

**Report on Toxicity of Sediments Produced
During Channel Dredging in
Port Phillip Bay**

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RESUME

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THESIS :

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Effect of Processing on the Distribution of Cadmium in Wheaten Products
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EXPERT WITNESS REPORT

Aldrin

Aldrin is an [organochlorine insecticide](#) which is [oxidized](#) in the [insect](#) to form [dieldrin](#), a [neurotoxin](#). Aldrin was formerly used to kill [soil](#) insects such as [termites](#) and [grasshoppers](#) to protect crops such as [corn](#) and [potatoes](#). It has been classified as a [persistent organic pollutant](#). Due to health concerns regarding dieldrin, it is no longer manufactured or used in the [United States](#). In addition, aldrin is itself a [carcinogen](#) and [mutagen](#).

Antimony

Antimony is a [chemical element](#) in the [periodic table](#) that has the symbol Sb ([Latin](#): *stibium*, meaning "mark") and [atomic number](#) 51. A [metalloid](#), antimony has four [allotropic](#) forms. The stable form of antimony is a blue-white metalloid. Yellow and black antimony are unstable non-metals. Antimony is used in flame-proofing, [paints](#), [ceramics](#), [enamels](#), a wide variety of [alloys](#), [electronics](#), and [rubber](#).

Antimony and many of its compounds are [toxic](#). Clinically, antimony poisoning is very similar to [arsenic](#) poisoning. In small doses, antimony causes [headache](#), [dizziness](#), and [depression](#). Larger doses cause violent and frequent vomiting, and will lead to death in a few days.

A study found that antimony is leaching from [PET](#) bottles (reported for some acidic fruit drinks), but at levels below drinking water guidelines. The guidelines are:

- WHO, 20 $\mu\text{g l}^{-1}$
- US EPA, Health Canada and the Ontario Ministry of Environment, 6 $\mu\text{g l}^{-1}$
- German Federal Ministry of Environment, 5 $\mu\text{g l}^{-1}$ ^[12]
- Japan, 15 $\mu\text{g l}^{-1}$ ^[13]

The acidic nature of the drink is sufficient to dissolve small amounts of [antimony oxide](#) contained in the packaging of the drink; modern manufacturing methods prevent this occurrence. However, researchers are concerned that antimony levels correspond to duration the bottle is left to stand - the longer the water has been bottled, the higher the antimony leached.

Arsenic

Arsenic is very similar chemically to its predecessor, [phosphorus](#). Similar to phosphorus, it forms colorless crystalline oxides As_2O_3 and As_2O_5 that are hygroscopic and readily soluble in water to form acidic solutions. Arsenic (V) acid, like phosphoric acid, is a strong acid. Like phosphorus, arsenic forms an unstable, gaseous hydride: arsine (AsH_3). The similarity is so great that arsenic will partly substitute for phosphorus in biochemical reactions and is thus [poisonous](#). However, in subtoxic doses, soluble arsenic compounds act as [stimulants](#), and were once popular in small doses as medicinals by people in the mid 18th century. [Lead hydrogen arsenate](#) has been used, well into the 20th century, as an [insecticide](#) on [fruit trees](#) (sometimes resulting in [brain damage](#) to those working the sprayers), and [Scheele's Green](#) (a copper arsenate) has even been recorded in the 19th century as a [coloring agent](#) in [sweets](#). In the last half century, [monosodium methyl arsenate](#) (MSMA), a less toxic organic form of arsenic, has replaced lead arsenate's role in agriculture.

Copper acetoarsenite was used as a green [pigment](#) known under many different names, including '[Paris Green](#)' and 'Emerald Green'. It caused numerous [arsenic poisonings](#). [Arsenic poisoning](#) kills by [allosteric inhibition](#) of essential metabolic [enzymes](#), leading to death from multi-system [organ failure](#).

The [LD50](#) for pure arsenic is 763 mg/kg (by ingestion) and 13 mg/kg (by intraperitoneal injection). For a 70 kg (~155 lb) human, this works out to about 53 grams (less than 2 ounces). However, compounds containing arsenic can be significantly more toxic. [Chronic](#) arsenic poisoning results from drinking water with high levels of [arsenic](#) over a long period of time. This may occur due to [Arsenic contamination of groundwater](#).

Effects include changes in skin colour, formation of hard patches on the skin, [skin cancer](#), [lung cancer](#), [cancer](#) of the [kidney](#) and [bladder](#), and can lead to [gangrene](#). The [World Health Organization](#) recommends a limit of 0.01 mg/L of arsenic in drinking water; consumption of higher levels over long periods of time can lead to arsenicosis. Non-[carcinogenic](#) chronic effects include liver injury - jaundice and cirrhosis, peripheral vascular disease involving blueness of the extremities, Raynaud's syndrome, and blackfoot disease (a type of gangrene), anemia, resulting from impaired heme biosynthesis, hyperkeratosis of the skin. There are also multiple lines of evidence for the carcinogenic effects of arsenic.

Arsenic has been known to cause many problems in third world countries where ground water supplies have been contaminated by arsenic derived from geologically recent fluvial deposits containing arseno-pyrites. This is a particular problem in [Bangladesh](#) where tube wells installed since the 1970s have intercepted ground waters flowing in the fluvial deposits. Concentrations in these wells can exceed 1 part per thousand whereas the WHO maximum level is 10 parts per billion.

It has also been confirmed that natural [arsenic contamination](#) of [drinking water](#) has also been a problem in [wells](#) in [New Hampshire](#), USA. Chronic low level arsenic poisoning, or arsenicosis, such as is seen in Bangladesh can potentially result in the victim developing [cancer](#).

Barium

Barium is a [chemical element](#). It has the symbol Ba, and [atomic number](#) 56. Barium is a soft silvery [metallic alkaline earth metal](#). It is never found in nature in its pure form due to its [reactivity](#) with [air](#). Its oxide is historically known as [baryta](#) but it reacts with water and carbon dioxide and is not found as a mineral.

Barium compounds are extremely [poisonous](#). At low doses, barium acts as a muscle stimulant, while higher doses affect the [nervous system](#), causing cardiac irregularities, tremors, [weakness](#), [anxiety](#), [dyspnea](#) and [paralysis](#). This may be due to its ability to block [potassium ion channels](#) which are critical to the proper function of the nervous system. Unlike other [heavy metals](#), barium does not [bioaccumulate](#). However, inhaled barium dust can accumulate in the lungs, a [benign](#) condition called [baritosis](#).

Beryllium

Beryllium is the [chemical element](#) that has the symbol Be and [atomic number](#) 4. A [bivalent](#) element, elemental beryllium is a steel grey, strong, light-weight yet brittle, [alkaline earth metal](#). It is primarily used as a hardening agent in [alloys](#) (most notably [beryllium copper](#)). Beryllium and its salts are [toxic](#) substances and potentially [carcinogenic](#). Chronic [berylliosis](#) is a [pulmonary](#) and [systemic granulomatous](#) disease caused by exposure to beryllium. Acute beryllium disease in the form of [chemical pneumonitis](#) was first reported in Europe in 1933 and in the United States in 1943. Cases of chronic berylliosis were first described in 1946 among workers in plants manufacturing [fluorescent lamps](#) in [Massachusetts](#). Chronic berylliosis resembles [sarcoidosis](#) in many respects, and the differential diagnosis is often difficult.

Some people (1-15%) become sensitive to beryllium. These individuals may develop an inflammatory reaction that principally targets the respiratory system and skin. This condition is called chronic beryllium disease (CBD), and can occur within a few months or many years after exposure to higher than normal levels of beryllium (greater than $0.02 \mu\text{g}/\text{m}^3$). This disease causes fatigue, weakness, night sweats and can cause difficulty in breathing and a persistent dry cough. It can result in anorexia, weight loss, and may also lead to right-side heart enlargement and heart disease in advanced cases. Some people who are sensitized to beryllium may not have any symptoms

There are no studies on the health effects of children exposed to beryllium, although individual cases of CBD have been reported in children of beryllium workers from the 1940s. It is likely that the health effects seen in children exposed to beryllium will be similar to the effects seen in adults. It is unknown whether children differ from adults in their susceptibility to beryllium. It is unclear whether beryllium is [teratogenic](#).

Compliance with the current U.S. Occupational Safety and Health Administration (OSHA) permissible exposure limit for beryllium of $2 \mu\text{g}/\text{m}^3$ has been determined to be inadequate to protect workers from developing beryllium sensitization and CBD. The American Conference of Governmental Industrial Hygienists (ACGIH), which is an independent organization of experts in the field of occupational health, has proposed a threshold limit value (TLV) of $0.05 \mu\text{g}/\text{m}^3$ in a 2006 Notice of Intended Change (NIC). This TLV is 40 times lower than the current OSHA permissible exposure limit, reflecting the ACGIH analysis of best available peer-reviewed research data concerning how little airborne beryllium is required to cause sensitization and CBD.

Cadmium

Cadmium is a [chemical element](#) in the [periodic table](#) that has the symbol Cd and [atomic number](#) 48. A relatively rare, soft, bluish-white, [transition metal](#), cadmium is known to cause [cancer](#) and occurs with [zinc](#) ores.

Cadmium is used largely in batteries and pigments, for example in [plastic](#) products. Cadmium is an [occupational hazard](#) associated with industrial processes such as metal plating and the production of nickel-cadmium batteries, pigments, plastics and other synthetics. The primary route of exposure in industrial settings is inhalation. Inhalation of cadmium-containing fumes can result initially in [metal fume fever](#) but may progress to chemical [pneumonitis](#), [pulmonary oedema](#), and death.

