REVIEW / ARTÍCULO DE REVISIÓN

Control of pesticides in Ecuador: An underrated problem?

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Abstract: Pesticides have become necessary control agents to guarantee food sovereignty and strengthen development in Ecuador. Nevertheless, the current management practices of pesticides in Ecuador restrain the progress of agriculture in this region. There is evidence of a knowledge gap regarding the correct handling of pesticides and the possible health impacts they generate, especially in small producers and surrounding communities. Furthermore, a lack of updated information on pesticide registration difficult their control and distribution. Given this, there is a need to implement new public policies that promote relations between science and technology, not only with the industry but also with local producers, to promote the growth of agriculture, minimizing risks to health and the environment in the sectors involved. The purpose of this review is to exhibit the most updated panorama regarding the management of pesticides in Ecuador.

KeyWords: Pesticides, human health, pesticide management, agriculture, agrocalidad, Ecuador.

Introduction

Agriculture in Developing Countries

Agriculture has a significant influence on various socioeconomic aspects of a country. Beyond ensuring the population's food supply and generating sources of employment, agriculture can accelerate the economy of a country by producing export goods that increase the national income. The increase in foreign exchange allows the acquisition of new goods and supplies that promote the development of the country. Furthermore, agriculture is a source of raw material for other industries, both national and international. However, the main challenge that developing countries face is to move away from a primary economy, which is dedicated to producing raw materials, and to enter into an economy that allows them to generate manufactured products with higher commercial value. Currently, the agricultural sector is subject to the availability of natural resources and changing climatic conditions, and the variability of prices imposed by large producers, which generates disparity in the distribution of profits between small and large farmers, accentuating levels of poverty in small producers.

Origin of pesticides

Agricultural practices have allowed food supply for the world's population since humans became sedentary. Although this practice has been industrialized over time, continuous worldwide demographic growth creates the need to increase crop yields to meet nutritional demands. The main internal factors that affect crop yields are plant genetics, and the external factors are primarily climatic conditions, water and nutrient supply, edaphic conditions, and the presence of diseases and pests[1]. According to the Food and Agricultural Organization of the United Nations (FAO), each year, approximately 40 % of food crops are lost due to plant pests and diseases, representing a loss of 220 billion dollars for the agricultural sector. [2] Moreover, the presence and dispersion of pests can be associated with climate change and human activities, since they give rise to alterations in ecosystems either due to the creation of new niches favorable to pests, or their spread through commercial activities[2]. Pest control has been varying across time, starting with an empirical selection of pest-resistant seeds since the Neolithic era, manual removal of pests to the use of chemical pesticides or biological control methods[3]. Pesticides are agents that allow pest control and their use has led the agricultural sector because they act as preventive agents that allow farmers to produce more in a smaller land, reduce production and market costs compared to organic products, diminish labor costs for tillage, improve human health by reducing the spread of diseases, among other benefits[4–6]. Therefore, the use of pesticides has allowed the improvement of not only crop yield but also its quality, generating higher profits for farmers and industry[4,7]. Thus, it is expected a global growth in the use of pesticides, around 11% in the coming years[7]. However, exposure to certain pesticides has become a severe risk to human and environmental health.

Evaluate the impact of a pesticide is complex because it implies analyze interactions between biotic and abiotic factors of an ecosystem, as well as consider the active and co-formulating components of the pesticide, where chemical alterations such as changes in polarity, molecular symmetry or spatial arrangement of molecules may be present, hence effects on the environment may be unpredictable[7]. The main problems associated with the use of pesticides involve the misuse at the time of handling, dispersion, and contamination through water and soils outside the cultivation area, lack of specificity, tissue bioaccumulation, and biological magnification through the food chain[8]. Thus, before their application, it is necessary to evaluate not only the effectiveness of each pesticide but also the potential risks to the safety and health of living beings and the ecosystem that surrounds them.

Type of pesticides

Carbamates

Carbamates are a type of pesticides derived from carbamic acids, which include herbicides, fungicides, and insecticides mostly. The chemical structure of carbamates is shown in

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Figure 1A. The mechanism of action of carbamate pesticides is to work as an inhibitor of the acetylcholinesterase enzyme (AChE) in a similar way to organophosphate pesticides[9]. The inhibition of AChE causes an increase of acetylcholine at synapses in the central nervous system, at parasympathetic effector junctions, and at neuromuscular junctions, which in turn causes an overstimulation of the nervous system[10–12]. This inhibition is reversible because of the spontaneous hydrolysis of the carbamylated enzyme[11]. Thus, as the carbamyl-acetylcholinesterase complex dissociates promptly than the phosphoryl-acetylcholinesterase complex, the possible toxic effects in mammalian are less aggressive and reversible than those produced by organophosphate pesticides[11,12]. That is why carbamates pesticides are widely used not only in agroindustry but also for domestic use and gardens.

