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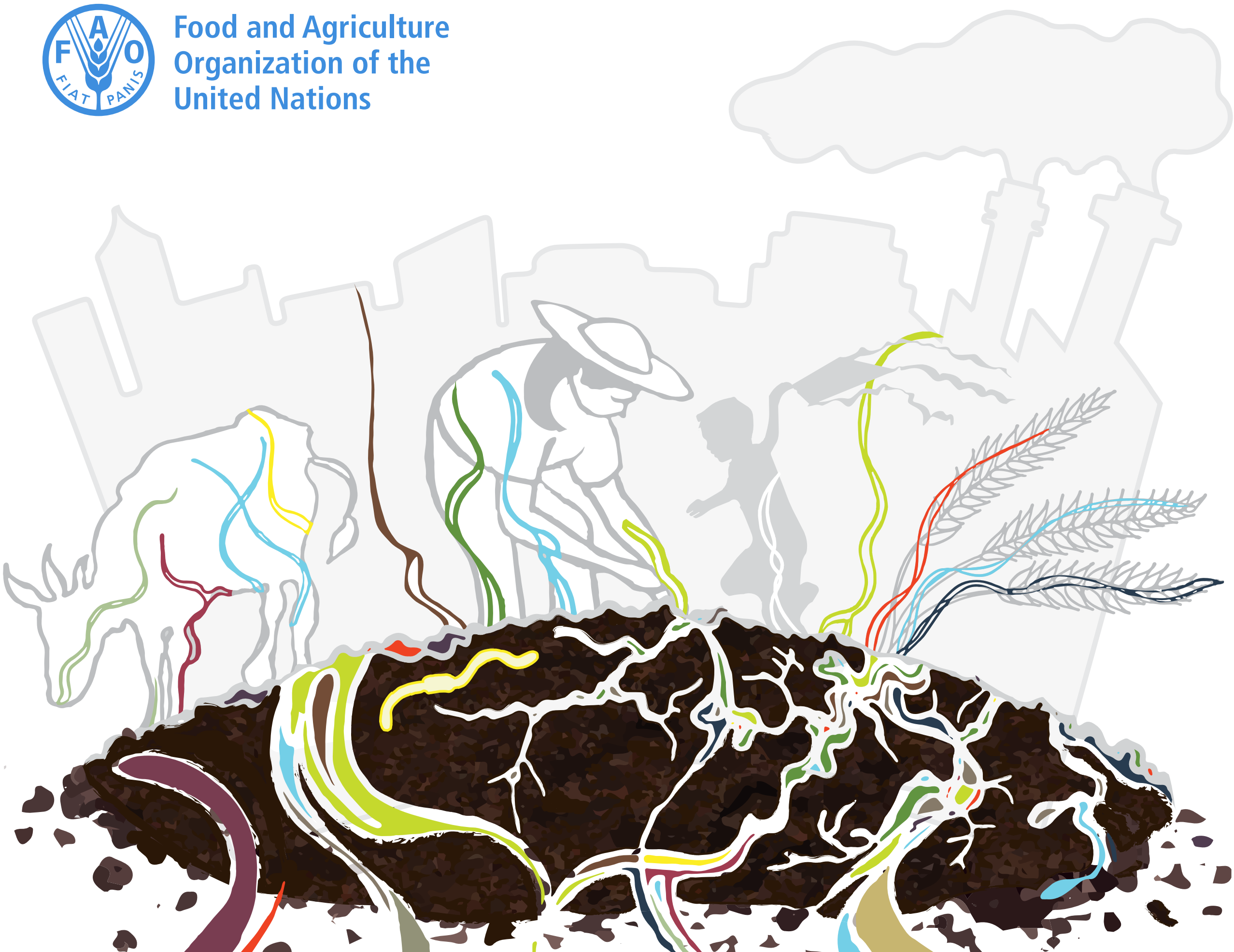

SOIL POLLUTION: A HIDDEN REALITY

GLOBAL SOIL PARTNERSHIP

SOIL POLLUTION A HIDDEN REALITY

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EXECUTIVE SUMMARY

"Soil pollution" refers to the presence in the soil of a chemical or substance out of place and/or present at a **higher than normal concentration** that has adverse effects on any non-targeted organism. Soil pollution often cannot be directly assessed or visually perceived, making it a hidden danger.

The Status of the World's Soil Resources Report (SWSR) identified soil pollution as one of the main soil threats affecting global soils and the ecosystems services provided by them.

Concerns about soil pollution are growing in every region. Recently, the United Nations Environmental Assembly (UNEA-3) adopted a resolution calling for accelerated actions and collaboration to address and manage soil pollution. This consensus, achieved by more than 170 countries, is a clear sign of the global relevance of soil pollution and of the willingness of these countries to develop concrete solutions to address the causes and impacts of this major threat.

The main anthropogenic sources of soil pollution are the chemicals used in or produced as byproducts of industrial activities, domestic, livestock and municipal wastes (including wastewater), agrochemicals, and petroleum-derived products. These chemicals are released to the environment accidentally, for example from oil spills or leaching from landfills, or intentionally, as is the case with the use of fertilizers and pesticides, irrigation with untreated wastewater, or land application of sewage sludge. Soil pollution also results from atmospheric deposition from smelting, transportation, spray drift from pesticide applications and incomplete combustion of many substances as well as radionuclide deposition from atmospheric weapons testing and nuclear accidents. New concerns are being raised about emerging pollutants such as pharmaceuticals, endocrine disruptors, hormones and toxins, among others, and biological pollutants, such as micropollutants in soils, which include bacteria and viruses.

Based on scientific evidence, soil pollution can severely degrade the major ecosystem services provided by soil. Soil pollution reduces food security by both reducing crop yields due to toxic levels of contaminants and by causing crops produced from polluted soils to be unsafe for consumption by animals and humans. Many contaminants (including major nutrients such as nitrogen and phosphorus) are transported from the soil to surface waters and ground water, causing great environmental harm through eutrophication and direct human health issues due to polluted drinking water. Pollutants also directly harm soil microorganisms and larger soil-dwelling organisms and hence affect soil biodiversity and the services provided by the affected organisms.

The results of scientific research demonstrate that soil pollution directly affects human health. Risks to human health arise from contamination from elements such as arsenic, lead, and cadmium, organic chemicals such as PCBs (polychlorinated biphenyls) and PAHs (polycyclic aromatic hydrocarbons), and pharmaceuticals such as antibiotics. The health risks associated with the widespread soil contamination by radionuclides from the Chernobyl disaster in 1986 are an enduring memory for many people.

Remediation of polluted soils is essential, and research continues to develop novel, science-based remediation methods. Risk assessment approaches are similar worldwide and consist of a series of steps to be taken to identify and evaluate whether natural or human-made substances are responsible for polluting the soil, and the extent to which that pollution is posing a risk to the environment and to human health. Increasingly expensive physical remediation methods such as chemical inactivation or sequestration in landfills are being replaced by science-based biological methods such as enhanced microbial degradation or phytoremediation.

FAO's *Revised World Soil Charter* recommends that national governments implement regulations on soil pollution and limit the accumulation of contaminants beyond established levels in order to guarantee human health and wellbeing, a healthy environment and safe food. Governments are also urged to facilitate remediation of contaminated soils that exceed levels established to protect the health of humans and the environment. It is also essential to limit pollution from agricultural sources by the global implementation of sustainable soil management practices.

This book aims to summarise the state of the art of soil pollution, and to identify the main pollutants and their sources affecting human health and the environment, paying special attention to those pollutants that are present in agricultural systems and that reach humans through the food chain. It concludes with some case studies of the best available techniques for assessing and remediating contaminated soils.

This book has been developed within the framework of the Global Symposium on Soil Pollution (GSOP18), identifying the main gaps in knowledge on soil pollution worldwide and serving as a basis for future discussions.

GLOSSARY

Contaminant: substance or agent present in the soil as a result of human activity (ISO, 2013).

Leaching: the dissolution and movement of dissolved substances by water (ISO, 2013).

Parent material: The original material (mineral and/or organic) from which soil developed by pedogenetic processes.

Persistent organic pollutant (POP): Synthesized carbon-based compounds from agrochemicals and industrial products that generally biodegrade very poorly and most of which will bioaccumulate in tissues of organisms. Some pesticides are POPs, as are Polychlorinated dibenzodioxins (PCDDs), Polychlorinated dibenzofurans (PCDFs), Polychlorinated biphenyls (PCBs), and Polycyclic aromatic hydrocarbons (PAHs).

Soil: the upper layer of the Earth's crust transformed by weathering and physical/chemical and biological processes. It is composed of mineral particles, organic matter, water, air and living organisms organized in genetic soil horizons (ISO, 2013).

Soil ecosystem functions: description of the significance of soils to humans and the environment. Examples are: (1) control of substance and energy cycles within ecosystems; (2) basis for the life of plants, animals and man; (3) basis for the stability of buildings and roads; (4) basis for agriculture and forestry; (5) carrier of genetic reservoir; (6) document of natural history; and (7) archaeological and paleo-ecological document (ISO, 2013).

Soil health: the continued capacity of the soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health (Doran, Stamatiadis and Haberern, 2002).

Soil ecosystem services: the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly (Groot, 1992).

Food security: it is defined as the availability, access, utilization and stability of food supply.

Soil contamination: occurs when the concentration of a chemical or substance is higher than would occur naturally but is not necessarily causing harm (this volume).

Soil pollution: refers to the presence of a chemical or substance out of place and/or present at higher than normal concentration that has adverse effects on any non-targeted organism (this volume).

2 | THE IMPACTS OF SOIL POLLUTION ON THE FOOD CHAIN AND ECOSYSTEM SERVICES

The predicted world's population of over nine billion by 2050 will require the provision of enough good quality food and water (Godfray *et al.*, 2010; McBratney, Field and Koch, 2014). According to Dubois (Dubois, 2011), food production will increase by 70 percent by 2050 globally, and by 100 percent in developing countries, compared with 2009 production levels. FAO's latest projections indicate that global food production will increase by 60 percent between 2005/07 and 2050 under its baseline scenario. This represents a downward revision, based on updated data and information, from the 70 percent increase projected for the same period in 2009. (World Agriculture Towards 2030/2050: The 2012 revision ESA E Working PaperNo. 12-03 http://www.fao.org/economic/esa/esag/en/). The quantity and nutritional quality of food supports human health, and 95 percent of food production depends on soils (Oliver and Gregory, 2015; FAO, 2015). Only healthy soils can provide the needed ecosystem services and secure supplies of more food and fibre. The provision of ecosystem services has received considerable attention and can be defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly" (Groot, 1992). Food security is defined as "the availability, access, utilization and stability of food supply." Soil pollution reduces food security both by reducing crop yields due to toxic levels of contaminants and by causing the produced crops to be unsafe for consumption (FAO and ITPS, 2015).

2.1 | SOIL POLLUTION, PLANT UPTAKE AND FOOD CHAIN CONTAMINATION

The pathways of contamination within the food chain by the transfer of soil pollutants through plants are shown in Figure 14.

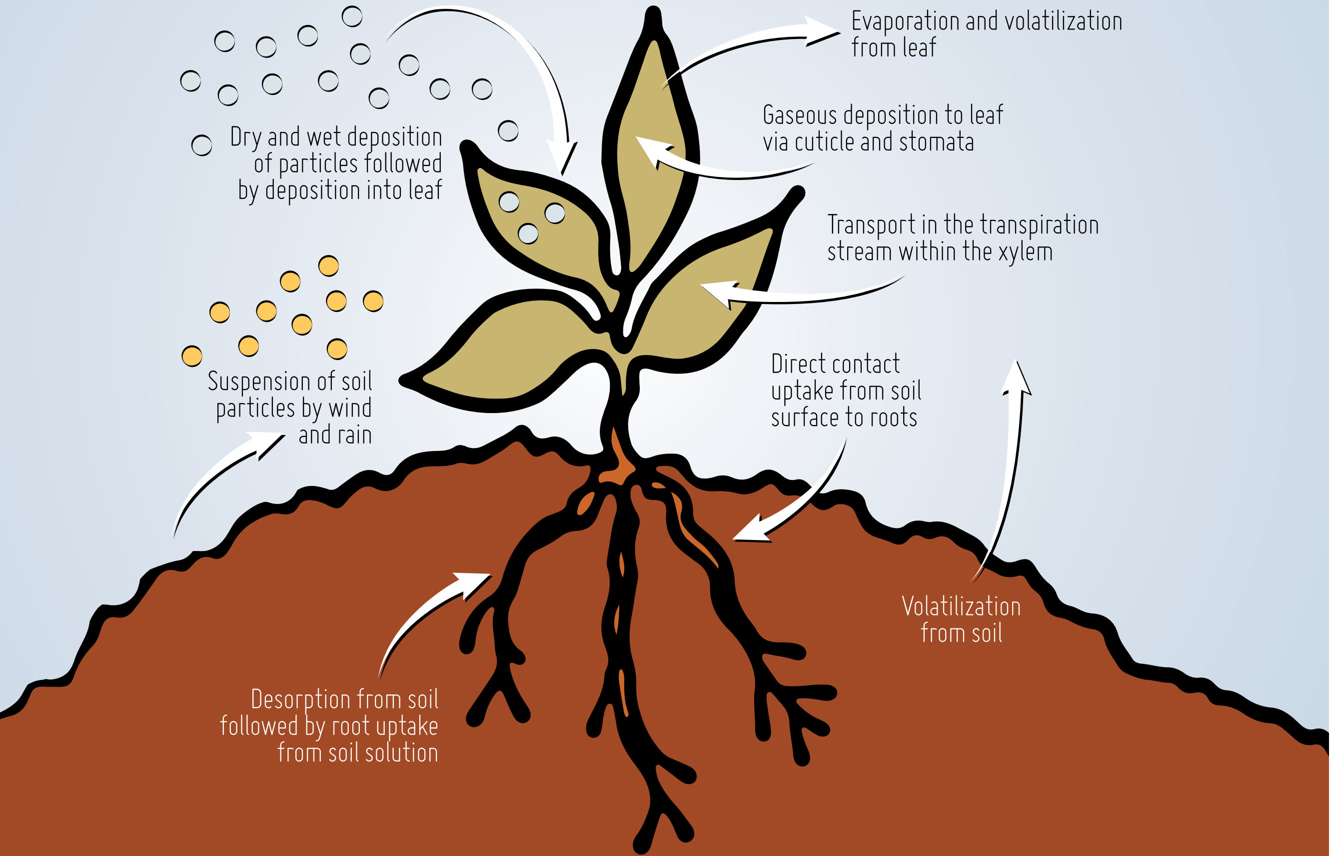

Figure 14. Principal uptake pathways for the uptake of soil contaminants by plants (adapted from Collins, Fryer and Grosso, 2006)

If a contaminant is highly toxic to plants at low concentrations and is not easily translocated to shoots, fruits or tubers to pose a hazard to animals and humans, it is unlikely to enter the food chain and become a hazard. This concept was termed the "Soil-Plant Barrier" by Chaney almost 40 years ago for metals and metalloids (Chaney, 1980). Chaney defined four groups of metals entering the food chain when sewage sludge was applied to soil, as a function of their danger to human health (Table 6).

Table 6. Metals/metalloids classified in groups according to potential food-chain risk via plant uptake.
Adapted from: Chaney, 1980

Group 1	Group 2	Group 3	Group 4
Silver (Ag)	Mercury (Hg)	Boron (B)	Arsenic (As)
Chromium (Cr)	Lead (Pb)	Copper (Cu)	Cadmium (Cd)
Tin (Sn)		Manganese (Mn)	Cobalt (Co)
Titanium (Ti)		Molybdenum (Mo)	Molybdenum (Mo)
Yttrium (Y)		Nickel (Ni)	Selenium (Se)
Zirconium (Zr)		Zinc (Zn)	Thallium (Tl)

Group 1 comprises the elements that pose a low risk of food chain contamination because they are not taken up by plants, due to their low solubility in soil, which means negligible uptake and translocation by plants. Elevated concentrations of these elements in foods usually indicate direct contamination through soil or dust accumulation. Group 2 includes elements that are strongly sorbed by soil surfaces, and while they may be absorbed by plant roots, they are not readily translocated to the edible tissues and therefore pose minimal risks to human health. These elements could, however, pose a risk to grazing animals (or humans) if contaminated soil is ingested. Group 3 comprises the elements that are readily taken up by plants, but that are phytotoxic at concentrations that pose little risk to human health. Conceptually, the "soil-plant barrier" protects the food chain from contamination by these elements. Group 4 consists of elements that are at the highest risk for food-chain contamination as they pose risks to human or animal health at plant tissue concentrations that are not generally phytotoxic. Chaney originally classified As in Group 2, but research over the last 20 years has indicated that flooded rice systems are at risk from As transfer through the food chain due to low redox conditions in flooded soils. This increases the solubility of As for uptake by rice and hence As should now be classified as a high-risk, Group 4 element. Contamination of soils by As and Cd is perhaps the most widespread risk to the food chain globally (Grant *et al.*, 1999; McLaughlin, Parker and Clarke, 1999), with large areas of South-East Asia having soils contaminated by As (Meharg, 2004) and Cd (Hu, Cheng and Tao, 2016).

In some parts of China, soils polluted by heavy metals are nevertheless used to grow grain. The grain grown in these soils is often in turn polluted with heavy metals. According to China Dialogue, an estimated 12 million tonnes of polluted grain must be disposed of each year, costing Chinese farmers up to CNY 20 billion, or about USD 2.57 billion (Lynn, 2017).

Excess heavy metals such as arsenic, cadmium, lead and mercury in soils can also impair plant metabolism and decrease crop productivity, ultimately putting pressure on arable land. When they enter the food chain, these pollutants also pose risks to food security, water resources, rural livelihoods and human health. The uptake and translocation of metals into above ground tissues are conditioned by genetic and physiological differences of plants (Chen, Li and Shen, 2004), as well as by the concentration of metals in the soil and the exposure time (Rizwan *et al.*, 2017; Tőzsér, Magura and Simon, 2017). Once metals enter plant tissues, they may interfere with several metabolic processes, reducing plant growth and causing toxicity and finally plant death. Decreases in germination rates, oxidative damage, lower roots and shoots elongation and alterations of sugar and protein metabolisms were the main effects reported (Ahmad and Ashraf, 2011). High levels of lead, for example, accelerate the production of reactive oxygen species, causing lipid membrane and chlorophyll damage that further leads to the alteration of photosynthetic processes and of the overall growth of the plant (Najeeb *et al.*, 2017). Cadmium can accumulate in different edible tissues (Baldantoni *et al.*, 2016), causing reduction of root, stem and leaf growth, decreasing net photosynthesis and water use efficiency and altering nutrient uptake (Rizwan *et al.*, 2017).

Radionuclides may also present a potential threat to food quality, through atmospheric deposition of radionuclides on soil from nuclear energy accidents, or the addition of radionuclides to the soil through fertilizers or through wastes and byproducts from the nuclear industry (Mortvedt, 1994). The potential for transfer of radionuclides from soil to plants and to the food chain was first identified in the 1950s both in restricted areas where nuclear weapons testing had taken place and more generally through deposition of fallout from bomb testing. The Chernobyl nuclear accident in 1986 caused widespread pollution of soils by radionuclides (principally ^{131}I, ^{134}Cs and ^{137}Cs) (Bell, Minski and Grogan, 1988). Uptake of pollutants from soils into forages was followed by the contamination of grazing animals and led to restrictions being placed on the sale and slaughter of sheep from affected areas in the United Kingdom of Great Britain and Northern Ireland (Smith *et al.*, 2000). Widespread contamination of the food chain by the same radionuclides also occurred after the Fukushima nuclear accident in Japan (Berends and Kobayashi, 2012).

Compared to metals, metalloids and radionuclides, the global footprint of soils that are highly contaminated by organic contaminants is much smaller, with contamination of the food chain being localized around industrial or urban centres. Contamination occurs through waste re-use on land and as a legacy of the use or disposal of persistent and bioaccumulative organic chemicals (principally organochlorines (OCs), polychlorinated dibenzo-p-dioxin (PCDD), polychlorinated dibenzofurans (PCDF) and poly- and perfluoroalkyl substances (PFAS)). Levels of soil contamination are usually lower than for metals/metalloids, generally in concentrations less than mg/kg in soil, especially for dioxins, furans and PFAS compounds.

The pathway of uptake of organic contaminants into the food chain depends on the properties of the organic contaminant – principally their volatility, hydrophobicity and solubility in water. Hydrophilic organic contaminants with low volatility (e.g. PFAS) will principally enter the food chain through root uptake and translocation to food parts (Navarro *et al.*, 2017). On the other hand, volatile hydrophobic contaminants (e.g. dioxins, furans and polychlorinated biphenyls (PCBs)) will tend to accumulate in the food chain through atmospheric uptake, as they are generally strongly sorbed in soils (Collins, Fryer and Grosso, 2006; Simonich and Hites, 1995). Some plant species, however, can accumulate these compounds through uptake from soil (Huelster, Mueller and Marschner, 1994). Sun *et al.*, were able to quantify organic pollutants and their residues in plants by measuring the uptake of ^{14}C-residues (Sun *et al.*, 2018). Many studies have demonstrated the uptake of pesticide residues through several main pathways. These residues are incorporated in plant tissues and transferred to the end consumer (Randhawa *et al.*, 2014). However, unlike metals and metalloids, the incidence and severity of adverse effects on human health caused by soil contamination by organic chemicals is much less well documented or demonstrated, likely because smaller areas of land are affected by this type of pollutant, and contamination levels are generally lower.

Atmospheric deposition and gas exchange through the stomata are the main mechanisms of absorption of POPs by plants; the pollutants are later translocated to other plant tissues and accumulated in their hydrophobic lipids and waxes (Odabasi *et al.*, 2016). Root uptake of POPs from soils is limited since POPs are tightly bound to soil particles (Collins, Fryer and Grosso, 2006). For that reason, soils can be viewed as a reservoir and as a source of POPs with low and medium volatility; these may enter the food chain after being taken up by plants from the atmosphere. Absorption efficiency of POPs across the gastro-intestinal tract and their storage and release dynamics are intimately linked to that of fat storage and metabolism (Sweetman, Thomas and Jones, 1999).

2.2 | IMPACT ON ECOSYSTEM SERVICES OF SOIL POLLUTION FROM AGRICULTURE

Entry of pollutants directly (release of effluents on land) or indirectly (use of polluted water as irrigation to crops) has been reported to contaminate vast areas of soil resources and groundwater bodies, affecting crop production as well as human and animal health through food contamination (Saha *et al.*, 2017).

Agricultural inputs such as fertilizers, pesticides, antibiotics contained in animal manure or the ones used for illness prevention and infection treatment in plants are major potential pollutants in agricultural lands and pose special challenges due to the fast-changing chemical formulas employed (GSP, 2017). Intensification of agriculture to produce enough food, fibre and biofuel has led to a heritage of polluted soils. In China, heavy metals contents have considerably increased in the last 30 years, with values oscillating between 48 percent for Zn to over 250 percent when Cd is compared with its background levels in 1990 (Zeng, Li and Mei, 2008). However, the transfer of pollutants from soil to plants is not yet well understood, and the question "is food produced in healthier soils also more nutritious?" needs stronger scientific evidence to engage policy makers, governments and land users towards sustainable and environmentally friendly practices and to leave behind more business-oriented approaches.

2.2.1 | SYNTHETIC FERTILIZERS

Modern agriculture practices accelerate soil pollution with the intensive use of fertilizer and pesticides in order to increase productivity and reduce crop losses. When pollutants reach high levels in the soil, not only do soil degradation processes take place, but crop productivity can also be affected. Therefore, in addition to endangering human health and the environment, soil pollution can also cause economic losses.

Excess N in soil has been identified as the main cause of soil acidification and salinization through nitrification and other N-transformation processes. Soils acidify very slowly under natural conditions over hundreds to millions of years (Guo *et al.*, 2010), but this process is significantly accelerated by agricultural practices, mainly excessive N fertilization, which causes reductions in soil pH by 0.26 pH units on average in different land uses (Lucas *et al.*, 2011; Tian *et al.*, 2015; Zhao *et al.*, 2014a). The analysis of acidification sources in agricultural soils in China demonstrated that anthropogenic acidification driven by N fertilization is indeed the main cause, being 10 to 100 times greater than that associated with acid deposition (Guo *et al.*, 2010).

2.2.3 | ACIDIFICATION AND CROP LOSS

Acidification of agricultural soils may contribute to further soil pollution, through the mobilization of toxic heavy metals. If the content of nitrogen applied to agricultural soils is higher than the plants' requirements, nitrification microbial activity will lead to the accumulation of nitrates (NO_3^-) that can easily leach to groundwater due to their high solubility, polluting it (Tian *et al.*, 2015). When soil nutrient availability increases, microbial biomass and activity increases as well, but the microbial biodiversity is altered, causing imbalances in the nutrient cycle (Lu and Tian, 2017).

The main risk from P fertilizers is transport to surface water bodies, which has been documented to cause eutrophication of aquatic ecosystems in many regions (Stork and Lyons, 2012; Syers, Johnson and Curtin, 2008). The P is transported to water bodies adsorbed to eroded soil particles or from excessive amounts of P fertilizer or animal manure applied when conditions are not suitable (Syers, Johnson and Curtin, 2008). Many farmlands receive more P inputs than the amount that crops are able to take up, causing a soil-P surplus, at least in the short term (Aarts, Habekotté and Keulen, 2000; Syers, Johnson and Curtin, 2008).

2.2.4 | PESTICIDES

An extensive review of scientific research about the effects of pesticide use on soil functions was recently undertaken by the Intergovernmental Technical Panel on Soil (FAO and ITPS, 2017). The main scientific-based evidence presented in this work showed an increase in the farmers' net return when they applied pesticides, however the benefits of pesticide use are usually assessed by comparing use of synthetic pesticides versus no use of pesticides rather than comparing synthetic pesticides to biological control of pests (Cai, 2008). Negative associated impacts of specific pesticides on soil organisms and soil functions have been also reported.