Cadmium is also a potential environmental hazard. Human exposures to environmental cadmium are primarily the result of the burning of fossil fuels and municipal wastes. However, there have been notable instances of toxicity as the result of long-term exposure to cadmium in contaminated food and water. In the decades following [World War II](#), Japanese mining operations contaminated the [Jinzu River](#) with cadmium and traces of other toxic metals. Consequently, cadmium accumulated in the rice crops growing along the riverbanks downstream of the mines. The local agricultural communities consuming the contaminated rice developed [Itai-itai](#) disease and renal abnormalities, including [proteinuria](#) and [glucosuria](#).

Cadmium has been reported by many workers to be harmful to all living systems with no known biological requirement. Although work by Von Zglinicki *et al* (1992) has postulated that very low levels of cadmium may stimulate DNA synthesis and cell growth. A relationship between the chemistry and the toxicity of cadmium was shown by Bienvenu *et. al.*, (1963) when he determined the dose of various soluble metal compounds given to mice that resulted in the death of 50 % of the animals within 30 days (LD₅₀). He noted regularities between the relative toxicity and the position of the element in the periodic table.

The strongest trend appears to be the general decrease in the LD₅₀ in the order : M⁺ ions of group Ia, M²⁺ ions of group IIa, M³⁺ ions of group IIIa, M²⁺ ions of the first transition series and then M⁺, M²⁺ and M³⁺ ions of the post transition element groups Ib - IIIb. A second trend appears in the M²⁺ transition metal cations, this is a decrease in the LD₅₀ with increasing atomic number. The greater toxicity of the heavy metals is also apparent within groups IIb and IIIb. The graph highlights cadmium, a divalent, post transition metal, as one of the most toxic elements with a LD₅₀ of 0.000033 g-moles/kg. Only indium (as In³⁺) and mercury (as Hg²⁺) were found to be more toxic .

All heavy metals can form a wide variety of coordination compounds and ions that bind to various polydentate organic ligands. The binding of such metal ions appears to link enzymes to substrates and may be partly responsible for the power of enzymes to catalyse biochemical reactions. The most important donor atoms that link metal ions to biological molecules are oxygen (O), nitrogen (N) and sulphur (S). This can be shown as a series of bidentate ligands which are attached to the metal ion by two donor atoms to form a chelate complex : oxalate (OO), glycine (ON), ethylene diamine (NN), mercaptyl acetate (SO) and mercaptyl amine (SN).

It can be shown that cadmium should not displace any of the metals shown from an oxygen donating ligand but will displace Mn^{2+} and Fe^{2+} from nitrogen donors. Cadmium is bound to sulfur more strongly than all the metals shown except Cu^{2+} and Hg^{2+} . The very extended capability of cadmium to bind to nucleophilic sites of macromolecules (proteins, DNA and RNA) accounts for the multiplicity of toxic effects observed *in vitro* and *in vivo*. These chemical reactions and the relatively strong bonding of cadmium to sulphur donating enzymes may partly explain the effect of small amounts of cadmium on living systems.

Long-term exposure to cadmium results in an irreversible tubular nephropathy that may develop into renal insufficiency. The cadmium-metlothionein complex is taken up almost quantitatively from the glomerular filtrate by epithelial cells of the proximal tubule and rapidly degraded by lysosomes. Although biosynthesis of metlothionein, in response to cadmium ions liberated by proteolysis, also occurs in these cells. It has been reported by a number of authors that part of the cadmium ions escapes this cytosolic binding system and reaches other subcellular targets (such as the mitochondria and the nucleus). As a result, the reabsorption of low molecular weight proteins (including β 2-microglobulin), ions (calcium and phosphate) and small solutes (glucose and aminoacids) is irreversibly impaired.

The relationship between the critical concentration of cadmium in renal cortex and the early signs of tubular dysfunction in humans has been the subject of numerous studies in both groups of exposed workers and populations living in polluted areas. A limit of urinary cadmium excretion of approximately 4 μ g/g of creatinine has been derived from surveys conducted in the Ishikawa prefecture of Japan (Itai-Itai disease). Beyond this level the excretion of β 2-metlothionein-cadmium complex becomes pathological

Belgian studies have found evidence that the threshold of urinary cadmium for increased excretion of low molecular weight proteins, aminoacids and calcium is approximately 2 μ g/g. This is reached in 10 % of subjects in the general population and increases to 16 % of the population over the age of 60 . The retrospective study of the causes of mortality, from 1969 to 1976, indicates a very significant increase in mortality from nephrosis and nephritis in women over 60 and living in the Liege conurbation. This area has been markedly polluted by cadmium emissions from zinc smelters.

Although the Itai-Itai syndrome, in which renal insufficiency is associated with osteoporosis and osteomalacia, has been studied for more than twenty years, the precise pathogenic mechanism of this disease has not been fully established. It is not known whether bone demineralisation is secondary to nephrotoxic damage or results from a direct effect on bone tissue. Studies conducted in Japan strongly suggest that osteopathies and mortality, at least in women, are closely related to the kidney damage characterised by the urinary excretion of β -metallothionein-cadmium complex.

Three hypotheses have been formulated for osteotoxicity and partially confirmed by experiments on animals, tissue and cells in culture. The first involves an inhibition of the formation of the dihydroxylated metabolite of vitamin D₃ leading to a reduction in the incorporation of cadmium in the bone and ultimately to osteomalacia. The production of this active metabolite of vitamin D₃ is dependant on cyclic AMP, adenylate cyclase, parathyroid hormone and cytochrome(s) P-450, all of which are factors adversely affected by exposure to cadmium. The second hypothesis implies that cadmium counteracts the absorption of calcium in the small intestine, decreasing the bioavailability of this element and producing a decalcification of bone that is the primary characteristic of osteoporosis. The third proposes a disturbance of collagen in bone by inhibition of lysyl-oxidase.

Nutritional deficiencies (calcium and vitamin D), multiparity and hormonal factors are key factors in the development of cadmium-induced bone pathology. It has been reported that cadmium causes bone lesions in rodents when associated with a hypocalcic diet but this is at a lesser magnitude than that found in Itai-Itai patients. In Japanese women with renal dysfunction that was associated with bone damage or not, the isozyme of alkaline phosphatase originating from bone tissue was elevated by cadmium exposure. This indicates a direct effect of cadmium on bone mineralisation.

Many studies, mostly carried out more than 15 years ago, have demonstrated that chronic oral administration of low levels of cadmium to rats, via food or drinking water, causes a rise of arterial pressure. These studies indicate that the pressor effect of cadmium can only be observed in the presence of a range of experimental conditions (strain, composition of the diet, exposure time, etc). None of these studies have shown the mechanism(s) of the hypertensive effect of cadmium.

This is not surprising as blood pressure is regulated by many systems that may be mutually compensating. The pressor effect of cadmium may be regarded as a direct effect on vasculature, a functional damage to the kidneys and an altered liberation of neuromediators. Some surveys, on small groups of human with low-level environmental exposure, have found a positive association between the accumulation of cadmium and an increase in blood pressure. Other surveys have failed to confirm it or even have revealed negative correlations between the two variables.

None of the studies conducted in several cadmium-polluted districts in Japan, the United Kingdom, Belgium or in the United States have shown evidence of a positive relationship between blood pressure, the prevalence of cardiovascular diseases and urinary cadmium. Also, the significant increase in mortality in Japanese suffering from tubular proteinuria is not associated with a greater prevalence of hypertension and cardiovascular disease.

In rodents, acute intratesticular administration has long been shown to produce vascular lesions and interstitial oedema provoking a reduction in the production of androgens and a failure of spermiation. However, the effect of low-level exposure on male reproductive organs is less obvious. Data relating to man is very limited and indicates that moderate long-term exposure has little effect on male sterility. Pre- and post-natal exposure of female rats to cadmium produced a reduction of oestrogen production and development of the utero-ovarian function. This function is also affected in adult females, particularly with regard to the implantation and growth of the embryo.

Exposure to cadmium during successive pregnancies increases the amount of metal stored in the kidneys of mice and it has been suggested that in mammals, including man, maternal exposure produces a placental accumulation of the metal with a subsequent loss of zinc. He suggested that the decrease in placental Zn/Cd ratio observed in mothers that smoke tobacco, may be associated with a reduced foetal growth and consequently a decreased birth weight.

Cadmium appears to be both a direct and indirect mutagenic agent in both bacteria and mammalian cells. The most frequent chromosomic aberrations in eucaryote cells are ruptures and lacunae (gaps) rather than exchanges. Aneuploidy and blockade of meiotic division have also been found in yeasts and oocytes, demonstrating that cadmium acts as a

cytoskeletal poison. Studies of lymphocyte chromosomes from human subjects exposed to cadmium in the workplace or suffering from Itai-Itai have produced conflicting results.

Epidemiological data on groups of exposed workers in the USA and Europe has been collected from the beginning of 1960 and updated periodically. This shows a very clear relationship between long-term exposure to cadmium oxide dust and fumes and the prevalence of cancers of the respiratory tract and a weaker relationship to prostate cancers. Cadmium has been placed in group I of the IARC classification of carcinogens. No clear relationship between the prevalence of internal cancers and the dietary intake of cadmium has been shown in countries such as Japan and Belgium where environmental contamination is high. Limited data from Canada and the USA suggest that there may be a positive link between the overall level of environmental pollution by cadmium and prostate cancer.

Chlordane

Chlordane is a manufactured chemical that was used as a [pesticide](#) in the [United States](#) from 1948 to 1988. It does not occur naturally in the environment. It was sold by [Chevron](#) as a white powdery dust. When mixed with water it becomes a colourless to amber thick liquid. Until 1983, chlordane was used as a pesticide on crops like [corn](#) and [citrus](#) and on home lawns and gardens. Chevron specifically marketed it as an [ant](#) and termite killer.

Because of concern about damage to the environment and harm to human health, the [Environmental Protection Agency](#) (EPA) banned all uses of chlordane in 1983 except to control termites. In 1988, the EPA banned all uses of chlordane. The EPA recommends that a child should not drink water with more than 60 parts of chlordane per billion parts of drinking water (60 ppb) for longer than 1 day. EPA has set a limit in drinking water of 2 ppb.

