 µg/L			
Me_3Sn^+	sea water	< 0.00001-0.0011 µg/L	Florida	Braman and Tompkins (1979)
	rain water	< 0.02-0.13 µg/L	Florida	Braman and Tompkins (1979)
	human urine	< 0.00001 mg/kg	Florida	Braman and Tompkins (1979)
	shell samples	n.d.-0.0003 mg/kg wet weight	San Diego Bay, California	Ishii (1982)
	algae	n.d.-19.4 µg/kg dry weight	general	
	sediment	n.d.-1.25 µg/kg dry weight	general	Tugrul et al. (1983)
	fish (<u>U. moluccensis</u> and <u>M. barbatus</u>)	0.4-6.3 µg/kg dry weight	general	Tugrul et al. (1983)
	limpet (<u>Patella caerulea</u>)	5.8 µg/kg dry weight	general	Tugrul et al. (1983)
	brown macroalgae seaweed	0.9 µg/kg dry weight	general	Tugrul et al. (1983)
	estuarine water	< 0.01-0.3 µg/L	Baltimore Harbor	Jackson et al. (1982)
Me_4Sn	invertebrates	n.d.-0.006 mg/kg	California coast	Seidel et al. (1980)
	algae	n.d.-0.012 mg/kg dry weight	San Diego Bay, California	Seidel et al. (1980)
	n.d.-0.012 mg/kg dry weight	San Francisco Bay, California	Seidel et al. (1980)	
	n.d.-0.012 mg/kg wet weight	San Diego Bay, California	Ishii (1982)	

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
n-BuSn ³⁺	fresh water	0.022-1.22 µg/L n.d.-8.5 µg/L	Lake Michigan lakes and rivers in Ontario	Hodge et al. (1979)
	estuarine water	n.d.-0.2 µg/L	Baltimore Harbor	Maguire et al. (1982)
sediment		n.d.-0.058 mg/kg dry weight	lakes and rivers in Ontario	Jackson et al. (1982)
		n.d.-0.012 mg/kg dry weight	California coast	Maguire (1984)
	algae	present, but not quantitated	Mission and San Diego Bays	Seidel et al. (1980)
n-Bu ₂ Sn ²⁺	fresh water	0.010-1.6 µg/L n.d.-7.3 µg/L n.d.-2600 µg/L	Lake Michigan lakes and rivers in Ontario lakes and rivers in Ontario	Ishii (1982)
	fresh water surface			Hodge et al. (1979)
microlayer				Maguire et al. (1982)
sediment		n.d.-0.35 mg/kg dry weight	lakes and rivers in Ontario	Maguire et al. (1982)
n-Bu ₃ Sn ⁺	fresh water	n.d.-2.9 µg/L	lakes and rivers in Ontario	Maguire (1984)
	fresh water surface	n.d.-60 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
microlayer				Maguire et al. (1982)
sediment		n.d.-0.54 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)
Me ₂ SnH ₂	estuarine water	< 0.005-0.05 µg/L	Baltimore Harbor	Jackson et al. (1982)
n-Bu ₃ H ₃	estuarine water	0.05-0.1 µg/L	Baltimore Harbor	Jackson et al. (1982)
n-Bu ₂ Me ₂ Sn	sediment	n.d.-0.01 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)
n-Bu ₃ MeSn	sediment	n.d.-0.02 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)

TABLE 3: Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Sn^{2+}	pure water	oxidation to Sn^{4+}	-2d	23°C	Fanchiang and Wood (1981)
	pure water	methylation to MeSn^{3+}	< 1 d	anaerobic; pH 1; 1 M NaCl; 20°C; with methylcobalamin and aquocobalamin. Possible Sn^{3+} intermediate. Quantitative yield	Dizikes et al. (1978)
