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Environmental Health Criteria

PREAMBLE

Objectives

In 1973 the WHO Environmental Health Criteria Programme was initiated with the following objectives:

(i) to assess information on the relationship between exposure to environmental pollutants and human health, and to provide guidelines for setting exposure limits;

(ii) to identify new or potential pollutants;

(iii) to identify gaps in knowledge concerning the health effects of pollutants;

(iv) to promote the harmonization of toxicological and epidemiological methods in order to have internationally comparable results.

The first Environmental Health Criteria (EHC) monograph, on mercury, was published in 1976 and since that time an ever-increasing number of assessments of chemicals and of physical effects have been produced. In addition, many EHC monographs have been devoted to evaluating toxicological methodology, e.g., for genetic, neurotoxic, teratogenic and nephrotoxic effects. Other publications have been concerned with epidemiological guidelines, evaluation of short-term tests for carcinogens, biomarkers, effects on the elderly and so forth.

Since its inauguration the EHC Programme has widened its scope, and the importance of environmental effects, in addition to health effects, has been increasingly emphasized in the total evaluation of chemicals.

The original impetus for the Programme came from World Health Assembly resolutions and the recommendations of the 1972 UN Conference on the Human Environment. Subsequently the work became an integral part of the International Programme on Chemical Safety (IPCS), a cooperative programme of UNEP, ILO and WHO. In this manner, with the strong support of the new partners, the importance of occupational health and environmental effects was fully recognized. The EHC monographs have become widely established, used and recognized throughout the world.

The recommendations of the 1992 UN Conference on Environment and Development and the subsequent establishment of the Intergovernmental Forum on Chemical Safety with the priorities for action in the six programme areas of Chapter 19, Agenda 21, all lend further weight to the need for EHC assessments of the risks of chemicals.

Scope

The criteria monographs are intended to provide critical reviews on the effect on human health and the environment of chemicals and of combinations of chemicals and physical and biological agents. As such, they include and review studies that are of direct relevance for

the evaluation. However, they do not describe *every* study carried out. Worldwide data are used and are quoted from original studies, not from abstracts or reviews. Both published and unpublished reports are considered and it is incumbent on the authors to assess all the articles cited in the references. Preference is always given to published data. Unpublished data are only used when relevant published data are absent or when they are pivotal to the risk assessment. A detailed policy statement is available that describes the procedures used for unpublished proprietary data so that this information can be used in the evaluation without compromising its confidential nature (WHO (1990) Revised Guidelines for the Preparation of Environmental Health Criteria Monographs. PCS/90.69, Geneva, World Health Organization).

In the evaluation of human health risks, sound human data, whenever available, are preferred to animal data. Animal and *in vitro* studies provide support and are used mainly to supply evidence missing from human studies. It is mandatory that research on human subjects is conducted in full accord with ethical principles, including the provisions of the Helsinki Declaration.

The EHC monographs are intended to assist national and international authorities in making risk assessments and subsequent risk management decisions. They represent a thorough evaluation of risks and are not, in any sense, recommendations for regulation or standard setting. These latter are the exclusive purview of national and regional governments.

Content

The layout of EHC monographs for chemicals is outlined below.

* Summary -- a review of the salient facts and the risk evaluation of the chemical
* Identity -- physical and chemical properties, analytical methods
* Sources of exposure
* Environmental transport, distribution and transformation
* Environmental levels and human exposure
* Kinetics and metabolism in laboratory animals and humans
* Effects on laboratory mammals and *in vitro* test systems
* Effects on humans
* Effects on other organisms in the laboratory and field
* Evaluation of human health risks and effects on the environment
* Conclusions and recommendations for protection of human health and the environment

* Further research
* Previous evaluations by international bodies, e.g., IARC, JECFA, JMPR

Selection of chemicals

Since the inception of the EHC Programme, the IPCS has organized meetings of scientists to establish lists of priority chemicals for subsequent evaluation. Such meetings have been held in: Ispra, Italy, 1980; Oxford, United Kingdom, 1984; Berlin, Germany, 1987; and North Carolina, USA, 1995. The selection of chemicals has been based on the following criteria: the existence of scientific evidence that the substance presents a hazard to human health and/or the environment; the possible use, persistence, accumulation or degradation of the substance shows that there may be significant human or environmental exposure; the size and nature of populations at risk (both human and other species) and risks for environment; international concern, i.e. the substance is of major interest to several countries; adequate data

on the hazards are available.