Chlordane sticks strongly to soil particles at the surface and is not likely to enter groundwater and so as a result it can stay in the soil for over 20 years and breaks down very slowly. Chlordane does not dissolve easily in water. It affects animal species because it builds up in the tissues of fish, birds, and mammals.

Chlordane affects the [nervous system](#), the [digestive system](#), and the [liver](#) in people and animals. Headaches, irritability, confusion, weakness, vision

problems, vomiting, [stomach cramps](#), [diarrhea](#), and [jaundice](#) have occurred in people who breathed air containing high concentrations of chlordane or accidentally swallowed small amounts of chlordane. Large amounts of chlordane taken by mouth can cause [convulsions](#) and [death](#) in people.

According to the [ATSDR](#), a man who had long-term skin contact with [soil](#) containing high levels of chlordane had convulsions. Japanese workers who used chlordane over a long period of time had minor changes in liver function. Animals given high levels of chlordane by mouth for short periods died or had convulsions. Long-term exposure caused harmful effects in the liver of test animals. It is not known if chlordane affects the ability of people to have children or whether it [causes birth defects](#). Animals exposed before birth or while nursing developed behavioural effects later.

Chromium

Trivalent chromium (Cr(III), or Cr³⁺) is required in trace amounts for [sugar metabolism](#) in humans ([Glucose Tolerance Factor](#)) and its deficiency may cause a disease called [chromium deficiency](#). In contrast, [hexavalent chromium](#) is very toxic and mutagenic when inhaled. Cr(VI) has not been established as a carcinogen when not inhaled but in solution it is well established as a cause of allergic [contact dermatitis](#) (ACD). Recently it was shown, that the popular dietary supplement [chromium picolinate](#) complex generates chromosome damage in hamster cells. In the United States, the dietary guidelines for daily chromium uptake were lowered from 50-200 [µg](#) for an adult to 35 [µg](#) (adult male) and to 25 [µg](#) (adult female).[\[1\]](#)

Chromium metal and chromium (III) compounds are not usually considered health hazards, but [hexavalent chromium](#) (chromium VI) compounds can be [toxic](#) if orally ingested or inhaled. The lethal dose of poisonous chromium (VI) compounds is about one half teaspoon of material. Most chromium (VI) compounds are irritating to eyes, skin and mucous membranes. Chronic exposure to chromium (VI) compounds can cause permanent eye injury, unless properly treated. Chromium(VI) is an established human [carcinogen](#). [World Health Organization](#) recommended [maximum allowable concentration](#) in drinking water for chromium (VI) is 0.05 [milligrams](#) per [liter](#). Hexavalent chromium is also one of the substances whose use is restricted by the European [Restriction of Hazardous Substances Directive](#). Hexavalent chromium in contact with skin acts as both sensitizer and irritant. After entering the organism, it gets reduced to trivalent chromium, which then binds to proteins and

creates [haptens](#) which trigger immune system reaction. Once developed, chrome sensitivity becomes fairly persistent; in such cases, even contact with chromate-dyed textiles or wearing of chromate-[tanned leather](#) shoes can cause or exacerbate [contact dermatitis](#).

In an organism, hexavalent chromium undergoes reduction, first to metastable pentavalent chromium, then to trivalent chromium. Pentavalent chromium is a known carcinogen. If the material gets lodged in tissues (lungs are especially vulnerable here, followed by fine [capillaries](#) in kidneys and intestines), its long-term action may lead to cancerous growth. In some parts of [Russia](#), pentavalent chromium was reported as one of the factors of incidence of premature [senility](#). The OSHA PEL for airborne exposures to hexavalent chromium is 5 $\mu\text{g}/\text{m}^3$ (0.005 mg/m^3).

Researchers have recently reported discovering that [vitamin C](#) reacts inside human lung cells with chromium 6, causing massive DNA damage. Low doses of chromium 6, combined with vitamin C, produce up to 15 times as many chromosomal breaks and up to 10 times more mutations, compared with cells lacking vitamin C. Outside cells, vitamin C actually protects against the cellular damage caused by hexavalent chromium.

As chromium compounds were used in [dyes](#) and [paints](#) and the [tanning of leather](#), these compounds are often found in soil and [groundwater](#) at abandoned industrial site, now needing [environmental cleanup](#) and [remediation](#) per the treatment of [brownfield land](#). [Primer paint](#) containing hexavalent chromium is still widely used for [aerospace](#) and [automobile](#) refinishing applications.

DDT

DDT or Dichloro-Diphenyl-Trichloroethane is the first modern [pesticide](#) and is one of the best known synthetic pesticides. It was developed early in [World War II](#), and initially used with great effect to combat [mosquitoes](#) spreading [malaria](#), [typhus](#), and other [insect](#)-borne human diseases among both military and civilian populations, and as an agricultural [insecticide](#). The Swiss chemist [Paul Hermann Müller](#) of [Geigy Pharmaceutical](#) in Switzerland was awarded the [Nobel Prize in Physiology or Medicine](#) in [1948](#) "for his discovery of the high efficiency of DDT as a contact poison against several [arthropods](#)."

DDT is an [organochlorine](#) insecticide. It is a highly [hydrophobic](#), colorless, [crystalline](#) solid with a weak, chemical [odour](#). It is nearly [insoluble](#) in [water](#) but has a good solubility in most [organic solvents](#), [fats](#), and [oils](#). It

is moderately toxic, with a rat [LD50](#) of 113 mg/kg. DDT has potent insecticidal properties; it kills by opening [sodium ion channels](#) in insect [neurons](#), causing the neuron to fire spontaneously. This leads to spasms and eventual death. Insects with certain mutations in their sodium channel gene may be resistant to DDT and other similar insecticides. DDT resistance is also conferred by up-regulation of genes expressing [cytochrome P450](#) in some insect species.

DDT is a [persistent organic pollutant](#) with a [half life](#) of between 2-15 years, and is immobile in most soils. Its half-life is 56 days in lake water and approximately 28 days in river water. Routes of loss and degradation include runoff, volatilization, photolysis and [biodegradation](#) (aerobic and anaerobic). These processes generally occur slowly. Breakdown products in the soil environment are [DDE](#) (1,1-dichloro-2,2-bis(p-dichlorodiphenyl)ethylene) and [DDD](#) (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane), which are also highly persistent and have similar chemical and physical properties. These products together are known as [total DDT](#).

DDT and its metabolic products DDE and DDD [magnify](#) through the [food chain](#), with [apex predators](#) such as raptors having a higher concentration of the chemicals (stored mainly in body fat) than other animals sharing the same environment. In the United States, human blood and fat tissue samples collected in the early [1970s](#) showed detectable levels in all samples. A later study of blood samples collected in the later half of the [1970s](#) (after the U.S. DDT ban) showed that blood levels were declining further, but DDT or metabolites were still seen in a very high proportion of the samples. Biomonitoring conducted by the CDC as recently as 2002 shows that more than half of subjects tested had detectable levels of DDT or metabolites in their blood, and of the 700+ milk samples tested by the [USDA](#) in 2005, 85% had detectable levels of DDE.

DDT is a [toxicant](#) across a certain range of [phyla](#). In particular, DDT has been cited as a major reason for the decline of the [bald eagle](#) in the [1950s](#) and [1960s](#) as well as the [peregrine falcon](#). DDT and its breakdown products are toxic to embryos and can disrupt calcium absorption thereby impairing egg-shell quality. Studies in the 1960s and 1970s failed to find a mechanism for the hypothesized thinning, however more recent studies in the 1990s and 2000s have laid the blame at the feet of [DDE](#), but not all experts accept those claims. Some studies have shown that although DDE levels have fallen dramatically that eggshell thinness remains 10-12 percent thinner than pre-DDT thicknesses. In general, however, DDT in small quantities has very little effect on birds; its primary [metabolite](#),

DDE, has a much greater effect. DDT is also highly toxic to aquatic life, including [crayfish](#), [daphnids](#), [sea shrimp](#) and many species of [fish](#). DDT may be moderately toxic to some [amphibian](#) species, especially in the larval stages. In addition to acute toxic effects, DDT may [bioaccumulate](#) significantly in fish and other aquatic species, leading to long-term exposure to high concentrations.

The effects of DDT on human health are disputed since studies have yielded conflicting results.

- DDT is classified as "moderately toxic" by the US National Toxicological Program and "moderately hazardous" by WHO. It is not considered to be highly toxic, and in fact it has been applied directly to clothes or used in soap. Indeed, DDT has on rare occasions been administered orally as a treatment for [barbiturate](#) poisoning.
- Occupational exposure to DDT was associated with reduced verbal attention, visuomotor speed, sequencing, and with increased neuropsychological and psychiatric symptoms in a dose-response pattern (ie, per year of DDT application) in retired workers aged 55-70 years in Costa Rica. DDT or DDE concentrations were not determined in this study.
- In one 1969 study, 24 [cynomolgus monkeys](#) and [rhesus monkeys](#) fed 20 mg/kg of DDT for 130 months were compared to a [control group](#) of 17 monkeys. The study demonstrated "clear evidence of [hepatic](#) and [CNS](#) toxicity following long-term DDT administration." Although the exposed group developed two [malignancies](#) and three [benign tumors](#), compared to zero in the control group, statistically this is still "inconclusive with respect to a carcinogenic effect of DDT in nonhuman primates."
- In another study, humans voluntarily ingested 35 mg of DDT daily for about two years, and were then tracked for several years afterward. Although there was "suggestive evidence of adverse liver effects", no other adverse effects were observed.
- The [EPA](#), in 1987, classified DDT as class B2, a *probable* human [carcinogen](#) based on "Observation of tumours (generally of the liver) in seven studies in various mouse strains and three studies in rats. DDT is structurally similar to other probable carcinogens, such as DDD and DDE." Regarding the Human Carcinogenicity Data, they stated "The existing epidemiological data are inadequate.

