Chapter 1
Causes and Effects of Pesticide and Metal Pollution on Different Ecosystems

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1.1 Introduction

The interference of human beings on the environment is harmful if it does not respect the principles of sustainability (Qadri and Bhat 2019). It can end up inserting synthetic substances in the environment that become persistent pollutants or promoting the disposal of a large amount of naturally occurring elements in a quantity that represents risk to the living organisms. In the first described scenario, the use of pesticides, and in the second scenario the pollution promoted by heavy metals are examples (Mehmood et al. 2019; Rashid et al. 2019; Singh et al. 2019). So, respectively, organic and inorganic pollutants can threat ecosystems as consequence of human activities like the attempt to improve agricultural production, mine exploitation, industrial production of different products, etc. (Jafari et al. 2013; Morillo and Villaverde 2017; Barrios-Estrada et al. 2018; Mateos et al. 2018; Bilal et al. 2019; Mendes et al. 2019; Pesantes et al. 2019; Pu et al. 2019; Rosculete et al. 2019; Aruliah et al. 2019; Vázquez-Luna and Cuevas-Díaz 2019: Zhang et al. 2019).

1.2 Causes and Effects of Heavy Metal Pollution

Heavy metals are naturally present in trace amounts in the environment and they can reach living forms through the occurrence of natural processes like volcanic eruptions and forest fires. However, when it comes to pollution, anthropogenic processes, involving water, soil and/or air, as causes of environments contamination with these

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harmful elements are the most relevant source. Human interference can cause these elements to accumulate, in a way dependent on metal characteristics and climate factors (Zupancic 2017; Herath et al. 2018), reaching quantities that are considered unsafe.

These elements (for example: arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se), and zinc (Zn)) with high atomic weight (Duffus 2002; Busairi and Syahir 2018) can, even at low concentration, threat health of living forms (Muszynska and Hanus-Fajerska 2015). The maximum allowable concentration for Hg, for example, is, according to the United States Environmental Protection Agency, 0.002 μg/mL. Zn is more efficiently tolerable possessing a limit of 5 μg/mL (Odobašić et al. 2019).

These inorganic contaminants represent a serious environmental problem due to the fact that their pollution is persistent, lasting for long time periods (long half-life) on contaminated sites. And besides that, they possess the ability to bioaccumulate through the food chain and cause biomagnification (Mehmood et al. 2019; Rashid et al. 2019; Singh et al. 2018).

The presence of organic matter can favor toxic metals pollution as it can improve the capacities of elements like Hg^{2+}, Ni^{2+}, and Pb^{2+} to binding and accumulate (Rikta et al. 2018).

Mining regions are a very relevant source of contamination where not only soil but also watercourses can be polluted. But different kind of industries (for example, dealing with dyes and pigments or petroleum) can also relevantly contribute by discharging their effluents containing heavy metals into water like rivers, for example (Salomons et al. 1995; Goyer 2001; Alkorta et al. 2004; Karthik et al. 2017; Zhu et al. 2017; Jacob et al. 2018; Ali et al. 2019; Wang et al. 2019).

Among the damages that heavy metals can cause to human health is cancer, once these contaminants are teratogenic and carcinogenic agents (Mushtaq et al. 2019). By poisoning different organs and tissues these elements can also affect the spleen, lungs (causing asthma, for example), skin, bones, liver, pancreas, cornea, gut/stomach, heart and vessels, reproductive organs, brain, and kidney (Farombi et al. 2012; Abarikwu et al. 2013; Tepanosyan et al. 2017; Liu et al. 2018; Boateng et al. 2019). However, they can also cause the organism death after poisoning once they can induce high rates of oxidative stress that, on its turn, can induce cells to die. They can accumulate in soft tissues after entering the body through mainly: skin absorption during industrial activities by adults or ingestion by kids (Jaishankar et al. 2014; Manzetti et al. 2014; Jacob et al. 2018; Masindi and Muedi 2018; Xiong et al. 2019; Yang et al. 2019).