Organophosphates

Organophosphates involve a family of pesticides that handle pests, causing interferences in the nervous system. This class of pesticides promotes the accumulation of acetylcholine, producing difficulties in the transmission of nerve impulses, similarly to carbamates, that is, inhibiting AChE enzyme activity[13]. However, the inhibition caused by organophosphates tends to be irreversible spontaneously, so that the neurotoxic effects have a longer duration, generating more significant threats, and long-term consequences if they are not treated early[14]. Moreover, due to its potential toxicity, some variations of this pesticide such as parathion have been withdrawn from the market or limited to agro-industrial use such as chlorpyrifos[13]. The toxic effects and effectiveness of the pesticide may vary depending on the functional group that carries the compound and other agents included in the formulation. The general chemical structure of organophosphates is shown in Figure 1B. The route of absorption can also influence the degree of toxicity of the compound; thus, inhalation or ingestion of organophosphates pesticides can generate more significant threats than dermal absorption[13].

Organochlorines

Pesticides containing at least one ring structure and several chlorine atoms are considered organochlorine[15]. This type of pesticides has been one of the most used during the years 1940-1960 due to their low cost. Among the best-known pesticides that belong to this group are dichlorodiphenyltrichloroethane (DDT), gamma-hexachlorocyclohexane (γ-HCH, or lindane), methoxychlor, endrin, endosulfan, among others[16]. DDT chemical structure is shown in Figure 1C. The mechanism of action of these pesticides affects the nervous system of the plague by causing disruptions in ion flow, which in turn affects the transmission of the nerve impulse[15]. DDT and derivatives, for example, alter the action potential generated by neurons through their interaction with sodium channels in axons, generating hyperexcitability of neurons[15,16].

On the other hand, another group of organochlorines known as cyclodienes interacts with the gamma-aminobutyric acid (GABA) receptors preventing the transmission of the action potential between neurons[15,16]. Organochlorine compounds are considered as persistent organic pollutants (POPs) due to their lipophilic properties, which means that they can be bioaccumulated and biomagnified in soils, waters, and living organisms, increasing their risk of toxicity and adverse effects[15]. Therefore, as of the 1970s, they begin to be banned due to the serious adverse health effects, and only remained to be used in some developing countries to control vector disease organisms such as the mosquito that spreads malaria or for specific purposes[17].

Pyrethrins and pyrethroids

Pyrethrins are organic compounds extracted from the *Chrysanthemum cinerariifolium* plant. This substance possesses natural insecticidal properties, which is why it is considered as an organic insecticide of low toxicity for humans and of low permanence in the environment because it degrades rapidly[18]. This is why pyrethrin-based insecticides are widely used in the home and on a small scale as a substitute for other pesticides such as organophosphates and organochlorines[19]. However, pyrethrins are not entirely stable under several environmental conditions, and many pests can develop resistance over time[18]. Pyrethroids, on the other hand, are substances of a synthetic nature similar to pyrethrin but with more significant insecticidal potential that require less application dose[20].

Nevertheless, new versions of pyrethroids seem to be more persistent in the environment and can affect non-targeted species such as beneficial insects, small invertebrates, and fish[20,21]. The mechanism of action for both pyrethrins and pyrethroids involves a delay in the closure of sodium channels, causing neuronal dysfunction in the affected organisms[19]. Figure 1D displays the chemical structure of a pyrethroid molecule.

Triazines

Triazines are chemical compounds used in the petroleum industry, in the manufacture of resins such as melamine, and as a basis for formulating herbicides. The best-known herbicide within the triazine group is atrazine, whose chemical structure is shown in Figure 1E. Triazines are responsible for controlling broadleaf weeds in crops such as corn, sugar cane, sorghum, cotton, among other fruits[22]. The triazines, like the organochlorines, are considered POP. Therefore, they generate a risk of accumulation in the environment. The mechanism of action of triazines is based on preventing the photosynthesis process through competitive inhibition, displacing plastoquinone from its binding site in photosystem II, limiting the nutrient resources of the pest and causing oxidative stress[23,24].

Ecuadorian situation

In 2008, to guarantee the quality of life through food security, ensure quality products for use and consumption, and to protect the health of consumers, the Ecuadorian State decrees the creation of the Ecuadorian Agency for Regulation and Phyto and Zoosanitary Control (Agencia de Regulación y Control Fito y Zoosanitario, AGROCALIDAD)[25]. This agency is assigned, among other functions, the design, implementation, and promotion of Good Agricultural Practices (GAP), which consist of a set of standards, principles, and technical recommendations applied to the entire food production chain considering social, economic, and environmental sustainability[25,26]. The implementation of GAP in Ecuador is based on three main aspects: [1] Food safety, guaranteeing a product free of physical, chemical or biological hazards to the consumer; [2] Environmental care and management, especially from sources of water, soil, and beneficial species to the ecosystem; and [3] Job security, through training of farmers and operators on the use of personal protective equipment (PPE) to take care of their health, and the importance of their work to assure the health of their