Autopsy studies relating tissue levels of DDT to cancer incidence have yielded conflicting results. Three studies reported that tissue levels of DDT and DDE were higher in cancer victims than in those dying of other diseases. In other studies, no such relationship was seen. Studies of occupationally exposed workers and volunteers have been of insufficient duration to be useful in assessment of the carcinogenicity of DDT to humans.

- With detailed work history of chemical manufacturing workers to estimate DDT exposure, a nested case-control study reported occupational DDT exposure associated with increased pancreatic cancer risk. A weak association of self-reported DDT use with pancreatic cancer was reported in another case-control study. A report indicated a higher standardised mortality ratio for pancreatic cancer in outdoor workers with a history of DDT exposure of less than 3 years, but the standardised mortality ratio of DDT workers with exposure of 3 years or more was not significantly raised.
- A study examined 35 workers exposed to 600 times the average DDT exposure levels over a period of 9 to 19 years. No elevated cancer risk was observed.^[34]

The journal *Cancer* recently published a review of all of the epidemiological studies on breast cancer and DDT and DDE published between 2000 and 2006. The authors state that "Positive findings for well-controlled studies in the early 1990s of associations between breast cancer risk and the insecticide DDT, its breakdown product DDE, and PCBs prompted additional study. Snedeker reviewed studies of DDT/DDE and dieldrin, concluding that existing research strategies provided conflicting and mostly negative evidence...Updating the picture to 2006 provides...essentially unchanged conclusions for DDT/DDE." Turning their attention to the recent studies, they conclude that "A few studies show elevated risk," but "most studies did not support an association of DDE and breast cancer overall or stratified by menopausal status, tumour hormone receptor status, parity, breast-feeding, or body mass index...In light of these findings, additional study of incident breast cancer in association with biological measures of DDE/DDT levels near the time of diagnosis is not a promising avenue."

DDT, like many other organochlorines, has been shown to have weak xenoestrogenic activity; meaning it is chemically similar enough to estrogen to trigger hormonal responses in contaminated animals. This hormonal-mimicking activity has been observed when DDT is used in

laboratory studies involving [mice](#) and [rats](#) as test [subjects](#), and available [epidemiological](#) evidence indicates that these effects may be occurring in humans as a result of DDT exposure. A recent study conducted by the [University of California, Berkeley](#) suggests children who have been exposed to DDT while in the womb have a greater chance to experience development problems.^[44]

A review article in [The Lancet](#) concludes:

"Although DDT is generally not toxic to human beings and was banned mainly for ecological reasons, subsequent research has shown that exposure to DDT at amounts that would be needed in malaria control might cause preterm birth and early weaning, abrogating the benefit of reducing infant mortality from malaria. ... DDT might be useful in controlling malaria, but the evidence of its adverse effects on human health needs appropriate research on whether it achieves a favourable balance of risk versus benefit."

Acute oral LD₅₀ for rats: 113-118, mice: 150-300, rabbits: 300, dogs: 500-750 and sheep and goats >1000 mg/kg. Acute percutaneous LD₅₀ for female rats is 2510 mg/kg. The no observable effect level (NOEL) for rats is 1 mg/kg diet and 17 people who consumed 0.5 mg/kg body weight daily for 1.75 years suffered no ill effect. The Codex JMPR (2000) allowable daily intake (ADI) is 0.01 mg/kg body weight and this is equivalent to 2 µg/L in water intake. DDT is moderately toxic to birds but is extremely toxic to fish and aquatic life. The LC₅₀ (96 hour) for Coho salmon: 4, rainbow trout: 7 and yellow perch: 9 µg/L. The LC₅₀ (48 hour) for daphnia is 1.10 µg/L and for *Crangon septemspinosa* (shrimp) is 0.4 µg/L.

Dieldrin

Dieldrin is a [chlorinated hydrocarbon](#) originally produced by [Bayer AG](#) as an [insecticide](#). The molecule has a ring structure based on [naphthalene](#). Dieldrin is closely related to [aldrin](#) which itself breaks down to form dieldrin. Aldrin is not toxic to insects, it is oxidised in the insect to form dieldrin that is the active compound. Both dieldrin and aldrin are named after the [Diels-Alder reaction](#) which is used to form aldrin from a mixture of norbornadiene and [hexachlorocyclopentadiene](#).

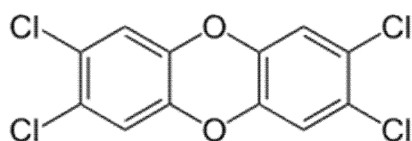
Originally developed in the [1940s](#) as an alternative to [DDT](#), dieldrin proved to be a highly effective insecticide and was very widely used

during the [1950s](#) to early [1970s](#). [Endrin](#) is a [stereoisomer](#) of dieldrin. However, it is an extremely [persistent organic pollutant](#), it does not easily [break down](#). Furthermore it tends to [accumulate](#) as it is passed along the [food chain](#). Acute (short-term) exposure is considered to be harmless[1], but long-term exposure has proven toxic to a very wide range of animals including humans, far greater than to the original insect targets. For this reason it is now [banned](#) in most of the world.

Dioxins

Dioxin is the common name for the group of compounds classified as polychlorinated dibenzodioxins (PCDDs). PCDDs, which are members of the family of [halogenated organic compounds](#), have been shown to [bioaccumulate](#) in humans and [wildlife](#) due to their [lipophilic](#) properties, and are known [teratogens](#), [mutagens](#), and suspected human [carcinogens](#). Dioxins are absorbed primarily through dietary intake of fat, as this is where they accumulate in animals and humans. In humans, the highly chlorinated dioxins are stored in fatty tissues and are neither readily metabolized nor excreted. The estimated elimination [half-life](#) for highly chlorinated dioxins (4-8 chlorine atoms) in humans ranges from 7.8 to 132 years.

The persistence of a particular dioxin congener in an animal is thought to be a consequence of its structure. It is believed that dioxins with few chlorines, which thus contain hydrogen atoms on adjacent pairs of carbons, can more readily be oxidized by [cytochromes P450](#). The oxidized dioxins can then be more readily excreted rather than stored for long time.



Structure of [2,3,7,8-tetrachlorodibenzo-p-dioxin](#) (TCDD)

2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is the most toxic of the [congeners](#). Other dioxin congeners (or mixtures thereof) are given a toxicity rating from 0 to 1, where TCDD = 1. This toxicity rating is called the Toxic Equivalence Factor, or TEF. TEFs are consensus values and, because of the strong species dependence for toxicity, are listed separately for mammals, fish, and birds. TEFs for mammalian species are generally applicable to human risk calculations. The TEFs have been

developed from detailed assessment of literature data to facilitate both risk assessment and regulatory control. Many other compounds may also have dioxin-like properties, particularly non-ortho [PCBs](#), some of which can have TEFs as high as 0.1.

The total dioxin toxic equivalence (TEQ) value expresses the toxicity as if the mixture were pure TCDD. The TEQ approach and current TEFs have been adopted internationally as the most appropriate way to estimate the potential health risks of mixture of dioxins. Recent data suggest that this type of linear scaling factor may not be the most appropriate treatment for complex mixtures of dioxins; further research into [non-linear](#) toxicity models is required to substantiate this hypothesis. Dioxins and other [persistent organic pollutants](#) (POPs) are subject to the [Stockholm Convention](#). The [treaty](#) obliges signatories to take measures to eliminate where possible, and minimize where not possible to eliminate, all sources of dioxin.

Dioxins build up primarily in fatty tissues over time ([bioaccumulate](#)), so even small exposures may eventually reach dangerous levels. In 1994, EPA reported that dioxin is a probable carcinogen, but notes that non-cancer effects (reproduction and sexual development, immune system) may pose an even greater threat to human health. [TCDD](#), the most toxic of the dibenzodioxins, has a half-life of approximately 8 years in humans, but at high concentrations, the elimination rate is enhanced by metabolism. The health effects of dioxins are mediated by their action on a cellular receptor, the [aryl hydrocarbon receptor](#) (AhR).

Dioxins also accumulate in food chains in a fashion similar to other chlorinated compounds ([bioaccumulate](#)). This means that even small concentrations in contaminated water can be concentrated up a food chain to dangerous levels due to the long biological half life and low solubility of dioxins.

Exposure to high levels of dioxin in humans causes a severe form of persistent [acne](#), known as [chloracne](#). Other effects in humans may include:

- Developmental abnormalities in the [enamel](#) of children's [teeth](#).
- Central and Peripheral Nervous System pathology
- Thyroid disorders

- Damage to the [Immune systems](#).
- [Endometriosis](#)
- [Diabetes](#)

While it has been difficult to prove that dioxins cause specific health effects in humans due to the lack of controlled dose experiments, studies in animals have shown that dioxin causes a wide variety of toxic effects. In particular, TCDD has been shown to be [teratogenic](#), [mutagenic](#), [carcinogenic](#), [immunotoxic](#), and [hepatotoxic](#). Furthermore, alterations in multiple [endocrine](#) and [growth factor](#) systems have been reported. The most sensitive effects, observed in multiple species, appear to be developmental, including effects on the developing [immune](#), [nervous](#), and [reproductive](#) systems. These effects are caused at [body burdens](#) close to those reported in humans.