If an EHC monograph is proposed for a chemical not on the priority list, the IPCS Secretariat consults with the Cooperating Organizations and all the Participating Institutions before embarking on the preparation of the monograph.

Procedures

The order of procedures that result in the publication of an EHC monograph is shown in the flow chart. A designated staff member of IPCS, responsible for the scientific quality of the document, serves as Responsible Officer (RO). The IPCS Editor is responsible for layout and language. The first draft, prepared by consultants or, more usually, staff from an IPCS Participating Institution, is based initially on data provided from the International Register of Potentially Toxic Chemicals, and reference data bases such as Medline and Toxline.

The draft document, when received by the RO, may require an initial review by a small panel of experts to determine its scientific quality and objectivity. Once the RO finds the document acceptable as a first draft, it is distributed, in its unedited form, to well over 150 EHC contact points throughout the world who are asked to comment on its completeness and accuracy and, where necessary, provide additional material. The contact points, usually designated by governments, may be Participating Institutions, IPCS Focal Points, or individual scientists known for their particular expertise. Generally some four months are allowed before the comments are considered by the RO and author(s). A second draft incorporating comments received and approved by the Director, IPCS, is then distributed to Task Group members, who carry out the peer review, at least six weeks before their meeting.

The Task Group members serve as individual scientists, not as representatives of any organization, government or industry. Their function is to evaluate the accuracy, significance and relevance of the information in the document and to assess the health and environmental risks from exposure to the chemical. A summary and recommendations for further research and improved safety aspects are also required. The composition of the Task Group is dictated by the range of expertise required for the subject of the meeting and by the need for a balanced geographical distribution.

The three cooperating organizations of the IPCS recognize the important role played by nongovernmental organizations. Representatives from relevant national and international associations may be invited to join the Task Group as observers. While observers may provide a valuable contribution to the process, they can only speak at the invitation of the Chairperson. Observers do not participate in the final evaluation of the chemical; this is the sole responsibility of the Task Group members. When the Task Group considers it to be appropriate, it may meet *in camera*.

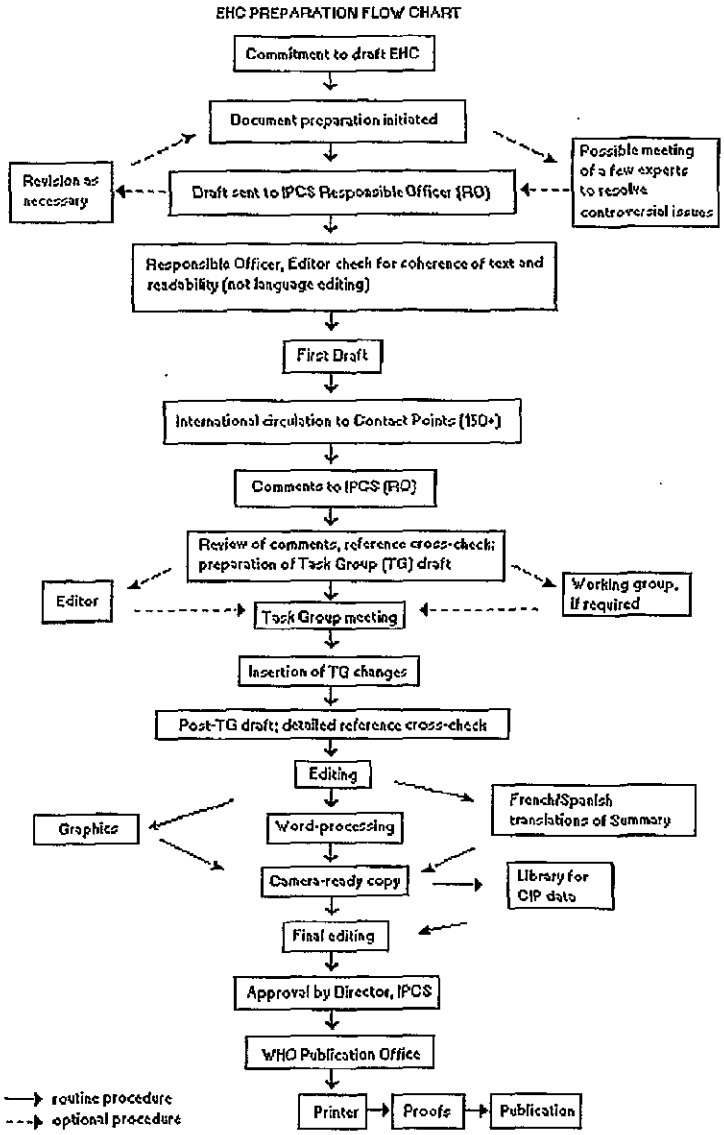
All individuals who as authors, consultants or advisers participate in the preparation of the EHC monograph must, in addition to serving in their personal capacity as scientists, inform the RO if at any time a conflict of interest, whether actual or potential, could be perceived in their work. They are required to sign a conflict of interest statement. Such a procedure ensures the transparency and probity of the process.

