Chapter 1

Introductory Chapter: Soil Contamination and Alternatives for Sustainable Development

Dinora Vázquez-Luna and
María del Carmen Cuevas-Díaz

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1. Introduction

Soil degradation and environmental pollution have a great impact on human life, because every year, 2 million people die worldwide due to air pollution [1]; countless numbers of people are exposed unnecessarily to chemicals in the workplace, such as in the external environment [2], because soil, air, and vegetation contain organochlorine pesticides with high carcinogenic risk [3, 4] and heavy metals [5].

Potentially, all previous health problems can be prevented [6]; it has been estimated that in industrialized countries, 20% of the total incidence of diseases can be attributed to environmental factors [7], constituting a big problem for the world population. Toyama, Japan, in 1970, high concentrations of cadmium in rice were found (2.6 and 3.3 g); chronic disease onset was due to rice consumed with 0.36 ppm Cd (155 μg Cd average daily dietary intake), for 58.4 years [8]. Another example was the case of Love Canal in the United States, which is one of the most notorious episodes of soil contamination, where an electrochemical company obtained, in 1942, permission to deposit more than 21,000 tons of its waste; 25 years later, weathering made pollution evident, creating a far-reaching movement for North American environmental policy with lasting effects on public policy [9]. For this reason, there are studies where plants like *Chromolaena odorata* have been found, which is a hyperaccumulating species (100 mg kg^{-1}), and this could be used to eliminate Cd from the soil [10]. Therefore, in this book, the main effects of soil contamination are discussed, as well as some alternatives for sustainable development, with the aim of reducing the harmful effects produced by human activities on the environment.

2. Soils contaminated by heavy metals

Currently, the agricultural soils suffer from high concentrations of metals, such as As, Cd, Cr, Cu, Pb, Ni, Zn [11, 12] and Hg [13], exceeding the maximum permissible levels and causing a potential risk; industrial soils can be up to 2600 mg kg^{-1} of lead [14], being important to know your inputs and outputs [15]. The countries with the highest cadmium concentrations are Jamaica (200 mg kg^{-1}), India and Pakistan (19–20 mg kg^{-1}), Tunisia, and UK (10–16 mg kg^{-1}) [16]. Other sources of soil contamination are the mining industries and the processing of minerals, which have been found in ascending values: Cd (0.7) → Cu (3.9) → Mn (76) → Fe (79) → Zn (110) → Pb (126) [17].

However, this pollution problem is an important issue for public policies, because the risk assessment must be integrated into the framework of public health and environmental security [18], because concentrations of heavy metals have been found in crops closely related to soil contamination, for example, according to the Chinese environmental quality standard for soil (GB15618–1995), 64.4, 78.9, 67.5, and 94.1% of the soil samples in Dexing, Yangjiazhangzhi, Hongqiling, and Baiyin exceed the maximum allowed concentration of Cd for farmland, respectively [19]. The risk assessment has indicated that priority attention is required due to the carcinogenic risk of Cr, Cd, and As in soil and rice grains, as well as the potential ecological risks [20].

In addition to this, associations have been found between some bacterial genera (*Geodermatophilus* spp., *Rhodovibrio* spp., and *Rubrobacter* spp.) with the presence of heavy metals such as copper, lead, and zinc, respectively [21]. In this regard, **Table 1** shows some examples of heavy metal remediation.

The cost and duration of soil remediation depend on the technique and the site specific, up to \$500 $tons^{-1}$ (\$1500 m^{-3} soil or \$100 m^{-2} soil) and 15 years [30], while it has estimated 20 million hectares of land contaminated by heavy metal.