For example, some organochlorine pesticides suppress symbiotic nitrogen fixation, resulting in lower crop yields (Fabra, 1997; Fox *et al.*, 2007; Santos and Flores, 1995). The FAO and ITPS report also highlights the knowledge gap on the relationship between pesticides and soil health, mainly on soil pollution (FAO and ITPS, 2017). The international efforts to assess the ecotoxicological risk of pesticides and to control their use and release in the environment, through the Rotterdam and Stockholm Conventions (UNEP, 1998, 2001), constitute an important achievement in preventing and controlling soil pollution, but more information is needed regarding their specific interactions with soil components, their mobility in the soil matrix and possible plant uptake, and their effect on crop production (Arias-Estévez *et al.*, 2008). Especially for low and middle income countries not every single compound within the great variability of pesticides available in the market has been analyzed for its ecotoxicological effects before authorization (Aktar, Sengupta and Chowdhury, 2009). For example pesticides that have been taken off the market in High Income Countries (HICs) due to their severe adverse effects on human health and the environment frequently remain registered in Low and Middle Income Countries (LMICs). As pesticides residues can be found throughout the entire ecosystem, pesticide monitoring programmes about the level of residues in soils, surface and groundwater as well as and drinking water but particularly in food items are very important. However, in many low and middle income countries monitoring programmes are inexistent due to their scarcity of regulation capacity (Brodesser *et al.*, 2006).

2.2.5 | MANURE

Application of untreated manure may lead to heavy metal pollution, which not only results in adverse effects on various parameters relating to plant quality and yield, but also causes changes in the size, composition and activity of the microbial community (Yao, Xu and Huang, 2003) affecting nutrient cycling and reducing nutrient availability.

As previously discussed, a high proportion of antibiotics given to livestock is poorly assimilated in the animals' guts and is excreted in urine and faeces. Untreated manure can thus contain high amounts of veterinary antibiotics (VA) that can lead to a rapid increase in antibiotic resistance in soils (see Section 2.3.2). The fate and effects of antibiotics in soils have gained great attention in the last few years, motivated in part by the results of the O'Neill commission report (O'Neill, 2014), which estimates that antimicrobial resistant infections may become the leading cause of death in the world by 2050.

Most common intestinal pathogens that enter the soil with manure and faeces are *Salmonella*, *Campylobacter*, and *Escherichia coli* viruses. The pathogen levels decrease with time and with high temperatures that are reached during storage before land application (Garcia *et al.*, 2010). Once spread on the soil, pathogens can survive for several months or years.

2.2.6 | URBAN WASTES IN AGRICULTURE

Considering that the positive effects of sewage sludge amendment – such as waste reduction, nutrient cycling, increase of soil fertility, improvement of soil structure and water holding capacity – are significantly more important than the negative effects, efforts should focus on reducing the content of pollutants in sewage sludge and wastewaters used for irrigation. As highlighted by Petrie *et al.,* the lack of knowledge on the fate of emerging pollutants and other pollutants present in wastewater and sewage sludge can be solved only by analyzing them before land application (Petrie, Barden and Kasprzyk-Hordern, 2015).

Composting and pretreatments reduce the content of contaminants and pathogen organisms present in urban waste before their application as amendments in soils, and provide an economical and environmentally friendly approach for stabilizing animal waste and converting it into a worthy organic fertilizer. Frequently, however, high levels of heavy metals such as Pb, Cd, Cu, Zn, Cr, Ni, and salts remain in the amendments and may affect soil properties and inhibit plant growth (Bolan *et al.,* 2014; Hargreaves, Adl and Warman, 2008; Stasinos and Zabetakis, 2013; Stratton, Barker and Rechcigl, 1995). The heterogeneous composition of biosolids produced in different wastewater treatment plants requires chemical and biological investigation prior to soil application or incorporation (Bauman-Kaszubska and Sikorski, 2009; Bien, Neczaj and Milczarek, 2013). Limited bioavailability and crop uptake of metals from composted biosolids in comparison with untreated sewage sludge demonstrates the need for pretreatment before its application to soils (Smith, 2009).

2.3 | HUMAN HEALTH RISKS ASSOCIATED WITH SOIL POLLUTION

Oliver and Gregory summarise six soil-related human health risks (Oliver and Gregory, 2015). Of these, three are related to soil pollution: risks from elemental contamination (e.g. As, Cd, Pb); organic chemical contamination (e.g. PCBs, PAHs, POPs); and pharmaceutical contamination (e.g. estrogen, antibiotics). The three other risks are from soil pathogens such as anthrax and prions, micronutrient deficiencies, and under-nutrition due to degraded soils.

Long-term impacts of soil pollution on human health and the environment are still unclear, and many efforts are underway to better understand the mechanisms involved in natural attenuation and the health impacts of toxic pollutants (Bernhardt and Gysi, 2016). Urban soils deserve special attention because anthropogenic activities are concentrated on those soils, and the exposure patterns are more complex due to interactions with other health determinants such as nutrition, air quality, and access to health services for illness prevention (WHO, 2013). However, non-urban areas are also subjected to many different sources of pollution, frequently from diffuse sources, which makes it difficult to trace and to estimate their extent and risk. Future efforts related to soil pollution control and remediation should include these areas in their risk assessment approaches.

Hermes Rivera on Unsplash

2.3.1 | PATHWAYS OF EXPOSURE OF HUMANS TO SOIL POLLUTANTS AND THEIR EFFECTS ON HUMAN HEALTH

The main pollutants related to industrial, mining, urban and agricultural land uses have been widely discussed in the previous chapters. This section will focus on the soil pollutants that are the most relevant to human health and the risks associated with them.

The route of human exposure to a soil contaminant will vary depending on the contaminant itself and on the conditions and activities at a particular site (Shayler, McBride and Harrison, 2009). Generally, people can be exposed to contaminants present in soil through ingestion or through the consumption of plants or animals that have accumulated large amounts of soil pollutants (Khan *et al.*, 2015); through dermal exposure, from using spaces such as parks and gardens (Chaparro Leal, Guney and Zagury, 2018); or by inhaling soil contaminants that have been vapourized (Figure 15). Humans may also be affected as a result of secondary contamination of water supplies and from deposition of air contaminants (Science Communication Unit, University of the West of England., 2013); in some situations, soils play an important role as the source of contaminants in these two processes.

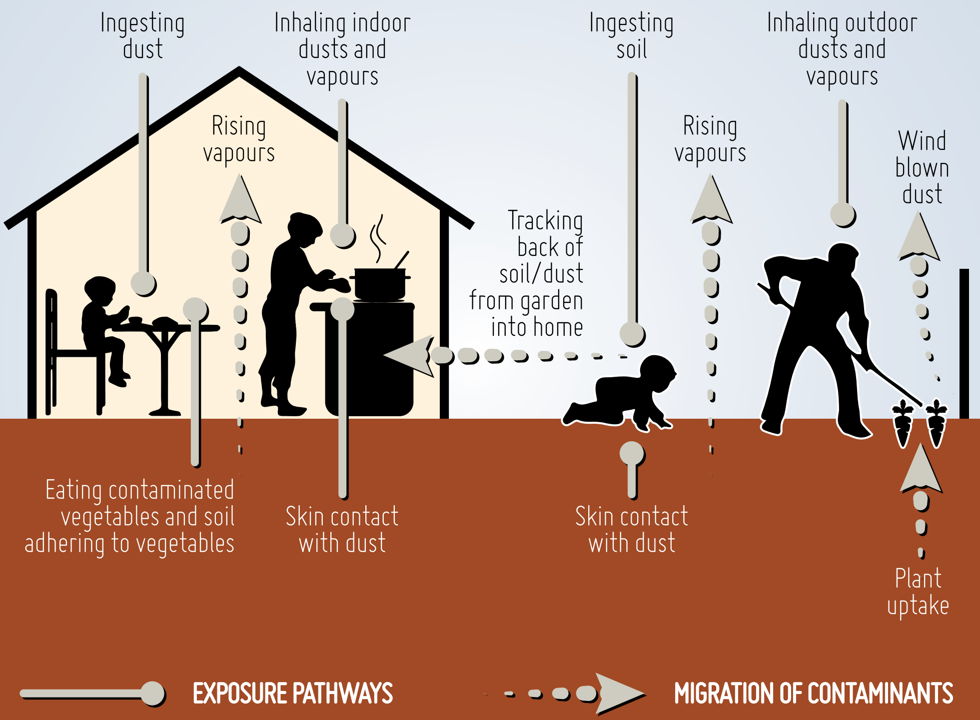

Figure 15. Possible exposure pathways of soil contamination in a residential scenario. Source: EA, 2008

Ten chemicals or groups of chemicals of major public health concern have been identified under the WHO's International Programme on Chemical Safety (WHO, 2010). The ten chemicals or groups of chemicals include soil pollutants such as, Cd, Pb and Hg; dioxin and dioxin-like substances and highly hazardous pesticides (HHP) - whose residues are transferred from contaminated soils to food and water bodies. HHPs are defined as those pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems or their listing in relevant binding international agreements or conventions. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous (FAO and WHO, 2016). All of them have chronic effects due to long-term exposure and children, pregnant women and malnourished people are particularly vulnerable to pesticide exposure. Pathogens present in soil may also contaminate food, posing risks to human health. More than 200 diseases – ranging from diarrhea to cancers – are related to contaminated food intake (WHO, 2017b) and 24 percent of the world's population suffers from infections by soil-transmitted helminth, causing nutritional imbalance and chronic anemia (WHO, 2017a).

The uptake of metals by plants from soils may result in a significant risk to health (Brevik, 2013; Burgess, 2013; Jordão *et al.*, 2006). The absorption by plant roots is one of the main routes of entrance of heavy metals into the food chain, and varies according to the level of consumption (Pan *et al.*, 2010; Wagner, 1993). Cadmium and lead are the most toxic elements for man (Volpe *et al.*, 2009). Food is the main source of Cd intake by humans. A well-known case was in Japan, where ingestion of rice contaminated with Cd generated the disease known as itaí-itaí (Abrahams, 2002). Cadmium absorbed via food intake can penetrate through the placenta during pregnancy, damaging membranes and DNA and disrupting the endocrine systems, and can induce kidney, liver and bone damage (Brzóska and Moniuszko-Jakoniuk, 2005; Souza Arroyo *et al.*, 2012). The toxic effects of Pb affect several organs, causing biochemical imbalance in the liver, kidneys, spleen and lungs, and causing neurotoxicity, mainly in infants and children (Guerra *et al.*, 2012; Jaishankar *et al.*, 2014). Organomercuric compounds, especially methylmercury, are considered highly toxic. Mercury may induce changes in human neural and gastric systems and can lead to death. Arsenic is absorbed in the body orally or inhaled and is stored mainly in the liver, kidneys, heart and lungs, with smaller amounts accumulating in muscle and nerve tissue, and has been defined as carcinogenic (Brevik, 2013). It can lead to nervous systems disorders, liver and kidney failure as well as anemia and skin cancer. Nickel causes gastric, liver, and kidney defects and neurological effects (Brevik, 2013). Zinc is associated with anemia and tissue lesions, and while the negative effects of copper are rare, liver and kidney damage in infants is possible if exposure is prolonged (Brevik, 2013).

An increasing awareness in terms of the importance of vegetables and fruits to human diet and the identification of food as the main source for many contaminants suggest that the monitoring of heavy metals in food crops should be carried out frequently. The World Health Organization and FAO developed the Codex Alimentarius (WHO and FAO, 1995), which identifies safe limits for contaminants present in fruits, vegetables, fish and fishery products, and animal feed.

Aktar, Sengupta and Chowdhury presented a review of pesticide residues in food commodities in the European Union (Aktar, Sengupta and Chowdhury, 2009). Even though the amount of pesticides residues in food did not exceed the acceptable daily intake (ADI), few studies have analyzed the long term risk associated with these persistent pollutants in organisms (Kim, Kabir and Jahan, 2017; Xu *et al.,* 2017). Hernández *et al.* highlighted the need for further studies of pesticide mixture effects on human health, because current legislation considers maximum residue levels (MRL) of individual pesticides in food and water, without taking into account possible synergetic interactions at their low concentrations (Hernández *et al.,* 2013). Occupational exposure to pesticides is associated with various diseases including cancer, hormone disruption, asthma, allergies, and hypersensitivity (Burgess, 2013; Van Maele-Fabry *et al.,* 2010).

Intake of persistent organic pollutants accumulated in soils has a high relevance for human health (Figure 16). The last results of the WHO/UNEP global monitoring plan (GMP) show that levels of PCDDs, PCDFs and PCBs in human milk are still significantly above those considered toxicologically safe in many regions of the world, with a higher incidence in India and in some European and African countries (van den Berg *et al.,* 2017). Ingestion of soils (geophagia) has been a common practice in many African and South American countries (Woywodt and Kiss, 2002) among children and pregnant and breast-feeding women, and its practice has extended to western societies (Reeuwijk *et al.,* 2013). The intake of contaminated clay with POPs and heavy metals is a soil-borne source of diseases, as daily exposure levels are frequently exceeded (Odongo, Moturi and Mbuthia, 2016). Bányiova *et al.* pointed out that the main source of POP exposure in the Czech Republic is through intake of polluted food (Bányiová *et al.,* 2017). Even though POP levels in human bodies have been reduced since the introduction of the Stockholm Convention, accidents still occur and they are an important source of soil and food contamination (Hilscherova *et al.,* 2007). The presence of POPs in human milk represents a high risk to the health of newborns and fetuses, as the POPs are circulating in the mother's body (Reeuwijk *et al.,* 2013).

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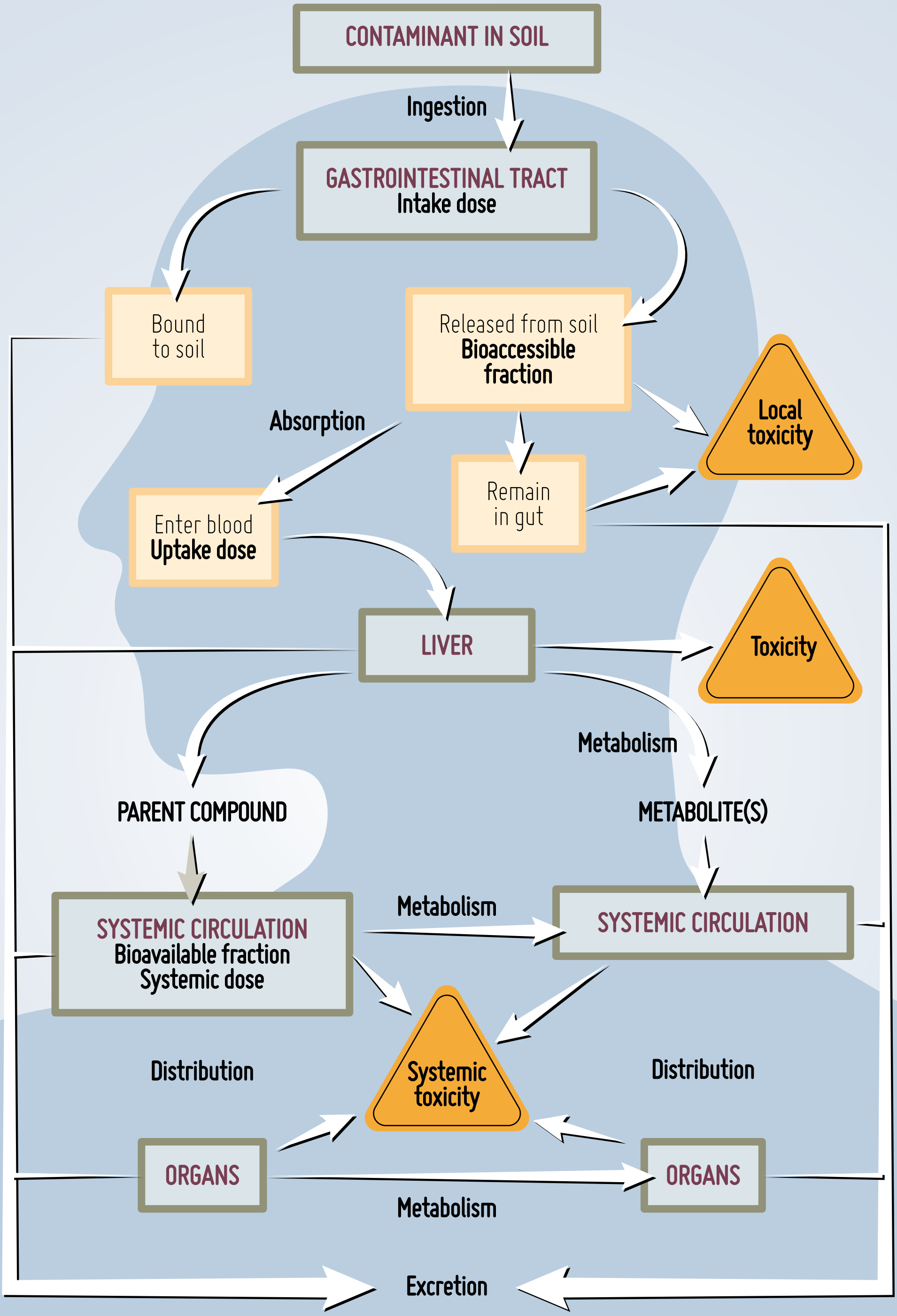

Figure 16. Simplified pathway for oral exposure to soil pollutants. Source: Hosford, 2008

The major exposure route for polycyclic PAHs is through contaminated food ingestion and they are a suspected carcinogenic risk (Brody *et al.*, 2007; Xia *et al.*, 2010). Due to the aromatic nature of PAHs, they easily penetrate cellular membranes and bind covalently with DNA molecules, where they may cause mutations (Muñoz and Albores, 2011). The establishment of a health risk assessment of PAHs would be complex because of the many uncertainties related to exposure and toxicity, which are still unsolved.

Regarding emerging pollutants, there are gaps in our understanding of how they behave in the environment, which interactions occur within the soil matrix, and their toxicity, bioaccumulation properties and transport mechanisms in human bodies, despite the already available information on exposure routes and levels in human tissues (Covaci *et al.*, 2011). Normally, these compounds appear at very low concentrations in human bodies, but the fact that many of them have only recently emerged as contaminants means that long-term studies that focus on the epidemiological aspects of this issue are needed.

Comprehensive assessments of the health effects of most forms of soil, heavy metals, and chemical pollution have not yet been published (Landrigan *et al.*, 2018). Basic toxicological data and knowledge on exposure routes and rates are needed in order to analyze the effects of soil pollutants on human health. A risk assessment based on a toxicological approach that considers tolerable doses is frequently used to establish hazard-related doses (Blume *et al.*, 2016; WHO, 2013). These acceptable doses are characterized for examining the harmful effects of individual substances on a person's health considering a conceptual exposure scenario that identifies sources, pathways and receptors.

As described in the WHO's report (WHO, 2013), there are several scientific tools that can be used to evaluate the risk posed to human health by soil pollution. Other models recently developed to assess the human exposure include BROWSE (Bystanders, Residents, Operators and WorkerS Exposure models for plant protection products) which contains more realistic scenarios (Butler Ellis *et al.*, 2017) and integrates large European guidance and regulatory databases to refine the assessment of human exposure (Lammoglia *et al.*, 2017). The real health risk assessment has not yet been well defined in the case of simultaneous exposure to two or more chemical substances, which occurs in real-life conditions and may have synergistic effects (Nicolopoulou-Stamati *et al.*, 2016).

2.3.2 | SOILS AS RESERVOIR OF ANTIMICROBIAL RESISTANT BACTERIA AND GENES

The transference of antibiotic resistance genes from the environment to human pathogens has created a great challenge due to an overall decrease in effectivity of antibiotics (Harbarth *et al.*, 2015; Thomas and Nielsen, 2005; WHO, 2018). As a result, infections persist in the body, increasing the risk of contamination of others (WHO, 2018). Each year approximately 700 000 deaths occur globally that are attributable to AMR bacteria; 25 000 deaths in Europe (EC, 2017) and around 23 000 in the United States of America (CDC, 2013). Furthermore, human health implications for intake of antibiotic residues and AMR bacteria present in food are largely unknown, although several potential adverse impacts have been observed.

These include allergic and toxic reactions or chronic toxic effects as a result of prolonged low-level exposure (McManus *et al.,* 2002; Sarmah, Meyer and Boxall, 2006). The risks of AMR are especially important in newborns, where AMR bacteria populate the newborns' guts (Brinkac *et al.,* 2017).

Soil is considered to represent a natural reservoir of antibiotic-resistant bacteria carrying a diverse set of known and unknown resistance determinants (Cytryn, 2013). Fungi and bacteria that occur naturally in the environment produce many antibiotics that humans have been using for centuries, and at the same time they have antibiotic-resistant genes against the antibiotics they produce (Hopwood, 2007). Allochthonous resistant bacteria and genes added to soil with manure or sewage sludge might not be well adapted to soil conditions as they are subject to selective pressure by native organisms (Heuer *et al.,* 2008).

When microorganisms (such as bacteria, fungi, viruses and parasites) are continuously exposed to antibiotics or another antimicrobial agent that kills or inhibits the growth of microorganisms, selection of resistant organisms occurs, even at low concentrations. As well, transference of the resistome (extrachromosomal antibiotic-resistant plasmids) or of the mutated genes inside the chromosome to other members of their own species and to other species occurs (Khachatourians, 1998).

Antibiotics are used worldwide for animal therapy and growth promotion in livestock production. A high percentage of these antibiotics are not assimilated by organisms' systems and are excreted into the environment. Assimilation rates by livestock depend on the pharmacokinetics and transformation of the antibiotics by the animal's metabolism. Heuer *et al.,* for example, found that more than 96 percent of the veterinary antibiotic sulfadiazine was excreted in its parental form or as metabolites ten days after administration to pigs (Heuer *et al.,* 2008). Excretion rates are lower for tetracyclines (Winckler and Grafe, 2001), but can reach high rates, over 90 percent for amoxicillin and difloxacine (Sukul *et al.,* 2009). Large amounts of these antibiotics end up in farm and urban wastes and soils, and they are not completely removed in wastewater treatment plants or during composting processes. Wastewater treatment plants were identified as the main source of antibiotic release into streams, with highly variable removal rates for different antibiotics (Michael *et al.,* 2013; Watkinson *et al.,* 2009).

Changes in soil microorganism communities and in crucial activities have been observed after the application of amendments to soil, promoting resistant populations (Ding *et al.,* 2014; Tian *et al.,* 2015; Tien *et al.,* 2017). Antimicrobial-resistant populations in manure may be responsible for the horizontal transference of resistant plasmid to soil-dwelling organisms, as confirmed under field conditions in manure-amended soils (Gotz and Smalla, 1997; Smit *et al.,* 1991). This transference process is promoted by the increase of nutrient sources, which activate microbial activity and population density (Ding *et al.,* 2014). Scientific evidence suggests that the presence of heavy metals, mainly Cu and Zn, in soils contributes to the co-selection of AMR (Grass, Rensing and Solioz, 2011; Hölzel *et al.,* 2012; Wales and Davies, 2015; Yu *et al.,* 2017). Mutations induced in soil microorganisms may lead to a range of metabolic phenotypes, including variations in the ability to use different carbon, nitrogen or phosphate sources (Perkins and Nicholson, 2008), altering global geochemical cycles (Allen *et al.,* 2010).

Wales and Davis also found that antimicrobial selection was enhanced by heavy metals even in the absence of antimicrobial substances when they were exposed to other biocides, such as disinfectants and antiseptics (Wales and Davies, 2015). Similar results were found in residential soils of Australia, where the high content of heavy metals stimulated the proliferation of antimicrobial-resistant genes (Knapp *et al.*, 2017). Thus, AMR becomes an even greater challenge in polluted soils. More research is needed to assess the risk of AMR spreading via sewage sludge and manure amendments (Bondarczuk, Markowicz and Piotrowska-Seget, 2016).

Antibiotic concentrations decrease rapidly after their entry in the soil through different processes (Figure 17), such as plant uptake, leaching to groundwater, sequestration in organic complexes, sorption to clay minerals or biodegradation (Jechalke *et al.*, 2014; Kuppusamy *et al.*, 2018). Despite this, an increase in resistant bacteria was observed even when antibiotic concentrations were very low (Gullberg *et al.*, 2011). Sequestration and sorption of antibiotics in soils reduce their bioavailability but increase their permanence and persistence in the environment (Jechalke *et al.*, 2014). The uptake of antibiotics by plants has been widely reported (Boxall *et al.*, 2006), and has gained attention as the food chain may be directly contributing to the spread of antibiotic resistance (Du and Liu, 2012). Furthermore, antibiotics may cause inhibition of seed germination and reduce crop growth (Du and Liu, 2012). If antibiotic-rich soils suffer any alteration that leads to changes in organic matter concentration and conformation (Gulkowska *et al.*, 2013), the sequestered antibiotics may be released in their bioavailable forms (Rosendahl *et al.*, 2011).