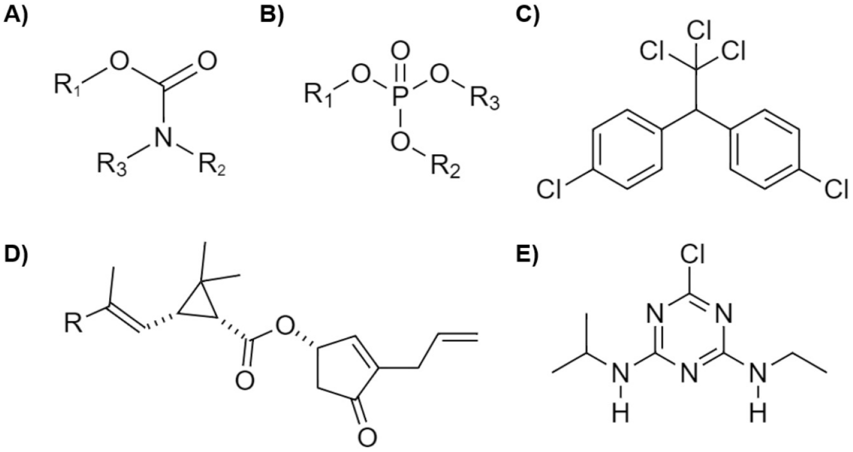

Figure 1. Chemical structure of the primary type of pesticides. A) carbamate, B) organophosphate functional group, C) DDT, an organochlorine pesticide, D) allethrin the first pyrethroid molecule to be synthesized, E) atrazine, a triazine pesticide. Figure created with ChemDraw.

family members and consumers[27]. Until January 2020, there were 242 Agricultural Production Units (APU) certified with GAP in Ecuador[28].

One of the stages required to become certified with the GAP is to plan processes to protect crops through the implementation of an Integrated Pest Management (IPM) plan. An IPM plan must contemplate strategies for prevention, monitoring, evaluation, and intervention against pests[27]. In the case that intervention is required to reduce pests' presence, the Ecuadorian normative recommends prioritizing physical, mechanical, biological, ethological, or genetic management. The use of agrochemicals should be used as a last resort, in cases of severe invasion, and according to the recommendations of a specialist[29]. Nevertheless, the results of the Continuous Agricultural Surface and Production Survey (ESPAC) 2016, show that the Ecuadorian reality moves away from the standards set by the regulations. Under the multi-frame sampling methodology, this survey has allowed obtaining information related to the production area and land use at a national level. A case study was carried out in which 24946 agricultural producers participated, to gather information about the use, management, and final disposal of pesticides and fertilizers. According to the National Institute of Statistics and Census (INEC) in 2016, 19% of the Ecuadorian surface area is for agricultural use, mainly for cultivated pastures (48%), permanent crops (31%), and temporary crops (21%)[30]. Figure 2 shows a standard distribution of agricultural crops in the Andean region of Ecuador. Beyond the productive losses in crops associated with the 2016 earthquake in Ecuador, the invasion of pests represents one of the main enemies of the farmers and the quality of both permanent and transient crops, creating the need to use pest control methods. Thus, between 2014-2016 approximately 50% of permanent crops and 75% of transient crops used agricultural products of chemical origin (fertilizers and pesticides), from which at least 25% of the pesticides used are cataloged in a moderately to a hazardous range[30].

On the other hand, although the amount of pesticide products used in crops is alarming, the main problem is related

Figure 2. Agricultural area in Otavalo, Imbabura province, Ecuador.

to the agricultural practices carried out by the farmer producers. Proper management of pesticides at the time of storage, application, and final disposal could significantly reduce the risks and health effects on producers, consumers, and the ecosystem surrounding the crop, as well as an improvement in production costs and product yield. Nevertheless, it is estimated that only two out of ten farmer producers have been trained for the use and management of agrochemicals[30]. Thus, in less than 4% of the cases studied, a specialized technician is in charge to apply the chemical products in the crops, in most of the cases the person in charge of the application is the same farmer (49%) or a laborer (34%)[30]. Education level also seems to play a decisive role in the treatment that the producers provide to their crops since the higher the education level, the greater the number of people who have performed a soil analysis before cultivating, which is necessary to determine the nutritional and pest control needs. However, in general, more than 80% of farmer producers have never performed a soil analysis of their lands, which could affect the long-term fertility of the land, and consequently, the production yields[30].

The proper handling of the pesticide containers before final disposal can minimize risks of poisoning due to the use of pesticide residues or contamination in soils and water sources. According to FAO, a pesticide container management plan must include immediate decontamination after use, disabling of the containers so that they cannot be reused with perforations, and availability of certified collection centers that can safely manage the waste[31]. Ecuadorian regulations require that water-soluble pesticide containers go through a triple wash process before final disposal for which they must be identified appropriately avoiding contamination of water sources, soil, or air. Therefore, as a ge-neral provision in Ecuador, empty containers of agrochemicals should not be incinerated, buried, or reused to store water or food[32]. Nevertheless, although eight out of ten people carry out the practice of triple washing to empty pesticide containers, approximately 17% of people pour the washing liquid into water sources or soil instead of the fumigation pump as established by national and international normative[30-32]. The ESPAC survey has revealed that, once the pesticide containers have been used, the final disposal varies between burning (47%), rubbish (29%), management (16%), and buried (8 %)[30]. However, burning occurs almost entirely in an open environment; in the case of disposal, more than three quarters go to common garbage or directly to land fields, one-fifth of the managed containers are reused, and more than half of the buried containers are deposited in diffe-rent unidentified places[30].