Type of remediation	Pollutant
Extracellular polysaccharides or exopolysaccharides (EPS) are bacterial by-products with various strains that can be bioremediated in contaminated soils [22]	Cu, Co, Pb, Cd, Fe [23]
	Cr, Ni, Cd [24]
Phytoremediation by *Erigeron canadensis* L., *Digitaria ciliaris* (Retz.) Koel., and *Solanum nigrum* L. [25]	Hg, Cd
Biopiles improved soil properties and reduced the solubility of contaminants [26]	Zn, Cu
Bioremediation using *Rhodobacter sphaeroides* [27]	Zn, Cu
Microbial electrochemical system (MES)	Cr [29]
Sodium tripolyphosphate for the synthesis of chitosan nanoparticles from fungal chitosan [28]	Pb, Cu

Table 1. Examples of remediation of soils contaminated by heavy metals.

3. Soils contaminated by hydrocarbons

The global economy based on the oil industry has deteriorated natural resources around the world, with soil being one of the most affected [31]. Total petroleum hydrocarbons (TPH) contain fractions that are toxic to the beneficial organisms of the soil and for humans; this has become an important issue for the development of public policies, food safety, and environmental health because it produces changes in structure and function of soil ecosystems (**Figure 1**) [32].

Oil activities have mainly affected the tropical areas; this pollution has deteriorated soil sustainability, because its toxic effect decreases the ability to support living organisms [33], disrupts the biogeochemical cycles deteriorating ecosystems and altering fertility [34], and reduces quality of soil and agricultural potential [35]. Even hydrocarbons such as benzo[a]pyrene (BaP), belonging to one of the most toxic polycyclic aromatic hydrocarbons (PAHs) in the soil–plant system, are potentially mutagenic and carcinogenic for humans [36]. According to results from researchers in China, they have found between 131,019 m^3 and 146,783 m^3 of soil contaminated with benzo [a] pyrene; it should be mentioned that pollutants are accumulated mainly in the first layer of the site (0–1 meter) [37]. Its main impact on human health is centered on its genotoxic properties (teratogenic, mutagenic, and carcinogenic) (**Figure 1**). The International Agency for Research on Cancer (IARC) and the World Health Organization (WHO) have reported as probable human carcinogens to benzo [a] anthracene, benzo [a] pyrene and dibenzo [a, h] anthracene, benzo [b] fluoranthene, benzo[k]fluoranthene, indene, pyrene and naphthalene; where some researchers have proposed the combination of risk assessments (governmental and computational) [38].

The refining and processing of petroleum can also send numerous chemical compounds to the atmosphere, such as naphthalene, which is considered a dangerous compound in the air

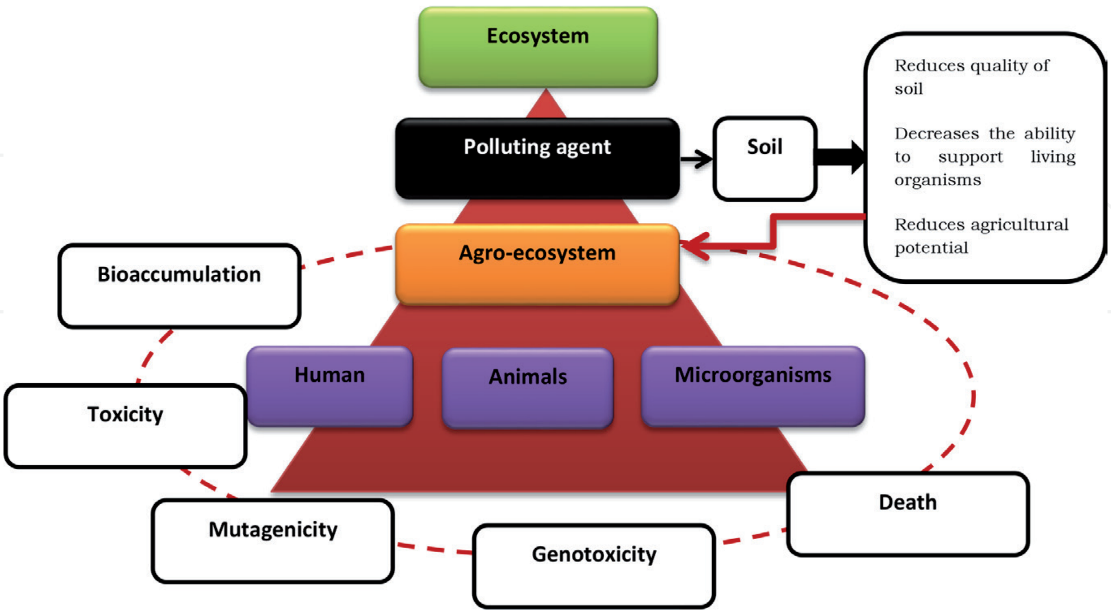

Figure 1. Scheme of the interaction of the pollutant with the agroecosystem.