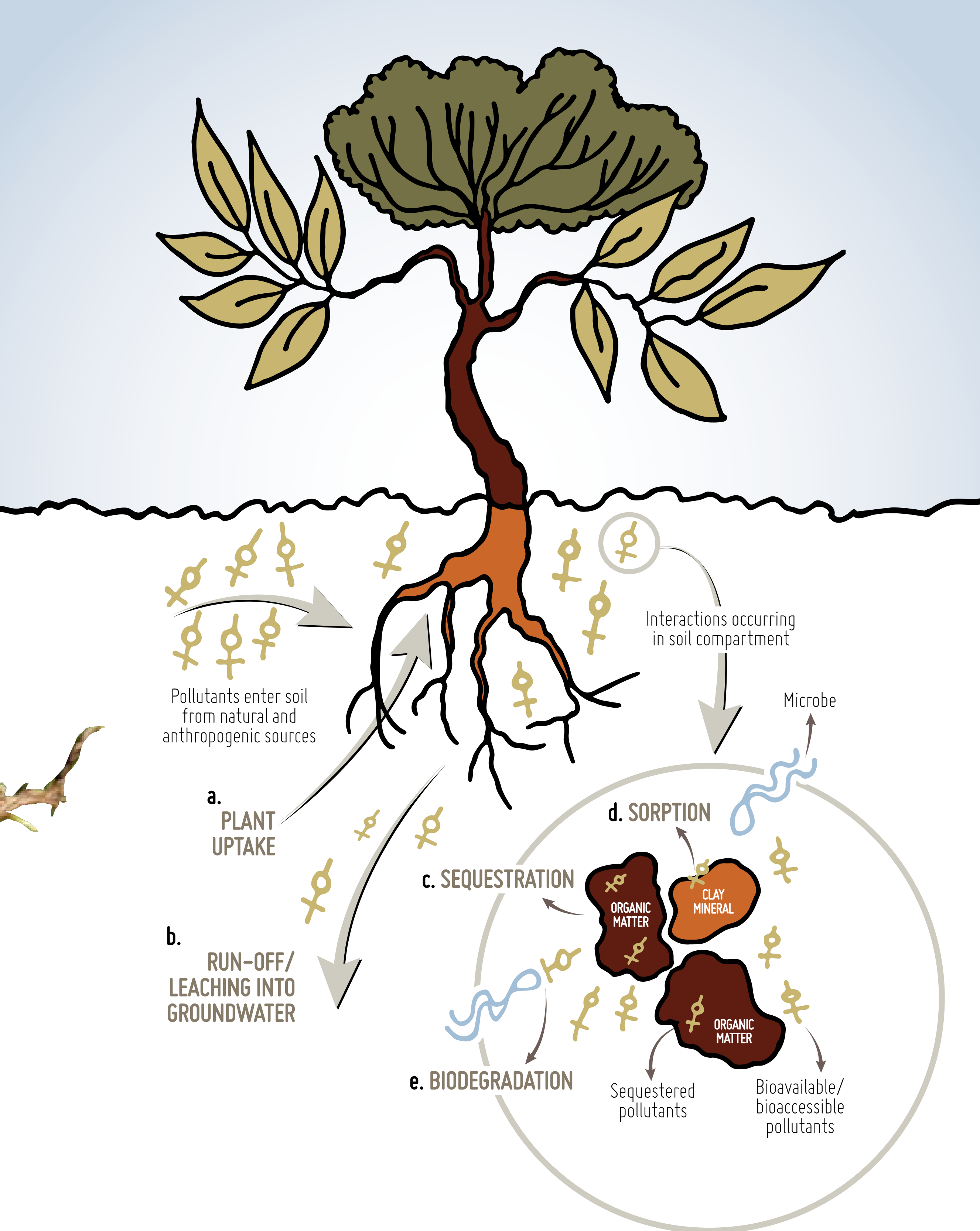

Figure 17. Fate of veterinary antibiotics in the environment. Source: Kuppusamy *et al.*, 2018

Different antibiotics have different target sites within cells; thus, organisms develop resistance to particular antibiotics and not a general resistance (Khachatourians, 1998). However, it has become more and more common to find multi-drug-resistant bacteria (CDC, 2013; EC, 2017; WHO, 2014). A recent study has shown a high co-presence of antibiotic-resistant genes and mobile genetic elements in a multi-drug-resistant bacteria community isolated from chicken manure (Yang *et al.*, 2017b). Bacteria present four main mechanisms that lead to antimicrobial resistance (Figure 18): 1) enzymatic degradation or modification of antibiotic compounds by intra and extracellular enzymes; 2) efflux pumps that actively remove antibiotic compounds outside the cell or in the periplasm; 3) modification or protection of the antibiotic binding site; and 4) natural or modified membrane permeability (Alekshun and Levy, 2007).

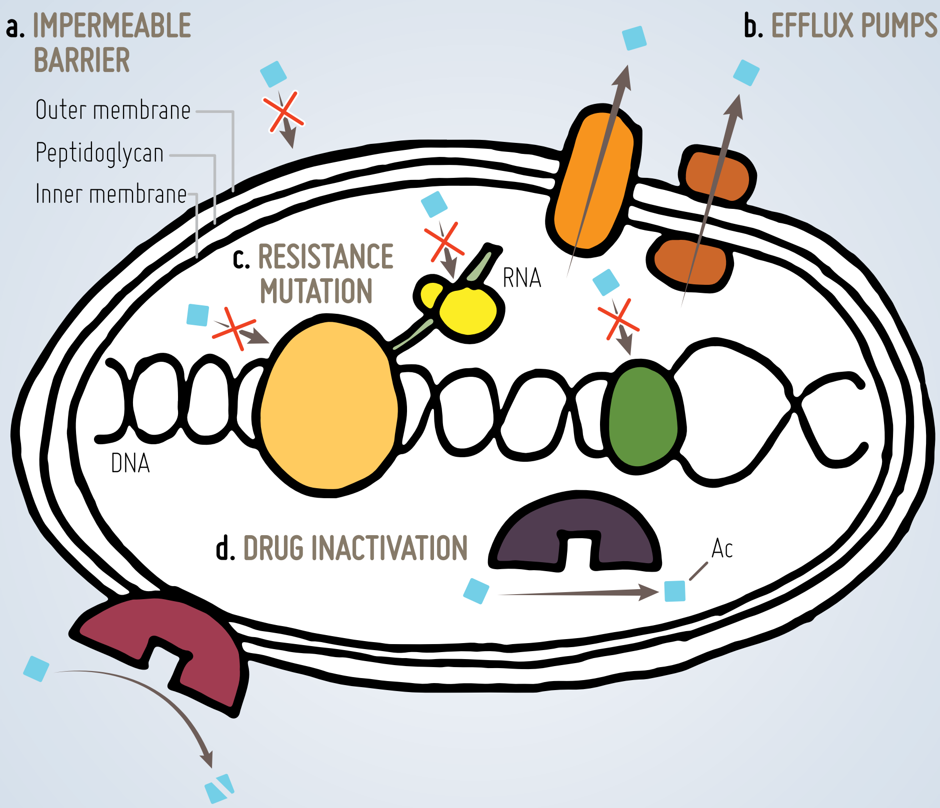

Figure 18. Main mechanisms of antimicrobial-resistance. Source: Allen *et al.*, 2010


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REFERENCES

Aarts, H.F.M., Habekotté, B. & Keulen, H. van. 2000. Phosphorus (P) management in the 'De Marke' dairy farming system. *Nutrient Cycling in Agroecosystems*, 56(3): 219–229. https://doi.org/10.1023/A:1009814905339

Abdel-Shafy, H.I. & Mansour, M.S.M. 2016. A review on polycyclic aromatic hydrocarbons: Source, environmental impact, effect on human health and remediation. *Egyptian Journal of Petroleum*, 25(1): 107–123. https://doi.org/10.1016/j.ejpe.2015.03.011

Abe, T., Ito, M., Takahashi, R., Honma, T., Sekiya, N., Shirao, K., Kuramata, M., Murakami, M. & Ishikawa, S. 2017. Breeding of a practical rice line 'TJTT8' for phytoextraction of cadmium contamination in paddy fields. *Soil Science and Plant Nutrition*, 63(4): 388–395. https://doi.org/10.1080/00380768.2017.1345598

Abrahams, P.W. 2002. Soils: their implications to human health. *Science of The Total Environment*, 291(1–3): 1–32. https://doi.org/10.1016/S0048-9697(01)01102-0

Absalom, J.P., Young, S.D. & Crout, N.M.J. 1995. Radio-caesium fixation dynamics: measurement in six Cumbrian soils. *European Journal of Soil Science*, 46(3): 461–469. https://doi.org/10.1111/j.1365-2389.1995.tb01342.x

Absalom, J.P., Young, S.D., Crout, N.M.J., Nisbet, A.F., Woodman, R.F.M., Smolders, E. & Gillett, A.G. 1999. Predicting Soil to Plant Transfer of Radiocesium Using Soil Characteristics. *Environmental Science & Technology*, 33(8): 1218–1223. https://doi.org/10.1021/es9808853

Ahmad, M.S. & Ashraf, M. 2011. Essential roles and hazardous effects of nickel in plants. *Reviews of environmental contamination and toxicology*, 214: 125–167. https://doi.org/10.1007/978-1-4614-0668-6_6

Aichner, B., Bussian, B., Lehnik-Habrink, P. & Hein, S. 2013. Levels and Spatial Distribution of Persistent Organic Pollutants in the Environment: A Case Study of German Forest Soils. *Environmental Science & Technology*, 47(22): 12703–12714. https://doi.org/10.1021/es4019833

Aktar, W., Sengupta, D. & Chowdhury, A. 2009. Impact of pesticides use in agriculture: their benefits and hazards. *Interdisciplinary Toxicology*, 2(1): 1–12. https://doi.org/10.2478/v10102-009-0001-7

Albanese, S., De Vivo, B., Lima, A. & Cicchella, D. 2007. Geochemical background and baseline values of toxic elements in stream sediments of Campania region (Italy). *Journal of Geochemical Exploration*, 93(1): 21–34. https://doi.org/10.1016/j.gexplo.2006.07.006

Albert, R.E. 1987. Issues in biochemical applications to risk assessment: how do we predict toxicity of complex mixtures? *Environmental Health Perspectives*, 76: 185–186.

Alekshun, M.N. & Levy, S.B. 2007. Molecular Mechanisms of Antibacterial Multidrug Resistance. *Cell*, 128(6): 1037–1050. https://doi.org/10.1016/j.cell.2007.03.004

Alexander, M. 1999. *Biodegradation and bioremediation*. 2nd ed edition. San Diego, Academic Press. 453 pp.

Allen, H.K., Donato, J., Wang, H.H., Cloud-Hansen, K.A., Davies, J. & Handelsman, J. 2010. Call of the wild: antibiotic resistance genes in natural environments. *Nature Reviews Microbiology*, 8(4): 251–259. https://doi.org/10.1038/nrmicro2312

Allende, A. & Monaghan, J. 2015. Irrigation Water Quality for Leafy Crops: A Perspective of Risks and Potential Solutions. *International Journal of Environmental Research and Public Health*, 12(7): 7457–7477. https://doi.org/10.3390/ijerph120707457

Alloway, B.J., ed. 2013. *Heavy Metals in Soils: Trace Metals and Metalloids in Soils and their Bioavailability*. Third edition. Environmental Pollution. Springer Netherlands. (also available at //www.springer.com/gp/book/9789400744691).

Amanullah. 2015. The Role of Beneficial Microbes (Biofertilizers) In Increasing Crop Productivity and Profitability. *EC Agriculture 2.6*: 504.

Amanullah & Inamullah. 2016. Residual phosphorus and zinc influence wheat productivity under rice–wheat cropping system. *SpringerPlus*, 5(1). https://doi.org/10.1186/s40064-016-1907-0

Amanullah, J. & Stewart, B.A. 2013. Dry Matter Partitioning, Growth Analysis and Water Use Efficiency Response of Oats (Avena sativa L.) to Excessive Nitrogen and Phosphorus Application. *Journal of Agricultural Science and Technology*, 15(3): 479–489.

Amanullah, Khan, S.-T., Iqbal, A. & Fahad, S. 2016. Growth and Productivity Response of Hybrid Rice to Application of Animal Manures, Plant Residues and Phosphorus. *Frontiers in Plant Science*, 7. https://doi.org/10.3389/fpls.2016.01440

AMAP. 1997. Arctic Pollution Issues: A State of the Arctic Environment Report. Oslo, Artic Monitoring and Assessment Programme. (also available at https://www.amap.no/documents/doc/arctic-pollution-issues-a-state-of-the-arctic-environment-report/67).

Anda, M. 2012. Cation imbalance and heavy metal content of seven Indonesian soils as affected by elemental compositions of parent rocks. *Geoderma*, 189–190: 388–396. https://doi.org/10.1016/j.geoderma.2012.05.009

Andersson, J.T. & Achten, C. 2015. Time to Say Goodbye to the 16 EPA PAHs? Toward an Up-to-Date Use of PACs for Environmental Purposes. *Polycyclic Aromatic Compounds*, 35(2–4): 330–354. https://doi.org/10.1080/10406638.2014.991042

Appel, C. & Ma, L. 2002. Concentration, pH, and Surface Charge Effects on Cadmium and Lead Sorption in Three Tropical Soils. *J. ENVIRON. QUAL.*, 31: 9.

Araújo, P.H.H., Sayer, C., Giudici, R. & Poço, J.G.R. 2002. Techniques for reducing residual monomer content in polymers: A review: Techniques for Reducing Residual Monomer Content. *Polymer Engineering & Science*, 42(7): 1442–1468. https://doi.org/10.1002/pen.11043

Arias-Estévez, M., López-Periago, E., Martínez-Carballo, E., Simal-Gándara, J., Mejuto, J.-C. & García-Río, L. 2008. The mobility and degradation of pesticides in soils and the pollution of groundwater resources. *Agriculture, Ecosystems & Environment*, 123(4): 247–260. https://doi.org/10.1016/j.agee.2007.07.011

Arikan, O.A., Mulbry, W. & Rice, C. 2009. Management of antibiotic residues from agricultural sources: Use of composting to reduce chlortetracycline residues in beef manure from treated animals. *Journal of Hazardous Materials*, 164(2–3): 483–489. https://doi.org/10.1016/j.jhazmat.2008.08.019

Australian Government. 2018. *Phthalates—final hazard assessment and compendium (NICNAS)* [online]. [Cited 3 April 2018]. https://www.nicnas.gov.au/chemical-information/other-assessments/reports/phthalates-hazard-assessments

Azanu, D., Mortey, C., Darko, G., Weisser, J.J., Styrishave, B. & Abaidoo, R.C. 2016. Uptake of antibiotics from irrigation water by plants. *Chemosphere*, 157: 107–114. https://doi.org/10.1016/j.chemosphere.2016.05.035

Baderna, D., Maggioni, S., Boriani, E., Gemma, S., Molteni, M., Lombardo, A., Colombo, A., Bordonali, S., Rotella, G., Lodi, M. & Benfenati, E. 2011. A combined approach to investigate the toxicity of an industrial landfill's leachate: Chemical analyses, risk assessment and in vitro assays. *Environmental Research*, 111(4): 603–613. https://doi.org/10.1016/j.envres.2011.01.015

Bais, H.P., Weir, T.L., Perry, L.G., Gilroy, S. & Vivanco, J.M. 2006. THE ROLE OF ROOT EXUDATES IN RHIZOSPHERE INTERACTIONS WITH PLANTS AND OTHER ORGANISMS. *Annual Review of Plant Biology*, 57(1): 233–266. https://doi.org/10.1146/annurev.arplant.57.032905.105159

Baldantoni, D., Morra, L., Zaccardelli, M. & Alfani, A. 2016. Cadmium accumulation in leaves of leafy vegetables. *Ecotoxicology and Environmental Safety*, 123: 89–94. https://doi.org/10.1016/j.ecoenv.2015.05.019

Bányiová, K., erná, M., Mikeš, O., Komprdová, K., Sharma, A., Gyalpo, T., upr, P. & Scheringer, M. 2017. Long-term time trends in human intake of POPs in the Czech Republic indicate a need for continuous monitoring. *Environment International*, 108: 1–10. https://doi.org/10.1016/j.envint.2017.07.008

Barba-Gutiérrez, Y., Adenso-Díaz, B. & Hopp, M. 2008. An analysis of some environmental consequences of European electrical and electronic waste regulation. *Resources, Conservation & Recycling*, 3(52): 481–495. https://doi.org/10.1016/j.resconrec.2007.06.002

Basile, B.P., Middleditch, B.S. & Oró, J. 1984. Polycyclic aromatic hydrocarbons in the Murchison meteorite. *Organic Geochemistry*, 5(4): 211–216. https://doi.org/10.1016/0146-6380(84)90008-1

Bauman-Kaszubska, H. & Sikorski, M. 2009. Selected problems of waste water disposal and sludge handling in the Mazovian province. *Journal of Water and Land Development*, 13b(1). https://doi.org/10.2478/v10025-010-0011-z

Bayat, J., Hashemi, S.H., Khoshbakht, K. & Deihimfard, R. 2016. Fingerprinting aliphatic hydrocarbon pollutants over agricultural lands surrounding Tehran oil refinery. *Environmental Monitoring and Assessment*, 188(11). https://doi.org/10.1007/s10661-016-5614-7

Bell, J.N.B., Minski, M.J. & Grogan, H.A. 1988. Plant uptake of radionuclides. *Soil Use and Management*, 4(3): 76–84. https://doi.org/10.1111/j.1475-2743.1988.tb00740.x

Berends, G. & Kobayashi, M. 2012. Food after Fukushima - Japan's Regulatory Response to the Radioactive Contamination of Its Food Chain. *Food and Drug Law Journal*, 67: 51.

van den Berg, M., Kypke, K., Kotz, A., Tritscher, A., Lee, S.Y., Magulova, K., Fiedler, H. & Malisch, R. 2017. WHO/UNEP global surveys of PCDDs, PCDFs, PCBs and DDTs in human milk and benefit–risk evaluation of breastfeeding. *Archives of Toxicology*, 91(1): 83–96. https://doi.org/10.1007/s00204-016-1802-z

Bernhardt, A. & Gysi, N. 2016. World's Worst Pollution Problems. The toxic beneath our feet. , p. 56. Green Cross Switzerland and Pure Earth Foundation. (also available at http://www.worstpolluted.org/docs/WorldsWorst2016.pdf).

Beuchat, L.R. 2002. Ecological factors influencing survival and growth of human pathogens on raw fruits and vegetables. *Microbes and Infection*, 4(4): 413–423.

Beyer, W.N. 1990. Evaluating Soil Contamination. , p. 25. No. 90(2). US Fish Wildlife Service. (also available at https://www.nwrc.usgs.gov/wdb/pub/others/FWS_Bio_Rep_90-2.pdf).

Beyond Pesticides. 2018. What Is Integrated Pest Management? In: *Beyond Pesticides* [online]. [Cited 3 April 2018]. https://beyondpesticides.org/resources/safety-source-on-pesticide-providers/what-is-integrated-pest-management

Bhatia, R., Shiau, R., Petreas, M., Weintraub, J.M., Farhang, L. & Eskenazi, B. 2005. Organochlorine Pesticides and Male Genital Anomalies in the Child Health and Development Studies. *Environmental Health Perspectives*, 113(2): 220–224. https://doi.org/10.1289/ehp.7382

Bhattacharya, P., Welch, A.H., Stollenwerk, K.G., McLaughlin, M.J., Bundschuh, J. & Panaullah, G. 2007. Arsenic in the environment: Biology and Chemistry. *The Science of the Total Environment*, 379(2–3): 109–120. https://doi.org/10.1016/j.scitotenv.2007.02.037

Bien, J., Neczaj, E. & Milczarek, M. 2013. CO – COMPOSTING OF MEAT PACKING WASTEWATER SLUDGE AND ORGANIC FRACTION OF MUNICIPAL SOLID WASTE. *Global NEST Journal*, 15(4): 513–521.

Bingham, F.T., Page, A.L., Mahler, R.J. & Ganje, T.J. 1975. Growth and Cadmium Accumulation of Plants Grown on a Soil Treated with a Cadmium-Enriched Sewage Sludge 1. *Journal of Environmental Quality*, 4(2): 207–211. https://doi.org/10.2134/jeq1975.00472425000400020015x

Björnsdotter, M. 2015. *Leaching of residual monomers, oligomers and additives from polyethylene, polypropylene, polyvinyl chloride, high-density polyethylene and polystyrene virgin plastics.* Örebro University. (also available at https://www.diva-portal.org/smash/get/diva2:855478/FULLTEXT01.pdf).

Blaser, P., Zimmermann, S., Luster, J. & Shotyk, W. 2000. Critical examination of trace element enrichments and depletions in soils: As, Cr, Cu, Ni, Pb, and Zn in Swiss forest soils. *The Science of the total environment*, 249(1–3): 257–280. https://doi.org/10.1016/S0048-9697(99)00522-7

Blum, W.E.H. 2005. Functions of Soil for Society and the Environment. *Reviews in Environmental Science and Bio/Technology*, 4(3): 75–79. https://doi.org/10.1007/s11157-005-2236-x

Blume, H.-P., Brümmer, G.W., Fleige, H., Horn, R., Kandeler, E., Kögel-Knabner, I., Kretzschmar, R., Stahr, K. & Wilke, B.-M. 2016. *Scheffer/Schachtschabel Soil Science*. Berlin Heidelberg, Springer-Verlag. (also available at //www.springer.com/us/book/9783642309410).

de Boer, J. & Fiedler, H. 2013. Persistent organic pollutants. *TrAC Trends in Analytical Chemistry*, 46: 70–71. https://doi.org/10.1016/j.trac.2013.03.001

Bolan, N., Kunhikrishnan, A., Thangarajan, R., Kumpiene, J., Park, J., Makino, T., Kirkham, M.B. & Scheckel, K. 2014. Remediation of heavy metal(loid)s contaminated soils – To mobilize or to immobilize? *Journal of Hazardous Materials*, 266: 141–166. https://doi.org/10.1016/j.jhazmat.2013.12.018

Bolívar, J.P., García-Tenorio, R. & García-León, M. 1995. Enhancement of natural radioactivity in soils and salt-marshes surrounding a non-nuclear industrial complex. *Science of The Total Environment*, 173–174: 125–136. https://doi.org/10.1016/0048-9697(95)04735-2

Bondarczuk, K., Markowicz, A. & Piotrowska-Seget, Z. 2016. The urgent need for risk assessment on the antibiotic resistance spread via sewage sludge land application. *Environment International*, 87: 49–55. https://doi.org/10.1016/j.envint.2015.11.011

Bossi, R., Dam, M. & Rigét, F.F. 2015. Perfluorinated alkyl substances (PFAS) in terrestrial environments in Greenland and Faroe Islands. *Chemosphere*, 129: 164–169. https://doi.org/10.1016/j.chemosphere.2014.11.044

Boxall, A.B.A., Johnson, P., Smith, E.J., Sinclair, C.J., Stutt, E. & Levy, L.S. 2006. Uptake of Veterinary Medicines from Soils into Plants. *Journal of Agricultural and Food Chemistry*, 54(6): 2288–2297. https://doi.org/10.1021/jf053041t

Boxall, A.B.A., Rudd, M.A., Brooks, B.W., Caldwell, D.J., Choi, K., Hickmann, S., Innes, E., Ostapyk, K., Staveley, J.P., Verslycke, T., Ankley, G.T., Beazley, K.F., Belanger, S.E., Berninger, J.P., Carriquiriborde, P., Coors, A., DeLeo, P.C., Dyer, S.D., Ericson, J.F., Gagné, F., Giesy, J.P., Gouin, T., Hallstrom, L., Karlsson, M.V., Larsson, D.G.J., Lazorchak, J.M., Mastrocco, F., McLaughlin, A., McMaster, M.E., Meyerhoff, R.D., Moore, R., Parrott, J.L., Snape, J.R., Murray-Smith, R., Servos, M.R., Sibley, P.K., Straub, J.O., Szabo, N.D., Topp, E., Tetreault, G.R., Trudeau, V.L. & Van Der Kraak, G. 2012. Pharmaceuticals and Personal Care Products in the Environment: What Are the Big Questions? *Environmental Health Perspectives*, 120(9): 1221–1229. https://doi.org/10.1289/ehp.1104477

Bradl, H.B. 2004. Adsorption of heavy metal ions on soils and soils constituents. *Journal of Colloid and Interface Science*, 277(1): 1–18. https://doi.org/10.1016/j.jcis.2004.04.005

Bragazza, L., Freeman, C., Jones, T., Rydin, H., Limpens, J., Fenner, N., Ellis, T., Gerdol, R., Hajek, M., Hajek, T., Iacumin, P., Kutnar, L., Tahvanainen, T. & Toberman, H. 2006. Atmospheric nitrogen deposition promotes carbon loss from peat bogs. *Proceedings of the National Academy of Sciences*, 103(51): 19386–19389. https://doi.org/10.1073/pnas.0606629104

Brahushi, F., Dörfler, U., Schroll, R. & Munch, J.C. 2004. Stimulation of reductive dechlorination of hexachlorobenzene in soil by inducing the native microbial activity. *Chemosphere*, 55(11): 1477–1484. https://doi.org/10.1016/j.chemosphere.2004.01.022

Brand, E., Otte, P. & Lijzen, J. 2007. CSOIL 2000 an exposure model for human risk assessment of soil contamination. A model description. (also available at http://rivm.openrepository.com/rivm/handle/10029/258236).

Brevik, E.C. 2013. Soils and human health: An overview. *In* E.C. Brevik & L.C. Burgess, eds. *Soils and human health*, pp. 29–58

Brinkac, L., Voorhies, A., Gomez, A. & Nelson, K.E. 2017. The Threat of Antimicrobial Resistance on the Human Microbiome. *Microbial Ecology*, 74(4): 1001–1008. https://doi.org/10.1007/s00248-017-0985-z

Brodesser, J., Byron, D.H., Cannavan, A., Ferris, I.G., Gross-Helmet, K., Hendrichs, J., Maestroni, B.M., Unsworth, J., Vaagt, G. & Zapata, F. 2006. Pesticides in developing countries and the International Code of Conduct on the Distribution and the Use of Pesticides. *Food and Environmental Protection Newsletter*, 9(2). (also available at http://www-naweb.iaea.org/nafa/fep/public/fep-nl-9-2.pdf).

Brody, J.G., Moysich, K.B., Humblet, O., Attfield, K.R., Beehler, G.P. & Rudel, R.A. 2007. Environmental pollutants and breast cancer: Epidemiologic studies. *Cancer*, 109(S12): 2667–2711. https://doi.org/10.1002/cncr.22655

Browne, M.A., Dissanayake, A., Galloway, T.S., Lowe, D.M. & Thompson, R.C. 2008. Ingested microscopic plastic translocates to the circulatory system of the mussel, Mytilus edulis (L). *Environmental Science & Technology*, 42(13): 5026–5031.

Brzóska, M.M. & Moniuszko-Jakoniuk, J. 2005. Disorders in bone metabolism of female rats chronically exposed to cadmium. *Toxicology and Applied Pharmacology*, 202(1): 68–83. https://doi.org/10.1016/j.taap.2004.06.007

Bundschuh, J., Litter, M.I., Parvez, F., Román-Ross, G., Nicolli, H.B., Jean, J.-S., Liu, C.-W., López, D., Armienta, M.A., Guilherme, L.R.G., Cuevas, A.G., Cornejo, L., Cumbal, L. & Toujaguez, R. 2012. One century of arsenic exposure in Latin America: a review of history and occurrence from 14 countries. *The Science of the Total Environment*, 429: 2–35. https://doi.org/10.1016/j.scitotenv.2011.06.024

Bünemann, E.K., Schwenke, G.D. & Van Zwieten, L. 2006. Impact of agricultural inputs on soil organisms—a review. *Australian Journal of Soil Research*, 44(4): 379. https://doi.org/10.1071/SR05125

Burgess, L.C. 2013. Organic pollutants in soil. *Soils and human health*, pp. 83–106. Boca Raton, Fla, CRC Press.