Among the animals for which TCDD toxicity has been studied, there is strong evidence for the following effects:

- Birth defects ([teratogenicity](#)) in rodents, including rats, mice, hamsters and guinea pigs, birds; and fish.
- Cancer (including [neoplasms](#) in the mammalian lung, oral/nasal cavities, [thyroid](#) and [adrenal](#) glands, and liver, [squamous cell carcinoma](#), and various animal [hepatocarcinomas](#)) in rodents and fish.
- Hepatotoxicity (liver toxicity) in rodents, chickens and fish.
- Endocrine disruption in rodents and fish.
- Immunosuppression in rodents and fish.
- Learning

Dioxin exposure incidents:

- In [1949](#) in herbicide production plant for [2,4,5-T](#) in [Nitro, West Virginia](#) 240 people were affected when a relief valve opened.
- In [1963](#) a dioxin cloud escapes after an explosion in a [Philips-Duphar](#) plant (now [Solvay Group](#)) near [Amsterdam](#). In the [1960s](#)

Philips-Duphar produced 2250 [tonnes](#) of '[Agent Orange](#)' for the US Army.

- In [1976](#) large amounts of dioxin were released in an industrial [accident at Seveso](#), although no immediate human fatalities or birth defects occurred.
- In [1978](#), dioxin was one of the contaminants that forced the evacuation of the [Love Canal](#) neighborhood of [Niagara Falls, New York](#). Dioxin also caused the [1983](#) evacuation of [Times Beach, Missouri](#).
- In the [1960s](#), parts of the Spolana chemical plant in [Neratovice, Czechoslovakia](#), were heavily contaminated by dioxins, when the [herbicide](#) 2,4,5-T (also a component of [Agent Orange](#)) was produced there. Workers in this factory were exposed to high concentrations of dioxins at that time. Dozens of them fell seriously ill. A possibly large amount of dioxins was flushed from the factory into the [Labe](#) river during the [2002 European flood](#). No direct consequences of this incident have thus far been recorded.
- From [1982](#) through to [1985](#), [Times Beach, Missouri](#) was bought out and evacuated under order of the U.S. [Environmental Protection Agency](#) due to high levels of dioxin in the soil. The town eventually disincorporated.
- In December [1991](#), an electrical explosion caused dioxin (created from the oxidation of [Polychlorinated Biphenyl](#)) to spread through four [Residence Halls](#) and two other buildings on the college campus of [SUNY New Paltz](#).
- In May [1999](#), there was a dioxin crisis in [Belgium](#): quantities of dioxin had entered the [food chain](#) through contaminated [animal feed](#). 7,000,000 chickens and 60,000 pigs had to be slaughtered. This scandal was followed by a landslide change in government in the elections one month later.
- On [September 11, 2001](#) explosions released massive amounts of dust into the air. The air was measured for dioxin from September 23, 2001 to November 21, 2001 and reported to be "likely the highest ambient concentration that have ever been reported." [in history]. The [EPA](#) report dated October 2002 and released in December of 2002 titled "Exposure and Human Health Evaluation

of Airborne Pollution from the World Trade Center Disaster" authored by the EPA Office of Research and Development in Washington states that dioxin levels recorded at a monitoring station on Park Row near City Hall Park in [New York](#) between October 12 and 29, 2001 averaged 5.6 parts per trillion/per cubic meter of air, or nearly six times the highest dioxin level ever recorded in the U.S. Dioxin levels in the rubble of the [World Trade Centers](#) was much higher with concentrations ranging from 10 to 170 parts per trillion. The report did no measuring of the toxicity of indoor air.

- In a [2001](#) case study, physicians reported clinical changes in a 30 year old woman who had been exposed to a massive dosage (144,000 pg/g blood fat) of dioxin equal to 16,000 times the normal body level; the highest dose of dioxin ever recorded in a human. She suffered from [chloracne](#), [nausea](#), [vomiting](#), [epigastric](#) pain, [loss of appetite](#), [leukocytosis](#), [anemia](#), [amenorrhoea](#) and [thrombocytopenia](#). However, other notable laboratory tests, such as immune function tests, were relatively normal. The same study also covered a second subject who had received a dosage equivalent to 2,900 times the normal level, who apparently suffered no notable negative effects other than chloracne. These patients were provided with [olestra](#) to accelerate dioxin elimination.
- In [2004](#), a notable individual case of dioxin poisoning, [Ukrainian](#) politician [Viktor Yushchenko](#) was exposed to the second-largest measured dose of dioxins, according to the reports of the physicians responsible for diagnosing him. This is the first known case of a single high dose of TCDD dioxin poisoning, and was diagnosed only after a toxicologist recognized the symptoms of chloracne while viewing television news coverage of his condition.
- In the early 2000s, residents of the city of [New Plymouth, New Zealand](#), report many illnesses of people living around and working at the Dow Chemical plant. This plant ceased production of 2,4,5-T in 1987.
- 1,995 people are suing DuPont, claiming dioxin emissions from its plant in DeLisle, Mississippi caused their cancers, illnesses or loved one's death. In August 2005, Glenn Strong, an oyster fisherman with the rare blood cancer multiple myeloma, was awarded \$14 million from DuPont. In another case, parents claim dioxin from pollution caused the death of their 8 year old daughter. DuPont's

DeLisle plant is one of three titanium dioxide facilities (including Edge Moor, DE and New Johnsonville, TN) that are the largest producers of dioxin in the country, according to the US EPA's Toxic Release Inventory.

Endosulfan

Endosulfan is a neurotoxic [organochlorine insecticide](#) of the [cyclodiene](#) family of pesticides. It is highly [toxic](#) and an [endocrine disruptor](#), and it is banned in several countries including [Germany](#), [Norway](#), and the [Philippines](#). It is still used extensively in many countries including the [US](#) and [India](#). Endosulfan is one of the more toxic pesticides on the market today, responsible for many fatal pesticide poisoning incidents around the world. Endosulfan is also a [xenoestrogen](#), and it can act as an [endocrine disruptor](#), causing reproductive and developmental damage in both animals and humans. Whether endosulfan can [cause cancer](#) is debated.

Endosulfan is acutely [neurotoxic](#) to both [insects](#) and [mammals](#), including humans. The US EPA classifies it as Category I: "Highly Acutely Toxic" based on a [LD50](#) value of 30 mg/kg for female [rats](#), while the World Health Organization classifies it as Class II "Moderately Hazardous" based on a rat LD50 of 80 mg/kg. It is a [GABA-gated chloride channel antagonist](#) and a Ca^{2+} , Mg^{2+} [ATPase inhibitor](#). Both of these [enzymes](#) are involved in the transfer of nerve impulses. Symptoms of acute poisoning include include hyperactivity, tremors, convulsions, lack of coordination, staggering, difficulty breathing, nausea/vomiting, diarrhea, and in severe cases, unconsciousness. Doses as low as 35mg/kg have been documented to cause death in humans and many cases of sub-lethal poisoning have resulted in permanent brain damage. Farm workers with [chronic](#) endosulfan exposure are at risk of rashes and skin irritation.

EPA's acute [reference dose](#) for dietary exposure to endosulfan is 0.015 mg/kg for adults and 0.0015 mg/kg for children. For chronic dietary exposure, the EPA references doses are 0.006 mg/kg-day and 0.0006 mg/kg-day for adults and children, respectively. Endosulfan is listed as a known endocrine disruptor and both the EPA and the [Agency for Toxic Substances and Disease Registry](#) consider endosulfan to be a potential endocrine disruptor based numerous [in vitro](#) studies documenting its estrogenic activity and animal studies demonstrating its reproductive and developmental toxicity especially among males.

Several studies have documented that endosulfan can also effect human development. Researchers studying children from a village in northern

[Kerala](#), India have linked endosulfan exposure to delays in sexual maturity among boys. The village is situated in a valley with a large [cashew](#) plantation in the hills above. Endosulfan—and only endosulfan—had been applied aerially to the plantation for more than 20 years, and contaminated the village environment. The researchers compared the villagers to a control group of boys from a demographically similar village that lacked a history of endosulfan pollution. Relative to the control group, the exposed boys had high levels of endosulfan in their bodies, lower levels of [testosterone](#), and delays in reaching sexual maturity. [Birth defects](#) of the male reproductive system including [cryptorchidism](#) were also more prevalent in the study group. The researchers concluded, "our study results suggest that endosulfan exposure in male children may delay sexual maturity and interfere with sex hormone synthesis."^[2] Increased incidences of cryptorchidism have been observed in other studies of endosulfan-exposed populations.

Endosulfan is not listed as known, probable, or possible carcinogen by the USEPA, [IARC](#), or other agencies. There are no epidemiological studies linking exposure to endosulfan specifically to cancer in humans, but *in vitro* assays have shown that endosulfan can promote proliferation of human [breast cancer](#) cells. Evidence of carcinogenicity in animals is mixed.

According to the USEPA, endosulfan breaks down into endosulfan sulfate and endosulfan diol, both of which have "structures similar to the parent compound and are also of toxicological concern...The estimated half-lives for the combined toxic residues (endosulfan plus endosulfan sulfate) range from roughly 9 months to 6 years." The EPA concluded that, "based on environmental fate laboratory studies, terrestrial field dissipation studies, available models, monitoring studies, and published literature, it can be concluded that endosulfan is a very persistent chemical which may stay in the environment for lengthy periods of time, particularly in acid media." The EPA also concluded "endosulfan has relatively high potential to [bioaccumulate](#) in fish." The [EPA](#) recommends not more than 74 ppb (part per billion) in lakes, streams, or rivers, and not more than 0.1 - 2 ppm (parts per million) on surfaces of [agricultural products](#).

The acute oral LD₅₀ for rats is 70 mg (in aqueous suspension)/kg, 110 mg (in oil)/kg and for dogs is 77 mg/kg. The acute subcutaneous LD₅₀ for rabbits is 359 mg (in oil)/kg, for male rats is > 4000 and for female rats is 500 mg/kg. The inhalation LC₅₀ (4 hour) for male rats is 0.0345 and for female rats is 0.0126 mg/L. The NOEL for rats (2 years) is 155 mg/kg diet and for dogs (1 year) is 10 mg/kg diet. The acute oral LD₅₀ for mallard ducks is 205-245 and for ring-necked pheasants is 620-1000

mg/kg. Endosulfan is highly toxic to fish and other aquatic life, the LC₅₀ for golden orfe is 0.002 mg/L water, daphnia (48 hour) is 75-750 µg/L and the EC₅₀ (72 hours) for green algae is 0.56 mg/L. The Codex JMPR (1998) ADI is 0.006 mg/kg body weight.

