A Small Dose of Soil Pollution
Or
An Introduction to the Health Effects of Soil Pollution

A book chapter of
A Small Dose of Toxicology - The Health Effects of Common Chemicals
3rd edition

By
Steven G. Gilbert, PhD, DABT
Institute of Neurotoxicology & Neurological Disorders (INND)
Seattle, WA 98105

E-mail: sgilbert@innd.org

Supporting websites
web: www.asmalldoseof.org - "A Small Dose of Toxicology"
web: www.toxipedia.org - Connecting Science and People
# Toxicology of Soil Pollution

<table>
<thead>
<tr>
<th><strong>Name:</strong> Soil Pollutants</th>
<th><strong>Definition of soil pollution:</strong> contamination of the indoor or outdoor soil by any chemical, physical, or biological agent that modifies the natural characteristics of the soil, reducing its beneficial usability for people and/or ecosystems</th>
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<td><strong>Use:</strong> no desired use unless mining of pollutants</td>
<td><strong>Recommended daily intake:</strong> none (not essential)</td>
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<td><strong>Absorption:</strong> skin, inhalation, and gut system</td>
<td><strong>Sensitive individuals:</strong> fetus and children, women of childbearing age, the elderly, people with chronic health problems</td>
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<td><strong>Toxicity/symptoms:</strong> varies depending on the chemicals</td>
<td><strong>Regulatory facts:</strong> in the US the EPA sets some standards for soil pollutants</td>
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<td><strong>General facts:</strong> emissions of billions of pounds of chemicals and particulate matter every year from a wide range of products and industries including agriculture, and from combustion of fossil fuels such as coal and gasoline</td>
<td><strong>Environmental effects:</strong> widely distributed in environment, linked with climate change and acid rain, and can affect wildlife and ecological health</td>
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<td><strong>Recommendations:</strong> minimize soil pollution on a global scale, avoid exposure by children and other sensitive groups, expand research on toxicity and alternative sources of energy, adopt precautionary approach, reduce the use of fossil fuels and pesticides, support international treaties, reduce use of all materials that generate waste</td>
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Notable Soil Pollution Events

Tacoma Smelter
The Tacoma Smelter furnace was fired up on September 12, 1889 and began melting metal ores to extract copper, lead, and arsenic that were easily shipped by water and rail but contaminated the surrounding area. The smelter was known for its tall 562-foot smokestack, which sent pollutants up and away from the smelter into surrounding communities. While the smelter was permanently closed in 1986 and the stack demolished in 1993, the environmental damage was already complete. The American Smelting and Refining Company (ASARCO) operated a copper smelter on the shores of Commencement Bay in Ruston, near Tacoma, Washington for almost 100 years. The facility began its life as a lead smelter in 1889, and was converted to a copper smelter in 1902. It was sold to ASARCO in 1905.

Coal Ash
Coal ash is the material that is left after burning coal. The makeup of the ash varies depending on the type of the coal but it typically includes substantial amounts of silicon dioxide (SiO2), aluminum oxide (Al2O3), and calcium oxide (CaO), as well as varying amounts of arsenic, lead, beryllium, cadmium, chromium, mercury, selenium, and small concentrations of dioxins and PAH compounds. The challenge is finding something to do with the large volume of waste. Some of the ash is recycled into other products such as concrete, and the unused ash is often stored in large ponds. On December 22, 2008, the largest release of coal ash occurred when a dyke broke on the Tennessee Valley Authority's Kingston Fossil Plant in Roane County, Tennessee, USA and released 1.1 billion US gallons of coal ash slurry into the surrounding environment. This spill of muddy ash covered over 300 acres and destroyed several houses. The sludge and contaminants were dredged from the local river. Many fish were killed and the river was blocked for over a year.
Radiation Pollution

Chernobyl Exclusion Zones
A nuclear reactor at the Chernobyl Nuclear Power Plant in the city of Pripyat, Ukraine exploded and caught fire on April 26, 1986, releasing enormous amounts of radiation into western USSR and Europe and contaminating the soil and vegetation. Following the expulsion and release of radioactive cesium and strontium an exclusion area of approximately 1000 square miles was established to significantly limit human use. Radioactive cesium-137 has a half-life of about 30 years and is readily taken up animals and plants. Radioactive strontium-90 has a half-live of about 28 years, substitutes for calcium, and also bioaccumulates. Similar exclusion zones were also established near Fukushima, Japan following the nuclear disaster there on March 11, 2011. Radioactive soil at this scale is extremely difficult to deal with, only leaving the option of waiting for the natural decline in radioactivity.