Buser, H.-R., Poiger, T. & Müller, M.D. 1999. Occurrence and Environmental Behavior of the Chiral Pharmaceutical Drug Ibuprofen in Surface Waters and in Wastewater. *Environmental Science & Technology*, 33(15): 2529–2535. https://doi.org/10.1021/es981014w

Butler Ellis, M.C., van de Zande, J.C., van den Berg, F., Kennedy, M.C., O'Sullivan, C.M., Jacobs, C.M., Fragkoulis, G., Spanoghe, P., Gerritsen-Ebben, R., Frewer, L.J. & Charistou, A. 2017. The BROWSE model for predicting exposures of residents and bystanders to agricultural use of plant protection products: An overview. *Biosystems Engineering*, 154: 92–104. https://doi.org/10.1016/j.biosystemseng.2016.08.017

Cachada, A., Ferreira da Silva, E., Duarte, A.C. & Pereira, R. 2016. Risk assessment of urban soils contamination: The particular case of polycyclic aromatic hydrocarbons. *Science of The Total Environment*, 551–552: 271–284. https://doi.org/10.1016/j.scitotenv.2016.02.012

Cachada, A., Rocha-Santos, T. & Duarte, A.C. 2018. Chapter 1 - Soil and Pollution: An Introduction to the Main Issues. *Soil Pollution*, pp. 1–28. Academic Press. (also available at https://www.sciencedirect.com/science/article/pii/B9780128498736000017).

Cai, D.W. 2008. Understand the role of chemical pesticides and prevent misuses of pesticides. *Bulletin of Agricultural Science and Technology*, 1: 36–38.

Callahan, M.A. & Sexton, K. 2007. If Cumulative Risk Assessment Is the Answer, What Is the Question? *Environmental Health Perspectives*, 115(5): 799–806. https://doi.org/10.1289/ehp.9330

Cameron, K.C., Di, H.J. & Moir, J.L. 2013. Nitrogen losses from the soil/plant system: a review: Nitrogen losses. *Annals of Applied Biology*, 162(2): 145–173. https://doi.org/10.1111/aab.12014

Canadian Council of Ministers of the Environment. 1999. Guidance Manual for Developing Site-Specific Soil Quality Remediation Objectives for Contaminated Sites in Canada. http://ceqg-rcqe.ccme.ca/download/en/251?redir=1522869161

Cang, L., Wang, Y., Zhou, D. & Dong, Y. 2004. Heavy metals pollution in poultry and livestock feeds and manures under intensive farming in Jiangsu Province, China. *Journal of Environmental Sciences (China)*, 16(3): 371–374.

Carlon, C., European Commission, Joint Research Centre & Institute for Environment and Sustainability. 2007. *Derivation methods of soil screening values in Europe: a review of national procedures towards harmonisation : a report of the ENSURE Action*. Luxembourg, EUR-OP.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. & Smith, V.H. 1998. NONPOINT POLLUTION OF SURFACE WATERS WITH PHOSPHORUS AND NITROGEN. *Ecological Applications*, 8(3): 559–568. https://doi.org/10.1890/1051-0761(1998)008[0559:NPOSWW]2.0.CO;2

Carson, R. 2002. *Silent spring*. 40th anniversary ed., 1st Mariner Books ed edition. Boston, Houghton Mifflin. 378 pp.

Carvalho, F.P. 2017. Pesticides, environment, and food safety. *Food and Energy Security*, 6(2): 48–60. https://doi.org/10.1002/fes3.108

CCICED. 2015. Special Policy Study on Soil Pollution Management. China Council for International Cooperation on Environment and Development. (also available at http://english.sepa.gov.cn/Events/Special_Topics/AGM_1/2015nh/document/201605/P020160524149463335883.pdf).

CDC. 2013. Antibiotic Resistance Threats in the United States. U. S. Department of Helath and Human Services, Centers for Disease Control and Prevention. (also available at https://www.cdc.gov/drugresistance/pdf/ar-threats-2013-508.pdf).

Cernansky, R. 2015. Agriculture: State-of-the-art soil. *Nature News*, 517(7534): 258. https://doi.org/10.1038/517258a

Certini, G., Scalenghe, R. & Woods, W.I. 2013. The impact of warfare on the soil environment. *Earth-Science Reviews*, 127: 1–15. https://doi.org/10.1016/j.earscirev.2013.08.009

Cestti, R., Srivastava, J.P. & Jung, S. 2003. *Agriculture Non-Point Source Pollution Control*. World Bank Working Papers. The World Bank. 54 pp. (also available at https://elibrary.worldbank.org/doi/abs/10.1596/0-8213-5523-6).

Cetin, B. 2016. Investigation of PAHs, PCBs and PCNs in soils around a Heavily Industrialized Area in Kocaeli, Turkey: Concentrations, distributions, sources and toxicological effects. *Science of The Total Environment*, 560–561: 160–169. https://doi.org/10.1016/j.scitotenv.2016.04.037

CFR. 2017. Sec. 178.3740 Plasticizers in polymeric substances. [Cited 3 April 2018]. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=178.3740

CGIAR & CCAFS. 2018. Integrated Soil Fertility Management (ISFM) | Climate-Smart Agriculture Guide. In: *CLIMATE-SMART AGRICULTURE* [online]. [Cited 3 April 2018]. https://csa.guide/csa/integrated-soil-fertility-management-isfm

Chalew, T.E.A. & Halden, R.U. 2009. Environmental Exposure of Aquatic and Terrestrial Biota to Triclosan and Triclocarban. *JAWRA Journal of the American Water Resources Association*, 45(1): 4–13. https://doi.org/10.1111/j.1752-1688.2008.00284.x

Chaney, R.L. 1980. Health risks associated with toxic metals in municipal sludges. *In* G. Bitton, B.L. Damron, G.T. Edds & J.M. (eds) Davidson, eds. *Sludge: health risks of land application.*, pp. 59–83. Ann Arbor, MI. (also available at https://www.osti.gov/biblio/6671808).

Chaney, R.L. & Hornick, S.B. 1977. Accumulation and effects of cadmium on crops. *Cadmium 77*. pp. 125–140. Paper presented at Proceedings of the First International Cadmium Conference, 1977, San Francisco.

Chaparro Leal, L.T., Guney, M. & Zagury, G.J. 2018. In vitro dermal bioaccessibility of selected metals in contaminated soil and mine tailings and human health risk characterization. *Chemosphere*, 197: 42–49. https://doi.org/10.1016/j.chemosphere.2018.01.008

Chaudhry, Q., Blom-Zandstra, M., Gupta, S.K. & Joner, E. 2005. Utilising the Synergy between Plants and Rhizosphere Microorganisms to Enhance Breakdown of Organic Pollutants in the Environment (15 pp). *Environmental Science and Pollution Research - International*, 12(1): 34–48. https://doi.org/10.1065/espr2004.08.213

Chen, C., Wang, Y., Qian, Y., Zhao, X. & Wang, Q. 2015. The synergistic toxicity of the multiple chemical mixtures: Implications for risk assessment in the terrestrial environment. *Environment International*, 77: 95–105. https://doi.org/10.1016/j.envint.2015.01.014

Chen, Y., Li, X. & Shen, Z. 2004. Leaching and uptake of heavy metals by ten different species of plants during an EDTA-assisted phytoextraction process. *Chemosphere*, 57(3): 187–196. https://doi.org/10.1016/j.chemosphere.2004.05.044

Civan, A., Worrall, F., Jarvie, H.P., Howden, N.J.K. & Burt, T.P. 2018. Forty-year trends in the flux and concentration of phosphorus in British rivers. *Journal of Hydrology*, 558: 314–327. https://doi.org/10.1016/j.jhydrol.2018.01.046

Clarke, J.M., Leisle, D., DePauw, R.M. & Thiessen, L.L. 1997. Registration of Five Pairs of Durum Wheat Genetic Stocks Near-Isogenic for Cadmium Concentration. *Crop Science*, 37(1): 297. https://doi.org/10.2135/cropsci1997.0011183X003700010071x

Cole, K.J. 2015. *Bacterial Counts In Composted And Fresh Recycled Dairy Manure Bedding*. The Ohio State University. (also available at https://etd.ohiolink.edu/pg_10?0::NO:10:P10_ACCESSION_NUM:osu1429188763).

Collins, C., Fryer, M. & Grosso, A. 2006. Plant Uptake of Non-Ionic Organic Chemicals. *Environmental Science & Technology*, 40(1): 45–52. https://doi.org/10.1021/es0508166

Committee on Bioavailability of Contaminants in Soils and Sediments. 2002. *Bioavailability of Contaminants in Soils and Sediments: Processes, Tools, and Applications*. Washington, National Research Council of the National Academies. (also available at https://www.nap.edu/catalog/10523/bioavailability-of-contaminants-in-soils-and-sediments-processes-tools-and).

Conselho Nacional do Meio Ambiente. 2009. *RESOLUÇÃO Nº 420, DE 28 DE DEZEMBRO DE 2009. Dispõe sobre critérios e valores orientadores de qualidade do solo quanto à presença de substâncias químicas e estabelece diretrizes para o gerenciamento ambiental de áreas contaminadas por essas substâncias em decorrência de atividades antrópicas.* [online]. [Cited 3 April 2018]. http://www.mma.gov.br/port/conama/res/res09/res42009.pdf

Contaminated Sites Management Working Group. 1999. A Federal approach to contaminated sites. Contaminated Sites Management Working Group (CSMWG).

Conte, P., Zena, A., Pilidis, G. & Piccolo, A. 2001. Increased retention of polycyclic aromatic hydrocarbons in soils induced by soil treatment with humic substances. *Environmental Pollution*, 112(1): 27–31. https://doi.org/10.1016/S0269-7491(00)00101-9

Covaci, A., Geens, T., Roosens, L., Ali, N., Van den Eede, N., Ionas, A.C., Malarvannan, G. & Dirtu, A.C. 2011. Human Exposure and Health Risks to Emerging Organic Contaminants. *In* D. Barceló, ed. *Emerging Organic Contaminants and Human Health*, pp. 243–305. Berlin, Heidelberg, Springer Berlin Heidelberg. (also available at http://link.springer.com/10.1007/698_2011_126).

Craig, Z.R., Wang, W. & Flaws, J.A. 2011. Endocrine-disrupting chemicals in ovarian function: effects on steroidogenesis, metabolism and nuclear receptor signaling. *Reproduction (Cambridge, England)*, 142(5): 633–646. https://doi.org/10.1530/REP-11-0136

Cruz, N., Rodrigues, S.M., Coelho, C., Carvalho, L., Duarte, A.C., Pereira, E. & Römkens, P.F.A.M. 2014. Urban agriculture in Portugal: Availability of potentially toxic elements for plant uptake. *Applied Geochemistry*, 44: 27–37. https://doi.org/10.1016/j.apgeochem.2013.07.003

Ćujić, M., Dragović, S., Đorđević, M., Dragović, R., Gajić, B. & Miljanić, Š. 2015. Radionuclides in the soil around the largest coal-fired power plant in Serbia: radiological hazard, relationship with soil characteristics and spatial distribution. *Environmental Science and Pollution Research*, 22(13): 10317–10330. https://doi.org/10.1007/s11356-014-3888-2

Cytryn, E. 2013. The soil resistome: The anthropogenic, the native, and the unknown. *Soil Biology and Biochemistry*, 63: 18–23. https://doi.org/10.1016/j.soilbio.2013.03.017

Dalkmann, P., Siebe, C., Amelung, W., Schloter, M. & Siemens, J. 2014. Does Long-Term Irrigation with Untreated Wastewater Accelerate the Dissipation of Pharmaceuticals in Soil? *Environmental Science & Technology*, 48(9): 4963–4970. https://doi.org/10.1021/es501180x

Darnerud, P.O. 2003. Toxic effects of brominated flame retardants in man and in wildlife. *Environment International*, 29(6): 841–853. https://doi.org/10.1016/S0160-4120(03)00107-7

Daughton, C.G. & Ternes, T.A. 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? *Environmental Health Perspectives*, 107 Suppl 6: 907–938.

DEA. 2010. Framework for the Management of Contaminated Land. Republic of South Africa, Department of Environmental Affairs. (also available at http://sawic.environment.gov.za/documents/562.pdf).

Deardorff, T., Karch, N. & Holm, S. 2008. Dioxin levels in ash and soil generated in Southern California fires. *Organohalogen Compounds*, 70: 2284–2288.

DECA. 2010. Assessment Levels for Soil, Sediment and Water. , p. 56. No. 4. Australia, Department of Environment and Conservation. (also available at https://www.der.wa.gov.au/images/documents/your-environment/contaminated-sites/guidelines/2009641_-_assessment_levels_for_soil_sediment_and_water_-_web.pdf).

Diaconu, A., enu, I., Ro ca, R. & Cârlescu, P. 2017. Researches regarding the reduction of pesticide soil pollution in vineyards. *Process Safety and Environmental Protection*, 108: 135–143. https://doi.org/10.1016/j.psep.2016.09.016

Díaz-Cruz, M.S. & Barceló, D. 2005. LC–MS2 trace analysis of antimicrobials in water, sediment and soil. *TrAC Trends in Analytical Chemistry*, 24(7): 645–657. https://doi.org/10.1016/j.trac.2005.05.005

Díez, M., Simón, M., Martín, F., Dorronsoro, C., García, I. & Van Gestel, C.A.M. 2009. Ambient trace element background concentrations in soils and their use in risk assessment. *Science of The Total Environment*, 407(16): 4622–4632. https://doi.org/10.1016/j.scitotenv.2009.05.012

Ding, G.-C., Radl, V., Schloter-Hai, B., Jechalke, S., Heuer, H., Smalla, K. & Schloter, M. 2014. Dynamics of Soil Bacterial Communities in Response to Repeated Application of Manure Containing Sulfadiazine. *PLoS ONE*, 9(3): e92958. https://doi.org/10.1371/journal.pone.0092958

Dœlsch, E., Saint Macary, H. & Van de Kerchove, V. 2006. Sources of very high heavy metal content in soils of volcanic island (La Réunion). *Journal of Geochemical Exploration*, 88(1–3): 194–197. https://doi.org/10.1016/j.gexplo.2005.08.037

Doran, J.W., Stamatiadis, S. & Haberern, J. 2002. Soil health as an indicator of sustainable management. *Publications from USDA-ARS / UNL Faculty*. (also available at https://digitalcommons.unl.edu/usdaarsfacpub/180).

Dores, E.F.G.C., Spadotto, C.A., Weber, O.L.S., Dalla Villa, R., Vecchiato, A.B. & Pinto, A.A. 2016. Environmental Behavior of Chlorpyrifos and Endosulfan in a Tropical Soil in Central Brazil. *Journal of Agricultural and Food Chemistry*, 64(20): 3942–3948. https://doi.org/10.1021/acs.jafc.5b04508

Dorta-Santos, M., Tejedor, M., Jiménez, C., Hernández-Moreno, J., Palacios-Díaz, M. & Díaz, F. 2014. Recycled Urban Wastewater for Irrigation of Jatropha curcas L. in Abandoned Agricultural Arid Land. *Sustainability*, 6(10): 6902–6924. https://doi.org/10.3390/su6106902

Du, L. & Liu, W. 2012. Occurrence, fate, and ecotoxicity of antibiotics in agro-ecosystems. A review. *Agronomy for Sustainable Development*, 32(2): 309–327. https://doi.org/10.1007/s13593-011-0062-9

Dubois, O. 2011. *The State of the World's Land and Water Resources for Food and Agriculture: Managing Systems at Risk*. Routledge. (also available at https://www.taylorfrancis.com/books/9780203142837).

EA, ed. 2008. *Updated technical background to the CLEA model: using science to create a better place*. Bristol, Environment Agency of Great Britain. 155 pp.

EC. 1986. Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. [Cited 3 April 2018]. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:31986L0278&from=EN

EC. 1991. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. [Cited 3 April 2018]. http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:31991L0676&from=EN

EC. 1996. Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control. [Cited 3 April 2018]. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0061:en:HTML

EC. 2002. Integrated Crop Management Systems in the EU. , p. 157. No. 1882/BDB/ May 2002. European Commission DG Environment.

EC. 2006. REGULATION (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 . and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC. [Cited 3 April 2018]. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02006R1907-20140410&from=EN

EC. 2011. Commission Regulation No 835/2011. amending Regulation (EC) No 1881/2006 as regards maximum levels for polycyclic aromatic. [Cited 3 April 2018]. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32011R0835&from=EN

EC. 2015. COM/2015/0614 final. Closing the loop - An EU action plan for the Circular Economy. [Cited 3 April 2018]. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52015DC0614&from=EN

EC. 2017. A European One Health Action Plan against Antimicrobial Resistance (AMR). European Commission. (also available at https://ec.europa.eu/health/amr/sites/amr/files/amr_action_plan_2017_en.pdf).

EEA. 2014. Progress in management of contaminated sites. European Environment Agency. (also available at https://www.eea.europa.eu/data-and-maps/indicators/progress-in-management-of-contaminated-sites/progress-in-management-of-contaminated-1).

EFSA. 2008. Scientific opinion of the panel on contaminants in the food chain on polycyclic aromatic hydrocarbons in food. *The EFSA Journal*, 724: 1–114.

Ensink, J.H.J., Mahmood, T., Hoek, W. van der, Raschid-Sally, L. & Amerasinghe, F.P. 2004. A nationwide assessment of wastewater use in Pakistan: an obscure activity or a vitally important one? *Water Policy*, 6(3): 197–206.

Ercumen, A., Pickering, A.J., Kwong, L.H., Arnold, B.F., Parvez, S.M., Alam, M., Sen, D., Islam, S., Kullmann, C., Chase, C., Ahmed, R., Unicomb, L., Luby, S.P. & Colford, J.M. 2017. Animal Feces Contribute to Domestic Fecal Contamination: Evidence from *E. coli* Measured in Water, Hands, Food, Flies, and Soil in Bangladesh. *Environmental Science & Technology*, 51(15): 8725–8734. https://doi.org/10.1021/acs.est.7b01710

European Commission, Joint Research Centre & Global Soil Biodiversity Initiative. 2016. *Global soil diversity atlas*. (also available at http://esdac.jrc.ec.europa.eu/public_path/JRC_global_soilbio_atlas_online.pdf).

EUROSTAT. 2018. *Chemicals production and consumption statistics - Statistics Explained* [online]. [Cited 3 April 2018]. http://ec.europa.eu/eurostat/statistics-explained/index.php/Chemicals_production_and_consumption_statistics

Fabiańska, M.J., Kozielska, B., Konieczyński, J. & Kowalski, A. 2016. Sources of organic pollution in particulate matter and soil of Silesian Agglomeration (Poland): evidence from geochemical markers. *Environmental Geochemistry and Health*, 38(3): 821–842. https://doi.org/10.1007/s10653-015-9764-2

Fabra, A. 1997. Toxicity of 2,4-Dichlorophenoxyacetic Acid to Rhizobium sp in Pure Culture. *Bulletin of Environmental Contamination and Toxicology*, 59(4): 645–652.

Falciglia, P.P., Cannata, S., Romano, S. & Vagliasindi, F.G. 2014. Stabilisation/solidification of radionuclide polluted soils - Part I: Assessment of setting time, mechanical resistance, g-radiation shielding and leachate g-radiation. *JOURNAL OF GEOCHEMICAL EXPLORATION*, 142: 104–111.

FAO. 2000. Assessing soil contamination A reference manual. Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/docrep/003/X2570E/X2570E00.HTM).

FAO. 2003. International Code of Conduct on the Distribution and Use of Pesticides. Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/docrep/005/Y4544E/y4544e00.htm).

FAO. 2006. International Code of Conduct on the Distribution and Use of Pesticides. Guidelines on Efficacy Evaluation for the Registration of Plant Protection Products. Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/Efficacy.pdf).

FAO. 2015a. *World fertilizer trends and outlook to 2018.* Rome, Food and Agriculture Organization of the United Nations Statistics. (also available at http://www.fao.org/3/a-i4324e.pdf).

FAO. 2015b. World Soil Charter. , p. 10. Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/3/a-i4965e.pdf).

FAO. 2015c. *FAO statistical pocketbook 2015: world food and agriculture.* Food and Agriculture Organization of the United Nations Statistics.

FAO. 2016. The FAO Action Plan on Antimicrobial Resistance 2016-2020. , p. 25. Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/3/a-i5996e.pdf).

FAO. 2017. Voluntary Guidelines for Sustainable Soil Management. Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/3/a-bl813e.pdf).

FAO & ITPS. 2015. Status of the World's Soil Resources (SWSR) - Main Report. Rome, Italy, ood and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils. (also available at http://www.fao.org/3/a-i5199e.pdf).

FAO & ITPS. 2017. Global assessment of the impact of plant protection products on soil functions and soil ecosystems. Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/3/I8168EN/i8168en.pdf).

FAO & WHO, eds. 2016. *International Code of Conduct on Pesticide Management. Guidelines on Highly Hazardous Pesticides.* Health and safety guide No. 41. Rome, Italy, Food and Agriculture Organization of the United Nations. 24 pp.

FAOSTAT. 2016. *FAOSTAT Inputs/Pesticides Use.* [online]. [Cited 3 April 2018]. http://www.fao.org/faostat/en/#data/RP

Farenhorst, A., Papiernik, S.K., Saiyed, I., Messing, P., Stephens, K.D., Schumacher, J.A., Lobb, D.A., Li, S., Lindstrom, M.J. & Schumacher, T.E. 2008. Herbicide Sorption Coefficients in Relation to Soil Properties and Terrain Attributes on a Cultivated Prairie. *Journal of Environment Quality*, 37(3): 1201. https://doi.org/10.2134/jeq2007.0109

Fesenko, S., Howard, B.J., Sanzharova, N.I. & Vidal, M. 2017. Remediation of areas contaminated by caesium: Basic mechanisms behind remedial options and experience in application. *In* D.K. Gupta & C. Walther, eds. *Impact of Cesium on Plants and the Environment*, pp. 265–310. Springer International Publishing. (also available at //www.springer.com/gp/book/9783319415246).

Fesenko, S.V., Alexakhin, R.M., Balonov, M.I., Bogdevitch, I.M., Howard, B.J., Kashparov, V.A., Sanzharova, N.I., Panov, A.V., Voigt, G. & Zhuchenka, Y.M. 2007. An extended critical review of twenty years of countermeasures used in agriculture after the Chernobyl accident. *Science of The Total Environment*, 383(1): 1–24. https://doi.org/10.1016/j.scitotenv.2007.05.011

Fiedler, H., Abad, E., van Bavel, B., de Boer, J., Bogdal, C. & Malisch, R. 2013. The need for capacity building and first results for the Stockholm Convention Global Monitoring Plan. *TrAC Trends in Analytical Chemistry*, 46: 72–84. https://doi.org/10.1016/j.trac.2013.01.010

Fiorino, D.J. 2010. Voluntary initiatives, regulations, and nanotechnology oversight: Charting a Path. Woodrow Wilson International Center for Scholars & The Pew ChariTable TrusTs. (also available at http://www.nanotechproject.org/process/assets/files/8347/pen-19.pdf).

Flores-Magdaleno, H., Mancilla-Villa, O.R., Mejía-Saenz, E., Olmedo-Bolaños, M.C. & Bautista-Olivas, A.L. 2011. Heavy metals In agricultural soils and Irrigation wastewater of Mixquiahuala, Hidalgo, Mexico. *African Journal of Agricultural Research*, 6(24). https://doi.org/10.5897/AJAR11.414

FOEN. 2013. *Fundamental approach* [online]. [Cited 3 April 2018]. https://www.bafu.admin.ch/bafu/en/home/topics/contaminated-sites/info-specialists/remediation-of-contaminated-sites/fundamental-approach.html

Fox, J.E., Gulledge, J., Engelhaupt, E., Burow, M.E. & McLachlan, J.A. 2007. Pesticides reduce symbiotic efficiency of nitrogen-fixing rhizobia and host plants. *Proceedings of the National Academy of Sciences*, 104(24): 10282–10287. https://doi.org/10.1073/pnas.0611710104

Fritt-Rasmussen, J., Jensen, P.E., Christensen, R.H.B. & Dahllöf, I. 2012. Hydrocarbon and Toxic Metal Contamination from Tank Installations in a Northwest Greenlandic Village. *Water, Air, & Soil Pollution*, 223(7): 4407–4416. https://doi.org/10.1007/s11270-012-1204-7

Frumin, G.T. & Gildeeva, I.M. 2014. Eutrophication of water bodies — A global environmental problem. *Russian Journal of General Chemistry*, 84(13): 2483–2488. https://doi.org/10.1134/S1070363214130015

García, C. & Lobo, M. 2013. Rehabilitación de suelos degradados y contaminados mediante la aplicación de compost. *In* J.M. Casco, ed. *Compostaje*, pp. 425–448. Madrid, Spain, Mundi-Prensa. (also available at https://library.biblioboard.com/content/ef8fbfdb-d094-4eea-b6f0-3be6e903c232).

Garcia, R., Baelum, J., Fredslund, L., Santorum, P. & Jacobsen, C.S. 2010. Influence of Temperature and Predation on Survival of Salmonella enterica Serovar Typhimurium and Expression of invA in Soil and Manure-Amended Soil. *Applied and Environmental Microbiology*, 76(15): 5025–5031. https://doi.org/10.1128/AEM.00628-10

García-Pérez, J., Boldo, E., Ramis, R., Pollán, M., Pérez-Gómez, B., Aragonés, N. & López-Abente, G. 2007. Description of industrial pollution in Spain. *BMC Public Health*, 7(1). https://doi.org/10.1186/1471-2458-7-40

García-Préchac, F., Ernst, O., Siri-Prieto, G. & Terra, J.A. 2004. Integrating no-till into crop–pasture rotations in Uruguay. *Soil and Tillage Research*, 77(1): 1–13. https://doi.org/10.1016/j.still.2003.12.002

Geissen, V., Mol, H., Klumpp, E., Umlauf, G., Nadal, M., van der Ploeg, M., van de Zee, S.E.A.T.M. & Ritsema, C.J. 2015. Emerging pollutants in the environment: A challenge for water resource management. *International Soil and Water Conservation Research*, 3(1): 57–65. https://doi.org/10.1016/j.iswcr.2015.03.002

Gevao, B., Semple, K.T. & Jones, K.C. 2000. Bound pesticide residues in soils: a review. *Environmental Pollution (Barking, Essex: 1987)*, 108(1): 3–14.