	lake water/ sediment	methylation to MeSn^{3+} , $\text{Me}_2\text{Sn}^{2+}$ and Me_3Sn^+	20°C; 10-14d; yields $\leq 0.004\%$		
	pure water	methylation by MeI to MeSn^{3+} , $\text{Me}_2\text{Sn}^{2+}$ and Me_3Sn^+	19°C; 5 d; yields 0.4%	Chau et al. (1981)	
Sn^{4+}	nutrient medium	bacterial production of $\text{Me}_2\text{Sn}^{2+}$	$\text{Me}_2\text{Sn}^{2+}$ identified tentatively; used tin-tolerant <i>Pseudomonas</i> strain; partially anaerobic conditions; no yield stated		Huey et al. (1974)
	nutrient medium	bacterial production of Me_4Sn and a methyltin hydride more volatile than Me_4Sn	used tin-tolerant <i>Pseudomonas</i> Jackson et al. strain; aerobic; 2 weeks at 23°C; no yield stated; the Me_4Sn may have resulted from chemical decomposition of a methyltin hydride		Jackson et al. (1982)
	lake water/ sediment	methylation to MeSn^{3+} , $\text{Me}_2\text{Sn}^{2+}$ and Me_3Sn^+	20°C; 10-14d; yields $\leq 0.008\%$		Chau et al. (1981)
	nutrient medium/sediment	methylation to $\text{Me}_2\text{Sn}^{2+}$ and Me_3Sn^+	25°C; 14 d; positive identification, but no yields stated		Hallas et al. (1982)
MeSn^{3+}	lake water/ sediment	methylation to $\text{Me}_2\text{Sn}^{2+}$ uv photolysis to Sn^{4+}	7 hr $\lambda \geq 235 \text{ nm}$		Chau et al. (1981)
	CCl_4				Blunden (1983)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$\text{Me}_2\text{Sn}^{2+}$	pure water	uv photolysis to Sn^{4+}	1500 hr (est.)	$\lambda \geq 200 \text{ nm}$	Blunden (1983), Chau et al. (1981)
	lake water/ sediment	methylation to Me_3Sn^+		$20^\circ\text{C}; 10\text{-}14 \text{ d}; \text{yield}=11.4\%$	
CCl_4	pure water	uv photolysis to $\text{Me}_3\text{Sn}^{3+}$	3 hr	$\lambda \geq 235 \text{ nm}$	Blunden (1983)
		uv photolysis	300 hr (est.)	$\lambda \geq 200 \text{ nm}; \text{SnO}_2$ detected, but not MeSn^{3+}	Blunden (1983)
Me_3Sn^+	sea water/ sediment	production of Me_4Sn		2.4% yield after 80 d at 16°C ; autoclaved controls also produce (less) Me_4Sn ; mechanism may be dispropor-	Guard et al. (1981)
		production of Me_4Sn		tionation	
	lake water/ sediment	demethylation to $\text{Me}_2\text{Sn}^{2+}$	$20^\circ\text{C}; 10\text{-}14 \text{ d}; \text{yield}=0.0003\%$	Chau et al. (1981)	
	lake water/ sediment	and MeSn^{3+}	$20^\circ\text{C}; 10\text{-}14 \text{ d}; \text{yield}=0.3\%$	Chau et al. (1981)	
CCl_4	pure water	uv photolysis to $\text{Me}_2\text{Sn}^{2+}$	2 hr	$\lambda \geq 235 \text{ nm}$	Blunden (1983)
	neat	uv photolysis to $\text{Me}_2\text{Sn}^{2+}$	30 hr	$\lambda \geq 200 \text{ nm}$	Blunden (1983)
		reaction with atmospheric CO_2		production of $(\text{Me}_3\text{Sn})_2\text{CO}_3$ in substantial yield	Brown et al. (1972)
Me_3SnOH or $(\text{Me}_3\text{Sn})_2\text{O}$	pure water	persistence	2 d	products not stated;	Mazayev et al.