Hanford Nuclear Reservation
Hanford Nuclear Reservation near Richland, WA is the most contaminated waste site in the Western Hemisphere. About two-thirds of the plutonium used during the Cold War to make and test nuclear weapons was created and extracted at Hanford, creating enormous contamination. Waste that contained a variety of compounds and radioactive materials would often be allowed to leak into soil or deliberately placed in trenches or ponds. The largest legacy that is already haunting future generations is 177 tanks that collectively hold 53 million gallons of hazardous waste. The tanks contain a witch’s brew of chemicals and radiological compounds, some in tanks that have leaked, or are leaking, into the soil.
Lead in Soil
Lead is probably one of the most serious and widespread soil contaminants. Lead exposure, particularly for children, is so serious that the US Centers for Disease Control and Prevention (CDC) lowered the blood lead action level to essentially 5 μg/dl and declared that there is no safe level of lead exposure. Lead exposure is common because lead is useful in a variety of applications and is relatively easy to mine. Soil near lead mines or other mining operations for other valuable metals such as silver or gold is often contaminated with lead. Lead ore is usually smelted, which can release large quantities of lead through smokestacks, distributing it over large areas. Children play in the dirt in their yards or neighborhood and then inhale or ingest the lead-laden dust. The lead-contaminated soil and dust are then tracked into the home, magnifying the family’s exposure. Children are not little adults in that not only are their developing organs more susceptible, they eat more, dink more, and breathe more per body weight than adults. In addition, lead was added to paint and gasoline. Lead-based paint can contaminate the soil around the home including in the garden and backyard. Lead from gasoline can also contaminate the soil along busy roadways. Fortunately, most uses of lead-based paint and gasoline have ended, but the contamination continues.

Introduction to Soil Contamination

In general soil is easily contaminated but it is far more difficult to clean up. Soil pollution or contamination is any change or addition to the soil that makes it harmful to plants or animals, including humans. Soil pollution is often difficult to separate from air and water pollution as there can be movement of the contaminant between these different media. Soil pollution is often associated with industrial activity or any intensive human activity.

Soil contamination can occur from spills of oil directly into the soil, from a smelter releasing contaminants such as lead and arsenic into the air which ultimately contaminate the soil, from a leaking home heating oil tank, from the waste from nuclear reactors, landfills, and illegal dumping of waste or industrial by products, and many other situations. Contaminated soil can act as a reservoir that gradually releases contaminants into the air or groundwater. Soil can also be tracked in to a car or home from a
contaminated area, increasing exposure to the contaminants, particularly by children. This had been well documented for lead and pesticides.

Ever since humans have started living in large communities, we have struggled with what to do with our waste. Improper disposal of human waste products can cause water contamination and lead to cholera. Sewage treatment plants combined with elaborate waste piping systems have largely solved this problem, but animal waste from large intensive farms remains a problem.

Tanks are another source of soil pollution. Tanks buried in the soil seem like a good idea until they start leaking. For example, there are thousands of home heating oil tanks buried in homeowners’ yards. Eventually these tanks leak and contaminate the soil and generate a costly cleanup bill. Larger commercial tanks, such as those at gas stations, have similar problems. Very large tanks were used at the Hanford Nuclear Reservation in Washington State to hold chemicals and radioactive material left after the extraction of plutonium. These tanks have leaked over a million gallons of contaminated waste into the soil but the material does not stop as it heads toward the Columbia River.

The point is that soil contamination can come from a wide variety of sources. It can be very difficult to characterize what chemicals are in the soil, and if they are migrating to a different place. Soil exposure also occurs in a wide variety of ways: kids eat it, our skin absorbs it, our shoes track soil indoors, and we are exposed to dirt in the home or the car.

**Examples of Soil Pollution**

**Radiological Contamination**

Soil contains radioactive elements that occur naturally or are released from human activities. Radon gas, for example, is a product of the natural radioactive decay of uranium. Radon particles can be inhaled into the lungs, where they undergo further decay, emitting energy that can damage DNA and cause lung cancer. Uranium is a naturally occurring element found in rocks and soil at varying concentrations. In the open, environment radon gas radially disperses so is of little concern, but hazardous levels can be reached in indoor environments of homes, schools, and workplaces, particularly in unventilated areas such as basements. (For more information on ionizing radiation see Chapter 13, A Small Dose of Radiation.)

About 2000 years ago uranium was used by the Romans to produce a yellow-colored glass but uranium became highly desirable during WW II as fuel for nuclear weapons. Uranium was mined around the world for generating plutonium and for fueling nuclear power reactors. The mining of uranium generated incredible amounts of radioactive contaminated soil. Despite the knowledge of the hazards of uranium and its daughter product radon, workers were not informed about the potential for lung cancer. The tailings and other contaminated soil were often left behind as the mines were abandoned.
Cleanup was left to others, including federal agencies. The Uranium Mill Tailings Radiation Control Act of 1978 was passed by the US Congress to address some of the cleanup. In 1990 the US Congress passed the Radiation Exposure Compensation Act, to compensate workers exposed to the hazards of mining uranium.