Another emerging problem related to the management of agrochemicals is the remaining presence of obsolete pestici-des in the national market. An obsolete pesticide is considered to be any expired, adulterated, unregistered or banned subs-tance that can no longer be used for the purpose for which they were made or that have more dangerous ecotoxicologi-cal characteristics than other existing pesticides[33]. According to FAO, developing countries contain the most substantial amount of obsolete pesticides, which are not handled with the appropriate safety measures, creating a risk of environmen-tal contamination and poisoning in surrounding populations. In Ecuador, in 2014, a comprehensive management plan for ob-solete pesticides began, safely eliminating 16 tons of obsolete pesticides accumulated throughout the country[34]. However, in 2017 a new inventory was made where 112.20 tons of toxic substances were found, indicating failures in the management of the institutions responsible for controlling these substan-ces[33]. A control measure established by national regulations is to keep a record of the application of pesticides indicating information such as dates, names of the product, the active ingredient, dose applied, among other characteristics[29]. Nevertheless, until 2008 a fifth of the agricultural producers were illiterate[35]. Therefore, it must be taken into consideration that many farmers are not able to keep track of the application of agrochemicals in their crops and require the implementation of other strategies for capacitation.

Thus, the results of the ESPAC survey demonstrate the need to increase control in the management of pesticides nationwide. Furthermore, the regulations in force have a more direct application to agroindustry. However, they do not demonstrate alternatives for waste management that can be used by small farmers who work independently and whose socioeconomic level does not allow them to access the necessary information and supplies through the channels currently offered. Small farmers distribute their food locally, generally in neighboring sectors precisely where the population is most vulnerable to the risks caused by the mismanagement of agrochemicals.

Most used pesticides in Ecuador

In Ecuador, pesticides are generally classified by risk of hazard based on the classification criteria of the World Health Organization (WHO). This categorization includes four different classes I, II, III, and U. Each class represents a hazard level: extremely hazardous (Ia), highly hazardous (Ib), moderately hazardous (II), slightly hazardous (III), unlikely to present an acute hazard (U, sometimes referred to as to IV)[36]. According to INEC, until 2016, more than 50% of pesticides used in Ecuador belong to classes III and IV, while 30-40% vary between classes Ia, Ib, and II, however a certain percentage of farmers are unaware of the type of pesticide they administer to their crops[30].

In 2015, Rivera carried out an analytical study about the registry of pesticides in Ecuador based on the information provided by AGROCALIDAD in 2014[37]. A record of 411 active ingredients of fungicides, insecticides, and herbicides was found, for which there were 2,076 trade names[37]. Table 1 shows information regarding the use, hazard classification, and type of pesticide of these registered products. The author states that there is a lack of standardization in the requirements to register a pesticide, which along with a large number of trade names, makes the identification more difficult for unskilled farmers to become familiar with the trade names rather than both the active ingredients and the relevant concentrations[37].

Furthermore, Table 1 shows that the most common crops that use a large number of pesticides are both those that represent export goods such as bananas and roses and those that are essential in the Ecuadorian basic food basket such as rice, potato, corn, sugar cane, and tomato. Carbofuran, alachlor, and methamidophos, pesticides used mainly in potato crops, have been banned more than five years ago in Ecuador, because of their demonstrated health risk. However, until 2016 some commercial products were still registered with the active ingredient of these pesticides[38]. On the other hand, paraquat, used in rice, banana, cocoa, potato, corn and pineapple crops; glyphosate, used in bananas, sugar cane, beans and pineapple; and mancozeb, used in bananas and potatoes, possess active ingredients that are still found in more than a hundred commercial products registered in AGROCALIDAD according to information of 2016[38].

Health consequences associated with pesticides misuse in Ecuador

Although the increase in productivity associated with the use of pesticides is indisputable, their use has been highly

Type of pesticide	Number of registered trade names	Hazard classification		Most common crops for registered use
Fungicide	804	94	II	Banana, roses, potato, tomato, rice
		450	III	
		260	IV/U	
Insecticide	556	3	Ia	Roses, tomato, corn, potato, rice
		27	Ib	
		137	II	
		216	III	
		73	IV/U	
Herbicide	716	89	II	Rice, corn, sugarcane, African palm, banana
		396	III	
		231	IV/U	

Table 1. Use hazard classification and number of registered trade names for different types of pesticides in Ecuador until 2014. Source: Rivera[37].