$\text{Et}_2\text{Sn}^{2+}$				reaction is described, with- out elaboration, as "hydrolysis"	
	pond water	persistence	1.5 d	products not stated;	Mazayev et al. (1976)
				reaction is described, with- out elaboration, as "hydrolysis"	
	pond water/mud	persistence	2.5 d	products not stated;	Mazayev et al. (1976)
				reaction is described, with- out elaboration, as "hydrolysis"	

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$\text{Et}_2\text{Sn}^{2+}$	pure water	uv-photolysis	1.7 d	wavelength not stated, nor are products; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)
Et_3Sn^+	fish	uptake by carp		accumulation principally in liver, brain, spinal cord, kidneys and red muscles	Stroganov et al. (1973)
	<u>In vitro</u> (male rat hepatocytes)	dealkylation		production of ethane and ethylene; ethylene production enhanced by pentobarbital pretreatment; no yields given, nor were organotin products specifically identified	Wielkini et al. (1982)
	<u>In vitro</u> (rabbit liver microsomes) and <u>In vivo</u> (rats and mice)	dealkylation		15% metabolism in one hour by microsomes; 1-hydroxyethyldiethyltin, $\text{Et}_2\text{Sn}^{2+}$ and EtSn^{3+} produced	Casida et al. (1971) and Kimmel et al. (1977)
Et_3SnOH or $(\text{Et}_3\text{Sn})_2\text{O}$	neat	reaction with atmospheric CO_2		production of $(\text{Et}_3\text{Sn})_2\text{CO}_3$ in substantial yield	Brown et al. (1972)
Et_4Sn	rabbits (i.v. administration)	dealkylation		20% conversion to Et_3Sn^+ after 3 hr; residue levels varied in different tissues	Arakawa et al. (1981)
	rats and rabbits (by different routes of administration)	dealkylation		conversion to Et_3Sn^+ varied with organ or tissue	Iwai et al. (1982)
	<u>In vitro</u> (male rat hepatocytes)	dealkylation		production of ethylene and ethane; ethylene production enhanced by pentobarbital pretreatment; no yields given, nor were organotin products specifically identified	Wielkini et al. (1982)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Et_4Sn	<u>In vitro</u> (rat liver microsomes)	dealkylation			
$n\text{-Pr}_3\text{Sn}^+$	nutrient medium	uptake by <u>E. coli</u>			
			uptake apparently the result of reaction with phospho- lipids and other phosphorus- containing compounds in cell walls	Yamada <u>et al.</u> (1977)	Kimmel <u>et al.</u> (1977)
			15% metabolism in one hour by microsomes; 1-hydroxy- propylid propyltin, and either $n\text{-Pr}_2\text{Sn}^{2+}$ or $n\text{-Pr}_3\text{Sn}^+$ produced	Casida <u>et al.</u> (1978) and Kimmel <u>et al.</u> (1977)	
			production of $(n\text{-Pr}_3\text{Sn})_2\text{CO}_3$ in substantial yield	Brown <u>et al.</u> (1972)	
			4% conversion to $n\text{-Pr}_3\text{Sn}^+$ after 3 hr; residue levels varied in different tissues	Arakawa <u>et al.</u> (1981)	
			conversion to $n\text{-Pr}_3\text{Sn}^+$ varied with organ or tissue	Iwai <u>et al.</u> (1982)	
			9-10 mg/L	Melinema <u>et al.</u> (1978)	
			$\lambda, \text{ nm} (\epsilon, \text{ L/mole}\cdot\text{cm}):$ 360 (0.07); 350 (0.08); 340 (0.10); 330 (0.23); 320 (0.54); 310 (1.21); 300 (2.38); 290 (3.53); 280 (3.73)	Maguire <u>et al.</u> (1983a)	
			Sn^{4+} produced in 68% yield	Maguire <u>et al.</u> (1983a)	
$n\text{-BuSn}^3+$	sea water	solubility			
	90% H_2O (v/v)- 10% MeOH	ultraviolet spectrum			
			0.4 ± 0.1 d		
			photolysis at 300 nm		
	90% H_2O (v/v)- 10% MeCN				

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₂ Sn ²⁺	sea water	solubility	6-8 mg/L		Mel'nikov et al. (1978)
90% H ₂ O (v/v)- 10% MeOH	ultraviolet spectrum			λ, nm (ε, L/mole·cm): 360 (0.03); 350 (0.04); 340 (0.05); 330 (0.06); 320 (0.07); 310 (0.10); 300 (0.16); 290 (0.29); 280 (0.75)	Maguire et al. (1983a)