When the Task Group has completed its review and the RO is satisfied as to the scientific correctness and completeness of the

document, it then goes for language editing, reference checking, and preparation of camera-ready copy. After approval by the Director, IPCS, the monograph is submitted to the WHO Office of Publications for printing. At this time a copy of the final draft is sent to the Chairperson and Rapporteur of the Task Group to check for any errors.

It is accepted that the following criteria should initiate the updating of an EHC monograph: new data are available that would substantially change the evaluation; there is public concern for health or environmental effects of the agent because of greater exposure; an appreciable time period has elapsed since the last evaluation.

All Participating Institutions are informed, through the EHC progress report, of the authors and institutions proposed for the drafting of the documents. A comprehensive file of all comments received on drafts of each EHC monograph is maintained and is available on request. The Chairpersons of Task Groups are briefed before each meeting on their role and responsibility in ensuring that these rules are followed.



WHO TASK GROUP ON ENVIRONMENTAL HEALTH CRITERIA FOR FLAME RETARDANTS: TRIS(2-BUTOXYETHYL) PHOSPHATE, TRIS(2-ETHYLHEXYL) PHOSPHATE AND TETRAKIS(HYDROXYMETHYL) PHOSPHONIUM SALTS

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ENVIRONMENTAL HEALTH CRITERIA FOR FLAME RETARDANTS: TRIS(2-BUTOXYETHYL) PHOSPHATE, TRIS(2-ETHYLHEXYL) PHOSPHATE AND TETRAKIS(HYDROXYMETHYL) PHOSPHONIUM SALTS

A WHO Task Group on Environmental Health Criteria for Flame retardants: tris(2-butoxyethyl) phosphate, tris(2-ethylhexyl) phosphate and tetrakis(hydroxymethyl) phosphonium salts met at the British Industrial Biological Research Association, Carshalton, United Kingdom from 18 to 22 January 1999. Dr P. Brantom opened the meeting and welcome the participants on behalf of the host institute. Dr M. Baril, IPCS, welcomed the participants on behalf of IPCS and the three cooperating organizations (UNEP/ILO/WHO). The Task Group reviewed and revised the draft criteria monograph and made an evaluation of the risk to human health and the environment from exposure to these flame retardants.

Financial support for this Task Group was provided by the United Kingdom Department of Health as part of its contribution to the IPCS.

The first draft of this monograph was prepared by Dr G. J. van Esch, Bilthoven, the Netherlands. The second draft prepared by Dr M. Baril incorporated the comments received following circulation of the first draft to the IPCS contact points for Environmental Health Criteria.

Dr P.G. Jenkins (IPCS Central Unit, Geneva) and Dr M. Baril (IPCS technical advisor, Montreal) were responsible for the overall technical editing and scientific content, respectively.

The efforts of all who helped in the preparation and finalization of the monograph are gratefully acknowledged.

* * *

ABBREVIATIONS

AChE	acetylcholinesterase
ALAT	alanine aminotransferase
ASAT	aspartate aminotransferase
BCME	bis(chloromethyl) ether
BEHP	bis(2-ethylhexyl) phosphate
BMPA	bishydroxymethyl phosphonic acid
BuCHE	butyrylcholinesterase
CHO	Chinese hamster ovary
DMSO	dimethyl sulfoxide
EC_{50}	median effective concentration
FDA	Food and Drug Administration (USA)
GC	gas chromatography
HPLC	high performance liquid chromatography
IC_{50}	median inhibitory concentration
LC_{50}	median lethal concentration
LD_{50}	median lethal dose
LOAEL	lowest-observed-adverse-effect level
LOEL	lowest-observed-effect level
MS	mass spectrometry
nd	not detected
NOAEL	no-observed-adverse-effect level
NOEC	no-observed-effect concentration
NOEL	no-observed-effect level
NPD	nitrogen-phosphorus sensitive detector
NTE	neuropathy target esterase
NTP	National Toxicology Program (USA)
OECD	Organisation for Economic Co-operation and Development
PVC	polyvinyl chloride
SCE	sister-chromatid exchange
TBEP	tris(2-butoxyethyl) phosphate
TEHP	tris(2-ethylhexyl) phosphate
THP	tetrakis(hydroxymethyl) phosphonium
THPC	tetrakis(hydroxymethyl) phosphonium chloride
THPO	trihydroxymethyl phosphine oxide
THPS	tetrakis(hydroxymethyl) phosphonium sulfate
TOCP	tri- *ortho*-cresyl phosphate