questioned due to the possible adverse health effects of non-target living organisms. Some pesticides are incredibly toxic to humans and the ecosystem, so their use has been prohibited. However, pesticides may remain unnoticed in water and soil for a long time due to several factors such as persistence and composition[8]. The damage caused by pesticides can be acute or chronic according to the chemical composition of the pesticide, quantity, time of exposure, route of exposure, and many other factors. People who are more exposed to the harmful effects of pesticides are those in direct contact with the product and do not use adequate personal protective equipment during handling. Communities near crop areas also have a high risk of poisoning as well as the final consumer if there would be pesticide residues above the safe limits

In 2012, according to the Center of Poison Information and Consulting (Centro de Información y Asesoramiento Toxicológico CIATOX, Ecuador), approximately 1592 cases of pesticide-associated poisoning were registered, of which the highest number of cases were associated with five pesticides: paraquat (175), bromadiolone (174), glyphosate (153), cypermethrin (125) and carbofuran (104)[38]. From this list, only carbofuran has been banned from the market. Nevertheless, some cases are treated with home remedies and go unnoticed for health center records.

The reactions produced by pesticides according to the time of exposure can vary between acute (short-term) and chronic (long-term). Acute poisoning can affect different organ systems like gastrointestinal (e.g., vomiting, diarrhea, constipation, abdominal cramping), respiratory (e.g., cough, airway irritation, rhinitis), or nervous (e.g., headache, profuse sweating, blurred vision)[39]. On the other hand, the effects of chronic exposure do not always leave noticeable traces; they can appear from months to years after exposure and are associated with the development of different types of cancer, reproductive disorders, developmental abnormalities, and diseases associated with the nervous system[39].

Few studies in Ecuador focus on making obvious chronic health risks caused by exposure to pesticides. A study carried out in the province of Carchi, published in 2003 by researchers from the International Development Research Center (IDRC) - Canada, highlights the use of highly toxic but cheap pesticides such as carbofuran and methamidophos-now banned- in potato crops[40]. Exposure to these pesticides is associated with genetic and reproductive disorders, skin diseases, and some types of cancer[40]. On the other hand, in the city of Pedro Moncayo (Pichincha Province), another study showed the emergence of alterations in neurobehavioral performance in children who live near to flower farms when Mother's Day is approaching, suggesting an association with the increased use of pesticides[41]. Researchers noted that the adverse effects tend to wear off over time, but further studies are required. This investigation was performed in children who do not work directly in the flower fields but who lived in neighboring communities or at least with one flower worker. At the same time, according to a study of the perception of risks to pesticides, populations bordering the banana sector in Machala showed to be affected by the disproportionate use of pesticides. Some of the workers blame the disregard and carelessness in the use of safety measures, also illegal use of airplanes for the irrigation of pesticides by large corporations put vulnerable groups and communities surrounding the sector at health risk[42].

Thus, it can be observed that the lack of updated information makes it more challenging to obtain an authentic panorama of the effects produced by the indiscriminate use of pesticides in Ecuador. However, the few studies carried out to date give indications of the potential risk they represent in the agricultural population and its surroundings. It is necessary to coordinate efforts between the health, production, and scientific innovation sectors to improve the quality of life of vulnerable populations.

Remediation strategies

The use of pesticides has been persistent for the past decades. Although many of the products causing environmental and health damage have been banned, there are remnants in soils and water that possess a potential risk to the well-being of surrounding communities. This is why it is necessary to develop remediation technologies, to diminish the possible negative impact associated with pesticide residues. The proper application of remediation technologies can help to reduce, eliminate, isolate, or stabilize the contaminant. However, to choose a remediation strategy, several factors must be considered among them: characteristics of the place such as climatic conditions and other present pollutants, type of contamination (point or diffuse), concentration, and type of pesticide[43]. Figure 3 shows the different physical, chemical, and biological processes that can be applied for the remediation of soils and bodies of water contaminated with pesticides. These processes are described in greater depth by Morillo and Villaverde[43].

A significant limitation of the remediation strategies is the variety of abiotic factors on *the field* that prevents standardized procedures, most investigations have been carried out at laboratory level and for a large-scale application would require significant investments[43]. Bioremediation technologies show