90% H ₂ O (v/v)- 10% MeCN 1.2% HCl	photolysis at 300 nm	> 9 d		small amount of BuSn ³⁺ and Sn ⁴⁺ produced	Maguire et al. (1983a)
pure water	photolysis	< 1 hr		wavelength not stated; dealkylation eventually to Sn ⁴⁺	Woggon and Jehle (1975)
pond water	persistence	1.1 d		products not stated; reaction is described without elaboration, as "hydrolysis"	Mazayev et al. (1976)
pond water	persistence	1.6 d		products not stated; reaction is described without elaboration, as "hydrolysis"	Mazayev et al. (1976)
pond water/mud	persistence	1.1 d		products not stated; reaction is described without elaboration, as "hydrolysis"	Mazayev et al. (1976)
pond water/sand	persistence	1.3 d		products not stated; reaction is described without elaboration, as "hydrolysis"	Mazayev et al. (1976)
pure water	uv-photolysis	0.8 d		wavelength not stated, nor are product; reaction is described, without elabora- tion, as "hydrolysis"	Mazayev et al. (1976)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₂ Sn ²⁺	In vitro (rat liver microsomes) and In vivo (mice) fungal culture medium	dealkylation		BuSn ³⁺ was major product	Kimmel et al. (1977)
		dealkylation	~ 14 d	BuSn ³⁺ identified as product upon aerobic incubation of <u>Coniothione putreana</u> ; 30°C	Barug (1981)
	solutions of reducing sugars	dealkylation	~ 1 d	BuSn ³⁺ major product	Barug (1981)
	In phosphate buffers				
	Lake water / sediment	production of Me ₃ Sn ⁺	20°C; 10-14 d; yield 0.002%		Chau et al. (1981)
n-Bu ₂ Sn-(SCH ₂ CO ₂ C ₈ H ₁₇) ₂ polyvinyl chloride	Incorporated in "artificial sunlight"	photolysis in	converted to n-Bu ₂ SnCl-(SCH ₂ CO ₂ C ₈ H ₁₇) after 17 d;		Brooks et al. (1982)
			prolonged irradiation led to formation of SnOC ₂ 3.2 at pH 6 and 20°C		
n-Bu ₃ Sn ⁺	pure water	log K _{ow}			Maguire et al. (1983a)
	pure water	adsorption to glass and Teflon	significant below 2 mg/L		Maguire et al. (1983a)
	pure water	volatilization	none over 62 d at 20°C		Maguire et al. (1983a)
	pure water	stability in dark	no loss of butyl groups from tin over 63 d at 20°C between pH 2.9 and 10.3		Maguire et al. (1983a)
90% H ₂ O (v/v)-10% MeOH	ultraviolet spectrum	$\lambda, \text{ nm } (\epsilon, \text{ L/mole} \cdot \text{cm})$:	360 (0.06); 350 (0.10); 340 (0.16); 330 (0.26), 320 (0.40); 310 (0.64); 300 (0.98); 290 (1.62); 280 (2.72)		Maguire et al. (1983a)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₃ Sn ⁺	pure water	photolysis at 300 nm	1.1 ± 0.2 d	products: Bu ₂ Sn ²⁺ , BuSn ³⁺ and Sn ⁴⁺ ; product yield ~50%	Maguire et al. (1983a)
	pure water	photolysis at 300 nm, sensitized with 15 mg/L fulvic acid	0.6 ± 0.2 d		Maguire et al. (1983a)
	pure water	photolysis at 350 nm	>18 d		Maguire et al. (1983a)
	pure water	photolysis at 350 nm, sensitized with 15 mg/L fulvic acid	6.2 ± 1.8 d		Maguire et al. (1983a)
fresh water or distilled water 12% HCl	sunlight photolysis	>89 d (>4x10 ⁴ langleys) < 1 hr	small amounts of Bu ₂ Sn ²⁺ , BuSn ³⁺ and Sn ⁴⁺ formed; wavelength not stated; dealkylation eventually to Sn ⁴⁺	Maguire et al. (1983a)	
plant surfaces	photolysis	~4 hr	Bu ₂ Sn ²⁺ , BuSn ³⁺ and Sn ⁴⁺ produced; wavelength not stated	Woggon and Jehle (1975)	
12% HCl	dealkylation		solution boiled; no product yield or kinetics given	Woggon and Jehle (1975)	
pure water	reaction with MeI		19°C; 5 d; products were MeSn ³⁺ (8x10 ⁻⁵ %), Me ₂ Sn ²⁺ (2x10 ⁻⁵ %) and Me ₃ Sn ⁺ (8x10 ⁻⁵ %)	Chau et al. (1981)	
pure water	persistence	19 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Nazayev et al. (1976)	