Ghisari, M. & Bonefeld-Jorgensen, E.C. 2009. Effects of plasticizers and their mixtures on estrogen receptor and thyroid hormone functions. *Toxicology Letters*, 189(1): 67–77. https://doi.org/10.1016/j.toxlet.2009.05.004

Giesy, J.P. & Kannan, K. 2001. Global Distribution of Perfluorooctane Sulfonate in Wildlife. *Environmental Science & Technology*, 35(7): 1339–1342. https://doi.org/10.1021/es001834k

Glick, B.R. 2003. Phytoremediation: synergistic use of plants and bacteria to clean up the environment. *Biotechnology Advances*, 21(5): 383–393. https://doi.org/10.1016/S0734-9750(03)00055-7

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. & Toulmin, C. 2010. Food Security: The Challenge of Feeding 9 Billion People. *Science*, 327(5967): 812–818. https://doi.org/10.1126/science.1185383

Gomes, H.I., Dias-Ferreira, C. & Ribeiro, A.B. 2013. Overview of in situ and ex situ remediation technologies for PCB-contaminated soils and sediments and obstacles for full-scale application. *Science of The Total Environment*, 445–446: 237–260. https://doi.org/10.1016/j.scitotenv.2012.11.098

González-Naranjo, V. & Boltes, K. 2014. Toxicity of ibuprofen and perfluorooctanoic acid for risk assessment of mixtures in aquatic and terrestrial environments. *International Journal of Environmental Science and Technology*, 11(6): 1743–1750. https://doi.org/10.1007/s13762-013-0379-9

González-Naranjo, V., Boltes, K., de Bustamante, I. & Palacios-Diaz, P. 2015. Environmental risk of combined emerging pollutants in terrestrial environments: chlorophyll a fluorescence analysis. *Environmental Science and Pollution Research*, 22(9): 6920–6931. https://doi.org/10.1007/s11356-014-3899-z

Good, A.G. & Beatty, P.H. 2011. Fertilizing Nature: A Tragedy of Excess in the Commons. *PLoS Biology*, 9(8): e1001124. https://doi.org/10.1371/journal.pbio.1001124

Gottesfeld, P., Were, F.H., Adogame, L., Gharbi, S., San, D., Nota, M.M. & Kuepouo, G. 2018. Soil contamination from lead battery manufacturing and recycling in seven African countries. *Environmental Research*, 161: 609–614. https://doi.org/10.1016/j.envres.2017.11.055

Gottschall, N., Topp, E., Metcalfe, C., Edwards, M., Payne, M., Kleywegt, S., Russell, P. & Lapen, D.R. 2012. Pharmaceutical and personal care products in groundwater, subsurface drainage, soil, and wheat grain, following a high single application of municipal biosolids to a field. *Chemosphere*, 87(2): 194–203. https://doi.org/10.1016/j.chemosphere.2011.12.018

Gotz, A. & Smalla, K. 1997. Manure Enhances Plasmid Mobilization and Survival of Pseudomonas putida Introduced into Field Soil. *Applied and Environmental Microbiology*, 63(5): 1980–1986.

van der Graaf, E.R., Koomans, R.L., Limburg, J. & de Vries, K. 2007. In situ radiometric mapping as a proxy of sediment contamination: Assessment of the underlying geochemical and -physical principles. *Applied Radiation and Isotopes*, 65(5): 619–633. https://doi.org/10.1016/j.apradiso.2006.11.004

Grant, C.A., Bailey, L.D., McLaughlin, M. & Singh, B.R. 1999. Management factors which inflience cadmium concentrations in crops. *In* M.J. McLaughlin & B.R. Singh, eds. *Cadmium in Soils and Plants*, pp. 151–198. Developments in Plant and Soil Sciences. Springer Netherlands. (also available at //www.springer.com/gp/book/9780792358435).

Grant, C.A., Clarke, J.M., Duguid, S. & Chaney, R.L. 2008. Selection and breeding of plant cultivars to minimize cadmium accumulation. *The Science of the Total Environment*, 390(2–3): 301–310. https://doi.org/10.1016/j.scitotenv.2007.10.038

Grass, G., Rensing, C. & Solioz, M. 2011. Metallic Copper as an Antimicrobial Surface. *Applied and Environmental Microbiology*, 77(5): 1541–1547. https://doi.org/10.1128/AEM.02766-10

Grathwohl, P. & Halm, D., eds. 2003. INTEGRATED SOIL AND WATER PROTECTION: RISKS FROM DIFFUSE POLLUTION. *Cluster meeting; 2nd, Innovative management of groundwater resources in Europe - training and RTD coordination; Sustainable management of soil and groundwater resources in urban areas*. Conference papers / Umweltbundesamt, Wien. Paper presented at, 2003, Wien.

Gregorič, A., Vaupotič, J., Kardos, R., Horváth, M., Bujtor, T. & Kovács, T. 2013. Radon emanation of soils from different lithological units. *Carpathian Journal of Earth and Environmental Sciences*, 8(2): 185–190.

Grobelak, A. 2016. Organic Soil Amendments in the Phytoremediation Process. *In* A.A. Ansari, S.S. Gill, R. Gill, G.R. Lanza & L. Newman, eds. *Phytoremediation*, pp. 21–39. Cham, Springer International Publishing. (also available at http://link.springer.com/10.1007/978-3-319-41811-7_2).

Grobelak, A. & Napora, A. 2015. The Chemophytostabilisation Process of Heavy Metal Polluted Soil. *PLOS ONE*, 10(6): e0129538. https://doi.org/10.1371/journal.pone.0129538

Groot, R.S. de. 1992. *Functions of nature: evaluation of nature in environmental planning. management and decision making*. Groningen, Wolters-Noordhoff. 315 pp.

GSP. 2017. Report of the Fifth Meeting of the Plenary Assembly (PA) of the Global Soil Partnership (GSP). Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/3/a-bs973e.pdf).

Guerra, F., Trevizam, A.R., Muraoka, T., Marcante, N.C. & Canniatti-Brazaca, S.G. 2012. Heavy metals in vegetables and potential risk for human health. *Scientia Agricola*, 69(1): 54–60. https://doi.org/10.1590/S0103-90162012000100008

Guillén, J., Muñoz-Muñoz, G., Baeza, A., Salas, A. & Mocanu, N. 2017. Modification of the 137Cs, 90Sr, and 60Co transfer to wheat plantlets by NH4+ fertilizers. *Environmental science and pollution research international*, 24(8): 7383–7391. https://doi.org/10.1007/s11356-017-8439-1

Gulkowska, A., Sander, M., Hollender, J. & Krauss, M. 2013. Covalent Binding of Sulfamethazine to Natural and Synthetic Humic Acids: Assessing Laccase Catalysis and Covalent Bond Stability. *Environmental Science & Technology*, 47(13): 6916–6924. https://doi.org/10.1021/es3044592

Gullberg, E., Cao, S., Berg, O.G., Ilbäck, C., Sandegren, L., Hughes, D. & Andersson, D.I. 2011. Selection of Resistant Bacteria at Very Low Antibiotic Concentrations. *PLoS Pathogens*, 7(7): e1002158. https://doi.org/10.1371/journal.ppat.1002158

Guo, J.H., Liu, X.J., Zhang, Y., Shen, J.L., Han, W.X., Zhang, W.F., Christie, P., Goulding, K.W.T., Vitousek, P.M. & Zhang, F.S. 2010. Significant Acidification in Major Chinese Croplands. *Science*, 327(5968): 1008–1010. https://doi.org/10.1126/science.1182570

Guo, K., Liu, Y.F., Zeng, C., Chen, Y.Y. & Wei, X.J. 2014. Global research on soil contamination from 1999 to 2012: A bibliometric analysis. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*, 64(5): 377–391. https://doi.org/10.1080/09064710.2014.913679

Guzzella, L., Poma, G., De Paolis, A., Roscioli, C. & Viviano, G. 2011. Organic persistent toxic substances in soils, waters and sediments along an altitudinal gradient at Mt. Sagarmatha, Himalayas, Nepal. *Environmental Pollution*, 159(10): 2552–2564. https://doi.org/10.1016/j.envpol.2011.06.015

Hafez, Y.I. & Awad, E.-S. 2016. Finite element modeling of radon distribution in natural soils of different geophysical regions. *Cogent Physics*, 3(1). https://doi.org/10.1080/23311940.2016.1254859

Halling-Sørensen, B., Jensen, J., Tjørnelund, J. & Montforts, M.H.M.M. 2001. Worst-Case Estimations of Predicted Environmental Soil Concentrations (PEC) of Selected Veterinary Antibiotics and Residues Used in Danish Agriculture. *In* K. Kümmerer, ed. *Pharmaceuticals in the Environment*, pp. 143–157. Berlin, Heidelberg, Springer Berlin Heidelberg. (also available at http://link.springer.com/10.1007/978-3-662-04634-0_13).

Halling-Sørensen, B., Nors Nielsen, S., Lanzky, P.F., Ingerslev, F., Holten Lützhøft, H.C. & Jørgensen, S.E. 1998. Occurrence, fate and effects of pharmaceutical substances in the environment- A review. *Chemosphere*, 36(2): 357–393. https://doi.org/10.1016/S0045-6535(97)00354-8

Hamon, R.E., Lombi, E., Fortunati, P., Nolan, A.L. & McLaughlin, M.J. 2004. Coupling Speciation and Isotope Dilution Techniques To Study Arsenic Mobilization in the Environment. *Environmental Science & Technology*, 38(6): 1794–1798. https://doi.org/10.1021/es034931x

Hamscher, G., Pawelzick, H.T., Höper, H. & Nau, H. 2004. Antibiotics in Soil: Routes of Entry, Environmental Concentrations, Fate and Possible Effects. *In* K. Kümmerer, ed. *Pharmaceuticals in the Environment*, pp. 139–147. Berlin, Heidelberg, Springer Berlin Heidelberg. (also available at http://www.springerlink.com/index/10.1007/978-3-662-09259-0_11).

Han, J., Shi, J., Zeng, L., Xu, J. & Wu, L. 2015. Effects of nitrogen fertilization on the acidity and salinity of greenhouse soils. *Environmental Science and Pollution Research*, 22(4): 2976–2986. https://doi.org/10.1007/s11356-014-3542-z

Handy, R.D., von der Kammer, F., Lead, J.R., Hassellöv, M., Owen, R. & Crane, M. 2008. The ecotoxicology and chemistry of manufactured nanoparticles. *Ecotoxicology*, 17(4): 287–314. https://doi.org/10.1007/s10646-008-0199-8

Hao, X., Chang, C., Travis, G.R. & Zhang, F. 2003. Soil carbon and nitrogen response to 25 annual cattle manure applications. *Journal of Plant Nutrition and Soil Science*, 166(2): 239–245. https://doi.org/10.1002/jpln.200390035

Harbarth, S., Balkhy, H.H., Goossens, H., Jarlier, V., Kluytmans, J., Laxminarayan, R., Saam, M., Van Belkum, A. & Pittet, D. 2015. Antimicrobial resistance: one world, one fight! *Antimicrobial Resistance and Infection Control*, 4(1). https://doi.org/10.1186/s13756-015-0091-2

Hargreaves, J., Adl, M. & Warman, P. 2008. A review of the use of composted municipal solid waste in agriculture. *Agriculture, Ecosystems & Environment*, 123(1–3): 1–14. https://doi.org/10.1016/j.agee.2007.07.004

Hashim, T., Abbas, H., Farid, I., El-Husseiny, O. & Abbas, M. 2017. Accumulation of some heavy metals in plants and soils adjacent to Cairo – Alexandria agricultural highway. *Egyptian Journal of Soil Science*, 0(0): 0–0. https://doi.org/10.21608/ejss.2016.281.1047

Heberer, T. 2002. Occurrence, fate, and removal of pharmaceutical residues in the aquatic environment: a review of recent research data. *Toxicology Letters*, 131(1–2): 5–17.

Hernández, A.F., Parrón, T., Tsatsakis, A.M., Requena, M., Alarcón, R. & López-Guarnido, O. 2013. Toxic effects of pesticide mixtures at a molecular level: Their relevance to human health. *Toxicology*, 307: 136–145. https://doi.org/10.1016/j.tox.2012.06.009

Heudorf, U., Mersch-Sundermann, V. & Angerer, J. 2007. Phthalates: toxicology and exposure. *International Journal of Hygiene and Environmental Health*, 210(5): 623–634. https://doi.org/10.1016/j.ijheh.2007.07.011

Heuer, H., Focks, A., Lamshöft, M., Smalla, K., Matthies, M. & Spiteller, M. 2008. Fate of sulfadiazine administered to pigs and its quantitative effect on the dynamics of bacterial resistance genes in manure and manured soil. *Soil Biology and Biochemistry*, 40(7): 1892–1900. https://doi.org/10.1016/j.soilbio.2008.03.014

Hilscherova, K., Dusek, L., Kubik, V., Cupr, P., Hofman, J., Klanova, J. & Holoubek, I. 2007. Redistribution of organic pollutants in river sediments and alluvial soils related to major floods. *Journal of Soils and Sediments*, 7(3): 167–177. https://doi.org/10.1065/jss2007.04.222

Holman, D.B., Hao, X., Topp, E., Yang, H.E. & Alexander, T.W. 2016. Effect of Co-Composting Cattle Manure with Construction and Demolition Waste on the Archaeal, Bacterial, and Fungal Microbiota, and on Antimicrobial Resistance Determinants. *PLOS ONE*, 11(6): e0157539. https://doi.org/10.1371/journal.pone.0157539

Hölzel, C.S., Müller, C., Harms, K.S., Mikolajewski, S., Schäfer, S., Schwaiger, K. & Bauer, J. 2012. Heavy metals in liquid pig manure in light of bacterial antimicrobial resistance. *Environmental Research*, 113: 21–27. https://doi.org/10.1016/j.envres.2012.01.002

Hoornweg, D. & Bhada-Tata, P. 2012. *What a waste. A Global review of solid waste management*. Knowledge papers. The World Bank. (also available at http://documents.worldbank.org/curated/en/302341468126264791/pdf/68135-REVISED-What-a-Waste-2012-Final-updated.pdf).

Hope, B.K. 2006. An examination of ecological risk assessment and management practices. *Environment International*, 32(8): 983–995. https://doi.org/10.1016/j.envint.2006.06.005

Hopwood, D.A. 2007. How do antibiotic-producing bacteria ensure their self-resistance before antibiotic biosynthesis incapacitates them? *Molecular Microbiology*, 63(4): 937–940. https://doi.org/10.1111/j.1365-2958.2006.05584.x

Horckmans, L., Swennen, R., Deckers, J. & Maquil, R. 2005. Local background concentrations of trace elements in soils: a case study in the Grand Duchy of Luxembourg. *CATENA*, 59(3): 279–304. https://doi.org/10.1016/j.catena.2004.09.004

Hosford, M. 2008. *Human health toxicological assessment of contaminants in soil: using science to create a better place*. Science report No. SC050021/SR2. Bristol, Environment Agency. 70 pp.

Hossain, M.F., White, S.K., Elahi, S.F., Sultana, N., Choudhury, M.H.K., Alam, Q.K., Rother, J.A. & Gaunt, J.L. 2005. The efficiency of nitrogen fertiliser for rice in Bangladeshi farmers' fields. *Field Crops Research*, 93(1): 94–107. https://doi.org/10.1016/j.fcr.2004.09.017

Hough, R.L. 2007. Soil and human health: an epidemiological review. *European Journal of Soil Science*, 58(5): 1200–1212. https://doi.org/10.1111/j.1365-2389.2007.00922.x

Howard, B.J., Beresford, N.A., Barnett, C.L. & Fesenko, S. 2009. Quantifying the transfer of radionuclides to food products from domestic farm animals. *Journal of Environmental Radioactivity*, 100(9): 767–773. https://doi.org/10.1016/j.jenvrad.2009.03.010

Hu, P., Huang, J., Ouyang, Y., Wu, L., Song, J., Wang, S., Li, Z., Han, C., Zhou, L., Huang, Y., Luo, Y. & Christie, P. 2013. Water management affects arsenic and cadmium accumulation in different rice cultivars. *Environmental geochemistry and health*, 35(6): 767–778. https://doi.org/10.1007/s10653-013-9533-z

Hu, Y., Cheng, H. & Tao, S. 2016. The Challenges and Solutions for Cadmium-contaminated Rice in China: A Critical Review. *Environment International*, 92–93: 515–532. https://doi.org/10.1016/j.envint.2016.04.042

Huelster, A., Mueller, J.F. & Marschner, H. 1994. Soil-Plant Transfer of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans to Vegetables of the Cucumber Family (Cucurbitaceae). *Environmental Science & Technology*, 28(6): 1110–1115. https://doi.org/10.1021/es00055a021

IAEA. 1998. *Guidelines for Integrated Risk Assessment and Management in Large Industrial Areas*. Vienna, INTERNATIONAL ATOMIC ENERGY AGENCY. (also available at http://www-pub.iaea.org/books/IAEABooks/5649/Guidelines-for-Integrated-Risk-Assessment-and-Management-in-Large-Industrial-Areas).

Ingham, S.C., Losinski, J.A., Andrews, M.P., Breuer, J.E., Breuer, J.R., Wood, T.M. & Wright, T.H. 2004. Escherichia coli Contamination of Vegetables Grown in Soils Fertilized with Noncomposted Bovine Manure: Garden-Scale Studies. *Applied and Environmental Microbiology*, 70(11): 6420–6427. https://doi.org/10.1128/AEM.70.11.6420-6427.2004

ISO. 2013. ISO 11074:2015 - Soil quality -- Vocabulary. (also available at https://www.iso.org/standard/59259.html).

Itai, T., Otsuka, M., Asante, K.A., Muto, M., Opoku-Ankomah, Y., Ansa-Asare, O.D. & Tanabe, S. 2014. Variation and distribution of metals and metalloids in soil/ash mixtures from Agbogbloshie e-waste recycling site in Accra, Ghana. *The Science of the Total Environment*, 470–471: 707–716. https://doi.org/10.1016/j.scitotenv.2013.10.037

Jacobsen, C.S. & Hjelmsø, M.H. 2014. Agricultural soils, pesticides and microbial diversity. *Current Opinion in Biotechnology*, 27: 15–20. https://doi.org/10.1016/j.copbio.2013.09.003

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B.B. & Beeregowda, K.N. 2014. Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 7(2). https://doi.org/10.2478/intox-2014-0009

Jechalke, S., Heuer, H., Siemens, J., Amelung, W. & Smalla, K. 2014. Fate and effects of veterinary antibiotics in soil. *Trends in Microbiology*, 22(9): 536–545. https://doi.org/10.1016/j.tim.2014.05.005

Jefatura del Estado. 2001. Plan Hidrológico Nacional. [Cited 3 April 2018]. https://www.boe.es/buscar/doc.php?id=BOE-A-2001-13042

Jennings, A.A. 2013. Analysis of worldwide regulatory guidance values for the most commonly regulated elemental surface soil contamination. *Journal of Environmental Management*, 118: 72–95. https://doi.org/10.1016/j.jenvman.2012.12.032

Jones, K.C. & de Voogt, P. 1999. Persistent organic pollutants (POPs): state of the science. *Environmental Pollution (Barking, Essex: 1987)*, 100(1–3): 209–221.

Jones, O.A., Voulvoulis, N. & Lester, J.N. 2001. Human pharmaceuticals in the aquatic environment a review. *Environmental Technology*, 22(12): 1383–1394. https://doi.org/10.1080/09593332208618186

Jordão, C.P., Nascentes, C.C., Cecon, P.R., Fontes, R.L.F. & Pereira, J.L. 2006. Heavy Metal Availability in Soil Amended with Composted Urban Solid Wastes. *Environmental Monitoring and Assessment*, 112(1–3): 309–326. https://doi.org/10.1007/s10661-006-1072-y

Joy, S.R., Bartelt-Hunt, S.L., Snow, D.D., Gilley, J.E., Woodbury, B.L., Parker, D.B., Marx, D.B. & Li, X. 2013. Fate and Transport of Antimicrobials and Antimicrobial Resistance Genes in Soil and Runoff Following Land Application of Swine Manure Slurry. *Environmental Science & Technology*, 47(21): 12081–12088. https://doi.org/10.1021/es4026358

Juhasz, A.L., Smith, E., Weber, J., Rees, M., Rofe, A., Kuchel, T., Sansom, L. & Naidu, R. 2007. In vitro assessment of arsenic bioaccessibility in contaminated (anthropogenic and geogenic) soils. *Chemosphere*, 69(1): 69–78. https://doi.org/10.1016/j.chemosphere.2007.04.046

Kannan, K., Corsolini, S., Falandysz, J., Fillmann, G., Kumar, K.S., Loganathan, B.G., Mohd, M.A., Olivero, J., Wouwe, N.V., Yang, J.H. & Aldous, K.M. 2004. Perfluorooctanesulfonate and Related Fluorochemicals in Human Blood from Several Countries. *Environmental Science & Technology*, 38(17): 4489–4495. https://doi.org/10.1021/es0493446

Kanter, D.R. 2018. Nitrogen pollution: a key building block for addressing climate change. *Climatic Change*, 147(1–2): 11–21. https://doi.org/10.1007/s10584-017-2126-6

Katz, D. 2016. Undermining Demand Management with Supply Management: Moral Hazard in Israeli Water Policies. *Water*, 8(4): 159. https://doi.org/10.3390/w8040159

Kemp, D.D. 1998. *The environment dictionary*. London; New York, Routledge.

Keraita, B.N. & Drechsel, P. 2004. Agricultural use of untreated urban wastewater in Ghana. *In* C.A. Scott, N.I. Faruqui & L. Raschid-Sally, eds. *Wastewater use in irrigated agriculture: confronting the livelihood and environmental realities*, pp. 101–112. Wallingford, CABI. (also available at http://www.cabi.org/cabebooks/ebook/20043115023).

Keyte, I.J., Harrison, R.M. & Lammel, G. 2013. Chemical reactivity and long-range transport potential of polycyclic aromatic hydrocarbons – a review. *Chemical Society Reviews*, 42(24): 9333. https://doi.org/10.1039/c3cs60147a

Khachatourians, G.G. 1998. Agricultural use of antibiotics and the evolution and transfer of antibiotic-resistant bacteria. *CMAJ: Canadian Medical Association journal = journal de l'Association medicale canadienne*, 159(9): 1129–1136.

Khalili, N.R., Scheff, P.A. & Holsen, T.M. 1995. PAH source fingerprints for coke ovens, diesel and, gasoline engines, highway tunnels, and wood combustion emissions. *Atmospheric Environment*, 29(4): 533–542. https://doi.org/10.1016/1352-2310(94)00275-P

Khan, A., Khan, S., Khan, M.A., Qamar, Z. & Waqas, M. 2015. The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: a review. *Environmental Science and Pollution Research*, 22(18): 13772–13799. https://doi.org/10.1007/s11356-015-4881-0

Khan, S., Afzal, M., Iqbal, S. & Khan, Q.M. 2013. Plant–bacteria partnerships for the remediation of hydrocarbon contaminated soils. *Chemosphere*, 90(4): 1317–1332. https://doi.org/10.1016/j.chemosphere.2012.09.045

Khandaghi, J., Razavilar, V. & Barzgari, A. 2010. Isolation of Escherichia coli O157:H7 from manure fertilized farms and raw vegetables grown on it, in Tabriz city in Iran. *Afr. J. Microbiol. Res.*: 5.

Kim, E.J., Choi, S.-D. & Chang, Y.-S. 2011. Levels and patterns of polycyclic aromatic hydrocarbons (PAHs) in soils after forest fires in South Korea. *Environmental Science and Pollution Research*, 18(9): 1508–1517. https://doi.org/10.1007/s11356-011-0515-3

Kim, H.S., Kim, K.-R., Kim, W.-I., Owens, G. & Kim, K.-H. 2017. Influence of Road Proximity on the Concentrations of Heavy Metals in Korean Urban Agricultural Soils and Crops. *Archives of Environmental Contamination and Toxicology*, 72(2): 260–268. https://doi.org/10.1007/s00244-016-0344-y

Kim, K.-H., Kabir, E. & Jahan, S.A. 2017. Exposure to pesticides and the associated human health effects. *Science of The Total Environment*, 575: 525–535. https://doi.org/10.1016/j.scitotenv.2016.09.009

Kim, K.-R., Owens, G., Kwon, S.-I., So, K.-H., Lee, D.-B. & Ok, Y.S. 2011. Occurrence and Environmental Fate of Veterinary Antibiotics in the Terrestrial Environment. *Water, Air, & Soil Pollution*, 214(1–4): 163–174. https://doi.org/10.1007/s11270-010-0412-2

Knapp, C.W., Callan, A.C., Aitken, B., Shearn, R., Koenders, A. & Hinwood, A. 2017. Relationship between antibiotic resistance genes and metals in residential soil samples from Western Australia. *Environmental Science and Pollution Research*, 24(3): 2484–2494. https://doi.org/10.1007/s11356-016-7997-y

Knox, A., Seaman, J., Mench, M. & Vangronsveld, J. 2001. Remediation of Metal- and Radionuclides-Contaminated Soils by In Situ Stabilization Techniques. *Environmental Restoration of Metals-Contaminated Soils*, pp. 21–60. Taylor & Francis Group. (also available at https://www.taylorfrancis.com/books/9781420026269/chapters/10.1201%2F9781420026269-2).

Kobayashi, A., ed. 2012. *Geographies of peace and armed conflict*. London, Routledge. 241 pp.

Komárek, M., Cadková, E., Chrastný, V., Bordas, F. & Bollinger, J.-C. 2010. Contamination of vineyard soils with fungicides: a review of environmental and toxicological aspects. *Environment International*, 36(1): 138–151. https://doi.org/10.1016/j.envint.2009.10.005

Komárek, M., Vaněk, A. & Ettler, V. 2013. Chemical stabilization of metals and arsenic in contaminated soils using oxides--a review. *Environmental Pollution (Barking, Essex: 1987)*, 172: 9–22. https://doi.org/10.1016/j.envpol.2012.07.045

Komprda, J., Komprdová, K., Sáňka, M., Možný, M. & Nizzetto, L. 2013. Influence of Climate and Land Use Change on Spatially Resolved Volatilization of Persistent Organic Pollutants (POPs) from Background Soils. *Environmental Science & Technology*, 47(13): 7052–7059. https://doi.org/10.1021/es3048784

Krapp, A. 2015. Plant nitrogen assimilation and its regulation: a complex puzzle with missing pieces. *Current Opinion in Plant Biology*, 25: 115–122. https://doi.org/10.1016/j.pbi.2015.05.010

Kukučka, P., Klánová, J., Sáňka, M. & Holoubek, I. 2009. Soil burdens of persistent organic pollutants – Their levels, fate and risk. Part II. Are there any trends in PCDD/F levels in mountain soils? *Environmental Pollution*, 157(12): 3255–3263. https://doi.org/10.1016/j.envpol.2009.05.029

Kumar, A. & Maiti, S.K. 2015. Assessment of potentially toxic heavy metal contamination in agricultural fields, sediment, and water from an abandoned chromite-asbestos mine waste of Roro hill, Chaibasa, India. *Environmental Earth Sciences*, 74(3): 2617–2633. https://doi.org/10.1007/s12665-015-4282-1

Kumar, K., Gupta, S.C., Baidoo, S.K., Chander, Y. & Rosen, C.J. 2005. Antibiotic Uptake by Plants from Soil Fertilized with Animal Manure. *Journal of Environment Quality*, 34(6): 2082. https://doi.org/10.2134/jeq2005.0026

Kumar, V. & Kothiyal, N.C. 2016. Analysis of Polycyclic Aromatic Hydrocarbon, Toxic Equivalency Factor and Related Carcinogenic Potencies in Roadside Soil within a Developing City of Northern India. *Polycyclic Aromatic Compounds*, 36(4): 506–526. https://doi.org/10.1080/10406638.2015.1026999

Kumpiene, J., Lagerkvist, A. & Maurice, C. 2008. Stabilization of As, Cr, Cu, Pb and Zn in soil using amendments--a review. *Waste Management (New York, N.Y.)*, 28(1): 215–225. https://doi.org/10.1016/j.wasman.2006.12.012

Kuo, S., Ortiz-escobar, M.E., Hue, N.V. & Hummel, R.L. 2004. Composting and Compost Utilization for Agronomic and Container Crops. *Recent Developments in Environmental Biology*, 1: 451–513.