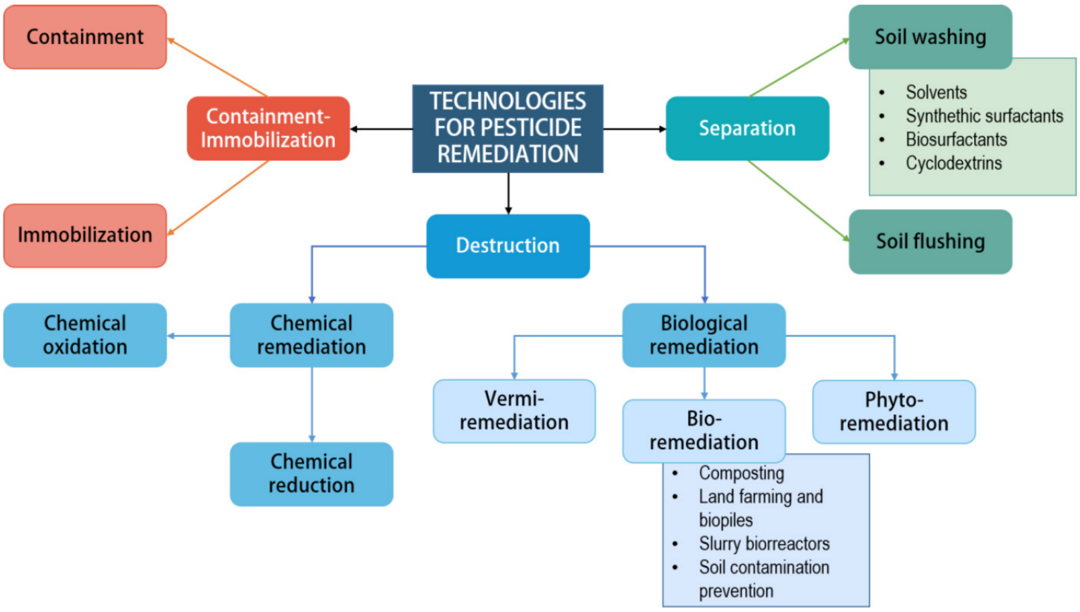

Figure 3. Physical, chemical, and biological technologies for pesticide remediation. Source: Morillo and Villaverde[43].

to be a relatively low-cost alternative in comparison with the other processes, and its implementation can be immediate. Nevertheless, bioremediation may imply observation of long-term results only, as well as the difficulty of predicting the outcome of the introduction of foreign organisms[43]. In Ecuador, there are still very few studies related to remediation against contamination caused by agrochemicals, most of them seek to develop bioremediation strategies through the study of organisms with the potential to degrade pesticides at harmful concentrations[44–47].

Conclusions

The use of pesticides in Ecuador has increased due to the need to satisfy local food needs, as well as to improve export goods to foreign markets. However, despite the benefits associated with the use of these agrochemicals, exposure to certain pesticides has created a risk to human and environmental health that is often disregarded over the necessity to generate economic profits. Ecuador lacks relevant regulations that allow all the actors involved to take adequate management measures. Although there are programs for the implementation of Good Agricultural Practices GAP, they ignore the reality of many small farmers who lack the training and knowledge for its proper and safe handling. In turn, this problem is accentuated by a disorganized registry of pesticides in the country, the prevalence of obsolete pesticides in the market, and the lack of control in the agroindustry over its environmental responsibility and the management of pesticides in vulnerable populations.

National policies should focus on strengthening information channels that guide the small farmers to become aware of the importance of environmental conservation, personal protection equipment, and health risks that may be implied by the misuse of pesticides. Although globally, most of the remediation strategies are still in development stages, the great diversity in both flora and fauna in Ecuador represents an excellent opportunity for the discovery of organisms with bioremediation potential. For this reason, the scientific academy plays an essential role in the development of new biotechnological tools for seed selection, use of natural resources, pest control, and the growth of the agro-industrial sector. However, to achieve these goals, it is necessary to create public policies that link science and innovation from the smallest levels of production.

Bibliographic references

1. Brussaard L, de Ruiter PC, Brown GG. Soil biodiversity for agricultural sustainability. Agric Ecosyst Environ. 2007;121(3):233–44.
2. FAO. International Year of Plant Health, 2020: Communication guide [Internet]. Rome; 2019. Available from: http://www.fao.org/publications/card/en/c/CA7186EN
3. Rasmussen WD, William A. Origins of agriculture. In: Encyclopædia Britannica [Internet]. Encyclopædia Britannica, inc.; 2019. Available from: https://www.britannica.com/topic/agriculture
4. Aktar W, Sengupta D, Chowdhury A. Impact of pesticides use in agriculture : their benefits and hazards. Interdiscip Toxicol. 2009;2(1):1–12.
5. Cooper J, Dobson H. The benefits of pesticides to mankind and the environment. Crop Prot. 2007;26:1337–48.
6. Gianessi LP. The increasing importance of herbicides in worldwide crop production. Pest Manag Sci. 2013;69(10):1099–105.
7. Braconi D, Bernardini G, Santucci A. Saccharomyces cerevisiae as a model in ecotoxicological studies: A post-genomics perspective. J Proteomics [Internet]. 2016;137:19–34. Available from: https://doi.org/10.1016/j.jprot.2015.09.001
8. WHO. Children ' s Health and the Environment [Internet]. 2008. p. 62. Available from: https://www.who.int/ceh/capacity/Pesticides.pdf
9. Fukuto TR. Mechanism of action of organophosphorus and carbamate insecticides. Environ Health Perspect. 1990;87:245–54.
10. Tiwari B, Kharwar S, Tiwari DN. Pesticides and Rice Agriculture. In: Cyanobacteria [Internet]. Varanasi: Elsevier Inc.; 2019. p. 303–25. Available from: https://doi.org/10.1016/B978-0-12-814667-5.00015-5
11. Vale A, Lotti M. Organophosphorus and carbamate insecticide poisoning. In: Lotti M, Bleecker ML, editors. Handbook of Clinical Neurology [Internet]. 1st ed. Elsevier B.V.; 2015. p. 149–68. Available from: http://dx.doi.org/10.1016/B978-0-444-62627-1.00010-X
12. Roberts JR, Reigart RJ. N-Methyl Carbamate Insecticides. In: Recognition and Management of Pesticide Poisonings. Sixth. Washington DC: EPA; 2013. p. 56–62.
13. Roberts JR, Reigart JR. Recognition and Management of Pesticide Poisonings. Sixth. Washington DC: EPA; 2013. 272 p.