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₃ Sn ⁺	tap water	chemical stability	> 16 d	chemical stability was defined as the length of time Berrois-Duran (1969) remained unchanged when dissolved in tap water at a concentration close to the 24h LC ₉₀ value for (unidentified) snails. The container used was made of wax-lined paper.	Ritchie and Ritchie and Berrois-Duran (1969)
	fresh water	stability	> 3 months		Woggon and Jehle (1975)
	sea water	reaction with CO ₂ to form (Bu ₃ Sn) ₂ CO ₃			Sheldan (1975)
	pond water	persistence	10.5 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Mazayev <u>et al.</u> (1976)
	pond water/sand	persistence	3.8 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Mazayev <u>et al.</u> (1976)
	In paint chips from ships' hulls which have been sandblasted	thermal decomposition to Sn ⁴⁺		k in temperatures > 625°C were effective	Schatzberg and Harris (1978)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₃ Sn ⁺	fresh water and seawater (pH 5-9)	stability in dark	little or no loss of butyl groups from tin over 35 d. Solubility limit exceeded in some tests. Possibility of adsorption to glass		Slesinger and Dressler (1978)
	water	photolysis under General Electric F40BL fluorescent lights	18.5 d (TBTO) 2 d (TBTF)	half-life varied with source of n-Bu ₃ Sn ⁺ , and was considerably shorter in the presence of acetone photosensitizer; the light source used approximates the spectral distribution of sunlight, but the relative intensities are unknown	Slesinger and Dressler (1978)
	lake water/ sediment soil	production of Me ₂ Sn ⁺ dealkylation (aerobic)	20°C; 10-14 d; yield 0.002%	Chau <i>et al.</i> (1981)	
	soil	leaching from soil	15-20 weeks	20°C in the dark; ¹⁴ CO ₂ and Bu ₂ Sn ²⁺ among products; considerable formation of unextractable residues	Baug and Vonk (1980)
	soil	leaching from soil	> 180 d	little leaching after 16 weeks (1 inch of rain per week); little experimental detail given	Schatzberg and Harris (1978)
	dissipation (aerobic)		~ 60 d	25°C; substantial production of Bu ₂ Sn ²⁺ and BuSn ³⁺ . Substantial unextractable residue combination of (at least) dealkylation and formation of unextractable residues	Sheldon (1978)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₃ Sn ⁺	soil	dealylation (anaerobic) > 180 d dissipation (anaerobic) > 200 d	25°C; substantial production of Bu ₂ Sn ²⁺ and BuSn ³⁺ . Substantial unextractable residue.	combination of (at least) dealylation and formation of unextractable residues 93.6% ¹⁴ C radiolabel retained in wood, 4.5% in surrounding soil, indicating very little migration after 2.5 months. Earthworms accumulated 7.9 mg/kg from the soil, indicating that soil-assolated residues were not biologically unavailable; however, no evidence presented to show that the radiolabel is unequivocally Bu ₃ Sn ⁺	Sheldon (1978) Gile et al. (1982)
	Impregnated in wood posts	mobility in terrestrial microcosm		Pseudomonas aeruginosa in aerobic medium degraded Bu ₃ Sn ⁺ to BuSn ³⁺ ; no Bu ₂ Sn ²⁺ detected, perhaps because Bu ₂ Sn ²⁺ was quickly converted to BuSn ³⁺ by reducing sugars in phosphate buffer	Barug (1981)
	culture medium	dealylation	5-10 d	Coniothraea puteana in aerobic medium effects the transformation Bu ₃ Sn ⁺ → Bu ₂ Sn ²⁺ → BuSn ³⁺	Barug (1981)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₃ Sn ⁺	culture medium	uptake by estuarine bacteria	Bu ₃ Sn ⁺ accumulated to 3.7- 7.7 mg Sn/g dry weight of cells, probably by simple adsorption to cell walls; no dealkylation noted	Ankistrodesmus <u>falcatus</u> had a maximum apparent algal bioconcentration factor of 3x10 ⁴ ; over 4 weeks at 20°C, 50% of the original Bu ₃ Sn ⁺ was converted to Bu ₂ Sn ²⁺ and small quantities of BuSn ³⁺ and Sn ⁴⁺	Blair <u>et al.</u> (1982); Maguire <u>et al.</u> (1983b)