Air can be highly polluted, especially in big cities with intense industrial activities and transportation based on the use of fossil fuel. Particulate matters can arise from natural events like volcanic eruptions, dust storms, and soil erosion but mainly from anthropogenic activities like waste incineration (Li et al. 2017; Weibel et al. 2017) causing the environment, especially near the incinerator, to contain, for example, As, Cd, Cu, Hg, Pb, and Zn (Ma et al. 2018). Eye irritation and respiratory problems are the most quickly harmful effects observed as a consequence of air

pollution. Heavy metals present on air pollution can be delivered to the soil by acid rain, for example (Zheng et al. 2012; Ventura et al. 2017).

Soil can accumulate nondegradable heavy metals in high amounts being an important source of food contamination. The presence of heavy metals in soil also affect microorganism, impairing the degradation of biodegradable organic pollutants making the pollution scenario worse. Soil quality is also decreased as heavy metals can, for example, alter soil pH and natural chemistry (Musilova et al. 2016). Landfill is a relevant source of soil contamination with heavy metals risking the life of people who directly deal with the wastes and also people far from the pollution site who can be indirectly exposed through water collaterally contaminated or through air (Wittsiepe et al. 2017). Agriculture soils can also contain heavy metals like Mn, Zn, and Pb in high amounts exceeding the safe exposure values for humans (Hu et al. 2018; Shen et al. 2019; Yang et al. 2019).

A contaminated soil can pollute water nearby and/or groundwater through leachates, endangering the entire ecosystem (Jaishankar et al. 2014; Nagajyoti et al. 2010). As previously mentioned, the presence of organic matter can favor heavy metal pollution and it can also originate hidden pollution. Bottom sediments containing these elements adsorbed into matter can be generated (Liang et al. 2015; Ali et al. 2016; Petrosyan et al. 2019).

Therefore, water can also be polluted by heavy metals from diverse sources directly or indirectly and end up endangering all food chains and food webs (exposing human beings, that are commonly at the extreme of this chain, to a high level of pollutant, and causing serious health problems (Lee et al. 2002)). Water from mining areas, for example, experiences a reduction in biodiversity (Netto et al. 2013; Masindi 2016). Acid mine drainage containing heavy metals can induce lowering of water (and soil) pH making the environment unsuitable for the survival of organisms that are not acidophile (Tutu et al. 2008; Simate and Ndlovu 2014; Torres et al. 2014).

1.3 Causes and Effects of Pesticide Pollution

According to Food and Agriculture Organization (FAO 2019), pesticides are any substance or mixture of substances of chemical or biological ingredients used in agriculture to protect plants against weeds, pests, and diseases. They are capable of repelling, destroying, or controlling any pest, or regulating plant growth. In addition, it is also used against ectoparasites for animal protection. They have a variety of chemical structures.

These substances can be classified according to the target group they attack, their chemical structure, or origin: insecticides (chlorinated hydrocarbons, organophosphates, carbamate insecticides, pyrethroids, botanical and biological products, and others not elsewhere classified); mineral oils, fungicides, and bactericides (inorganic, dithiocarbamates, benzimidazoles, triazoles, diazoles, diazines, morpholines, others not elsewhere classified); herbicides (phenoxy hormone products, triazines,

amides, carbamate herbicides, dinitroanilines, urea derivatives, sulfonylurea, bipiridils, uracil, others not elsewhere classified); disinfectants, plant growth regulators, rodenticides (anti-coagulants, cyanide generators, hypercalcemics, narcotics, others not elsewhere classified); seed treatment—fungicides (dithiocarbamates, benzimidazoles, triazoles, diazoles, diazines, morpholines, botanical products and biological, others not elsewhere classified), seed treatment—insecticides (organophosphates, carbamate insecticides, pyrethroids, others not elsewhere classified); and other pesticides not elsewhere specified. In addition, they can also be classified into synthetic (carbamate (nitrogen), chlorinated, phosphorus, and chlorophosphorus), botanical (based on nicotine, pyrethrin, sabadine, rotenone), and inorganic, as some elements (including heavy metals) can also possess pesticide's activity (arsenic, thallium, barium, nitrogen, phosphorus, cadmium, iron, selenium, lead, copper, mercury, and zinc) (FAO 2019).