according to the Environmental Protection Agency of the United States (USEPA), as it can cause irritation in the eyes, skin, and respiratory tract and in high concentrations can destroy red blood cells causing hemolytic anemia [39], besides being considered as a possible carcinogenic in humans (**Figure 2A**).

Another important factor is the contamination associated with heavy metals such as nickel and vanadium which depends on the oil field [40]. Another example is the Amazonia, located in northern Peru, where heavy metal pollution has been found, due to the extraction of hydrocarbons threatening wildlife and local populations that depended on subsistent hunting and fishing [41]; this risk has also been found in La Venta, Tabasco (**Figure 2B**) y en Minatitlán, Veracruz, México (**Figure 2C** and **D**). In this regard, recent studies indicate that the carcinogenic risks of 16 PAH increase with the history of oil extraction; ingestion and dermal contact are the predominant pathways of exposure of the inhabitants to PAH residues in soils [42], representing a risk to the inhabitants, farmers, fishermen, and consumers of these areas.

On the other hand, oil also has various effects on plants due to the changes they produce in the soil; oil can inhibit water retention, causing reduction of germination, emergence, growth, and accumulation of biomass, and cause nutritional imbalance, reduction in pasture production, and, therefore, lower percentage of livestock hectare.

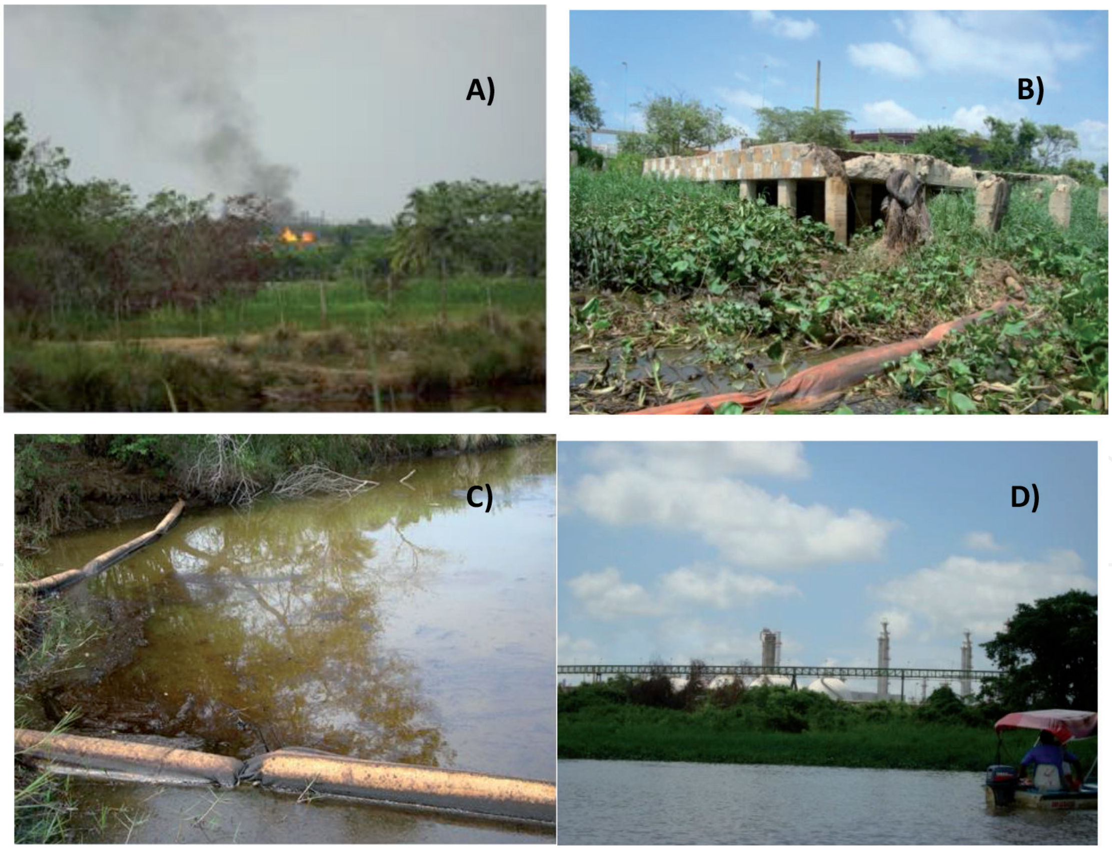

Figure 2. (A) Burning of waste by the petrochemical La Venta, Tabasco, Mexico; (B) sludge in contaminated sites in La Venta, Tabasco, Mexico; (C) petrochemical complex of Minatitlán, Veracruz, México; (D) Santa Alejandrina reservoir adjacent to the Minatitlán petrochemical complex, Veracruz, Mexico.

4. Research proposals

The strategies would be directed toward the integral management of the investigations: (1) the epidemiological study in contaminated areas, (2) the remediation of contaminated soils, and (3) the control of atmospheric emissions.

4.1. Health proposals

we recommend conducting epidemiological studies differentiated by sex, age, and chronic diseases (various types of cancer, asthma, allergic rhinitis, mental problems, depression, etc.); poor air quality, derived from industrial emissions, can influence the increase of diseases, including allergic ones, such as asthma and chronic bronchitis [43], whose pathologies are of high economic cost, in addition, its potential risks as a carcinogenic factor [42].

4.2. Proposals in soils