Lead

Lead is a [chemical element](#) in the [periodic table](#) that has the symbol Pb ([Latin: plumbum](#)) and [atomic number](#) 82. A soft, [heavy](#), [toxic](#) and [malleable](#) metal, lead is bluish white when freshly cut but tarnishes to dull gray when exposed to air. Lead is used in building construction, [lead-acid batteries](#), [bullets](#) and [shot](#), and is part of [solder](#), [pewter](#), and fusible [alloys](#). Lead has the highest [atomic number](#) of all [stable elements](#) and like mercury, another heavy metal, lead is a potent [neurotoxin](#) which accumulates in soft tissues and bone over time.

Lead is a [poisonous](#) metal that can damage nervous connections (especially in young children) and cause blood and brain disorders. Long term exposure to lead or its salts (especially soluble salts or the strong oxidant PbO₂) can cause [nephropathy](#), and [colic](#)-like abdominal pains. The historical use of [lead acetate](#) (also known as *sugar of lead*) by the [Roman Empire](#) as a sweetener for wine is considered by some to be the cause of the [dementia](#) which affected many of the [Roman Emperors](#). At one point in time, some lead compounds, because of their sweetness, were used by candy makers. Although this has been banned in industrialized nations, there was a 2004 scandal involving lead-laced Mexican candy being eaten by children in California. The concern about lead's role in cognitive deficits in children has brought about widespread reduction in its use (lead exposure has been linked to [schizophrenia](#)). Lead-white paint has been withdrawn from sale in industrialised countries.

Lead salts used in pottery glazes have on occasion caused poisoning, when acid drinks, such as fruit juices, have leached lead ions out of the glaze.[\[citation needed\]](#) It has been suggested that what was known as "[Devon colic](#)" arose from the use of lead-lined presses to extract [apple](#) juice in the manufacture of [cider](#). Lead is considered to be particularly harmful for women's ability to reproduce. For that reason many universities do not hand out lead-containing samples to women for instructional laboratory analyses. Lead as a [soil contaminant](#) is a widespread issue, since lead may enter soil through (leaded) gasoline leaks from [underground storage tanks](#) or through a wastestream of lead paint or lead grindings from certain industrial operations.

Lead inhibits α -aminolevulinic acid (ALA) dehydratase and ferrochelatase, preventing both porphobilinogen formation and the incorporation of iron into protoporphyrin IX, the final step in heme synthesis. Inhibition of both of these steps results in ineffective heme synthesis and subsequent microcytic (hemoglobin-poor) anemia. The symptoms of chronic lead poisoning include neurological problems, such as reduced [IQ](#), or [nausea](#), [abdominal pain](#), [irritability](#), [insomnia](#), metal taste in oral cavity, excess [lethargy](#) or [hyperactivity](#), [headache](#) and, in extreme cases, [seizure](#) and [coma](#). There are also associated gastrointestinal problems, such as [constipation](#), [diarrhea](#), [vomiting](#), [poor appetite](#), [weight loss](#), which are common in acute poisoning. Other associated effects are [anemia](#), kidney problems, and reproductive problems.

In humans, lead toxicity sometimes causes the formation of a bluish line along the [gums](#), which is known as the "Burton's line", although this is very uncommon in young children. [Blood film](#) examination may reveal "basophilic stippling" of red blood cells, as well as the changes normally associated with iron deficiency anemia (microcytosis and hypochromia). A direct link between early lead exposure and extreme [learning disability](#) has been confirmed by multiple researchers and [child advocacy](#) groups.

Lead has no known biological role in the body. The toxicity comes from its ability to mimic other biologically important [metals](#), the most notable of which are [calcium](#), [iron](#) and [zinc](#). Lead is able to bind to and interact with the same [proteins](#) and [molecules](#) as these metals, but after displacement, those molecules function differently and fail to carry out the same reactions, such as in producing [enzymes](#) necessary for certain biological processes.

Most lead poisoning symptoms are thought to occur by interfering with an essential [enzyme](#) [Delta-aminolevulinic acid dehydratase](#), or ALAD. ALAD is a zinc-binding protein which is important in the biosynthesis of [heme](#), the cofactor found in [hemoglobin](#). Lead poisoning also inhibits the enzyme [ferrochelatase](#) which catalyzes the joining of [protoporphyrin IX](#) and Fe^{2+} to form a [Heme](#). Lead also interferes with excitatory neurotransmission by glutamate, which is the transmitter at more than half the synapses in the brain and is critical for learning. The glutamate receptor thought to be associated with neuronal development and plasticity is the N-methyl-D-aspartate ([NMDA](#)) receptor, which is blocked selectively by lead. This disrupts long-term potentiation, which compromises the permanent retention of newly learned information.

It has been known for some time that lead is a potent inhibitor of the NMDA receptor, a protein known to play an important role in brain development and cognition. Ezra Susser and his colleagues at Columbia University in New York followed 12,000 children born in Oakland, California, between 1959 and 1966, whose mothers had given samples of blood serum while they were pregnant, which were frozen and stored for later analysis. They found that children who had been exposed to high levels of lead in the womb were more than twice as likely to go on to develop schizophrenia. Their research was presented at the 2004 annual meeting of the American Association for the Advancement of Science in Seattle, Washington.

Outside of occupational hazards, the majority of lead poisoning occurs in children under age twelve. The main sources of poisoning are from ingestion of lead contaminated [soil](#) (this is less of a problem in countries that no longer have [leaded gasoline](#)) and from ingestion of lead dust or chips from deteriorating lead-based [paints](#). This is particularly a problem in older houses where the sweet-tasting lead paint is likely to chip, but deteriorating lead-based paint can also powder and be inhaled. Small children also tend to teeth and suck on painted windowsills as they look outside. Lead has also been found in drinking water. It can come from plumbing and fixtures that are either made of lead or have trace amounts of lead in them.

One measure of lead in the body is the [blood lead level](#) (BLL), measured in micrograms of lead per deciliter of [blood](#) ($\mu\text{g}/\text{dL}$). Nearly everyone has a measurable BLL. [The Centers for Disease Control and Prevention](#) (CDC) states that a BLL of $10 \mu\text{g}/\text{dL}$ or above is a cause for concern. However, lead can impair development even at BLLs below $10 \mu\text{g}/\text{dL}$.^[14] However, BLL measures current exposure to lead, but lead may also be incorporated into bone from prior exposures that will not show in BLLs until this bone-lead becomes "mobilized" through pregnancy or fracture healing. A fetus can be poisoned in utero if its mother had high bone-lead from either childhood exposure or a later occupational or other exposure that is subsequently mobilized by the fetal need for calcium. K-fluorescent X-ray metering can measure bone-lead.

The average person has less than 10 [micrograms](#) per [deciliter](#), or 100 [parts per billion](#), ppb, of lead in their blood. People who have been exposed to an unusual amount of lead will have blood lead levels higher

than 200 ppb—most clinical symptoms of lead poisoning begin at around 100 ppb. The effect on children's IQ has been noted at very low levels.

Mercury

Mercury, also called quick silver, is a [chemical element](#) in the [periodic table](#) that has the symbol Hg ([Latinized Greek](#): *hydrargyrum*, meaning *watery* or *liquid silver*) and [atomic number](#) 80. A heavy, silvery [transition metal](#), mercury is one of five elements that are [liquid](#) at or near room temperature and pressure (the others are the metals [caesium](#), [francium](#), and [gallium](#), and the [non-metal bromine](#)). Mercury is used in [thermometers](#), [barometers](#) and other scientific apparatus, though concerns about the element's toxicity have led to mercury thermometers being largely phased out in clinical environments in favor of [alcohol](#)-filled, digital or [thermistor](#)-based instruments. It remains in use in a number of other ways in scientific and scientific research applications, and in [dental amalgam](#). Mercury is mostly obtained by reduction from the [mineral cinnabar](#).

From the mid-18th to the mid-19th centuries, a process called "carroting" was used in the making of [felt hats](#). Animal skins were rinsed in an orange solution of the mercury compound [mercuric nitrate](#), $\text{Hg}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$. This process separated the fur from the pelt and matted it together. This solution and the vapors it produced were highly toxic. Its use resulted in widespread cases of [mercury poisoning](#) among hatters. Symptoms included [tremors](#), [emotional lability](#), [insomnia](#), [dementia](#) and [hallucinations](#). The [United States Public Health Service](#) banned the use of mercury in the felt industry in December 1941. The psychological symptoms associated with mercury poisoning may have inspired the phrase "mad as a hatter"

Compounds of mercury tend to be much more toxic than the element itself, and [organic compounds](#) of mercury are often extremely toxic. [Dimethylmercury](#), for example, is a potent [neurotoxin](#) that is lethal in amounts of a fraction of a milliliter. Mercury damages the [central nervous system](#), [endocrine system](#), [kidneys](#), and other organs, and adversely affects the mouth, gums, and teeth. Exposure over long periods of time or heavy exposure to mercury vapor can result in brain damage and ultimately death. Mercury and its compounds are particularly toxic to [fetuses](#) and infants. Women who have been exposed to mercury in pregnancy have sometimes given birth to children with serious birth defects.

Some of the toxic effects of mercury are reversible, either through specific therapy or through natural elimination of the metal after exposure has been discontinued. However, heavy or prolonged exposure can do irreversible damage, particularly in fetuses, infants, and young children. Exposure to certain highly toxic compounds of mercury such as dimethylmercury can be fatal within hours or less. Mercury exposure in very young children can have severe neurological consequences, preventing nerve sheaths from forming properly. Research has been done that demonstrates the inhibitory effect that mercury has on [myelin](#), the building block protein that forms these sheaths.