In recent years their effects on the environment and living organisms have attracted great attention because they are highly toxic substances to human beings. According to the Pesticide Actions Network UK (PAN UK 2019), after a single episode of inhalation, skin contact or ingestion, the symptoms may be immediately evident or can arise within 48 h in the acute toxicity (allergic sensitization, nausea, vomiting, diarrhea, eye and skin irritation, respiratory tract irritation, sore throat and/or cough, headache, loss of consciousness, extreme weakness, seizures and/or death). The effects of long-term toxicity include depression and anxiety, Parkinson's disease, asthma, cancer, attention deficit and hyperactivity disorder (ADHD).

When pesticides are released or applied to the environment, their effects are affected by environmental conditions, such as soil interaction and properties, agricultural practice characteristics, and local climatology (Bhat et al. 2018a; Quaglia et al. 2019).

Agricultural chemicals, for example, consist of fertilizers and pesticides. The main cause of pollution by these substances is their improper use: due to their excessive use or lack of knowledge when they are used, problems were already reported in several plantations such as cotton, maize, wheat and rice (Jin et al. 2015). The amount of insecticides, fungicides, herbicides' use is also increasing to try to provide the growing population with food (Gavrilescu 2005).

Pesticide soil pollution affects soil quality in different ways. The microorganisms present in it, for example, may have their growth rate and activities modified by the chemical, which will lead to modification of the nutrient cycle in the soil. The accumulation of macro and micronutrients such as sulfur (S), manganese (Mn), magnesium (Mg), phosphorus (P), and potassium (K) present in the hybrid Bermuda grass leaf tissues can be reduced, for example, due to the use of isoxaben, prodiamine, and indaziflam (Brosnan 2015). In addition, the root mass of this plant was also reduced compared to plants not treated by these pesticides (FAO 2019).

Another effect to be highlighted is the influence of pesticides on nutrient availability in the soil. For example, sulfur is an essential nutrient especially for crop agricultural production. The monocrotophos application significantly changes the oxidation rate of this nutrient in black and red soils in India. Thus, this rate increases

after 7–14 days of application of this substance alone or in combination with mancozeb in black soils (Srinivasulu et al. 2015).

In addition, the presence of pesticides in the soil may lead to changes in enzymatic activity. For example, the arylamidase and myrosinase enzymes may be stimulated by the acetamiprid and carbofuran insecticides. However, these same substances have a toxic effect on enzymatic activity in black and red clay soils (Mohiddin et al. 2015).

Thus, it is necessary to apply pesticide remediation techniques in order to try to eliminate these pollutants from the environment. However, it is also necessary to realize that remediation efficiency depends on factors such as chemical and physical properties of pesticides, climatic conditions, extent and concentration of pesticides, and the presence of other contaminants mixed in the soil/water. Remediation can be done by physical treatments such as soil washing or electro-remediation, or by bioremediation, through phytoremediation and microbial remediation in which plants and microorganisms, respectively, sequester, metabolize, or even release enzymes capable of destroying pesticides (Bhat et al. 2018a; Sun et al. 2018).

When it comes to water pollution, it can be divided into two types: diffuse sources and point sources (Vasilescu and Medvedovici 2005). Diffuse source pollution comes from unlicensed sources and dispersed land use activities. Examples of pollutants are: sediments, toxic substances, salts, acid sulfate soils in drained wetlands, raw pollutants, fertilizers, soil erosion by pathogens such as septic tank leaking bacteria. Pesticide spraying is one of the prime examples of diffuse source and, near the water surface, leads to its contamination. Pesticides enter the surface and soil through water runoff especially in agricultural areas, but also along roadsides, forested areas, golf courses, suburban, and urban landscape areas (Srivastava et al. 2019).

According to FAO, pesticide water contamination is related not only to agriculture but also to forestry in the forest industry, especially in Canada. In this industry, these substances are used to control forest pests, mainly insects, and are sprayed over large areas by aircraft. This use is mainly due to the generation of a habitat conducive to the creation of disease-bearing insects by modifying the water regime in irrigated agriculture in tropical and subtropical environments. In addition, to control disease vectors it is necessary in some cases to add insecticides such as DDT (FAO 2019).