PART A

Tris(2-butoxyethyl) phosphate

(TBEP)

A. SUMMARY, EVALUATION AND RECOMMENDATIONS

A1. Tris(2-butoxyethyl) phosphate (TBEP)

A1.1 Summary

Tris(2-butoxyethyl) phosphate (TBEP) is used in floor polishes and as a plasticizer in rubber and plastics. The worldwide production volume is not available but is estimated to be in the range of 5000-6000 tonnes.

TBEP occurs in the environment only as a result of human

activity. Its distribution in the environment has been investigated in certain industrialized countries. Concentrations in surface water were found to be below 300 ng/litre, whereas concentrations in sediment were between 100 and 1000 µg/kg. None of 167 analyses detected TBEP in fish. It has been detected in outdoor air in a single study (<200 ng/m^3). Measurement of TBEP in indoor air in offices showed concentrations of 25 ng/m^3 or less. TBEP is associated with particulates and the source is considered to be the application of floor polish. It has been detected at µg/kg levels in human adipose tissue. The reported daily dietary intake from market basket studies, for a range of age groups, was <0.02 µg/kg body weight per day. Drinking-water concentrations of up to 270 µg/litre have been reported, this is considered to arise from migration from rubber gaskets in the plumbing.

TBEP is considered to be readily biodegradable. Sewage treatment plant measurements and semi-continuous sludge laboratory tests have indicated substantial elimination of TBEP (>80%). In river and coastal water TBEP was completely degraded. The half-life in estuarine water was reported to be about 50 days and there was little degradation in unadapted seawater.

The acute systemic mammalian toxicity and irritation potential are low.

Several subchronic studies in laboratory animals have shown that the liver is the target organ for TBEP toxicity. One study in male Sprague-Dawley rats suggested that TBEP might cause focal myocarditis. Neurotoxic effects in rats after single doses of TBEP are inconsistent. In rats repeatedly given high doses by gavage, TBEP decreased nerve conduction velocity and increased the refractory period. It did not cause delayed neurotoxicity in hens but did inhibit brain and plasma cholinesterases.

Based on an 18-week repeated dose study in rats, the no-observed-effect level (NOEL) for liver effects was reported to be 15 mg/kg body weight per day, while the lowest-observed-effect level (LOEL) was 150 mg/kg body weight per day.

The long-term toxicity and carcinogenicity of TBEP have not been studied.

Bacterial and mammalian cell tests for gene mutation gave negative results, but no tests for chromosomal damage have been reported.

Teratogenicity was not observed in one study in rats. Other aspects of reproductive toxicity have not been reported.

A Repeat Human Insult Patch Test indicated no skin sensitization and minimal skin irritation.

The toxicity of TBEP to aquatic organisms is moderate. The 48-h LC_{50} in *Daphnia magna* is 75 mg/litre and the 96-h LC_{50} values in fish range between 16 and 24 mg/litre.

A1.2 Evaluation

Occupational exposure to TBEP is likely to be by the dermal route during manufacture (accidental exposure) and from the use of floor polishes. The compound is absorbed dermally in experimental animals but no information is available on its kinetics and metabolism. Dermal exposure cannot, therefore, be quantified but is expected to be low. Inhalation exposure in the office environment has been measured to be

25 ng/m³ or less.

Exposure of the general population is principally via food (from use of TBEP as a plasticizer in packaging plastics) and drinking-water (contaminated by leaching from synthetic rubbers used in plumbing washers). Exposure from both sources is very low (estimated to be <0.2 µg/kg body weight per day from the diet and concentrations in drinking-water of <270 µg/litre).

Given the reported NOEL from animal studies of 15 mg/kg body weight per day from a repeated dose oral study, the risk to the general population is very low. The risk to the occupationally exposed is also considered to be very low, though this cannot be quantified.