Mercury poisoning in the young is suspected as a possible cause of [autistic](#) behaviors, however there is a lack of quality [peer-reviewed](#) work on this matter and the claim of autism as mercury poisoning is considered suspect by mainstream medicine. Furthermore, the autistic community considers this theory offensive, as there is much evidence to suggest that autism is present from birth.

The mercury that is released in the environment ends up in surface water or soils eventually. When the [pH values](#) in acidic surface waters are between five and seven, the mercury concentrations in the water will increase. This is due to the mobilization of mercury in the ground near a water source. [Microorganisms](#) are able to convert the mercury that reaches the surface water to methyl mercury and most organisms absorb this substance quickly. Methyl mercury is also known to cause nerve damage. Fish are among the organisms that absorb methyl mercury in great amounts from water. As a consequence, methyl mercury accumulates in fish and passes into the food chain. The deleterious effects of mercury consumed by animals that eat fish include reproductive failure, damage to intestines, stomach disruption, DNA alteration, and kidney damage.

p-Cresol

Cresols are [organic compounds](#) which are methylphenols. They are a widely occurring natural and manufactured group of [aromatic organic compounds](#) which are categorized as [phenols](#) (sometimes called *phenolics*). In its [chemical structure](#), a cresol [molecule](#) has a [methyl group](#) substituted onto the [benzene ring](#) of a [phenol](#) molecule. There are three forms of cresols that are only slightly different in their chemical structure: *ortho*-cresol (*o*-cresol), *meta*-cresol (*m*-cresol), and *para*-cresol (*p*-cresol). Short-term and long-term studies with animals have shown similar effects from exposure to cresols. No human or animal

studies have shown harmful effects from cresols on the ability to have children. It is not known what the effects are from long-term ingestion or skin contact with low levels of cresols.

Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) are a class of [organic compounds](#) with 1 to 10 [chlorine](#) atoms attached to [biphenyl](#) and a general [chemical formula](#) of $C_{12}H_{10-x}Cl_x$. Most PCBs were manufactured as cooling and insulating fluids for industrial transformers and capacitors. PCB production was banned in the 1970s due to the high [toxicity](#) of most PCB [congeners](#) and mixtures. PCB's are classified as [persistent organic pollutants](#). Most of the 209 [congeners](#) of PCB are [colourless](#), [odourless crystals](#). The commercial mixtures are clear [viscous liquids](#) (the more highly chlorinated mixtures are more viscous, for example, Aroclor 1260 is a "sticky [resin](#)"). Although the physical and chemical properties vary widely across the class, PCBs have low [water solubilities](#) and low [vapor pressures](#). They are soluble in most organic [solvents](#), oils, and [fats](#). PCBs are very stable compounds and do not [degrade](#) readily.

PCBs may be destroyed by chemical, thermal, and biochemical processes, though it is extremely difficult to achieve full destruction, and there is the risk of creating extremely toxic [dibenzodioxins](#) and [dibenzofurans](#) through partial oxidation. Because of the high thermodynamic stability of PCBs, all degradation mechanisms are difficult to sustain. Intentional degradation as a treatment of unwanted PCBs generally requires high heat or [catalysis](#). Environmental and metabolic degradation generally proceeds quite slowly relative to most other compounds.

PCBs are [persistent organic pollutants](#) and have entered the environment through both use and disposal. The environmental transport of PCBs is complex and nearly global in scale. The public, legal, and scientific concerns about PCBs arose from research indicating they were likely [carcinogens](#) having the potential to adversely impact the environment and therefore undesirable as commercial products. Despite active research spanning five decades, extensive regulatory actions, and an effective ban on their production since the 1970s, PCBs still persist in the environment and remain a focus of attention.

The only North American producer, [Monsanto](#), marketed PCBs under the trade name Aroclor from [1930](#) to [1977](#). These were sold under trade names followed by a 4 digit number. The first two digits generally refer to the number of carbon atoms in the biphenyl skeleton (for PCBs this is

12), the second two numbers indicate the percentage of chlorine by mass in the mixture. Thus Aroclor 1260 has 12 carbon atoms and contains 60% chlorine by mass. An exception is Aroclor 1016, which also has 12 carbon atoms, but has 42% chlorine by mass. PCB mixtures have been used for a variety of applications, including [dielectric](#) fluids for [capacitors](#) and [transformers](#), heat transfer fluids, hydraulic fluids, [lubricating](#) and [cutting oils](#), and as additives in [pesticides](#), [paints](#), [carbonless copy \("NCR"\) paper](#), [adhesives](#), [sealants](#), [plastics](#), reactive [flame retardants](#), and as a [fixative](#) for microscopy. They were also used in surgical implants.

Manufacture peaked in the 1960s, by which time the electrical industry had lobbied congress to make them mandatory safety equipment, knowing all the while that they were extremely toxic. In 1966, they were discovered by Swedish chemist Dr. Soren Jensen as an environmental contaminant, and according to a 1994 article in [Sierra](#), it was Dr. Jensen who named them. Previously, they had been called "phenols" or referred to by various trade names, such as Aroclor, Kennechlor, Pyrenol and others. Their commercial utility was based largely on their chemical stability, including low [flammability](#), and desirable physical properties, including electrical insulating properties. Their chemical and physical stability has also been responsible for their continuing persistence in the environment, and the lingering interest decades after regulations were imposed to control environmental contamination.

[The General Electric Co.](#) discharged between 209,000 and 1.3 million pounds (94,800 and 590,000 kg) of PCBs into the [Hudson River](#) from two [capacitor](#) manufacturing plants located in [Hudson Falls, New York](#) and [Fort Edward, New York](#). Since that time, the spread of PCBs throughout the river and its [food chain](#) has created an extensive [toxic waste](#) problem. About 200 miles of the river is designated as a [Superfund](#) site. In 1976, because of the concern over the [bioaccumulation](#) of PCBs in fish and other aquatic organisms and their subsequent consumption by people, the State of New York banned fishing in the Upper Hudson River and commercial fishing of [striped bass](#), and several other species, in the Lower Hudson. In August 1995, the Upper Hudson was re-opened to fishing, but only on a [catch and release](#) basis.

From the late 1950's through 1977, [Westinghouse Electric](#) used PCBs in the manufacture of capacitors in its Bloomington, Indiana plant. Reject capacitors were hauled and dumped in area salvage yards and landfills. Workers also dumped PCB oil down factory drains that contaminated the city sewage treatment plant. The City of Bloomington gave away the sludge to area farmers and gardeners, creating anywhere from 200 to

2000 sites which remain unaddressed. Over 2,000,000 pounds of PCBs were estimated to have been dumped in Monroe and Owen Counties, making it the biggest concentration of PCBs in the world. Although federal and state authorities have been working on the site remediation, many areas remain contaminated. Concerns have been raised regarding the removal of PCBs from the [karst](#) limestone topography, and regarding the possible disposal options. To date, the Westinghouse Bloomington PCB Superfund site case does not have a RI/FS (Remedial Investigation/Feasibility Study) and ROD (Record of Decision), although Westinghouse signed a US Department of Justice Consent Decree in 1985.

PCBs have been detected globally, from the most urbanized areas that are the centers for PCB pollution, to regions north of the arctic circle. Typical urban atmospheric concentrations are in the picogram per cubic meter range. The atmosphere serves as the primary route for global transport of PCBs, particularly for those congeners with 1 to 4 chlorine atoms. The [toxicity](#) of PCBs to animals was first noticed in the 1970s when emaciated seabird corpses with very high PCB body burdens were washed up on beaches. The source(s) of the PCBs was (were) unknown though, because seabirds may die at sea and be washed ashore from a very wide area. Where they were found was no reliable indicator of where they had died.

The toxicity of PCBs varies considerably among congeners. The coplanar PCBs, known as non-ortho PCBs because they are not substituted at the ring positions [ortho](#) to (next to) the other ring, (i.e. PCBs 77, 126, 169, etc), tend to have [dioxin](#)-like properties, and generally are among the most toxic congeners. Because PCBs are almost invariably found in complex mixtures, the concept of toxic equivalency factors (TEFs) has been developed to facilitate risk assessment and regulatory control, where more toxic PCB congeners are assigned higher TEF values. One of the most toxic compounds known, [2,3,7,8-tetrachlorodibenzo\[p\]dioxin](#), is assigned a TEF of 1.

The most commonly observed [health effects](#) in people exposed to large amounts of PCBs are skin conditions such as [chloracne](#) and [rashes](#), but these were known to be symptoms of systemic poisoning dating back to the 1920s. Studies in exposed workers have shown changes in [blood](#) and [urine](#) that may indicate [liver](#) damage. PCB exposures in the general population are not likely to result in skin and liver effects. Most of the

studies of health effects of PCBs in the general population examined children of mothers who were exposed to PCBs.

Animals that ate food containing large amounts of PCBs for short periods of time had mild liver damage and some died. Animals that ate smaller amounts of PCBs in food over several weeks or months developed various kinds of health effects, including [anaemia](#); acne-like skin conditions ([chloracne](#)); and liver, [stomach](#), and [thyroid](#) gland injuries (including hepatocarcinoma). Other effects of PCBs in animals include changes in the [immune system](#), behavioural alterations, and impaired reproduction. PCBs are not known to cause birth defects in humans, although those that have [dioxin](#)-like activity are known to cause a variety of [teratogenic](#) effects in animals.

Women who were exposed to relatively high levels of PCBs in the workplace or ate large amounts of fish contaminated with PCBs had babies that weighed slightly less than babies from women who did not have these exposures. Babies born to women who ate PCB-contaminated fish also showed abnormal responses in tests of infant behaviour. Some of these behaviours, such as problems with motor skills and a decrease in short-term memory, lasted for several years. Other studies suggest that the immune system was affected in children born to and nursed by mothers exposed to increased levels of PCBs. The most likely way infants will be exposed to PCBs is from breast [milk](#). Transplacental transfers of PCBs were also reported. Because an infant will receive more than ten times the amount of PCBs from breast milk than it will for the rest of its life, it is being debated whether the benefits of breast-feeding are greater than the risks from exposure to PCBs.