	culture medium	accumulation and dealkylation by a green alga	4 weeks	15% metabolism in one hour by microsomes; 1-hydroxybutyldibutyltin produced along with a tributyltin compound having 1 or 2 hydroxyl groups not at the 1-position, and 3 unidentified debutylated metabolites	Casida <u>et al.</u> (1971)
	<u>In vitro</u> (rabbit liver microsomes) and <u>In vivo</u> (rats and mice)	dealkylation	Initial products were α, β, γ- and δ-hydroxybutyldibutyltin, and γ-ketobutyldibutyltin. The δ- (24%) and β-hydroxy (50%) products predominated, but were unstable in neutral or acidic solution, yielding 1-butanol and 1-butene, respectively, with concomitant formation of Bu ₂ Sn ²⁺	Fish <u>et al.</u> (1976) and Klimm <u>et al.</u> (1977)	

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₃ Sn ⁺	sheepshead minnow <i>(Cyprinodon variegatus)</i>	uptake and dealkylation	maximum observed bioconcentration factor for whole fish was 2.6x10 ³ . Depuration "first half-life" was 7 d.	Ward <i>et al.</i> (1981)	
n-Bu ₃ SnOH (or (n-Bu ₃ Sn) ₂ O (n-Bu ₃ Sn) ₂ O)	neat	reaction with atmospheric CO ₂	production of (n-Bu ₃ Sn) ₂ CO ₃	Brown <i>et al.</i> (1972)	
	adsorbed on cellulose materials	reaction with atmospheric CO ₂	In substantial yield		
	sea water	solubility	production of (n-Bu ₃ Sn) ₂ CO ₃	Smith <i>et al.</i> (1977)	
	pure water	solubility	8-10 mg/L	Melinema <i>et al.</i> (1978)	
	neat	vapour pressure	0.7-7 mg/L at 20°C and pH 5-7; increasing with both increasing and decreasing pH 6.7x10 ⁻⁷ mm Hg at 20°C; estimated by a kinetic comparative technique	Maguire <i>et al.</i> (1983a)	
	neat	uv photolysis	wavelength not stated; irradiation for 24 hr at 24°C; products were 1-butene and traces of polymeric Bu ₂ SnO and aldehydes	Komara and Popl (1978)	
n-Bu ₄ Sn	rabbits (i.v. administration)	dealkylation	1% conversion to n-Bu ₃ Sn ⁺ after 3 hr; residue levels varied in different tissues conversion to n-Bu ₃ Sn ⁺	Arakawa <i>et al.</i> (1981)	
	rats and rabbits (by different routes of administration)		varied with organ or tissue	Iwai <i>et al.</i> (1982)	

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu ₄ Sn	In vitro (rat liver microsomes)	dealkylation		8 metabolites, including (β -HOBu) Bu ₃ Sn, (γ -HOBu)-Bu ₃ Sn and all products detected with Bu ₃ Sn ⁺ as substrate (see above) except (γ -C=O-Bu)Bu ₂ Sn ⁺	Kimmel et al. (1977)
n-Pen ₃ Sn ⁺	In vitro (rabbit liver microsomes) and In vivo (rats and mice)	dealkylation		metabolism slower than analogous Et, Pr and Bu compounds; 10 metabolites detected, including (probably) (α -HOPen)Pen ₂ Sn ⁺ , 2 other acid-labile Pen ₃ Sn ⁺ metabolites, 2 acid-stable Pen ₃ Sn ⁺ metabolites, and 5 Pen ₂ Sn ²⁺ and PenSn ³⁺ metabolites of the 10 metabolites (see above), Pen ₂ Sn ²⁺ and (β -HOOpen)Pen ₂ Sn ⁺ were major metabolites	Casida et al. (1971)
n-Hex ₃ Sn ⁺	In vitro (rabbit liver microsomes) and In vivo (rats and mice)	dealkylation		metabolism slower than Pen ₃ Sn ⁺ ; 5 metabolites detected, including (γ -HOHex)Hex ₂ Sn ⁺ , 2 acid-stable Hex ₃ Sn ⁺ metabolites, and 2 Hex ₂ Sn ²⁺ and HexSn ³⁺ metabolites of the 5 metabolites (see above), Hex ₂ Sn ²⁺ and (β -HOHex)Hex ₂ Sn ⁺ were major metabolites	Kimmel et al. (1977)