Kuppusamy, S., Kakarla, D., Venkateswarlu, K., Megharaj, M., Yoon, Y.-E. & Lee, Y.B. 2018. Veterinary antibiotics (VAs) contamination as a global agro-ecological issue: A critical view. *Agriculture, Ecosystems & Environment*, 257: 47–59. https://doi.org/10.1016/j.agee.2018.01.026

Kuppusamy, S., Palanisami, T., Megharaj, M., Venkateswarlu, K. & Naidu, R. 2016. In-Situ Remediation Approaches for the Management of Contaminated Sites: A Comprehensive Overview. *Reviews of Environmental Contamination and Toxicology*, 236: 1–115. https://doi.org/10.1007/978-3-319-20013-2_1

Kuppusamy, S., Thavamani, P., Venkateswarlu, K., Lee, Y.B., Naidu, R. & Megharaj, M. 2017. Remediation approaches for polycyclic aromatic hydrocarbons (PAHs) contaminated soils: Technological constraints, emerging trends and future directions. *Chemosphere*, 168: 944–968. https://doi.org/10.1016/j.chemosphere.2016.10.115

ter Laak, T.L., Agbo, S.O., Barendregt, A. & Hermens, J.L.M. 2006. Freely Dissolved Concentrations of PAHs in Soil Pore Water: Measurements via Solid-Phase Extraction and Consequences for Soil Tests. *Environmental Science & Technology*, 40(4): 1307–1313. https://doi.org/10.1021/es0514803

Lammoglia, S.-K., Kennedy, M.C., Barriuso, E., Alletto, L., Justes, E., Munier-Jolain, N. & Mamy, L. 2017. Assessing human health risks from pesticide use in conventional and innovative cropping systems with the BROWSE model. *Environment International*, 105: 66–78. https://doi.org/10.1016/j.envint.2017.04.012

Landrigan, P.J., Fuller, R., Acosta, N.J.R., Adeyi, O., Arnold, R., Basu, N.N., Baldé, A.B., Bertollini, R., Bose-O'Reilly, S., Boufford, J.I., Breysse, P.N., Chiles, T., Mahidol, C., Coll-Seck, A.M., Cropper, M.L., Fobil, J., Fuster, V., Greenstone, M., Haines, A., Hanrahan, D., Hunter, D., Khare, M., Krupnick, A., Lanphear, B., Lohani, B., Martin, K., Mathiasen, K.V., McTeer, M.A., Murray, C.J.L., Ndahimananjara, J.D., Perera, F., Potočnik, J., Preker, A.S., Ramesh, J., Rockström, J., Salinas, C., Samson, L.D., Sandilya, K., Sly, P.D., Smith, K.R., Steiner, A., Stewart, R.B., Suk, W.A., van Schayck, O.C.P., Yadama, G.N., Yumkella, K. & Zhong, M. 2018. The Lancet Commission on pollution and health. *Lancet (London, England)*, 391(10119): 462–512. https://doi.org/10.1016/S0140-6736(17)32345-0

Lauer, N.E., Harkness, J.S. & Vengosh, A. 2016. Brine Spills Associated with Unconventional Oil Development in North Dakota. *Environmental Science & Technology*, 50(10): 5389–5397. https://doi.org/10.1021/acs.est.5b06349

Lee, R.J., Strohmeier, B.R., Bunker, K.L. & Van Orden, D.R. 2008. Naturally occurring asbestos—A recurring public policy challenge. *Journal of Hazardous Materials*, 153(1–2): 1–21. https://doi.org/10.1016/j.jhazmat.2007.11.079

Lerda, D. 2011. Polycyclic Aromatic Hydrocarbons (PAHs) Factsheet. , p. 34. Belgium, Joint Research Centre, European Commission. (also available at https://ec.europa.eu/jrc/sites/jrcsh/files/Factsheet%20PAH_0.pdf).

Lewis, S.E., Silburn, D.M., Kookana, R.S. & Shaw, M. 2016. Pesticide Behavior, Fate, and Effects in the Tropics: An Overview of the Current State of Knowledge. *Journal of Agricultural and Food Chemistry*, 64(20): 3917–3924. https://doi.org/10.1021/acs.jafc.6b01320

Li, A. 2009. PAHs in Comets: An Overview. *In* H.U. Käufl & C. Sterken, eds. *Deep Impact as a World Observatory Event: Synergies in Space, Time, and Wavelength*, pp. 161–175. Berlin, Heidelberg, Springer Berlin Heidelberg. (also available at http://link.springer.com/10.1007/978-3-540-76959-0_21).

Li, J.-S., Beiyuan, J., Tsang, D.C.W., Wang, L., Poon, C.S., Li, X.-D. & Fendorf, S. 2017. Arsenic-containing soil from geogenic source in Hong Kong: Leaching characteristics and stabilization/solidification. *Chemosphere*, 182: 31–39. https://doi.org/10.1016/j.chemosphere.2017.05.019

Li, Z., Ma, Z., van der Kuijp, T.J., Yuan, Z. & Huang, L. 2014. A review of soil heavy metal pollution from mines in China: Pollution and health risk assessment. *Science of The Total Environment*, 468–469: 843–853. https://doi.org/10.1016/j.scitotenv.2013.08.090

Liang, Y., Bradford, S.A., Simunek, J., Heggen, M., Vereecken, H. & Klumpp, E. 2013. Retention and Remobilization of Stabilized Silver Nanoparticles in an Undisturbed Loamy Sand Soil. *Environmental Science & Technology*, 47(21): 12229–12237. https://doi.org/10.1021/es402046u

Lin, C., Liu, J., Wang, R., Wang, Y., Huang, B. & Pan, X. 2013. Polycyclic Aromatic Hydrocarbons in Surface Soils of Kunming, China: Concentrations, Distribution, Sources, and Potential Risk. *Soil and Sediment Contamination: An International Journal*, 22(7): 753–766. https://doi.org/10.1080/15320383.2013.768201

Lindstrom, A.B., Strynar, M.J. & Libelo, E.L. 2011. Polyfluorinated Compounds: Past, Present, and Future. *Environmental Science & Technology*, 45(19): 7954–7961. https://doi.org/10.1021/es2011622

Lithner, D., Larsson, A. & Dave, G. 2011. Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition. *The Science of the Total Environment*, 409(18): 3309–3324. https://doi.org/10.1016/j.scitotenv.2011.04.038

Liu, X., Zhang, W., Hu, Y., Hu, E., Xie, X., Wang, L. & Cheng, H. 2015. Arsenic pollution of agricultural soils by concentrated animal feeding operations (CAFOs). *Chemosphere*, 119: 273–281. https://doi.org/10.1016/j.chemosphere.2014.06.067

Logan, T.J. 2000. Soils and Environmental Quality. *In* M.E. Sumner, ed. *Handbook of Soil Science*, pp. G155–G170. Boca Raton, Fla, CRC Press.

Loganathan, B.G. & Lam, P.K.S., eds. 2012. *Global contamination trends of persistent organic chemicals*. Boca Raton, CRC Press. 638 pp.

Lu, C. & Tian, H. 2017. Global nitrogen and phosphorus fertilizer use for agriculture production in the past half century: shifted hot spots and nutrient imbalance. *Earth System Science Data*, 9(1): 181–192. https://doi.org/10.5194/essd-9-181-2017

Lu, Y., Song, S., Wang, R., Liu, Z., Meng, J., Sweetman, A.J., Jenkins, A., Ferrier, R.C., Li, H., Luo, W. & Wang, T. 2015. Impacts of soil and water pollution on food safety and health risks in China. *Environment International*, 77: 5–15. https://doi.org/10.1016/j.envint.2014.12.010

Lucas, R.W., Klaminder, J., Futter, M.N., Bishop, K.H., Egnell, G., Laudon, H. & Högberg, P. 2011. A meta-analysis of the effects of nitrogen additions on base cations : Implications for plants, soils, and streams. *Forest Ecology and Management*, 262(2): 95–104.

Luo, L., Meng, H., Wu, R. & Gu, J.-D. 2017. Impact of nitrogen pollution/deposition on extracellular enzyme activity, microbial abundance and carbon storage in coastal mangrove sediment. *Chemosphere*, 177: 275–283. https://doi.org/10.1016/j.chemosphere.2017.03.027

Luo, Y., Wu, L., Liu, L., Han, C. & Li, Z. 2009. Heavy Metal Contamination and Remediation in Asian Agricultural Land. p. 9. Paper presented at MARCO Symposium, 2009, Japan.

Luque, J. 2014. Guía para la elaboración de los Planes de Descontaminación de Suelos.

Lv, B., Xing, M. & Yang, J. 2016. Speciation and transformation of heavy metals during vermicomposting of animal manure. *Bioresource Technology*, 209: 397–401. https://doi.org/10.1016/j.biortech.2016.03.015

Lynn, M. 2017. Ways to Prevent Soil Pollution. In: *LIVESTRONG.COM* [online]. [Cited 3 April 2018]. https://www.livestrong.com/article/171421-ways-to-prevent-soil-pollution/

Mackay, A.K., Taylor, M.P., Munksgaard, N.C., Hudson-Edwards, K.A. & Burn-Nunes, L. 2013. Identification of environmental lead sources and pathways in a mining and smelting town: Mount Isa, Australia. *Environmental Pollution*, 180: 304–311. https://doi.org/10.1016/j.envpol.2013.05.007

Mansouri, A., Cregut, M., Abbes, C., Durand, M.-J., Landoulsi, A. & Thouand, G. 2017. The Environmental Issues of DDT Pollution and Bioremediation: a Multidisciplinary Review. *Applied Biochemistry and Biotechnology*, 181(1): 309–339. https://doi.org/10.1007/s12010-016-2214-5

Mato, Y., Isobe, T., Takada, H., Kanehiro, H., Ohtake, C. & Kaminuma, T. 2001. Plastic resin pellets as a transport medium for toxic chemicals in the marine environment. *Environmental Science & Technology*, 35(2): 318–324.

McBratney, A., Field, D.J. & Koch, A. 2014. The dimensions of soil security. *Geoderma*, 213: 203–213. https://doi.org/10.1016/j.geoderma.2013.08.013

McBride, M.B. 1994. *Environmental chemistry of soils*. New York, Oxford University Press.

McLaughlin, M.J., Palmer, L.T., Tiller, K.G., Beech, T.A. & Smart, M.K. 1994. Increased Soil Salinity Causes Elevated Cadmium Concentrations in Field-Grown Potato Tubers. *Journal of Environmental Quality*, 23(5): 1013–1018. https://doi.org/10.2134/jeq1994.00472425002300050023x

McLaughlin, M.J., Parker, D.R. & Clarke, J.M. 1999. Metals and micronutrients – food safety issues. *Field Crops Research*, 60(1): 143–163. https://doi.org/10.1016/S0378-4290(98)00137-3

McManus, P.S., Stockwell, V.O., Sundin, G.W. & Jones, A.L. 2002. Antibiotic use in plant agriculture. *Annual Review of Phytopathology*, 40(1): 443–465. https://doi.org/10.1146/annurev.phyto.40.120301.093927

Meek, M., Boobis, A., Crofton, K., Heinemeyer, G., Raaij, M. & Vickers, C. 2011. Risk assessment of combined exposure to multiple chemicals: A WHO/IPCS framework. *Regulatory Toxicology and Pharmacology*, 60(2): S1–S14. https://doi.org/10.1016/j.yrtph.2011.03.010

Meharg, A.A. 2004. Arsenic in rice--understanding a new disaster for South-East Asia. *Trends in Plant Science*, 9(9): 415–417. https://doi.org/10.1016/j.tplants.2004.07.002

Mehra, R., Kumar, S., Sonkawade, R., Singh, N.P. & Badhan, K. 2010. Analysis of terrestrial naturally occurring radionuclides in soil samples from some areas of Sirsa district of Haryana, India using gamma ray spectrometry. *Environmental Earth Sciences*, 59(5): 1159–1164. https://doi.org/10.1007/s12665-009-0108-3

Michael, I., Rizzo, L., McArdell, C.S., Manaia, C.M., Merlin, C., Schwartz, T., Dagot, C. & Fatta-Kassinos, D. 2013. Urban wastewater treatment plants as hotspots for the release of antibiotics in the environment: A review. *Water Research*, 47(3): 957–995. https://doi.org/10.1016/j.watres.2012.11.027

Middeldorp, P.J.M., van Doesburg, W., Schraa, G. & Stams, A.J.M. 2005. Reductive dechlorination of hexachlorocyclohexane (HCH) isomers in soil under anaerobic conditions. *Biodegradation*, 16(3): 283–290. https://doi.org/10.1007/s10532-004-1573-8

Miège, C., Choubert, J.M., Ribeiro, L., Eusèbe, M. & Coquery, M. 2009. Fate of pharmaceuticals and personal care products in wastewater treatment plants – Conception of a database and first results. *Environmental Pollution*, 157(5): 1721–1726. https://doi.org/10.1016/j.envpol.2008.11.045

Mielke, H.W. & Reagan, P.L. 1998. Soil is an important pathway of human lead exposure. *Environmental Health Perspectives*, 106 Suppl 1: 217–229.

Mileusnić, M., Mapani, B.S., Kamona, A.F., Ružičić, S., Mapaure, I. & Chimwamurombe, P.M. 2014. Assessment of agricultural soil contamination by potentially toxic metals dispersed from improperly disposed tailings, Kombat mine, Namibia. *Journal of Geochemical Exploration*, 144: 409–420. https://doi.org/10.1016/j.gexplo.2014.01.009

MINAM. 2017. Aprueban Criterios para la Gestión de Sitios Contaminados-DECRETO SUPREMO-N° 012-2017-MINAM. [Cited 3 April 2018]. http://busquedas.elperuano.pe/normaslegales/aprueban-criterios-para-la-gestion-de-sitios-contaminados-decreto-supremo-n-012-2017-minam-1593392-6/

Minh, N.H., Minh, T.B., Kajiwara, N., Kunisue, T., Subramanian, A., Iwata, H., Tana, T.S., Baburajendran, R., Karuppiah, S., Viet, P.H., Tuyen, B.C. & Tanabe, S. 2006. Contamination by Persistent Organic Pollutants in Dumping Sites of Asian Developing Countries: Implication of Emerging Pollution Sources. *Archives of Environmental Contamination and Toxicology*, 50(4): 474–481. https://doi.org/10.1007/s00244-005-1087-3

Mirsal, I. 2008. *Soil Pollution: Origin, Monitoring & Remediation*. Springer Science & Business Media. 310 pp.

MMA. 2013. Guía Metodológica para la Gestión de Suelos con Potencial Presencia de Contaminantes. http://portal.mma.gob.cl/transparencia/mma/doc/Res_406_GuiaMetodologicaSuelosContaminantes.pdf

Morgan, R. 2013. Soil, heavy metals, and human health. *Soils and human health*, pp. 59–82. Boca Raton, Fla, CRC Press.

Mortvedt, J.J. 1994. Plant and soil relationships of uranium and thorium decay series radionuclides - a review. *Journal of Environmental Quality*, 23(4): 643–650.

Muir, D.C.G. & de Wit, C.A. 2010. Trends of legacy and new persistent organic pollutants in the circumpolar arctic: Overview, conclusions, and recommendations. *Science of The Total Environment*, 408(15): 3044–3051. https://doi.org/10.1016/j.scitotenv.2009.11.032

Muñiz, O. 2008. *Los microelementos en la agricultura.* La Habana, Cuba, Agroinfo.

Muñoz, B. & Albores, A. 2011. DNA Damage Caused by Polycyclic Aromatic Hydrocarbons: Mechanisms and Markers. *Selected Topics in DNA Repair*: 125–144.

Murakami, M., Nakagawa, F., Ae, N., Ito, M. & Arao, T. 2009. Phytoextraction by Rice Capable of Accumulating Cd at High Levels: Reduction of Cd Content of Rice Grain. *Environmental Science & Technology*, 43(15): 5878–5883. https://doi.org/10.1021/es8036687

Mwakalapa, E.B., Mmochi, A.J., Müller, M.H.B., Mdegela, R.H., Lyche, J.L. & Polder, A. 2018. Occurrence and levels of persistent organic pollutants (POPs) in farmed and wild marine fish from Tanzania. A pilot study. *Chemosphere*, 191: 438–449. https://doi.org/10.1016/j.chemosphere.2017.09.121

Naidu, R., Channey, R., McConnell, S., Johnston, N., Semple, K.T., McGrath, S., Dries, V., Nathanail, P., Harmsen, J., Pruszinski, A., MacMillan, J. & Palanisami, T. 2015. Towards bioavailability-based soil criteria: past, present and future perspectives. *Environmental Science and Pollution Research*, 22(12): 8779–8785. https://doi.org/10.1007/s11356-013-1617-x

Najeeb, U., Ahmad, W., Zia, M.H., Zaffar, M. & Zhou, W. 2017. Enhancing the lead phytostabilization in wetland plant Juncus effusus L. through somaclonal manipulation and EDTA enrichment. *Arabian Journal of Chemistry*, 10: S3310–S3317. https://doi.org/10.1016/j.arabjc.2014.01.009

Nathanail, P. 2011. Sustainable remediation: Quo vadis? *Remediation Journal*, 21(4): 35–44. https://doi.org/10.1002/rem.20298

Navarro, I., de la Torre, A., Sanz, P., Porcel, M.Á., Pro, J., Carbonell, G. & Martínez, M. de L.Á. 2017. Uptake of perfluoroalkyl substances and halogenated flame retardants by crop plants grown in biosolids-amended soils. *Environmental Research*, 152: 199–206. https://doi.org/10.1016/j.envres.2016.10.018

Navarro, S., Vela, N. & Navarro, G. 2007. Review. An overview on the environmental behaviour of pesticide residues in soils. *Spanish Journal of Agricultural Research*, 5(3): 357. https://doi.org/10.5424/sjar/2007053-5344

Navas, A., Soto, J. & Machín, J. 2002. 238U, 226Ra, 210Pb, 232Th and 40K activities in soil profiles of the Flysch sector (Central Spanish Pyrenees). *Applied Radiation and Isotopes*, 57(4): 579–589. https://doi.org/10.1016/S0969-8043(02)00131-8

Nel, A., Xia, T., Madler, L. & Li, N. 2006. Toxic Potential of Materials at the Nanolevel. *Science*, 311(5761): 622–627. https://doi.org/10.1126/science.1114397

Nguyen, D.B., Rose, M.T., Rose, T.J., Morris, S.G. & van Zwieten, L. 2016. Impact of glyphosate on soil microbial biomass and respiration: A meta-analysis. *Soil Biology and Biochemistry*, 92: 50–57. https://doi.org/10.1016/j.soilbio.2015.09.014

Nicholson, F.., Chambers, B.., Williams, J.. & Unwin, R.. 1999. Heavy metal contents of livestock feeds and animal manures in England and Wales. *Bioresource Technology*, 70(1): 23–31. https://doi.org/10.1016/S0960-8524(99)00017-6

Nicholson, F.A., Smith, S.R., Alloway, B.J., Carlton-Smith, C. & Chambers, B.J. 2003. An inventory of heavy metals inputs to agricultural soils in England and Wales. *The Science of the Total Environment*, 311(1–3): 205–219. https://doi.org/10.1016/S0048-9697(03)00139-6

NICNAS. 1989. Industrial Chemicals (Notification and Assessment) Act 1989. [Cited 3 April 2018]. https://www.legislation.gov.au/Details/C2013C00643

Nicolopoulou-Stamati, P., Maipas, S., Kotampasi, C., Stamatis, P. & Hens, L. 2016. Chemical Pesticides and Human Health: The Urgent Need for a New Concept in Agriculture. *Frontiers in Public Health*, 4. https://doi.org/10.3389/fpubh.2016.00148

Nihei, N. 2013. Chapter 8. Radioactivity in Agricultural Products in Fukushima. *In* T.M. Nakanishi & K. Tanoi, eds. *Agricultural Implications of the Fukushima Nuclear Accident*, pp. 73–85. Tokyo, Springer Japan. (also available at http://link.springer.com/10.1007/978-4-431-54328-2).

Nisbet, A.F., Konoplev, A.V., Shaw, G., Lembrechts, J.F., Merckx, R., Smolders, E., Vandecasteele, C.M., Lönsjö, H., Carini, F. & Burton, O. 1993. Application of fertilisers and ameliorants to reduce soil to plant transfer of radiocaesium and radiostrontium in the medium to long term — a summary. *Science of The Total Environment*, 137(1): 173–182. https://doi.org/10.1016/0048-9697(93)90386-K

Norton, G.J., Islam, M.R., Deacon, C.M., Zhao, F.-J., Stroud, J.L., McGrath, S.P., Islam, S., Jahiruddin, M., Feldmann, J., Price, A.H. & Meharg, A.A. 2009. Identification of low inorganic and total grain arsenic rice cultivars from Bangladesh. *Environmental Science & Technology*, 43(15): 6070–6075.

Ockleford, C., Adriaanse, P., Berny, P., Brock, T., Duquesne, S., Grilli, S., Hernandez Jerez, A.F., Bennekou, S.H., Klein, M., Kuhl, T., Laskowski, R., Machera, K., Pelkonen, O., Pieper, S., Stemmer, M., Sundh, I., Teodorovic, I., Tiktak, A., Topping, C.J., Wolterink, G., Craig, P., de Jong, F., Manachini, B., Sousa, P., Swarowsky, K., Auteri, D., Arena, M. & Rob, S. 2017. Scientific Opinion addressing the state of the science on risk assessment of plant protection products for in-soil organisms. *EFSA Journal*, 15(2). https://doi.org/10.2903/j.efsa.2017.4690

Odabasi, M., Dumanoglu, Y., Ozgunerge Falay, E., Tuna, G., Altiok, H., Kara, M., Bayram, A., Tolunay, D. & Elbir, T. 2016. Investigation of spatial distributions and sources of persistent organic pollutants (POPs) in a heavily polluted industrial region using tree components. *Chemosphere*, 160: 114–125. https://doi.org/10.1016/j.chemosphere.2016.06.076

Odongo, A.O., Moturi, W.N. & Mbuthia, E.K. 2016. Heavy metals and parasitic geohelminths toxicity among geophagous pregnant women: a case study of Nakuru Municipality, Kenya. *Environmental Geochemistry and Health*, 38(1): 123–131. https://doi.org/10.1007/s10653-015-9690-3

OECD. 2008. *OECD Environmental Outlook to 2030*. OECD Environmental Outlook. OECD Publishing. (also available at http://www.oecd-ilibrary.org/environment/oecd-environmental-outlook-to-2030_9789264040519-en).

Ogundele, L.T., Owoade, O.K., Hopke, P.K. & Olise, F.S. 2017. Heavy metals in industrially emitted particulate matter in Ile-Ife, Nigeria. *Environmental Research*, 156: 320–325. https://doi.org/10.1016/j.envres.2017.03.051

Okere, U.V. 2011. Biodegradation of PAHs in Pristine Soils from Different Climatic Regions. *Journal of Bioremediation & Biodegradation*, s1. https://doi.org/10.4172/2155-6199.S1-006

Oldeman, L.R. 1991. World map on status of human-induced soil degradation. Nairobi, Kenya : Wageningen, Netherlands, UNEP ; ISRIC.

Oliver, D., Schultz, J., Tiller, K. & Merry, R. 1993. The effect of crop rotations and tillage practices on cadmium concentration in wheat grain. *Australian Journal of Agricultural Research*, 44(6): 1221. https://doi.org/10.1071/AR9931221

Oliver, D.P., Hannam, R., Tiller, K.G., Wilhelm, N.S., Merry, R.H. & Cozens, G.D. 1994. The Effects of Zinc Fertilization on Cadmium Concentration in Wheat Grain. *Journal of Environmental Quality*, 23(4): 705–711. https://doi.org/10.2134/jeq1994.00472425002300040013x

Oliver, M.A. & Gregory, P.J. 2015. Soil, food security and human health: a review: Soil, food security and human health. *European Journal of Soil Science*, 66(2): 257–276. https://doi.org/10.1111/ejss.12216

O'Neill, J. 2014. Review on Antimicrobial Resistance: Tackling a crisis for the health and wealth of nations. Review on Antimicrobial Resistance. London. (also available at https://amr-review.org/Publications.html).