In the environment, TBEP is expected (from its low volatility, high adsorption coefficient and moderate water solubility) to partition to sediment. The few measured data confirm this. Degradation in environmental media is expected to be rapid. No information is available on breakdown products; phosphate released during breakdown is not expected to contribute significantly to environmental nutrient levels. Fig. 1 plots measured environmental concentrations in surface water against reported acute toxicity values. The margin of safety between highest reported concentrations and lowest reported toxicity values is several orders of magnitude, indicating low risk to organisms in the aquatic environment. No assessment of risk can be made for the terrestrial compartment.

A1.3 Recommendations

For a full scientific evaluation of the compound, identification and assessment of metabolites in mammals would be required, given the toxicological profile of one of the suggested metabolites, 2-butoxyethanol.

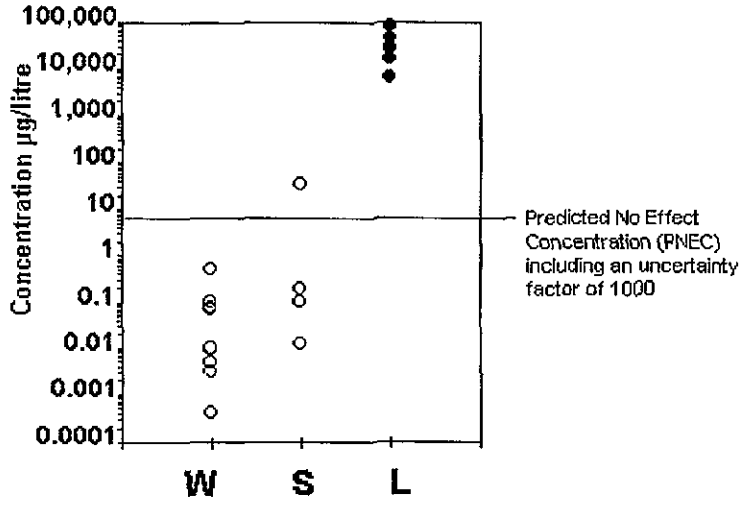
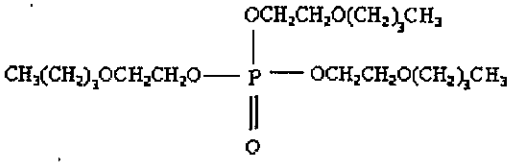


Fig. 1. Plot of measured concentrations in surface waters (W) and sewage effluents (S), and reported acute toxicity values (L) for TBEP (o= measured concentrations in the environment; ● = calculated LC_{50})

A2. IDENTITY, PHYSICAL AND CHEMICAL PROPERTIES, AND ANALYTICAL METHODS

A2.1 Identity

Molecular structure:



Empirical formula: $C_{18}H_{39}O_7P$

Relative molecular mass: 398.54

Common name: tris(2-butoxyethyl) phosphate

Synonyms: phosphoric acid, tris(2-butoxyethyl) ester; tri(2-butoxyethanol) phosphate; tris(2- *n*-butoxyethyl) phosphate; tributoxyethyl phosphate; TBOP; TBEP; TBXP (only in Japanese literature); 2-butoxyethanol phosphate (RTCES, 1989); tri(2-butylethylether) phosphate; tris(butylglycol) phosphate; tributyl cello solve phosphate

Trade names: Kronitex KP-140; KP-140; Phosflex T-BEP; Phosflex 176C; Amgard TBEP

CAS registry number: 78-51-3

CAS name: Ethanol, 2-butoxy, phosphate (3:1)

EINECS number: 201-122-9

RTECS number: KJ9800000

A2.2 Physical and chemical properties

TBEP is a technical product that may contain as impurities tributyl phosphate (about 3%) and traces of 2-butoxyethanol and phosphoric acid (FMC, 1990; Albright & Wilson (1999) personal communication to IPCS). There is no information on the concentration of mono- or diesters or other impurities in the technical product.

TBEP is a light-coloured, high-boiling, non-flammable viscous liquid with a butyl-like odour under normal conditions. It is more soluble in non-polar than in polar solvents.