n-Oct ₂ Sn ²⁺	pure water	persistence	3.2 d	products not stated; reaction is described, without elaboration as "hydrolysis"	Mazayev et al. (1976)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Oct ₂ Sn ²⁺	pond water	persistence	6.2 d	products not stated; reaction is described, without elaboration as "hydrolysis"	Mazayev <i>et al.</i> (1976)
	pond water/mud	persistence	1.9 d	products not stated; reaction is described, without elaboration as "hydrolysis"	Mazayev <i>et al.</i> (1976)
	pond water/sand	persistence	4.7 d	products not stated; reaction is described, without elaboration as "hydrolysis"	Mazayev <i>et al.</i> (1976)
nOct ₃ Sn ⁺	In vitro (rabbit liver microsomes)	dealkylation		metabolism very much slower than n-Hex ₃ Sn ⁺ ; only trace amounts of n-Oct ₂ Sn ²⁺ detected as metabolite wavelength not stated; cyclohexanone and cyclohexanol were prominent products	Kimmel <i>et al.</i> (1977)
CySn ³⁺	water	photolysis		wavelength not stated; cyclohexanone and cyclohexanol were prominent products	Casida <i>et al.</i> (1971)
Cy ₂ Sn ²⁺	water	photolysis		wavelength not stated; cyclohexanone and cyclohexanol were prominent products	Casida <i>et al.</i> (1971)
	In vitro (rabbit liver microsomes)	dealkylation		major products were CySn ³⁺ cyclohexanone and cyclohexanol	Casida <i>et al.</i> (1971)
	In vivo (rats and mice) (as Cy ₂ SnO, on glass plates)	volatilization	10% loss over 100 days		Kimmel <i>et al.</i> (1977)
					Smith <i>et al.</i> (1976)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Cy ₃ Sn ⁺	In vitro (rabbit liver microsomes) and In vivo (rats and mice)	photolysis	wavelength not stated; cyclo- hexane and cyclohexanol were prominent products	rate of metabolism intermediate between n-Pen ₃ Sn ⁺ and n-Hex ₃ Sn ⁺ ; 7 metabolites - 2 acid-labile, 3 acid-stable and 2 Cy ₂ Sn ²⁺ and/or CySn ³⁺ metabolites	Casida et al. (1971)
	water		< 5 weeks	products were Cy ₂ Sn ²⁺ , CySn ³⁺ Getzendaner and Sn ⁴⁺ ; some loss by rain; Corbin (1972)	
	soil	dealkylation		very little translocation of residue from surface to the insides of apples and pears orchards treated with Pictran for up to 3 years had residues consisting of 80% Cy ₃ Sn ⁺ , 14% Cy ₂ Sn ²⁺ and 6% CySn ³⁺ ; there was little leaching from soil since the residue was found almost entirely in the 0-15 cm layer products were (2-HOcy)Cy ₂ Sn ⁺ Kimmel et al. (1977) (tentative), Cy ₂ Sn ²⁺ (major), 3 acid-stable Cy ₃ Sn ⁺ derivatives (possibly hydroxy- lated at 3 or 4 position)	Blair (1975)
	In vitro (rabbit liver microsomes)			In addition to products shown Kimmel et al. (1980) above, further evidence for (3-HOcy)Cy ₂ Sn ⁺ and (4-HOcy)Cy ₂ Sn ⁺	

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Cy ₃ Sn ⁺	on glass plates and on "apple wax"	photolysis	~8 hr	corresponds roughly to 8 d irradiation in a sunny climate. Reaction pathway appears to be by sequential dealkylation; 80% conversion to Sn ⁴⁺ over 32 d	Smith <i>et al.</i> (1976)
	neat (as Cy ₃ SnOH), on glass plates pure water	vapORIZATION	none over 100 d		Smith <i>et al.</i> (1976)
PhSn ³⁺	water	stability	several minutes	evidence for "co- distillation" with water at [PhSn] ₀ ³⁺ > 4 mg/L, 80-90% recovery of Sn ⁴⁺ ; at [PhSn] ₀ ³⁺ < 0.1 mg/L, Sn ⁴⁺ accounted for only 10% of the products; evidence for production of water-soluble polymeric tin species	Smith <i>et al.</i> (1976)
Ph ₂ Sn ²⁺	water	stability	2-3 d	21°C, pH 5.5-8.5; no PhSn ³⁺ or Sn ⁴⁺ produced - no wall adsorption	Soderquist and Crosby (1980)
	5% aqueous acetone	sensitized sunlight photolysis	~5 hr	acetone photosensitizer; the dark control was also un- stable (see above); evidence for production of water- soluble polymeric tin species	Soderquist and Crosby (1980)