In the case of contaminated waters and soils, physical, chemical, and biological processes can be used to remove contaminants. However, there is evidence that some of these technologies can cause damage to biota and prevent the recovery of certain habitats [44]. The use of technologies such as bioremediation and phytoremediation are recommended; we propose a mixed process involving several types of remediation, for example, phytoremediation with fibrous root grasses that promote a dense rhizosphere, being the ideal type of vegetation for phytoremediation; it would also be recommended to combine these with biostimulation and bioaugmentation of autochthonous soil remediation bacteria. The vegetal cover besides contributing to the cleaning of contaminated soils can also reduce the transport of contaminants, improving the physical and chemical properties and increasing the microbial activity with better associations of microorganisms with the root and with the toxic compounds in the contaminated soil. Despite this, another problem of great importance is the accumulation of salts, whose effects can greatly harm the growth and development of many plants, so the use of tolerant plants is recommended. It is also necessary to develop sustainable alternatives that reduce pollution and allow the recovery of contaminated resources through remediation processes of soil and water, until pollutants are below the maximum permissible limits.

4.3. Proposals to control atmospheric emissions

In the case of Mexico, it is necessary to follow the guidelines of the Official Mexican Standards on Air Pollution (NOM-085-ECOL-1994). However, it is also necessary to develop sustainable alternatives that reduce greenhouse gas emissions. In addition, to have records and controls of atmospheric emissions, this must be available through the Federal Transparency Law.

5. Conclusions

Anthropogenic activities have caused changes from the global to the local. The health of the inhabitants have deteriorated due to exposure to various pollutants, the incidence of diseases that has increased, new ones that have emerged, and others that have changed their patterns. Therefore, we need to take measures to protect the environment in favor of human health, with synergistic effects on agroecosystem and food safety.

Author details

Dinora Vázquez-Luna* and María del Carmen Cuevas-Díaz

*Address all correspondence to: dra.vazquez.luna@gmail.com

Faculty of Engineering in Agricultural Production Systems (FISPA), Universidad Veracruzana, Mexico

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