14. Hurtado Clavijo CM, Gutiérrez de Salazar M. Organophosphorates: acute intoxication practical issues. Rev la Fac Med [Internet]. 2005 [cited 2020 Mar 10];53(4):244–58. Available from: http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0120-00112005000400006&lng=en&nrm=iso&tlng=es
15. Blus LJ. Organochlorine pesticides. In: Handbook of Ecotoxicology, Second Edition. Carbondale; 2002. p. 313–39.
16. Coats JR. Mechanisms of toxic action and structure-activity relationships for organochlorine and synthetic pyrethroid insecticides. Environ Health Perspect. 1990;87:255–62.
17. Van Den Berg H, Manuweera G, Konradsen F. Global trends in the production and use of DDT for control of malaria and other vector-borne diseases. Malar J. 2017;16(1):1–8.
18. Atkinson BL, Blackman AJ, Faber H. The Degradation of the Natural Pyrethrins in Crop Storage. J Agric Food Chem. 2004;52(2):280–7.
19. Valentine WM. Pyrethrin and pyrethroid insecticides. Vet Clin North Am - Small Anim Pract [Internet]. 1990;20(2):375–82. Available from: http://dx.doi.org/10.1016/S0195-5616(90)50031-5
20. Metcalf RL, Hotowitz AR. Insect Control, 1. Fundamentals. In: Ullmann's Encyclopedia of Industrial Chemistry. Wiley-VCH; 2014. p. 23.
21. Thatheyus AJ, Gnana Selvam AD. Synthetic Pyrethroids: Toxicity and Biodegradation. Appl Ecol Environ Sci. 2013;1(3):33–6.
22. Lebaron HM, Mcfarland JE. The Triazine Herbicides: A Milestone in the Development of Weed Control Technology. Agriculture. 1952;2016:1–12.
23. Trebst A. The Mode of Action of Triazine Herbicides in Plants. Triazine Herbic. 2008;101–10.
24. Klementova S, Keltnerova L. Triazine Herbicides in the Environment. In: Herbicides, Physiology of Action, and Safety. Ceske Budějovice; 2015. p. 71–89.
25. Agrocalidad. Creación [Internet]. 2008. Available from: http://web.agrocalidad.gob.ec/creacion/
26. FAO. A scheme and training manual on good agricultural practices (GAP) for fruits and vegetables [Internet]. Bangkok; 2016. Available from: http://www.fao.org/3/a-i6677e.pdf
27. Agrocalidad. Buenas Prácticas Agrícolas -BPA. Quito; p. 24.
28. Agrocalidad. AGROCALIDAD TRABAJA EN LA IMPLEMENTACIÓN DE BUENAS PRÁCTICAS AGROPECUARIAS A ESCALA NACIONAL [Internet]. 2020 [cited 2020 Feb 7]. Available from: https://www.agricultura.gob.ec/agrocalidad-trabaja-en-la-implementacion-de-buenas-practicas-agropecuarias-a-escala-nacional/
29. Agrocalidad. Buenas Prácticas Agrícolas para Hortalizas y Verduras [Internet]. Quito; 2015. p. 68. Available from: http://web.agrocalidad.gob.ec/wp-content/uploads/Guía-de-BPA-para-hortalizas-y-verduras.pdf
30. INEC. Información Ambiental en la Agricultura 2016 [Internet]. 2016. Available from: http://www.ecuadorencifras.gob.ec/documentos/web-inec/Encuestas_Ambientales/Informacion_ambiental_en_la_agricultura/2016/PRESENTACION_AGRO_AMBIENTE_2016.pdf
31. WHO, FAO. Código Internacional de conducta sobre la distribución y utilización de plaguicidas. Directrices sobre opciones de manejo de envases vacíos de plaguicidas. [Internet]. Rome; 2008. Available from: http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/Code/SP_Advertisingfinal10.pdf
32. Instituto Ecuatoriano de Normalizacion. Pesticides and related products used in Agriculture. Handiling and Disposal of empty treated with Triple Wash. Requirements [Internet]. Ecuador Ecuador; 2013 p. 1–19. Available from: http://www.ambiente.gob.ec/wp-content/uploads/downloads/2014/05/NTE-INENE-2634-Plasticos-post-consumo.pdf
33. Agrocalidad. ACTUALIZACIÓN DEL INVENTARIO NACIONAL DE PLAGUICIDAS OBSOLETOS [Internet]. 2019 [cited 2020 Feb 10]. Available from: http://web.agrocalidad.gob.ec/actualizacion-del-inventario-nacional-de-plaguicidas-obsoletos/