Boiling point: 200-230°C at 5.0-5.3 hPa

Melting point: -70°C

Density: 1.02 g/ml at 20°C

Viscosity: 11-15 mPa.s at 20°C

Vapour pressure:
at 25°C 2.8×10^{-7} hPa
at 150°C 0.33 hPa (0.03 mmHg)

Refractive index: 1.434 at 25°C

Solubility: 1.1-1.3 g/litre water at 20°C; miscible in petroleum at 20°C

Acidity/alkalinity: (1 g/litre water at 20°C)	neutral
Flashpoint:	210°C (approximately); 159 ± 2°C
Ignition point:	251-52°C
Auto-ignition temperature:	322 ± 5°C; 261°C
Log K_{oc}:	4.38 (calculated)
n-Octanol/water partition coefficient:	4.78 (calculated); 3.65

References: Eldefrawi et al. (1977); Keith & Walters (1985); Laham et al. (1985b); Hoechst (1987); Watts & Moore (1988); Leo (1989); FMC (1990); Hinckley et al. (1990); Lenga (1993); Tremain & Bartlett (1994).

A2.3 Conversion factors

1 ppm = 16.53 mg/m^3 at 20°C
1 mg/m^3 = 0.0605 ppm at 20°C

A2.4 Analytical methods

TBEP is usually analysed by gas chromatography (GC) coupled with mass spectrometry (MS), infrared spectroscopy or nuclear magnetic resonance spectrometry. The detection limit is <1 ng/g (adipose tissue) using any of these methods or a nitrogen/phosphorus-selective detector (LeBel et al., 1981; Rivera et al., 1987).

A2.4.1 Air

TBEP has been found associated with particulate matter in the air of offices. Of the methods that can be used to collect the particles, Weschler (1980) used a four-stage impactor with a back-up filter and extracted with a mixture of water and methanol. Later Weschler (1984) and Weschler & Fong (1986) collected particles on Teflon(R) membranes, separating the particles according to whether the aerodynamic diameter was greater or less than 2.5 µm. The samples were analysed by GC/MS after thermal desorption of the collector membranes. Sometimes samples were desorbed or dissolved with toluene.

A2.4.2 Water

TBEP has been extracted either with dichloromethane after acidification to pH 2 or by passage through a column filled with Amberlite XAD-2 resin which is subsequently extracted with acetone and hexane. After dehydration and concentration, extracts are analysed. The concentrated extracts are determined by GC/MS, or with other detection methods, as described above (LeBel et al., 1981; Watts & Moore, 1988). LeBel et al. (1987) used large-volume resin sampling cartridges to obtain sufficient organic extracts from water for analysis. Recovery at 10 ng TBEP/litre fortification level was 103.4%.

Frimmel et al. (1987) described an analytical method to determine TBEP in water by extracting TBEP with granulated activated carbon and analysing the extract with GC/MS.

Rivera et al. (1987) analysed water samples with different

procedures, liquid-liquid extraction, adsorption on granular activated carbon, extraction with dichloromethane, followed by GC/MS/DS (Daughter spectral) detection. Ether-insoluble organic fractions were analysed and fractionated by high-performance liquid chromatography (HPLC) and ultraviolet absorbency detection was carried out with a 2140 diode-array detector, followed by fast atom bombardment (FAB) and FAB-collision-induced dissociation - mass analysis kinetic energy spectroscopy (CID-MIKES) mass spectrometry.

A2.4.3 Sediment

After decanting the supernatant water, the sediment samples are mixed with an equal volume of pre-extracted anhydrous sodium sulfate and transferred to a Soxhlet thimble. Soxhlet extraction is carried out overnight using dichloromethane (300 ml) (Watts & Moore, 1988).

A2.4.4 Soils and foodstuffs

There are no reports of extraction or clean-up methods for soil or food (ECETOC, 1992b).

A2.4.5 Biological media

LeBel & Williams (1983b, 1986) and LeBel et al. (1989) analysed human adipose tissue for TBEP by extraction with a mixture of acetone/hexane in the presence of anhydrous sodium sulfate. The solution was centrifuged and the supernatant filtered and evaporated. The resulting extract was dissolved in a mixture of 5% dichloromethane in cyclohexane for gel permeation chromatography (GPC) to separate residual lipids from phosphate esters. Using this method the recovery of TBEP from adipose tissue was approximately 90%.

Anderson et al. (1984) measured peaks of TBEP determined by HPLC in spiked samples of serum during the development of an analytical refinement. There was a marked inter-individual variation in peak height, which correlated with serum lipoprotein concentration.

A3. SOURCES OF HUMAN AND ENVIRONMENTAL EXPOSURE

A3.1 Natural occurrence

TBEP has not been found to occur naturally in the environment (ECETOC, 1992b).