**Pesticides**

Soil is essential for life and has a very complex ecosystem all its own. A healthy soil promotes the growth of plant life and enhances the growth of food crops. Pesticides have long been used to manage seemingly undesirable plants, animals, insects, and fungi, and can be applied to the plant or to the soil. Pesticides become a problem or a pollutant when they harm humans or upset the ecological balance by harming desirable insects or wildlife. Some pesticides are highly persistent and accumulate in the environment and soil. From the soil the pesticide can be tracked into a worker’s home and expose family members. Soil fumigants are applied directly into the soil where they typically form a gas that can kill insects, fungi, or plants. The problem with pesticides and soil pollutants in general is that they can be blown by the wind and contaminate neighboring areas. Consideration must also be given to the entire pesticide product, which includes the active ingredient as well as other agents. These other ingredients are usually considered confidential business information but can include preservatives, petroleum products, and chemicals to aid distribution and absorption of the active ingredient.

**Lead Pollution**

Lead has been a well-known hazard for over 2000 years; Dioscorides first noted that “Lead makes the mind give way” in the 2nd century BC (see Chapter 8 on the health effects of lead). It is now acknowledged that there is no safe level of lead exposure for children. After 20 years, in 2011, the US CDC lowered the blood lead action level for children to effectively 5 µg/dL from 10 µg/dL. Prior to this the US EPA set lead soil contamination levels of 400 ppm for bare soil in residential areas and 1,200 ppm for industrial areas in an effort to provide children with a great level of protection. For uncontaminated or “natural” soil the level found was about 50 ppm. These numbers are difficult to establish because they are based on estimates of children’s soil consumption or exposure to contaminated soil. Ideally as the CDC lowered the blood lead level, the EPA would have lowered the acceptable soil lead level to less than 400 ppm.

Lead arsenate was widely used as a pesticide in apple orchards to control a variety of insects. The pesticide accumulated in the soil or was tracked indoors, exposing farmworkers’ family members. While the use of lead arsenate pesticides declined significantly after WW II, it was not banned by the EPA until 1988. Lead in soil became a problem as orchards were subsequently used for housing or schools.

Lead can also contaminate the soil of local gardens. The lead can come from airborne deposits from the past use of leaded gasoline or from flaking of lead-based paint. Vegetables that fruit above the ground generally do not accumulate lead, such as
tomatoes or squash. Vegetables that fruit in the ground, such as carrots or potatoes, tend to have higher concentrations of lead, and are also covered in the lead-contaminated dirt.

**Regulation of Soil Pollution**

Water and air pollution were usually the first to impact the health of people to a significant enough extent to provoke regulation. Soil pollution was not a priority because no one eats or breathes soil to survive. The increase in population, along with the Industrial Revolution and the development of radiological sciences, have generated large quantities of solid waste that contaminate soil. To address these issues the United States Congress passed a series of laws to regulate, manage, and reduce the amount of waste generated.

The US The Environmental Protection Agency (EPA) is responsible for enforcing all the solid waste laws. The first law to address solid waste was the Solid Waste Disposal Act (SWDA), an Act of Congress passed in 1965. This act was in response to the large volume of solid waste generated by businesses; it was common practice to dump waste in nearby landfills. SWDA was quickly recognized as not being strong enough as it was repeatedly amended. The Resource Recovery Act (RRA) of 1970 was the first to increase government involvement in waste management. Major revisions occurred when Congress enacted the Resource Conservation and Recovery Act (RCRA) of 1976. The primary goal of RCRA was to protect human health and the natural environment from the hazards of industrial waste.

**Regulations Related to Soil Pollution**

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<th>Year</th>
<th>Name</th>
<th>Comment</th>
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<td>1936</td>
<td>Soil Conservation and Domestic Allotment Act of 1936</td>
<td>Paid farmers to reduce production so as to conserve soil and prevent erosion</td>
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<tr>
<td>1965</td>
<td>Solid Waste Disposal Act (SWDA)</td>
<td>First federal effort to improve waste disposal technology</td>
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<tr>
<td>1970</td>
<td>Resource Recovery Act (RRA)</td>
<td>Increased government involvement in waste management</td>
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<tr>
<td>1976</td>
<td>Resource Conservation and Recovery Act (RCRA)</td>
<td>Regulated disposal of solid waste and hazardous waste</td>
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<tr>
<td>1984</td>
<td>The Hazardous and Solid Waste Amendments (HSWA)</td>
<td>Increased EPA involvement with hazardous waste and storage tanks</td>
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<td>1980</td>
<td>Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)</td>
<td>Identified polluters and recovered natural resource damages caused by hazardous substances (cleanup with Superfund)</td>
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**Recommendation and Conclusions**

Soil pollution comes in many forms, knows no boundaries, and is thus a regional, national, and international issue. Clean productive soil is an essential part of life as we know it. Like air and water, we must consider soil as an essential resource that needs to be protected and not spoiled with hazardous chemicals or exploited for short-term gain.

**More Information and References**

**Slide Presentation**

A Small Dose of Soil Pollution presentation material and references online: http://www.toxipedia.org or http://www.toxipedia.org/display/dose/Soil+Pollution
Website contains presentation material related to the health effects of soil pollution.

**European, Asian, and International Agencies**


North American Agencies


Non-Government Organizations


References


An excellent history of the use of lead arsenate pesticides