Ongeng, D., Vasquez, G.A., Muyanja, C., Ryckeboer, J., Geeraerd, A.H. & Springael, D. 2011. Transfer and internalisation of Escherichia coli O157:H7 and Salmonella enterica serovar Typhimurium in cabbage cultivated on contaminated manure-amended soil under tropical field conditions in Sub-Saharan Africa. *International Journal of Food Microbiology*, 145(1): 301–310. https://doi.org/10.1016/j.ijfoodmicro.2011.01.018

Pan, B. & Xing, B. 2008. Adsorption Mechanisms of Organic Chemicals on Carbon Nanotubes. *Environmental Science & Technology*, 42(24): 9005–9013. https://doi.org/10.1021/es801777n

Pan, B. & Xing, B. 2012. Applications and implications of manufactured nanoparticles in soils: a review. *European Journal of Soil Science*, 63(4): 437–456. https://doi.org/10.1111/j.1365-2389.2012.01475.x

Pan, J., Plant, J.A., Voulvoulis, N., Oates, C.J. & Ihlenfeld, C. 2010. Cadmium levels in Europe: implications for human health. *Environmental Geochemistry and Health*, 32(1): 1–12. https://doi.org/10.1007/s10653-009-9273-2

Panagiotakis, I. & Dermatas, D. 2015. Remediation of Contaminated Sites. *Bulletin of Environmental Contamination and Toxicology*, 94(3): 267–268. https://doi.org/10.1007/s00128-015-1490-z

Park, J.H., Lamb, D., Paneerselvam, P., Choppala, G., Bolan, N. & Chung, J.-W. 2011. Role of organic amendments on enhanced bioremediation of heavy metal(loid) contaminated soils. *Journal of Hazardous Materials*, 185(2–3): 549–574. https://doi.org/10.1016/j.jhazmat.2010.09.082

Passatore, L., Rossetti, S., Juwarkar, A.A. & Massacci, A. 2014. Phytoremediation and bioremediation of polychlorinated biphenyls (PCBs): state of knowledge and research perspectives. *Journal of Hazardous Materials*, 278: 189–202. https://doi.org/10.1016/j.jhazmat.2014.05.051

Paye, H. de S., Mello, J.W.V. de & Melo, S.B. de. 2012. Métodos de análise multivariada no estabelecimento de valores de referência de qualidade para elementos-traço em solos. *Revista Brasileira de Ciência do Solo*, 36(3): 1031–1042. https://doi.org/10.1590/S0100-06832012000300033

Paz-Alberto, A.M. & Sigua, G.C. 2013. Phytoremediation: A Green Technology to Remove Environmental Pollutants. *American Journal of Climate Change*, 02(01): 71–86. https://doi.org/10.4236/ajcc.2013.21008

Pedrero, F., Kalavrouziotis, I., Alarcón, J.J., Koukoulakis, P. & Asano, T. 2010. Use of treated municipal wastewater in irrigated agriculture—Review of some practices in Spain and Greece. *Agricultural Water Management*, 97(9): 1233–1241. https://doi.org/10.1016/j.agwat.2010.03.003

Perkins, A.E. & Nicholson, W.L. 2008. Uncovering New Metabolic Capabilities of Bacillus subtilis Using Phenotype Profiling of Rifampin-Resistant rpoB Mutants. *Journal of Bacteriology*, 190(3): 807–814. https://doi.org/10.1128/JB.00901-07

Perkins, D.N., Brune Drisse, M.-N., Nxele, T. & Sly, P.D. 2014. E-Waste: A Global Hazard. *Annals of Global Health*, 80(4): 286–295. https://doi.org/10.1016/j.aogh.2014.10.001

Petrie, B., Barden, R. & Kasprzyk-Hordern, B. 2015. A review on emerging contaminants in wastewaters and the environment: Current knowledge, understudied areas and recommendations for future monitoring. *Water Research*, 72: 3–27. https://doi.org/10.1016/j.watres.2014.08.053

Pierzynski, G.M., Sims, J.T. & Vance, G.F. 2005. *Soils and environmental quality*. 2nd ed edition. Boca Raton, CRC Press. 459 pp.

Pietrzak, U. & McPhail, D.C. 2004. Copper accumulation, distribution and fractionation in vineyard soils of Victoria, Australia. *Geoderma*, 122(2–4): 151–166. https://doi.org/10.1016/j.geoderma.2004.01.005

du Plessis, E.M., Duvenage, F. & Korsten, L. 2015. Determining the Potential Link between Irrigation Water Quality and the Microbiological Quality of Onions by Phenotypic and Genotypic Characterization of Escherichia coli Isolates. *Journal of Food Protection*, 78(4): 643–651. https://doi.org/10.4315/0362-028X.JFP-14-486

Podolský, F., Ettler, V., Šebek, O., Ježek, J., Mihaljevič, M., Kříbek, B., Sracek, O., Vaněk, A., Penížek, V., Majer, V., Mapani, B., Kamona, F. & Nyambe, I. 2015. Mercury in soil profiles from metal mining and smelting areas in Namibia and Zambia: distribution and potential sources. *Journal of Soils and Sediments*, 15(3): 648–658. https://doi.org/10.1007/s11368-014-1035-9

Popp, J., Pető, K. & Nagy, J. 2013. Pesticide productivity and food security. A review. *Agronomy for Sustainable Development*, 33(1): 243–255. https://doi.org/10.1007/s13593-012-0105-x

Posthuma, L., Eijsackers, H.J.P., Koelmans, A.A. & Vijver, M.G. 2008. Ecological effects of diffuse mixed pollution are site-specific and require higher-tier risk assessment to improve site management decisions: A discussion paper. *Science of The Total Environment*, 406(3): 503–517. https://doi.org/10.1016/j.scitotenv.2008.06.065

Prestt, I., Jefferies, D.J. & Moore, N.W. 1970. Polychlorinated biphenyls in wild birds in Britain and their avian toxicity. *Environmental Pollution (1970)*, 1(1): 3–26. https://doi.org/10.1016/0013-9327(70)90003-0

Pretty, J.N., Mason, C.F., Nedwell, D.B., Hine, R.E., Leaf, S. & Dils, R. 2003. Environmental Costs of Freshwater Eutrophication in England and Wales. *Environmental Science & Technology*, 37(2): 201–208. https://doi.org/10.1021/es020793k

Provoost, J., Cornelis, C. & Swartjes, F. 2006. Comparison of Soil Clean-up Standards for Trace Elements Between Countries: Why do they differ? (9 pages). *Journal of Soils and Sediments*, 6(3): 173–181. https://doi.org/10.1065/jss2006.07.169

Puglisi, E. 2012. Response of microbial organisms (aquatic and terrestrial) to pesticides. *EFSA Supporting Publications*, 9(11). https://doi.org/10.2903/sp.efsa.2012.EN-359

Puschenreiter, M., Horak, O., Friesl, W. & Hartl, W. 2005. Low-cost agricultural measures to reduce heavy metal transfer into the food chain - a review. *Plant, Soil and Environment*, 51(1): 1–11.

Raffa, D., Tubiello, F., Turner, D. & Montero Serrano, J. 2018. Nitrogen inputs to agricultural soils from livestock manure. New statistics. , p. 86. Rome, Italy, Food and Agriculture Organization of the United Nations. (also available at http://www.fao.org/3/I8153EN/i8153en.pdf).

Randhawa, M.A., Salim-ur-Rehman, Anjum, F.M. & Awan, J.A. 2014. Pesticide residues in food: Health implications for children and women. *In* R. Bhat & V.M. Gomez-Lopez, eds. *Practical Food Safety: Contemporary Issues and Future Directions*, pp. 145–167. Hoboken, UNITED KINGDOM, John Wiley & Sons, Incorporated. (also available at http://ebookcentral.proquest.com/lib/bull-ebooks/detail.action?docID=1655929).

Rankin, K., Mabury, S.A., Jenkins, T.M. & Washington, J.W. 2016. A North American and global survey of perfluoroalkyl substances in surface soils: Distribution patterns and mode of occurrence. *Chemosphere*, 161: 333–341. https://doi.org/10.1016/j.chemosphere.2016.06.109

Rao, G., Lu, C. & Su, F. 2007. Sorption of divalent metal ions from aqueous solution by carbon nanotubes: A review. *Separation and Purification Technology*, 58(1): 224–231. https://doi.org/10.1016/j.seppur.2006.12.006

Ratcliffe, D.A. 1970. Changes Attributable to Pesticides in Egg Breakage Frequency and Eggshell Thickness in Some British Birds. *The Journal of Applied Ecology*, 7(1): 67. https://doi.org/10.2307/2401613

Reeuwijk, N.M., Talidda, A., Malisch, R., Kotz, A., Tritscher, A., Fiedler, H., Zeilmaker, M.J., Kooijman, M., Wienk, K.J.H., Traag, W.A. & Hoogenboom, R.L.A.P. 2013. Dioxins (polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-furans) in traditional clay products used during pregnancy. *Chemosphere*, 90(5): 1678–1685. https://doi.org/10.1016/j.chemosphere.2012.09.064

Reeves, W.R., Barhoumi, R., Burghardt, R.C., Lemke, S.L., Mayura, K., McDonald, T.J., Phillips, T.D. & Donnelly, K.C. 2001. Evaluation of Methods for Predicting the Toxicity of Polycyclic Aromatic Hydrocarbon Mixtures. *Environmental Science & Technology*, 35(8): 1630–1636. https://doi.org/10.1021/es001689a

Reimann, C., Filzmoser, P. & Garrett, R.G. 2005. Background and threshold: critical comparison of methods of determination. *Science of The Total Environment*, 346(1–3): 1–16. https://doi.org/10.1016/j.scitotenv.2004.11.023

Ren, X., Chen, C., Nagatsu, M. & Wang, X. 2011. Carbon nanotubes as adsorbents in environmental pollution management: A review. *Chemical Engineering Journal*, 170(2–3): 395–410. https://doi.org/10.1016/j.cej.2010.08.045

Rensing, C. & Pepper, I.L. 2006. Chapter 30. Antibiotic-Resistant Bacteria and Gene Transfer. *Environmental and Pollution Science*, pp. 499–505. San Diego, UNITED STATES, Elsevier Science & Technology. (also available at http://ebookcentral.proquest.com/lib/bull-ebooks/detail.action?docID=297063).

Rigol, A., Vidal, M. & Rauret, G. 2002. An overview of the effect of organic matter on soil–radiocaesium interaction: implications in root uptake. *Journal of Environmental Radioactivity*, 58(2–3): 191–216. https://doi.org/10.1016/S0265-931X(01)00066-2

Rillig, M.C. 2012. Microplastic in Terrestrial Ecosystems and the Soil? *Environmental Science & Technology*, 46(12): 6453–6454. https://doi.org/10.1021/es302011r

Rizwan, M., Ali, S., Adrees, M., Ibrahim, M., Tsang, D.C.W., Zia-ur-Rehman, M., Zahir, Z.A., Rinklebe, J., Tack, F.M.G. & Ok, Y.S. 2017. A critical review on effects, tolerance mechanisms and management of cadmium in vegetables. *Chemosphere*, 182: 90–105. https://doi.org/10.1016/j.chemosphere.2017.05.013

Robinson, B.H. 2009. E-waste: An assessment of global production and environmental impacts. *Science of The Total Environment*, 408(2): 183–191. https://doi.org/10.1016/j.scitotenv.2009.09.044

Rocha-Santos, T. & Duarte, A.C. 2015. A critical overview of the analytical approaches to the occurrence, the fate and the behavior of microplastics in the environment. *TrAC Trends in Analytical Chemistry*, 65: 47–53. https://doi.org/10.1016/j.trac.2014.10.011

Rodrigues, S.M., Pereira, M.E., Duarte, A.C. & Römkens, P.F.A.M. 2012. Soil–plant–animal transfer models to improve soil protection guidelines: A case study from Portugal. *Environment International*, 39(1): 27–37. https://doi.org/10.1016/j.envint.2011.09.005

Romero-Freire, A., Martin Peinado, F.J. & van Gestel, C.A.M. 2015. Effect of soil properties on the toxicity of Pb: Assessment of the appropriateness of guideline values. *Journal of Hazardous Materials*, 289: 46–53. https://doi.org/10.1016/j.jhazmat.2015.02.034

Rosal, R., Rodea-Palomares, I., Boltes, K., Fernández-Piñas, F., Leganés, F. & Petre, A. 2010. Ecotoxicological assessment of surfactants in the aquatic environment: Combined toxicity of docusate sodium with chlorinated pollutants. *Chemosphere*, 81(2): 288–293. https://doi.org/10.1016/j.chemosphere.2010.05.050

Rosendahl, I., Siemens, J., Groeneweg, J., Linzbach, E., Laabs, V., Herrmann, C., Vereecken, H. & Amelung, W. 2011. Dissipation and Sequestration of the Veterinary Antibiotic Sulfadiazine and Its Metabolites under Field Conditions. *Environmental Science & Technology*, 45(12): 5216–5222. https://doi.org/10.1021/es200326t

Safronova, V.I., Stepanok, V.V., Engqvist, G.L., Alekseyev, Y.V. & Belimov, A.A. 2006. Root-associated bacteria containing 1-aminocyclopropane-1-carboxylate deaminase improve growth and nutrient uptake by pea genotypes cultivated in cadmium supplemented soil. *Biology and Fertility of Soils*, 42(3): 267–272. https://doi.org/10.1007/s00374-005-0024-y

Saha, J.K., Selladurai, R., Coumar, M.V., Dotaniya, M.L., Kundu, S. & Patra, A.K. 2017. *Soil Pollution - An Emerging Threat to Agriculture*. Environmental Chemistry for a Sustainable World. Singapore, Springer Singapore. (also available at http://link.springer.com/10.1007/978-981-10-4274-4).

Salminen, R. & Gregorauskiene, V. 2000. Considerations regarding the definition of a geochemical baseline of elements in the surficial materials in areas differing in basic geology. *Applied Geochemistry*, 15(5): 647–653. https://doi.org/10.1016/S0883-2927(99)00077-3

Santos, A. & Flores, M. 1995. Effects of glyphosate on nitrogen fixation of free-living heterotrophic bacteria. *Letters in Applied Microbiology*, 20(6): 349–352. https://doi.org/10.1111/j.1472-765X.1995.tb01318.x

Sarigiannis, D.A. & Hansen, U. 2012. Considering the cumulative risk of mixtures of chemicals – A challenge for policy makers. *Environmental Health*, 11(Suppl 1): S18. https://doi.org/10.1186/1476-069X-11-S1-S18

Sarmah, A.K., Meyer, M.T. & Boxall, A.B.A. 2006. A global perspective on the use, sales, exposure pathways, occurrence, fate and effects of veterinary antibiotics (VAs) in the environment. *Chemosphere*, 65(5): 725–759. https://doi.org/10.1016/j.chemosphere.2006.03.026

Sassman, S.A. & Lee, L.S. 2005. Sorption of Three Tetracyclines by Several Soils: Assessing the Role of pH and Cation Exchange. *Environmental Science & Technology*, 39(19): 7452–7459. https://doi.org/10.1021/es0480217

Sauvé, S. & Desrosiers, M. 2014. A review of what is an emerging contaminant. *Chemistry Central Journal*, 8(1): 15. https://doi.org/10.1186/1752-153X-8-15

Scallan, E., Griffin, P.M., Angulo, F.J., Tauxe, R.V. & Hoekstra, R.M. 2011. Foodborne Illness Acquired in the United States—Unspecified Agents. *Emerging Infectious Diseases*, 17(1): 16–22. https://doi.org/10.3201/eid1701.P21101

Schafer, R. 1995. Results of the contaminated-site survey. pp. 309–322. Paper presented at Proceedings of the International Workshop on Military and Armament Contaminated Sites, 1995, Berlin.

Schmidt, C. 2010. How PCBs Are Like Grasshoppers. *Environmental Science & Technology*, 44(8): 2752–2752. https://doi.org/10.1021/es100696y

Schnug, E. & Lottermoser, B.G. 2013. Fertilizer-Derived Uranium and its Threat to Human Health. *Environmental Science & Technology*, 47(6): 2433–2434. https://doi.org/10.1021/es4002357

Science Communication Unit, University of the West of England. 2013. Science for Environment Policy In-depth Report: Soil Contamination: Impacts on Human Health. Bristol, UK, European Commission DG Environment. (also available at http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR5_en.pdf).

Scott, K.., Ashley, P.. & Lawie, D.. 2001. The geochemistry, mineralogy and maturity of gossans derived from volcanogenic Zn–Pb–Cu deposits of the eastern Lachlan Fold Belt, NSW, Australia. *Journal of Geochemical Exploration*, 72(3): 169–191. https://doi.org/10.1016/S0375-6742(01)00159-5

Scullion, J. 2006. Remediating polluted soils. *Naturwissenschaften*, 93(2): 51–65. https://doi.org/10.1007/s00114-005-0079-5

Shacklette, H.T. & Boerngen, J.G. 1984. Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States. , p. 63. US Geological Survey.

Shaw, G. 1993. Blockade by fertilisers of caesium and stronium uptake into crops: effects on the root uptake process. *Science of The Total Environment*, 137(1): 119–133. https://doi.org/10.1016/0048-9697(93)90381-F

Shayler, H., McBride, M. & Harrison, E. 2009. Sources and Impacts of Contaminants in Soils. (also available at http://ecommons.cornell.edu/handle/1813/14282).

Shen, W., Lin, X., Shi, W., Min, J., Gao, N., Zhang, H., Yin, R. & He, X. 2010. Higher rates of nitrogen fertilization decrease soil enzyme activities, microbial functional diversity and nitrification capacity in a Chinese polytunnel greenhouse vegetable land. *Plant and Soil*, 337(1–2): 137–150. https://doi.org/10.1007/s11104-010-0511-2

Shiralipour, A., McConnell, D.B. & Smith, W.H. 1992. Uses and benefits of MSW compost: A review and an assessment. *Biomass and Bioenergy*, 3(3–4): 267–279. https://doi.org/10.1016/0961-9534(92)90031-K

Simonich, S.L. & Hites, R.A. 1995. Organic Pollutant Accumulation in Vegetation. *Environmental Science & Technology*, 29(12): 2905–2914. https://doi.org/10.1021/es00012a004

Singh, D.K., ed. 2012. *Toxicology: Agriculture And Environment: Pesticide Chemistry And Toxicology*. BENTHAM SCIENCE PUBLISHERS. (also available at http://www.eurekaselect.com/50654/volume/1).

Singh, R., Singh, A., Misra, V. & Singh, R. 2011. Degradation of Lindane Contaminated Soil Using Zero-Valent Iron Nanoparticles. *Journal of Biomedical Nanotechnology*, 7(1): 175–176. https://doi.org/10.1166/jbn.2011.1256

Šmídová, K., Hofman, J., Ite, A.E. & Semple, K.T. 2012. Fate and bioavailability of 14C-pyrene and 14C-lindane in sterile natural and artificial soils and the influence of aging. *Environmental Pollution*, 171: 93–98. https://doi.org/10.1016/j.envpol.2012.07.031

Smit, E., Elsas, J.D. van, Veen, J.A. van & Vos, W.M. de. 1991. Detection of Plasmid Transfer from Pseudomonas fluorescens to Indigenous Bacteria in Soil by Using Bacteriophage ϕR2f for Donor Counterselection. *Applied and Environmental Microbiology*, 57(12): 3482–3488.

Smith, J.T., Comans, R.N.J., Beresford, N.A., Wright, S.M., Howard, B.J. & Camplin, W.C. 2000. Chernobyl's legacy in food and water: Pollution. *Nature*, 405(6783): 141–141. https://doi.org/10.1038/35012139

Smith, S. 2009. A critical review of the bioavailability and impacts of heavy metals in municipal solid waste composts compared to sewage sludge. *Environment International*, 35(1): 142–156. https://doi.org/10.1016/j.envint.2008.06.009

Souza Arroyo, V., Martínez Flores, K., Bucio Ortiz, L., Gómez-Quiroz, L.E. & Gutiérrez-Ruiz, M.C. 2012. Liver and Cadmium Toxicity. *Journal of Drug Metabolism & Toxicology*, 03(06). https://doi.org/10.4172/2157-7609.S5-001

Srogi, K. 2007. Monitoring of environmental exposure to polycyclic aromatic hydrocarbons: a review. *Environmental Chemistry Letters*, 5(4): 169–195. https://doi.org/10.1007/s10311-007-0095-0

SSR. 2010. Soil Contamination in West Africa | Environmental Remediation | Pollution. (also available at https://www.scribd.com/doc/71599035/Soil-Contamination-in-West-Africa).

Stasinos, S. & Zabetakis, I. 2013. The uptake of nickel and chromium from irrigation water by potatoes, carrots and onions. *Ecotoxicology and Environmental Safety*, 91: 122–128. https://doi.org/10.1016/j.ecoenv.2013.01.023

Steinnes, E., Allen, R.O., Petersen, H.M., Rambæk, J.P. & Varskog, P. 1997. Evidence of large scale heavy-metal contamination of natural surface soils in Norway from long-range atmospheric transport. *Science of The Total Environment*, 205(2–3): 255–266. https://doi.org/10.1016/S0048-9697(97)00209-X

Steinnes, E., Berg, T. & Uggerud, H.T. 2011. Three decades of atmospheric metal deposition in Norway as evident from analysis of moss samples. *Science of The Total Environment*, 412–413: 351–358. https://doi.org/10.1016/j.scitotenv.2011.09.086

Stewart, W.M., Dibb, D.W., Johnston, A.E. & Smyth, T.J. 2005. The Contribution of Commercial Fertilizer Nutrients to Food Production. *Agronomy Journal*, 97(1): 1. https://doi.org/10.2134/agronj2005.0001

Sthiannopkao, S. & Wong, M.H. 2013. Handling e-waste in developed and developing countries: Initiatives, practices, and consequences. *Science of The Total Environment*, 463–464: 1147–1153. https://doi.org/10.1016/j.scitotenv.2012.06.088

Stockholm Convention. 2018. *All POPs listed in the Stockholm Convention.* [online]. [Cited 3 April 2018]. http://chm.pops.int/TheConvention/ThePOPs/ListingofPOPs/tabid/2509/Default.aspx

Stork, P.R. & Lyons, D.J. 2012. Phosphorus loss and speciation in overland flow from a plantation horticulture catchment and in an adjoining waterway in coastal Queensland, Australia. *Soil Research*, 50(6): 515. https://doi.org/10.1071/SR12042

Stratton, M.L., Barker, A.V. & Rechcigl, J.E. 1995. Compost. *In* J.E. Rechcigl, ed. *Soil amendments and environmental quality*, p. Agriculture & environment series. New York, Lewis Publishers.

Štrok, M. & Smodiš, B. 2012. Transfer of natural radionuclides from hay and silage to cow's milk in the vicinity of a former uranium mine. *Journal of Environmental Radioactivity*, 110: 64–68. https://doi.org/10.1016/j.jenvrad.2012.02.009

Strzebońska, M., Jarosz-Krzemińska, E. & Adamiec, E. 2017. Assessing Historical Mining and Smelting Effects on Heavy Metal Pollution of River Systems over Span of Two Decades. *Water, Air, & Soil Pollution*, 228(4). https://doi.org/10.1007/s11270-017-3327-3

Sukul, P., Lamshöft, M., Kusari, S., Zühlke, S. & Spiteller, M. 2009. Metabolism and excretion kinetics of 14C-labeled and non-labeled difloxacin in pigs after oral administration, and antimicrobial activity of manure containing difloxacin and its metabolites. *Environmental Research*, 109(3): 225–231. https://doi.org/10.1016/j.envres.2008.12.007

Sun, F., Ma, Y., Guo, H. & Ji, R. 2018. Fate of Several Typical Organic Pollutants in Soil and Impacts of Earthworms and Plants. *In* Y. Luo & C. Tu, eds. *Twenty Years of Research and Development on Soil Pollution and Remediation in China*, pp. 575–589. Singapore, Springer Singapore. (also available at http://link.springer.com/10.1007/978-981-10-6029-8_35).

Swartjes, F.A., ed. 2011. *Dealing with Contaminated Sites*. Dordrecht, Springer Netherlands. (also available at http://link.springer.com/10.1007/978-90-481-9757-6).

Swartjes, F.A., Rutgers, M., Lijzen, J.P.A., Janssen, P.J.C.M., Otte, P.F., Wintersen, A., Brand, E. & Posthuma, L. 2012. State of the art of contaminated site management in The Netherlands: Policy framework and risk assessment tools. *Science of The Total Environment*, 427–428: 1–10. https://doi.org/10.1016/j.scitotenv.2012.02.078

Swartjes, F.A. & Tromp, P.C. 2008. A Tiered Approach for the Assessment of the Human Health Risks of Asbestos in Soils. *Soil and Sediment Contamination: An International Journal*, 17(2): 137–149. https://doi.org/10.1080/15320380701870484

Swati, Ghosh, P., Das, M.T. & Thakur, I.S. 2014. In vitro toxicity evaluation of organic extract of landfill soil and its detoxification by indigenous pyrene-degrading Bacillus sp. ISTPY1. *International Biodeterioration & Biodegradation*, 90: 145–151. https://doi.org/10.1016/j.ibiod.2014.03.001

Sweetman, A.J., Thomas, G.O. & Jones, K.C. 1999. Modelling the fate and behaviour of lipophilic organic contaminants in lactating dairy cows. *Environmental Pollution*, 104(2): 261–270. https://doi.org/10.1016/S0269-7491(98)00177-8

Syers, J.K., Johnson, A.E. & Curtin, D. 2008. *Efficiency of soil and fertilizer phosphorus use*. FAO Fertilizer and Plant Nutrition Bulletin No. 18. Rome, Italy, Food and Agriculture Organization of the United Nations. 108 pp. (also available at http://www.fao.org/docrep/010/a1595e/a1595e00.htm).

Szasz, F.M. 1995. The Impact of World War II on the Land: Gruinard Island, Scotland, and Trinity Site, New Mexico as Case Studies. *Environmental History Review*, 19(4): 15–30. https://doi.org/10.2307/3984690

Tang, X., Li, Q., Wu, M., Lin, L. & Scholz, M. 2016. Review of remediation practices regarding cadmium-enriched farmland soil with particular reference to China. *Journal of Environmental Management*, 181: 646–662. https://doi.org/10.1016/j.jenvman.2016.08.043

Tarazona, J.V. 2014. Pollution, Soil. *Encyclopedia of Toxicology*, pp. 1019–1023. Elsevier. (also available at http://linkinghub.elsevier.com/retrieve/pii/B9780123864543005315).