Studies have shown that PCBs alter estrogen levels in the body and contribute to reproduction problems. In the womb, males can be feminized or the baby may be intersex, neither a male nor a female. Also, both sets of reproductive organs may develop. More instances of this are being reported. Biological magnification of PCBs has also led to polar bears and whales that have both male and female sex organs and males that cannot reproduce. This effect is also known as [endocrine disruption](#). Endocrine Disrupting Chemicals ([EDC's](#)) pose a serious threat to reproduction in top-level predators.

A few studies of workers indicate that PCBs were associated with specific kinds of [cancer](#) in humans, such as cancer of the liver and [biliary tract](#). Rats that ate food containing high levels of PCBs for two years

developed liver cancer. The USA Department of Health and Human Services (DHHS) has concluded that PCBs may reasonably be anticipated to be [carcinogens](#). The [US Environmental Protection Agency](#) (USEPA) and the [International Agency for Research on Cancer](#) (IARC) have determined that PCBs are probably carcinogenic to humans. PCBs are also classified as probable human carcinogens by the [National Cancer Institute](#), [World Health Organization](#), and the [Agency for Toxic Substances and Disease Registry](#). Recent research by the [National Toxicology Program](#) has confirmed that PCB126 (Technical Report 520) and a binary mixture of PCB126 and PCB153 (Technical Report 531) are [carcinogens](#).

As discussed, PCBs exhibit a wide range of toxic effects. These effects may vary depending on the specific PCB. Toxicity of coplanar PCBs (such as dioxin) and mono-ortho-PCBs may be primarily mediated via binding to [aryl hydrocarbon receptor](#) (AhR). Because AhR is a [transcription factor](#), abnormal activation may disrupt cell function by altering the [transcription](#) of [genes](#). The concept of toxic equivalency factors (TEF) is based on the ability of a PCB to activate AhR. However, not all effects may be mediated by the AhR receptor. For example, di-ortho-substituted non-coplanar PCBs interfere with intracellular [signal transduction](#) dependent on [calcium](#); this may lead to [neurotoxicity](#). Ortho-PCBs may disrupt [thyroid hormone](#) transport by binding to [transthyretin](#).

Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are [chemical compounds](#) that consist of fused [aromatic rings](#) and do not contain [heteroatoms](#) or carry [substituents](#) ^[1]. These compounds can be point source pollutants (e.g. oil spill) or non-point source (e.g. atmospheric deposition) and are one of the most widespread organic pollutants. Some of them are known or suspected [carcinogens](#), and are linked to other health problems. They are primarily formed by incomplete [combustion](#) of [carbon](#)-containing fuels such as [wood](#), [coal](#), [diesel](#), [fat](#), or [tobacco](#). [Tar](#) also contains PAHs. Since human civilization relies so heavily on combustion, PAHs are inevitably linked to our energy production. In this sense, PAH can be thought of as marker molecules as their abundance can be directly proportional to combustion processes in the region and therefore directly related to air quality. Different types of combustion yield different distributions of PAHs. Thus, those produced from coal burning are different than those produced by motor-fuel combustion, which differ from those produced by forest fires. Some PAHs occur within crude oil, arising from chemical conversion of natural product molecules, such as steroids, to aromatic hydrocarbons.

PAHs of three rings or more have low solubilities in water and a low [vapor pressure](#). As molecular weight increases, aqueous solubility and vapor pressure decrease. The aqueous solubility decreases approximately one order of magnitude for each additional ring. PAHs with two rings are more soluble in water and more volatile. Because of these properties, PAHs in the environment are found primarily in [soil](#) and sediment, as opposed to in water or air. PAHs, however, are also often found in particles suspended in water and air. Natural crude oil and coal deposits contain significant amounts of PAHs, as do combustion products and smoke from naturally occurring forest fires.

PAHs toxicity is very structurally dependent, with isomers (PAHs with the same formula and number of rings) varying from being nontoxic to being extremely toxic. Thus, highly carcinogenic PAHs may be small or large. One PAH compound, [benzo\[a\]pyrene](#), is notable for being the first chemical carcinogen to be discovered (and is one of many carcinogens found in [cigarette smoke](#)). The EPA has classified seven PAH compounds as probable human carcinogens: benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene.

Worksafe Australia has regulated for naphthalene that the eight hour time weighted average (TWA) exposure limit is 10 parts per million, with the short term exposure limit (STEL) concentration not to exceed 15 parts per million. *Australian Drinking Water Quality Guidelines (NHMRC and ARMCANZ, 1996)*: Benzo-(a)-pyrene: Maximum of 0.00001 mg/L (i.e. 0.00000001 g/L).

Polycyclic aromatic hydrocarbons have moderate to high acute (short-term) toxicity to aquatic life and birds. Some cause damage and death to agricultural and ornamental crops. They have moderate to high chronic (long-term) toxicity to aquatic life. Insufficient data are available on the acute or chronic toxicity to land animals. Polycyclic aromatic hydrocarbons are moderately persistent in the environment, and can bioaccumulate. The concentrations of polycyclic aromatic hydrocarbons found in fish and shellfish is expected to be much higher than the environment from which it was taken.

Selenium

Selenium is a [chemical element](#) with [atomic number](#) 34, with the chemical symbol Se. Selenium occurs only rarely in the free state in nature. It is a

[nonmetal](#) that is chemically related to [sulfur](#) and [tellurium](#). It is toxic in large amounts, but trace amounts of it, forming the active center of certain enzymes, are necessary for the function of all cells in (probably) all animals. Selenium requirements in plants differ by species, with some plants apparently requiring none. Although selenium is an essential [trace element](#) it is toxic if taken in excess. Exceeding the [Tolerable Upper Intake Level](#) of 400 micrograms per day can lead to selenosis.^[4] Symptoms of selenosis include a garlic odour on the breath, gastrointestinal disorders, hair loss, sloughing of nails, fatigue, irritability and neurological damage. Extreme cases of selenosis can result in [cirrhosis](#) of the liver, [pulmonary edema](#) and death.

Elemental selenium and most metallic [selenides](#) have relatively low toxicities because of their low [bioavailability](#). By contrast, [selenate](#) and [selenite](#) are very toxic, and have modes of action similar to that of arsenic. [Hydrogen selenide](#) is an extremely toxic, corrosive gas.^[6] Selenium also occurs in organic compounds such as dimethyl selenide, [selenomethionine](#) and [selenocysteine](#), all of which have high [bioavailability](#) and are toxic in large doses. [Selenium poisoning](#) of water systems may result whenever new agricultural runoff courses through normally-dry undeveloped lands. This process leaches natural soluble selenium compounds (such as selenates) into the water, which may then be concentrated in new "wetlands" as it evaporates. High selenium levels produced in this fashion have been found to have caused certain congenital disorders in wetland birds.

Tributyl tin

Tributyltin (TBT, Bu_3SnH) is a trialkyl [organotin](#) compound. Tributyltin compounds are a subgroup of the trialkyl organotin family of compounds. They are the main active ingredients in [biocides](#) used to control a broad spectrum of organisms. Uses include [wood preservation](#) and preservation, [antifouling](#) of boats (in marine [paints](#)), [antifungal](#) action in textiles and industrial water systems, such as cooling tower and refrigeration water systems, wood pulp and paper mill systems, and breweries. It is also used for control of [schistosomiasis](#) in various parts of the world. [Tributyltin oxide](#) is the widely used compound in TBT containing commercial products. TBT compounds are considered as toxic chemicals which have negative effects on human and environment. Tributyltin compounds are moderately to highly [persistent organic pollutants](#). One common example is leaching of TBT from marine paints into the aquatic environment, causing irreversible damage to the aquatic life.

TBT is harmful to some marine organisms, including the [dog whelk](#). TBT causes dog whelks to suffer from [imposex](#): females develop male sexual characteristics such as a penis. This causes them to become infertile or even die. In severe cases males can develop egg sacs. Studies have shown that wild, dead sea otters (*Enhydra lutra*) and stranded bottlenose dolphins can have extremely high levels of tributyltin in their livers. Both tributyltin and dibutyltin, a metabolite byproduct, cause immunosuppression, leading to secondary infections. This was supported by the finding that otters dying of infectious causes tend to have higher levels of tissue butyltins than those dying of trauma or other causes. Butyltin residues in Southern sea otters (*Enhydra lutris nereis*) were found dead along California coastal waters. *Environ. Sci. Technol.* 32:1169-1175).

TBT is extremely toxic to molluscs. In the case of bivalve larvae, the effective concentration (EC50) of TBT is 1000 times lower than that of any other toxic compound introduced into the marine environment (see Fig.15 on p. 134 in: His et al. 1999. The assessment of marine pollution - bioassays with marine embryos and larvae. *Adv Mar Biol* 37:3-178). TBT also causes imposex in marine gastropods and is probably responsible for reductions in their populations in zones with important ship traffic. It is reported to be an endocrine and immune system toxicant and ranked as 'most hazardous (worst 10%) to ecosystems by the USEPA.

USEPA Aquatic Life Criteria for Tributyltin (TBT)

Except possibly where a locally important species is very sensitive, saltwater aquatic life and their uses should not be affected unacceptably if the one-hour average concentration of TBT does not exceed 0.42 $\mu\text{g/L}$ more than once every three years on the average (acute criterion) and if the four-day average concentration of TBT does not exceed 0.0074 $\mu\text{g/L}$ more than once every three years on the average (chronic criterion).

I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance that I regard as relevant have to my knowledge been withheld from the panel.

Lindsay Swinden PhD
CEO
OMIC Australia