Several factors are associated with the effects of pesticide on water quality. Highlights include impurities contaminating the active ingredient, additives mixed with the active ingredient such as buffers, preservatives, solvents, etc., active ingredients in the pesticide formulation, degraded by microbiological, photochemical, chemical degradation of active ingredients. Some factors are employed as criteria for measuring the effects of pesticides on the aquatic environment. They are: toxicity (expressed in Lethal Dose concentration), degraded, persistence (measured in half-life that may be influenced by metabolism and biodegradation in biotic factors, and hydrolysis, photolysis, and oxidation in abiotic factors), fate (this factor is influenced by the chemical's affinity with the environmental compartment: liquid, solid matter, gaseous form, and biota (FAO 2019)).

The effects of pesticides are varied and generally interrelated, and depend on the organism and the type of substance. Chronic, non-lethal effects are not noticeable, although they still have consequences in the food chain. The consequences are cancer, tumor, injury to fish and animals, suppression of the immune system, genetic and cellular damage, inhibition or failure of reproduction, death, disruption of the endocrine system, impoverishment of fish health marked by low red blood cells and white, intergenerational effects (effects are not apparent until subsequent generations of the organism) (Srivastava et al. 2019).

The main cause of air pollution by pesticides is the indiscriminate use of these substances especially in agriculture in an attempt to improve crop quality. Misuse of pesticides includes use of substances prohibited by local governments, lack of protective equipment, excessive spraying, reuse of washed pesticide containers such as food and drinking water containers, and improper storage. Pesticide use can be influenced by gender, age, chemical knowledge, cultural differences, and perceptions. In air, the main source of contamination is due to inhalation by crop sprays. Thus, the humans who are most affected by this pollution are those who live or work on farms (Özkara et al. 2015).

Organophosphates can enter animals through inhaled particles, ingestion, or skin contact. These pesticides are stored in their muscles and fat and can be found in the liver, lungs, and brain. In addition, these substances can be brought to humans through milk and other animal foods (Zhu et al. 2015).

Pesticide use is highly dangerous as poisoning can be lethal (Mushtaq et al. 2018). Organophosphate poisoning can lead to cholinergic syndrome with symptoms such as coma, blurred vision, delayed neuropathy, blockage of the respiratory center, headache, slurred speech. Although it is possible to reverse an acute bout of contamination, there are likely to be long-term nervous system effects. Other consequences of contamination with these substances are immunological endocrine disruption, function damage, female spontaneous abortions and preterm, and children neuro-developmental delays. In this way, it is essential to control the use of these substances and to study alternatives to their use and forms to revert their effect (Schierow and Esworthy 2012; Niti et al. 2013; Cheng et al. 2016; Liu et al. 2018; Reeves et al. 2019).

1.4 Conclusion

Human intervention on environment to economically explore it without considering sustainability induces an increasing concern and threat to life: pollution. As pollution increases in number of sites affected and its effects are increasingly noticed, researches have been dedicating attention to understand its causes and effects. Heavy metals and pesticides are two important persistent pollutants capable of biomagnifying and accumulating in the food chain. So, they are harmful to air, soil, and water, and consequently to the existence of life on the planet.

1.5 Future Perspectives

It is expected that humanity can understand the importance of interacting with the environment in a sustainable way to reduce the amount of pollutants accumulated. It is also necessary to find new ways to detect the presence of heavy metals and pesticides in water, air, and soil, and quantify their concentration to verify their compliance with the legislation parameters. Through multidisciplinary work, a strategy for monitoring these substances that is most economically viable, fast, reproducible, specific, and practical should be achieved. A good strategy is to adapt and refine existing techniques. Perhaps, this is the first step towards a sustainable environmental model, always remembering that each human being is part of it and by avoiding contamination he/she can protect his or her own health and the health from the others.

The great challenge of this process is the considerable diversity of pesticide's chemical structures, the interactions of heavy metals in each organism, and the interaction of contaminated living beings in the food chain. However, it is expected that in the future a viable alternative or, preferably, viable alternatives, will be reached.

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