Ph ₃ Sn ⁺	glass plate	u.v. photolysis		products were Ph ₂ Sn ²⁺ , PhSn ³⁺ and Sn ⁴⁺	Chapman and Price (1972)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Ph_3Sn^+	soil	binding		strong binding indicated by 50% decrease in extractability over 40 days from sterile or non-sterile soil. Little leaching from soil with water	Barnes et al. (1973)
	silica gel plates	u.v. photolysis degradation	~140 d	$\lambda \geq 254 \text{ nm}$; degradation to Sn_{4+} , $\text{vP}_2\text{Sn}^{2+}$ and PhSn^{3+} . 50% of ^{14}C label evolved as $^{14}\text{CO}_2$ over 140 d from non-sterile soil	Barnes et al. (1973)
	culture medium	degradation		$^{14}\text{CO}_2$ released by <i>Aspergillus</i> sp., <u>conidia</u> and a Gram-negative bacterium	Barnes et al. (1973)
	on sugar beet leaves exposed to sunlight but protected from rain	dealkylation	~14 d	production of $\text{Ph}_2\text{Sn}^{2+}$, PhSn^{3+} and Sn^{4+} ; significant amounts of unextractable ^{113}Sn residue	Freitag and Bock (1974b)
	rats (by stomach tube)	dealkylation		substantial amounts of $\text{Ph}_2\text{Sn}^{2+}$, PhSn^{3+} and Sn^{4+} excreted	Freitag and Bock (1974b)
12% HCl		u.v. photolysis	<10 min	wavelength not stated; dealkylation eventually to Sn^{4+}	Woggon and Jehle (1975)
rats (oral or i.p. administration)		dealkylation		substantial amounts of $\text{Ph}_2\text{Sn}^{2+}$, PhSn^{3+} and Sn^{4+} excreted; large amounts of unextractable ^{113}Sn residue in feces; no metabolism by rabbit liver microsomes	Casida et al. (1977)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Ph_3Sn^+	soil	persistence	1 d	first half-life 1 day, second half-life ~6 d; no products identified; may simply have been observing strong binding to soil	Kuwahara et al. (1980)
		production of Me_3Sn^+			
		stability in dark			
		fresh water and sea water (pH 5-9)		no loss of Ph_3Sn^+ over 35 d at pH 5-7 and in sea water; 43% loss at pH 9	Slesinger and Dressler (1978)
	water	photolysis under General Electric F40BL fluorescent lights	54 d	$t_{1/2}=12.5$ d in presence of acetone photosensitizer; the light source used approxi- mates the spectral distribu- tion of sunlight, but the relative intensities are unknown	Slesinger and Dressler (1978)
	water	stability		no loss of Ph_3Sn^+ over 30 d at pH 4.2-10.0 and 21-32°C	Soderquist and Crosby (1980)
	water	volatilization		none over 6 d at 32°C even though the water loss from the test beakers was 55 mL/ day	
	water	photolysis (sunlight)	14-21 d	ph 7.2; similar results with a laboratory photoreactor ($\lambda > 290$ nm, $t \sim 14$ d); the photolysis was accelerated considerably by acetone and rose Bengal ($t \ll 1$ d), but not by filtered rice-field water; evidence for mechanism featuring production of Ph_2Sn^+ accompanied by further formation of water-soluble polymeric tin species	Soderquist and Crosby (1980)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
CyPh ₂ Sn ⁺	In vitro (rat liver micro-somes)	hydroxylation		trans-2-HOCyPh ₂ Sn ⁺ was major product; also produced were 3- and 4-HOCyPh ₂ Sn ⁺ . No metabolism involving phenyl groups	Kimmel et al. (1980)
CyPh ₃ Sn	In vitro (rat liver micro-somes)	hydroxylation		major product (85.6%) was trans-4-HOCyPh ₃ Sn; also formed were cis-3-HOCyPh ₃ Sn (6.5%), trans-3-HOCyPh ₃ Sn (30%), trans-2-HOCyPh ₃ Sn (1.6%), 4-ketoCyPh ₃ Sn (1.9%) and 3-ketoCyPh ₃ Sn (1.4%). The trans-2H0 metabolite undergoes 1,2-deoxygenation in acid to yield Ph ₃ Sn ⁺ and cyclohexene	Fish et al. (1977)

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