34. FAO. Prevention and Disposal of Obsolete Pesticides [Internet]. [cited 2020 Feb 10]. Available from: http://www.fao.org/agriculture/crops/obsolete-pesticides/presentacion/es/
35. INEC. Estructura del sector agropecuario, según el enfoque de las características del productor agropecuario y de las unidades de producción agropecuaria. Quito; 2008.
36. WHO. The WHO recommended classification of pesticides by hazard and guidelines to classification, 2019 edition [Internet]. WHO Library Cataloguing-in-Publication Data "World Health Organization." 2020. 1–92 p. Available from: https://apps.who.int/iris/bitstream/handle/10665/332193/9789240005662-eng.pdf?ua=1
37. Rivera S. El Registro de Plaguicidas en el Ecuador. Un estudio desde la perspectiva de la agroecología [Internet]. Universidad Politécnica Salesiana; 2015. Available from: https://dspace.ups.edu.ec/bitstream/123456789/9021/1/UPS-QT06808.pdf
38. Naranjo A. La otra guerra: La situación de los plaguicidas en el Ecuador [Internet]. Maldonado A, Chérrez C, Bravo E, editors. Quito; 2017. 141 p. Available from: http://www.swissaid.org.ec/sites/default/files/images/plaguicidas_web.pdf
39. Thundiyil J, Stober J, Besbelli N, Pronczuk J. Acute pesticide poisoning: a proposed classification tool. Bull World Health Organ. 2008;86(3):205–9.
40. Dale S. Preventing pesticide poisonings in Ecuador. Int Dev Res Cent [Internet]. 2003;4. Available from: https://www.idrc.ca/sites/default/files/sp/Documents EN/preventing-pesticide-poisonings-in-ecuador.pdf
41. Suarez-Lopez JR, Checkoway H, Jacobs DR, Al-Delaimy WK, Gahagan S. Potential short-term neurobehavioral alterations in children associated with a peak pesticide spray season: The Mother's Day flower harvest in Ecuador. Neurotoxicology [Internet]. 2017;60:125–33. Available from: http://dx.doi.org/10.1016/j.neuro.2017.02.002
42. Brisbois B. Bananas, pesticides and health in southwestern Ecuador: A scalar narrative approach to targeting public health responses. Soc Sci Med [Internet]. 2016;150(January 2016):184–91. Available from: http://dx.doi.org/10.1016/j.socscimed.2015.12.026
43. Morillo E, Villaverde J. Advanced technologies for the remediation of pesticide-contaminated soils. Sci Total Environ [Internet]. 2017;586:576–97. Available from: http://dx.doi.org/10.1016/j.scitotenv.2017.02.020
44. Abad Y. CARACTERIZACIÓN, IDENTIFICACIÓN Y EVALUACIÓN DE MICROORGANISMOS AUTÓCTONOS BIORREMEDIADORES DE SUELOS CONTAMINADOS POR AGROQUÍMICOS EN LA PROVINCIA DE LOJA. [Internet]. Universidad de Cuenca; 2013. Available from: http://dspace.ucuenca.edu.ec/bitstream/123456789/26974/1/TESIS _ YURI.pdf
45. Maldonado L. EVALUACIÓN DE LA BIODEGRADACIÓN DE UN INSECTICIDA ORGANOFOSFORADO EN MUESTRAS DE SUELO DE CULTIVO DE PAPA MEDIANTE *Trichoderma harzianum* y *Pleurotus ostreatus*. [Internet]. Universidad Politécnica Salesiana Sede Quito; 2017. Available from: https://dspace.ups.edu.ec/bitstream/123456789/13678/1/UPS-QT11512.pdf
46. Pérez M. EVALUACIÓN DE LA CAPACIDAD DEGRADADORA Y ACCIÓN DE BIORREMEDIACIÓN DE BACTERIAS PRESENTES EN SUELOS CON RESIDUOS DE PESTICIDAS DE LA FLORÍCOLA PENCAFLOR [Internet]. Universidad de las Américas; 2014. Available from: http://dspace.udla.edu.ec/bitstream/33000/2272/1/UDLA-EC-TIAM-2014-03.pdf
47. Paredes M. EVALUACIÓN DE LA BIODEGRADACIÓN DE UN INSECTICIDA CARBAMATO EN MUESTRA DE SUELO DE CULTIVO DE PAPA, MEDIANTE *Trichoderma harzianum* y *Pleurotus ostreatus*. [Internet]. Tesis. Universidad Politécnica Salesiana Sede Quito; 2017. Available from: https://dspace.ups.edu.ec/bitstream/123456789/13842/1/UPS-QT11514.pdf

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