A3.2 Anthropogenic sources

A3.2.1 Production levels and processes

TBEP is produced by reacting phosphorus oxychloride and butoxyethanol (butyl glycol) and stripping hydrochloric acid and excess of butoxyethanol. Another production method uses the sodium salt of the glycol. In this case, the by-product is sodium chloride (ECETOC, 1992b).

The world global production has been estimated to be 5000-6000 tonnes, with less than 1000 tonnes in Europe.

A3.2.2 Uses

TBEP is used mainly as a component in floor polishes, a solvent in some resins, a viscosity modifier in plastisols, an antifoam and also as a plasticizer in synthetic rubber, plastics and lacquers. TBEP is widely used as a plasticizer in rubber stoppers for vacutainer

tubes and plastic ware.

A4. ENVIRONMENTAL TRANSPORT, DISTRIBUTION AND TRANSFORMATION

A4.1 Transport and distribution between media

All environmental TBEP derives from human activities but the input rate to the environment cannot be estimated from the available data. The input is expected to be mainly to soil, sediments and surface waters from leachates from plastics on landfills, from spillages and from effluents (ECETOC, 1992b).

The low vapour pressure, the high soil sorption coefficient (K_{oc}) and the water solubility of approximately 1 g/litre suggests that TBEP in the environment will be found mainly in water and sediment. TBEP has been detected in surface water and sediments (ECETOC, 1992b).

A4.2 Biodegradation

No data are available on mechanisms of abiotic or biotic transformation. Analogy with other phosphate esters suggests that enzymatic hydrolysis would be expected to dominate (ECETOC, 1992b).

TBEP was readily biodegradable when tested in the OECD 301B assay, achieving 87% degradation within 28 days (Mead & Handley 1998).

In a test of primary biodegradation using the semi-continuous activated sludge procedure and an addition rate of 3 mg TBEP/litre per test cycle, 88% of TBEP was eliminated. The ultimate biodegradability (using the Monsanto shake-flask procedure) was 51% of the theoretical CO_2 generated after 28 days (Monsanto, 1976).

Hattori et al. (1981) studied the degradation of TBEP in environmental water in 1979-1980. Using the molybdenum blue colorimetric method, the increase of phosphate ions was analysed in Oh and Neya river water and seawater from Osaka Bay to which 1 mg TBEP/litre had been added. The degradation depended on the source of the water (Table 1).

Table 1. Biodegradation of TBEP in water in percentages (from Hattori et al., 1981)

Test duration (days)	Oh River	Neya River	Osaka Bay	
			Tomagashima seawater	Senboku seawater
7	29.1	0	1.9[a]	0
14	100[b]	100	17.6	100

[a] Test duration 8 days
[b] Test duration 15 days

A sterilized distilled water control did not show any degradation after 15 days. TBEP was rapidly degraded in less than 14 days after an acclimatization period of several days in water containing micro-organisms. Where degradation was rapid, the phosphatase activity increased during the test period.

TBEP was eliminated from estuarine water with a half-life of

approximately 50 days (Ernst, 1988).

A4.2.1 Migration

LeBel & Williams (1983a) investigated the difficulties of obtaining representative water samples and the importance of designing suitable sampling protocols. TBEP was detected in tap water at concentrations from 11.0 to 5400 ng/litre. The authors suggested that the TBEP originated from the O-ring and seal in the tap.

A5. ENVIRONMENTAL LEVELS AND HUMAN EXPOSURE

A5.1 Environmental levels

A5.1.1 Air

An indoor aerosol sample was collected in a large building in New Jersey, USA. The abundance of TBEP was greatest both for particles larger than 7.0 μm diameter and for those smaller than 1.1 μm; there was considerably less material present in the intermediate size ranges. This pattern is consistent with its use in floor polish. Buffing operations generate relatively large particles which are likely to contain TBEP. However, this compound may also migrate from the floor polish and be attached to particles. In this case the majority of the adsorbed TBEP would accumulate in the submicron size range (Weschler, 1980). The mean concentrations measured in representative samples of dust from air in 7 offices in the USA was reported to be 15 ng/m^3 (Weschler & Shields, 1986). The significance of floor polish, which may contain 1% TBEP (Nakashima et al., 1993), as a source of these particulates is suggested by the fact that the highest concentration measured (25 ng/m^3) was found immediately following floor polishing work by a night crew.