Teh, T., Nik Norulaini, N.A.R., Shahadat, M., Wong, Y. & Mohd Omar, A.K. 2016. Risk Assessment of Metal Contamination in Soil and Groundwater in Asia: A Review of Recent Trends as well as Existing Environmental Laws and Regulations. *Pedosphere*, 26(4): 431–450. https://doi.org/10.1016/S1002-0160(15)60055-8

Thiele, S. & Brümmer, G.W. 2002. Bioformation of polycyclic aromatic hydrocarbons in soil under oxygen deficient conditions. *Soil Biology and Biochemistry*, 34(5): 733–735. https://doi.org/10.1016/S0038-0717(01)00204-8

Thomas, C.M. & Nielsen, K.M. 2005. Mechanisms of and Barriers to, Horizontal Gene Transfer between Bacteria. *Nature Reviews Microbiology*, 3(9): 711–721. https://doi.org/10.1038/nrmicro1234

Thompson, R.C. 2004. Lost at Sea: Where Is All the Plastic? *Science*, 304(5672): 838–838. https://doi.org/10.1126/science.1094559

Tian, W., Wang, L., Li, Y., Zhuang, K., Li, G., Zhang, J., Xiao, X. & Xi, Y. 2015. Responses of microbial activity, abundance, and community in wheat soil after three years of heavy fertilization with manure-based compost and inorganic nitrogen. *Agriculture, Ecosystems & Environment*, 213: 219–227. https://doi.org/10.1016/j.agee.2015.08.009

Tien, Y.-C., Li, B., Zhang, T., Scott, A., Murray, R., Sabourin, L., Marti, R. & Topp, E. 2017. Impact of dairy manure pre-application treatment on manure composition, soil dynamics of antibiotic resistance genes, and abundance of antibiotic-resistance genes on vegetables at harvest. *Science of The Total Environment*, 581–582: 32–39. https://doi.org/10.1016/j.scitotenv.2016.12.138

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. & Polasky, S. 2002. Agricultural sustainability and intensive production practices. *Nature*, 418(6898): 671–677. https://doi.org/10.1038/nature01014

Topp, E. 2003. Bacteria in agricultural soils: Diversity, role and future perspectives. *Canadian Journal of Soil Science*, 83(Special Issue): 303–309. https://doi.org/10.4141/S01-065

Torrent, J., Barberis, E. & Gil-Sotres, F. 2007. Agriculture as a source of phosphorus for eutrophication in southern Europe. *Soil Use and Management*, 23(s1): 25–35. https://doi.org/10.1111/j.1475-2743.2007.00122.x

Tőzsér, D., Magura, T. & Simon, E. 2017. Heavy metal uptake by plant parts of willow species: A meta-analysis. *Journal of Hazardous Materials*, 336: 101–109. https://doi.org/10.1016/j.jhazmat.2017.03.068

Tran, B.C., Teil, M.-J., Blanchard, M., Alliot, F. & Chevreuil, M. 2015. Fate of phthalates and BPA in agricultural and non-agricultural soils of the Paris area (France). *Environmental Science and Pollution Research*, 22(14): 11118–11126. https://doi.org/10.1007/s11356-015-4178-3

Trendel, J.M., Lohmann, F., Kintzinger, J.P., Albrecht, P., Chiarone, A., Riche, C., Cesario, M., Guilhem, J. & Pascard, C. 1989. Identification of des-A-triterpenoid hydrocarbons occurring in surface sediments. *Tetrahedron*, 45(14): 4457–4470. https://doi.org/10.1016/S0040-4020(01)89081-5

Turick, C.E., Knox, A.S. & Kuhne, W.W. 2013. Radioactive elements in soil. Interactions, health risks, remediation, and monitoring. *Soils and human health*, pp. 137–154. Boca Raton, Fla, CRC Press.

TwEPA. 2014. Taiwan Toxic Chemical Substance Control Act (TCSCA). [Cited 3 April 2018]. http://www.chemsafetypro.com/Topics/Taiwan/Taiwan_Toxic_Chemical_Substance_Control_Act_TCSCA.html

Ulrich, A.E., Schnug, E., Prasser, H.-M. & Frossard, E. 2014. Uranium endowments in phosphate rock. *Science of The Total Environment*, 478: 226–234. https://doi.org/10.1016/j.scitotenv.2014.01.069

UN. 2016. Political declaration of the high-level meeting of the General Assembly on antimicrobial resistance. [Cited 4 April 2018]. http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/71/3

UNECE. 2011. Globally Harmonized System of classification and labelling of chemicals (GHS). New York and Geneva, United Nations. (also available at https://www.unece.org/fileadmin/DAM/trans/danger/publi/ghs/ghs_rev04/English/ST-SG-AC10-30-Rev4e.pdf).

UNEP. 1998. Rotterdan Convention on the Prior Informed Consent Procedure for Certain Hazardous chemicals and Pesticides in International Trade. [Cited 4 April 2018]. http://www.pic.int/TheConvention/Overview/TextoftheConvention/tabid/1048/language/en-US/Default.aspx

UNEP. 2001. The Stockholm Convention on Persistent Organic Pollutants as amended in 2009. [Cited 4 April 2018]. http://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx

UNEP. 2018. World commits to pollution-free planet at environment summit. In: *UN Environment* [online]. [Cited 4 April 2018]. http://www.unenvironment.org/news-and-stories/press-release/world-commits-pollution-free-planet-environment-summit

UNFCCC. 2015. The Paris Agreement - main page. In: *United Nations Framework Convention on Climate Change* [online]. [Cited 4 April 2018]. http://unfccc.int/paris_agreement/items/9485.php

US Agency for Toxic Subtances and Disease Registry. 2011. Public Health Assessment: U.S. Smelter and Lead Refinery. East Chigaco, Indiana, USS Lead. (also available at https://www.atsdr.cdc.gov/hac/pha/ussmelterandleadrefinery/ussleadphablue01272011.pdf).

US EPA. 1984. Method 610: Polynuclear Aromatic Hydrocarbons. , p. 25. Cincinati, Environmental Monitoring and Support Laboratory.

US EPA. 1986. Guidelines for the health risk assessment of chemical mixtures. No. EPA/630/R-98/002. Washington. (also available at https://www.epa.gov/sites/production/files/2014-11/documents/chem_mix_1986.pdf).

US EPA. 1998. Method 3051A. Microwave assisted acid digestion of sedments, sludges, soils, and oils. Washington. (also available at https://www.epa.gov/sites/production/files/2015-12/documents/3051a.pdf).

US EPA. 2012. Phthalates Action Plan., p.16. (also available at https://www.epa.gov/sites/production/files/2015-09/documents/phthalates_actionplan_revised_2012-03-14.pdf).

US EPA. 2013. Protecting and restoring land: Making a visible difference in communities: OSWER FY13 end of year accomplishments report. , p. 47. (also available at https://www.epa.gov/sites/production/files/2014-03/documents/oswer_fy13_accomplishment.pdf).

US EPA. 2014a. Sampling and Analysis Plan. Field sampling Plan and Quality Assurance Project Plan. No. R9QA/009.1. Washington. (also available at https://www.epa.gov/sites/production/files/2015-06/documents/sap-general.pdf).

US EPA, O. 2014b. Persistent Organic Pollutants: A Global Issue, A Global Response. In: *US EPA* [online]. [Cited 4 April 2018]. https://www.epa.gov/international-cooperation/persistent-organic-pollutants-global-issue-global-response

US EPA, O. 2014c. Research on Per- and Polyfluoroalkyl Substances (PFAS). In: *US EPA* [online]. [Cited 4 April 2018]. https://www.epa.gov/chemical-research/research-and-polyfluoroalkyl-substances-pfas

US Federal Register. 1993. 40 CFR Part 503: Standards for the use and disposal of sewage sludge. In: *LII / Legal Information Institute* [online]. [Cited 4 April 2018]. https://www.law.cornell.edu/cfr/text/40/part-503

Uzen, N. 2016. Use of wastewater for agricultural irrigation and infectious diseases. Diyarbakir example. *Journal of Environmental Protection and Ecology*, 17(2): 488–497.

Van der Putten, W.H., Jeffery, S., European Commission, Joint Research Centre & Institute for Environment and Sustainability. 2011. *Soil born human diseases.* Luxembourg, Publications Office.

Van Kauwenbergh, S.J. 2010. *World Phosphate Rock Reserves and Resources*. Alabama, US, International Fertilizer Development Center (IFDC). (also available at https://pdf.usaid.gov/pdf_docs/Pnadw835.PDF).

Van Maele-Fabry, G., Lantin, A.-C., Hoet, P. & Lison, D. 2010. Childhood leukaemia and parental occupational exposure to pesticides: a systematic review and meta-analysis. *Cancer Causes & Control*, 21(6): 787–809. https://doi.org/10.1007/s10552-010-9516-7

Vandenhove, H. & Turcanu, C. 2011. Agricultural land management options following large-scale environmental contamination. *Integrated Environmental Assessment and Management*, 7(3): 385–387. https://doi.org/10.1002/ieam.234

Vasseur, P. & Cossu-Leguille, C. 2006. Linking molecular interactions to consequent effects of persistent organic pollutants (POPs) upon populations. *Chemosphere*, 62(7): 1033–1042. https://doi.org/10.1016/j.chemosphere.2005.05.043

Venuti, A., Alfonsi, L. & Cavallo, A. 2016. Anthropogenic pollutants on top soils along a section of the Salaria state road, central Italy. *Annals of Geophysics*(5). https://doi.org/10.4401/ag-7021

Viret, O., Siegfried, W., Holliger, E. & Raisigl, U. 2003. Comparison of spray deposits and efficacy against powdery mildew of aerial and ground-based spraying equipment in viticulture. *Crop Protection*, 22(8): 1023–1032. https://doi.org/10.1016/S0261-2194(03)00119-4

Vitousek, P.M., Naylor, R., Crews, T., David, M.B., Drinkwater, L.E., Holland, E., Johnes, P.J., Katzenberger, J., Martinelli, L.A., Matson, P.A., Nziguheba, G., Ojima, D., Palm, C.A., Robertson, G.P., Sanchez, P.A., Townsend, A.R. & Zhang, F.S. 2009. Nutrient Imbalances in Agricultural Development. *Science*, 324(5934): 1519–1520. https://doi.org/10.1126/science.1170261

Vollaro, M., Galioto, F. & Viaggi, D. 2017. The circular economy and agriculture: new opportunities for re-using Phosphorus as fertilizer. Bio-based and Applied Economics.

Volpe, M.G., La Cara, F., Volpe, F., De Mattia, A., Serino, V., Petitto, F., Zavalloni, C., Limone, F., Pellecchia, R., De Prisco, P.P. & Di Stasio, M. 2009. Heavy metal uptake in the enological food chain. *Food Chemistry*, 117(3): 553–560. https://doi.org/10.1016/j.foodchem.2009.04.033

Wagner, G.J. 1993. Accumulation of Cadmium in Crop Plants and Its Consequences to Human Health. *Advances in Agronomy*, pp. 173–212. Elsevier. (also available at http://linkinghub.elsevier.com/retrieve/pii/S0065211308605933).

Wales, A. & Davies, R. 2015. Co-Selection of Resistance to Antibiotics, Biocides and Heavy Metals, and Its Relevance to Foodborne Pathogens. *Antibiotics*, 4(4): 567–604. https://doi.org/10.3390/antibiotics4040567

Wallova, G., Kandler, N. & Wallner, G. 2012. Monitoring of radionuclides in soil and bone samples from Austria. *Journal of Environmental Radioactivity*, 107: 44–50. https://doi.org/10.1016/j.jenvrad.2011.12.007

Walsh, S.., Maillard, J.-Y., Russell, A.., Catrenich, C.., Charbonneau, D.. & Bartolo, R.. 2003. Development of bacterial resistance to several biocides and effects on antibiotic susceptibility. *Journal of Hospital Infection*, 55(2): 98–107. https://doi.org/10.1016/S0195-6701(03)00240-8

Walters, E., McClellan, K. & Halden, R.U. 2010. Occurrence and loss over three years of 72 pharmaceuticals and personal care products from biosolids–soil mixtures in outdoor mesocosms. *Water Research*, 44(20): 6011–6020. https://doi.org/10.1016/j.watres.2010.07.051

Wan, X., Lei, M. & Chen, T. 2016. Cost–benefit calculation of phytoremediation technology for heavy-metal-contaminated soil. *Science of The Total Environment*, 563–564: 796–802. https://doi.org/10.1016/j.scitotenv.2015.12.080

Wang, F., Wang, Z., Kou, C., Ma, Z. & Zhao, D. 2016. Responses of Wheat Yield, Macro- and Micro-Nutrients, and Heavy Metals in Soil and Wheat following the Application of Manure Compost on the North China Plain. *PLOS ONE*, 11(1): e0146453. https://doi.org/10.1371/journal.pone.0146453

Wang, S. & He, J. 2013. Dechlorination of Commercial PCBs and Other Multiple Halogenated Compounds by a Sediment-Free Culture Containing *Dehalococcoides* and *Dehalobacter*. *Environmental Science & Technology*: 130904143020001. https://doi.org/10.1021/es4017624

Wang, T., Wang, Y., Liao, C., Cai, Y. & Jiang, G. 2009. Perspectives on the Inclusion of Perfluorooctane Sulfonate into the Stockholm Convention on Persistent Organic Pollutants [1]. *Environmental Science & Technology*, 43(14): 5171–5175. https://doi.org/10.1021/es900464a

Wang, Z., Li, J., Zhao, J. & Xing, B. 2011. Toxicity and Internalization of CuO Nanoparticles to Prokaryotic Alga *Microcystis aeruginosa* as Affected by Dissolved Organic Matter. *Environmental Science & Technology*, 45(14): 6032–6040. https://doi.org/10.1021/es2010573

Wania, F. & MacKay, D. 1996. Peer Reviewed: Tracking the Distribution of Persistent Organic Pollutants. *Environmental Science & Technology*, 30(9): 390A-396A. https://doi.org/10.1021/es962399q

Watkinson, A.J., Murby, E.J., Kolpin, D.W. & Costanzo, S.D. 2009. The occurrence of antibiotics in an urban watershed: From wastewater to drinking water. *Science of The Total Environment*, 407(8): 2711–2723. https://doi.org/10.1016/j.scitotenv.2008.11.059

Watson, A.P. & Griffin, G.D. 1992. Toxicity of vesicant agents scheduled for destruction by the Chemical Stockpile Disposal Program. *Environmental Health Perspectives*, 98: 259–280.

Wauchope, R.D., Yeh, S., Linders, J.B.H.J., Kloskowski, R., Tanaka, K., Rubin, B., Katayama, A., Kördel, W., Gerstl, Z., Lane, M. & Unsworth, J.B. 2002. Pesticide soil sorption parameters: theory, measurement, uses, limitations and reliability. *Pest Management Science*, 58(5): 419–445. https://doi.org/10.1002/ps.489

Wawer, M., Magiera, T., Ojha, G., Appel, E., Kusza, G., Hu, S. & Basavaiah, N. 2015. Traffic-Related Pollutants in Roadside Soils of Different Countries in Europe and Asia. *Water, Air, & Soil Pollution*, 226(7). https://doi.org/10.1007/s11270-015-2483-6

Welch, R.M., Hart, J.J., Norvell, W.A., Sullivan, L.A. & Kochian, L.V. 1999. Effects of nutrient solution zinc activity on net uptake, translocation, and root export of cadmium and zinc by separated sections of intact durum wheat (Triticum turgidum L. var durum) seedling roots. *Plant and Soil*, 208(2): 243–250. https://doi.org/10.1023/A:1004598228978

WHO. 1993. *The WHO recommended classification of pesticides by hazard and guidelines to classifications 1992-1993.* Ginebra, World Health Organization.

WHO. 2001a. Integrated Risk Assessment. (also available at http://www.who.int/ipcs/publications/new_issues/ira/en/).

WHO. 2001b. Schistosomiasis and soil-transmitted helminth infections. [Cited 4 April 2018]. http://www.who.int/neglected_diseases/mediacentre/WHA_54.19_Eng.pdf

WHO. 2008. Anthrax in humans and animals. Geneva, World Health Organization. (also available at http://www.who.int/csr/resources/publications/AnthraxGuidelines2008/en/).

WHO. 2010. Preventing Disease Through Healthy Environments. Action is needed on chemicals of major public health concern. , p. 6. Geneva, World Health Organization.

WHO. 2013. Contaminated sites and health. Copenhagen, Denmark. (also available at http://www.euro.who.int/__data/assets/pdf_file/0003/186240/e96843e.pdf).

WHO, ed. 2014. *Antimicrobial resistance: global report on surveillance*. Geneva, Switzerland, World Health Organization. 232 pp.

WHO. 2017a. Soil-transmitted helminth infections. In: *WHO* [online]. [Cited 4 April 2018]. http://www.who.int/mediacentre/factsheets/fs366/en/

WHO. 2017b. Food safety. In: *WHO* [online]. [Cited 4 April 2018]. http://www.who.int/mediacentre/factsheets/fs399/en/

WHO. 2018. Antimicrobial resistance. In: *WHO* [online]. [Cited 4 April 2018]. http://www.who.int/mediacentre/factsheets/fs194/en/

WHO & FAO. 1995. General Standard for Contaminants and Toxins in Food and Feed. [Cited 4 April 2018]. http://www.fao.org/fileadmin/user_upload/livestockgov/documents/1_CXS_193e.pdf

Wierzbicka, M., Bemowska-Kałabun, O. & Gworek, B. 2015. Multidimensional evaluation of soil pollution from railway tracks. *Ecotoxicology*, 24(4): 805–822. https://doi.org/10.1007/s10646-015-1426-8

Wilcke, W. 2007. Global patterns of polycyclic aromatic hydrocarbons (PAHs) in soil. *Geoderma*, 141(3–4): 157–166. https://doi.org/10.1016/j.geoderma.2007.07.007

Winckler, C. & Grafe, A. 2001. Use of veterinary drugs in intensive animal production: Evidence for persistence of tetracycline in pig slurry. *Journal of Soils and Sediments*, 1(2): 66–70. https://doi.org/10.1007/BF02987711

Wislocka, M., Krawczyk, J., Klink, A. & Morrison, L. 2006. Bioaccumulation of Heavy Metals by Selected Plant Species from Uranium Mining Dumps in the Sudety Mts., Poland. *Polish Journal of Environmental Studies*, 15(5): 811–818.

Withers, P.J.A., Sylvester-Bradley, R., Jones, D.L., Healey, J.R. & Talboys, P.J. 2014. Feed the Crop Not the Soil: Rethinking Phosphorus Management in the Food Chain. *Environmental Science & Technology*, 48(12): 6523–6530. https://doi.org/10.1021/es501670j

Witte, W. 1998. BIOMEDICINE: Medical Consequences of Antibiotic Use in Agriculture. *Science*, 279(5353): 996–997. https://doi.org/10.1126/science.279.5353.996

Woywodt, A. & Kiss, A. 2002. Geophagia: The History of Earth-Eating. *Journal of the Royal Society of Medicine*, 95(3): 143–146. https://doi.org/10.1177/014107680209500313

Wu, C., Spongberg, A.L. & Witter, J.D. 2009. Adsorption and Degradation of Triclosan and Triclocarban in Soils and Biosolids-Amended Soils. *Journal of Agricultural and Food Chemistry*, 57(11): 4900–4905. https://doi.org/10.1021/jf900376c

Wu, C., Spongberg, A.L., Witter, J.D., Fang, M., Ames, A. & Czajkowski, K.P. 2010. Detection of Pharmaceuticals and Personal Care Products in Agricultural Soils Receiving Biosolids Application. *CLEAN - Soil, Air, Water*, 38(3): 230–237. https://doi.org/10.1002/clen.200900263

Wuana, R.A. & Okieimen, F.E. 2011. Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. *ISRN Ecology*, 2011: 1–20. https://doi.org/10.5402/2011/402647

Xia, L., Lam, S.K., Yan, X. & Chen, D. 2017. How Does Recycling of Livestock Manure in Agroecosystems Affect Crop Productivity, Reactive Nitrogen Losses, and Soil Carbon Balance? *Environmental Science & Technology*, 51(13): 7450–7457. https://doi.org/10.1021/acs.est.6b06470

Xia, L., Wang, S. & Yan, X. 2014. Effects of long-term straw incorporation on the net global warming potential and the net economic benefit in a rice–wheat cropping system in China. *Agriculture, Ecosystems & Environment*, 197: 118–127. https://doi.org/10.1016/j.agee.2014.08.001

Xia, Z., Duan, X., Qiu, W., Liu, D., Wang, B., Tao, S., Jiang, Q., Lu, B., Song, Y. & Hu, X. 2010. Health risk assessment on dietary exposure to polycyclic aromatic hydrocarbons (PAHs) in Taiyuan, China. *Science of The Total Environment*, 408(22): 5331–5337. https://doi.org/10.1016/j.scitotenv.2010.08.008

Xu, M.-Y., Wang, P., Sun, Y.-J., Yang, L. & Wu, Y.-J. 2017. Joint toxicity of chlorpyrifos and cadmium on the oxidative stress and mitochondrial damage in neuronal cells. *Food and Chemical Toxicology*, 103: 246–252. https://doi.org/10.1016/j.fct.2017.03.013

Yablokov, A.V., Nesterenko, V.B. & Nesterenko, A.V. 2009. Chapter III. Consequences of the Chernobyl Catastrophe for the Environment. *Annals of the New York Academy of Sciences*, 1181(1): 221–286. https://doi.org/10.1111/j.1749-6632.2009.04830.x

Yang, G., Chen, C., Wang, Y., Peng, Q., Zhao, H., Guo, D., Wang, Q. & Qian, Y. 2017a. Mixture toxicity of four commonly used pesticides at different effect levels to the epigeic earthworm, Eisenia fetida. *Ecotoxicology and Environmental Safety*, 142: 29–39. https://doi.org/10.1016/j.ecoenv.2017.03.037

Yang, H., Huang, X., Thompson, J.R. & Flower, R.J. 2014. Soil Pollution: Urban Brownfields. *Science*, 344(6185): 691–692. https://doi.org/10.1126/science.344.6185.691-b

Yang, Q., Tian, T., Niu, T. & Wang, P. 2017b. Molecular characterization of antibiotic resistance in cultivable multidrug-resistant bacteria from livestock manure. *Environmental Pollution*, 229: 188–198. https://doi.org/10.1016/j.envpol.2017.05.073

Yang, S., Liao, B., Yang, Z., Chai, L. & Li, J. 2016. Revegetation of extremely acid mine soils based on aided phytostabilization: A case study from southern China. *Science of The Total Environment*, 562: 427–434. https://doi.org/10.1016/j.scitotenv.2016.03.208

Yao, H., Xu, J. & Huang, C. 2003. Substrate utilization pattern, biomass and activity of microbial communities in a sequence of heavy metal-polluted paddy soils. *Geoderma*, 115(1–2): 139–148. https://doi.org/10.1016/S0016-7061(03)00083-1

Yaron, B., Dror, I. & Berkowitz, B. 2012. *Soil-Subsurface Change*. Berlin, Heidelberg, Springer Berlin Heidelberg. (also available at http://link.springer.com/10.1007/978-3-642-24387-5).

Yen, T.-H., Lin-Tan, D.-T. & Lin, J.-L. 2011. Food safety involving ingestion of foods and beverages prepared with phthalate-plasticizer-containing clouding agents. *Journal of the Formosan Medical Association = Taiwan Yi Zhi*, 110(11): 671–684. https://doi.org/10.1016/j.jfma.2011.09.002

Ying, G.-G., Yu, X.-Y. & Kookana, R.S. 2007. Biological degradation of triclocarban and triclosan in a soil under aerobic and anaerobic conditions and comparison with environmental fate modelling. *Environmental Pollution*, 150(3): 300–305. https://doi.org/10.1016/j.envpol.2007.02.013

Yu, Z., Gunn, L., Wall, P. & Fanning, S. 2017. Antimicrobial resistance and its association with tolerance to heavy metals in agriculture production. *Food Microbiology*, 64: 23–32. https://doi.org/10.1016/j.fm.2016.12.009

Yuan, Z., Jiang, S., Sheng, H., Liu, X., Hua, H., Liu, X. & Zhang, Y. 2018. Human Perturbation of the Global Phosphorus Cycle: Changes and Consequences. *Environmental Science & Technology*, 52(5): 2438–2450. https://doi.org/10.1021/acs.est.7b03910

Zahran, S., Laidlaw, M.A.S., McElmurry, S.P., Filippelli, G.M. & Taylor, M. 2013. Linking Source and Effect: Resuspended Soil Lead, Air Lead, and Children's Blood Lead Levels in Detroit, Michigan. *Environmental Science & Technology*, 47(6): 2839–2845. https://doi.org/10.1021/es303854c

Zeng, F., Cui, K., Xie, Z., Wu, L., Liu, M., Sun, G., Lin, Y., Luo, D. & Zeng, Z. 2008. Phthalate esters (PAEs): Emerging organic contaminants in agricultural soils in peri-urban areas around Guangzhou, China. *Environmental Pollution*, 156(2): 425–434. https://doi.org/10.1016/j.envpol.2008.01.045

Zeng, X., Li, L. & Mei, X. 2008. Heavy Metal Content in Chinese Vegetable Plantation Land Soils and Related Source Analysis. *Agricultural Sciences in China*, 7(9): 1115–1126. https://doi.org/10.1016/S1671-2927(08)60154-6

Zhang, H., Luo, Y., Wu, L., Huang, Y. & Christie, P. 2015a. Residues and potential ecological risks of veterinary antibiotics in manures and composts associated with protected vegetable farming. *Environmental Science and Pollution Research*, 22(8): 5908–5918. https://doi.org/10.1007/s11356-014-3731-9

Zhang, H., Wang, Z., Zhang, Y., Ding, M. & Li, L. 2015b. Identification of traffic-related metals and the effects of different environments on their enrichment in roadside soils along the Qinghai–Tibet highway. *Science of The Total Environment*, 521–522: 160–172. https://doi.org/10.1016/j.scitotenv.2015.03.054

Zhanqiang, Q.X.F. 2010. Degradation of Halogenated Organic Compounds by Modified Nano Zero-Valent Iron. *Progress in Chemistry*: Z1.

Zhao, S., Qiu, S., Cao, C., Zheng, C., Zhou, W. & He, P. 2014a. Responses of soil properties, microbial community and crop yields to various rates of nitrogen fertilization in a wheat–maize cropping system in north-central China. *Agriculture, Ecosystems & Environment*, 194: 29–37. https://doi.org/10.1016/j.agee.2014.05.006

Zhao, Y., Yan, Z., Qin, J. & Xiao, Z. 2014b. Effects of long-term cattle manure application on soil properties and soil heavy metals in corn seed production in Northwest China. *Environmental Science and Pollution Research*, 21(12): 7586–7595. https://doi.org/10.1007/s11356-014-2671-8

Zhou, X. & Zhang, Y. 2014. Temporal dynamics of soil oxidative enzyme activity across a simulated gradient of nitrogen deposition in the Gurbantunggut Desert, Northwestern China. *Geoderma*, 213: 261–267. https://doi.org/10.1016/j.geoderma.2013.08.030

Zhu, J.H., Li, X.L., Christie, P. & Li, J.L. 2005. Environmental implications of low nitrogen use efficiency in excessively fertilized hot pepper (Capsicum frutescens L.) cropping systems. *Agriculture, Ecosystems & Environment*, 111(1–4): 70–80. https://doi.org/10.1016/j.agee.2005.04.025

Zhu, Y.G. & Shaw, G. 2000. Soil contamination with radionuclides and potential remediation. *Chemosphere*, 41(1–2): 121–128.

Zouboulis, A.I., Moussas, P.A. & Nriagu, E.-C.J.O. 2011. Groundwater and Soil Pollution: Bioremediation. *Encyclopedia of Environmental Health*, pp. 1037–1044. Elsevier. (also available at http://linkinghub.elsevier.com/retrieve/pii/B9780444522726000350).

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