Airborne concentrations of fine (2.5 μm) and coarse aerosol (2.5-15 μm) particles were simultaneously measured outside and inside two buildings, one in Wichita, Kansas, USA, during the fall and early winter (1981-1982) and the second one in Lubbock, Texas, USA, during late winter and spring 1982. The average indoor concentrations of TBEP in Wichita and Lubbock were 4 and 25 ng/m^3, mainly in fine aerosol particles. TBEP was not found in outdoor aerosol particles (Weschler, 1984).

Yasuda (1980) reported the results of a study of 19 outdoor air samples from 7 locations in 1976. Two samples from Kawauchi Town contained 149.1 and 176.8 ng TBEP/m^3 and one from Ehime University 9.6 ng TBEP/m^3. TBEP was not detected in the other 16 samples.

A5.1.2 Water (drinking-water and surface water)

Levels of TBEP have been determined in rivers, sewage, tap water, lakes and estuaries. The investigations have been carried out in the Great Lakes area of Canada, USA, Japan, Germany and the United Kingdom.

The lower part of the River Weser (over 33 km), Germany, was examined for the presence of TBEP during the period May 1985 to April 1987. TBEP was found at a mean concentration of 125 ng/litre. Systematic measurements of effluent samples from five sewage treatment plants in the Bremen region showed concentrations of TBEP ranging from 800 to 34 900 ng/litre (Bohlen et al., 1989).

Ernst (1988) analysed water of the estuary of the Rivers Elbe and Weser, Germany, for the presence of TBEP during the period 1983-1985.

The concentrations that were found ranged from 5 to 70 ng/litre.

One hundred samples of surface water were collected from various locations throughout Japan in 1975 and analysed for the presence of TBEP. TBEP was identified in none of the samples (the limit of determination ranged from 0.02 to 0.5 µg/litre). In 1978, 114 samples were analysed in Japan and TBEP was not identified (the limit of determination ranged from 0.005 to 1.5 µg/litre) (Environmental Agency Japan, 1978, 1983, 1987).

In a survey conducted between 1989 and 1990, Fukushima et al. (1992) identified TBEP in Lake Biwa, Yodo River and also in the Yamato Osaka Rivers and Osaka Bay at levels of about 0.2-2.5 µg/litre.

Drinking-water was collected in Japan over a 12-month period and analysed. Concentrations ranging up to 0.0585 ng/litre were found (Adachi et al., 1984).

Two samples of drinking-water collected from six Eastern Ontario water treatment plants in the period June-October 1978 contained 0.9-75.4 ng/litre (LeBel et al., 1981). In another study two samples of drinking-water were collected from five Great Lakes water treatment plants of Eastern Ontario and analysed for TBEP. The concentration found in surface water samples ranged from 9.8 to 54.4 ng/litre as determined by GC/MS. When determined by GC/NPD, concentrations of 0.4 to 73.8 ng/litre were found (LeBel et al., 1987).

Williams et al. (1982) collected samples of drinking-water from 12 Ontario municipal water treatment plants which draw their water from the Great Lakes system in January and August 1980. All samples contained TBEP at concentrations ranging from 1.6 to 271.6 µg/litre. The authors noted that TBEP is a common constituent of rubber gaskets and washers and can be introduced into water from components of the tap used for sampling.

In 1983, LeBel et al. (1983a) found up to 5400 ng/litre in a sample of drinking-water taken after non-use of the tap for 65 h.

In the period August 1976 to March 1977, 16 grab samples of river water were collected from the Delaware River, USA (between river mile 78 and 132). In addition to other compounds, TBEP was identified in all samples. The concentrations ranged from 0.3 to 3.0 µg/litre in the winter and from 0.4 to 2.0 µg/litre in the summer (Sheldon & Hites, 1978).

A5.1.3 Soils and sediment

TBEP was detected in 7 out of 80 samples of sediment collected at different locations in Japan in 1975. The concentrations ranged from 0.22 to 0.54 mg/kg and the limit of determination was 0.002-0.1 mg/kg. In 1978, none of the 114 sediment samples collected at different places in Japan contained TBEP (limit of determination 0.0005-0.12 mg/kg) (Environmental Agency Japan, 1978, 1983).

Watts & Moore (1988) did not detect TBEP in suspended particles or bottom sediments in a river in the United Kingdom, even though TBEP was found in corresponding water columns.

A5.1.4 Aquatic organisms

No TBEP could be detected in 74 samples of fish from numerous locations throughout Japan (limit of determination 0.005-0.1 mg/kg). Another report from the same agency stated that TBEP was not found in 93 fish samples (limit of determination 0.0005-0.15 mg/kg)