Chapter

Consequences of Herbicide Use in Rural Environments and Their Effect on Agricultural Workers

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Abstract

The herbicides are used frequently to fight the proliferation of weeds. The use of herbicides correlates with an improvement in agricultural yield, but the harm to the health of human populations is well established and has been demonstrated in numerous scientific studies. In many developing countries, farmers build their own homes, and this, along with the application of herbicides in their fields, increases their exposure, through both contact with skin and respiration. It is scientifically proven that herbicides cause infertility, kidney problems, endocrine disruption, apoptosis, cytotoxicity, and neurotoxic effects. Such diseases impact the quality of those affected, and naturally the contaminated environment negatively affects human health. This chapter focuses on revising the most relevant studies regarding the health effects on agricultural workers living in rural environments due to herbicide contamination and how to sustain the herbicide use.

Keywords: occupational health, herbicide pollution, quality of life, economic vulnerability, agriculture sustainability

1. Introduction

Agriculture has enormous global environmental repercussion and still is an important sector responsible for the greater part of the rural communities' income in developing countries [1]. Agricultural land occupies a third of the ice-free global land area, and it is expected that this percentage will rise due to increased demand for agricultural products to support the continued growth in the human population [2].

Agricultural practices can be harmful to human and surrounding ecosystems. The environmental/occupational exposure to agrochemicals (pesticide or fertilizers) has become a concern for human health [3]. Sixty percent of agrochemicals are used in the soil, and the others drain into the ground polluting the water supply; these chemicals are toxic for living organisms as they are absorbed by plants and successively accumulate in human tissue through biomagnifications of the food chain, causing human health and environment concerns [4]. Chemical pollutants are a serious and growing global problem. Pollution has become one of the greatest threats to humankind and is caused by their prevalence in water, on land, and in air.

At least 7 million people die as a result of air pollution, 842,000 from water pollution, and 420,000 from consuming contaminated food. In 2015, 9 million people died (16% of deaths worldwide) due to poor waste management, generating more deaths than AIDS, malaria, and tuberculosis together [5]. According to the World Health Organization (WHO), more than 1000 pesticides [6], among them the herbicides, fungicides, bactericides, and insecticides, are used agriculturally today; however, as many as 140,000 pesticides have been synthesized since 1950.

One global concern is that genetically modified seeds permit farmers to spray herbicides even during the growing season. This leaves their crops unharmed—primarily soybeans and corn—but also leaves them with carcinogenic levels of the systemic herbicide glyphosate [7], according to the International Agency for Research on Cancer (IARC) [8]. Actually, 90% of the soybean and corn seeds are herbicide resistant [7]. A huge list of commercial food products containing soy, corn, and honey maintains traces of herbicides; glyphosate has also been reported in oat products [9].

In addition to the trace exposure of herbicides in various foods, the greatest levels are in the agricultural fields. The herbicides can be classified according to their chemical structure as organophosphates, organochlorines, carbamates, and pyrethroids, comprising a large portion of herbicides in the overall market. In developing countries, the most common herbicides based on their popularity are glyphosate, paraquat, atrazine, and 2,4-D. The use of these chemicals is well adapted for rural workers because they are of low cost, replace manual weeding, and improve yields [10]. However, accidental exposure to herbicides can be highly dangerous to human beings and other living organisms, and training programs by the sellers of herbicides that inform workers of the risk of exposure due to direct contact with the chemicals do not exist [11]. FAO reported that 800 million individuals in the world are undernourished, of which 780 million live in developing regions. Therefore, the possible health effects from the use of herbicides, in these regions, are considered by locals as less significant compared to the importance of eradicating famine [1, 12]. Because of this, it is important to balance the use of herbicides and their possible effect on the environment and health and reach sustainability. This review aims to present the key problems that can occur due to the mismanagement of herbicides in developing countries and how these chemicals can affect the health of farmworkers.

2. Methodology

A literature search was conducted to describe the health effects on agricultural workers in rural environments due to herbicide exposure and contamination. The following data sources were used: Medline, EMBASE, Science Direct, PubMed, and Redalyc, with published studies not older than 10 years. The key terms of the search were about farmer's health and herbicide contamination, although the search was not restricted. After deleting duplicate records, all remaining retrieved references to the bibliographic search were selected using only the title and summary. Research with irrelevant topics was eliminated to focus on the articles of interest in our study. The results were organized according to the type of health disorder due to occupational exposure. Studies focused on how to support the use of herbicides were also considered. Two hundred and one articles were selected for review of their abstracts, and 101 were classified for full analysis. After the revision of these full texts, only 61 studies were finally cited in this paper.

This review analyzes the impact of the excessive use of herbicides on specific health disorders in exposed agricultural workers and the environment damage.

Many studies expose the health effects caused by herbicides; however, those in developing countries are rare. It is necessary to emphasize agriculture-related poor practices, the almost inexistent farmer training, and the health risk that this entails.

3. Environmental impact of bad practices on agriculture

The unpromising future of agriculture in developing countries faces many challenges as a result of social pressure, increased migration, labor shortages, climate change, and food insecurity and is now an accelerating phenomenon that has resulted in the use of inadequate herbicides and depletion of natural resources, in particular the soil [12].

These events have led to the erosion of natural resources due to overexploitation of soils, to meet the growing demand for food [13], resulting in the excessive use of herbicides. It is well known that a significant portion of the chemicals applied has proven to be excessive, expensive, and sometimes unnecessary. In several countries such as in Europe and Japan, the use has been reduced; however, in the rest of the world, it has even increased [1].

Globally, in environmental government instances of some countries, are established permissible limits of herbicides in water and soil, however, in developing countries herbicides are not monitored, or simply this standards do not exist; nevertheless, several studies have shown that herbicides and their derivative compounds contaminate natural resources such as water and soil, for example, aminomethylphosphonic acid (AMPA), a secondary compound of glyphosate, can persist for several years in the soil [14]. The relationship between herbicide environmental pollution and the risk of harm to health is caused by failure to apply the adequate quantity, frequency of the products and the resistance of pests to herbicides, which causes them to tend to be accumulated in soil and water, depending on their physicochemical nature and their dynamics of interaction with the environment [15].

Table 1 shows residual soil and water values from the most commonly used herbicides worldwide. The concentrations found exceed the maximum permissible levels by international laws [22]. The reported values are evidence of progressive accumulation, which represents a risk factor for human health.

Reference	Compound	Concentration	Country/year
[15]	2,4-D (dichlorophenoxyacetic acid)*	609 μg/kg	Brazil, 2013
[16]	Terbuthylazine*	37.6 μg/kg	Arable, 2015
[17]	Phenolic herbicide*	0.4 mg/kg	Bosnia, 2016
[18]	AMPA*	342.75 mg/kg	Mexico, 2018
[19]	Glyphosate+	27.8 μg/L	USA, 2013
[20]	Atrazine+	15.66 μg/L	USA, 2008
[21]	Glyphosate+	1.42 μg/L	Mexico, 2015
[18]	Glyphosate+ AMPA+	≤5 μg/L 36.8 μg/L	Mexico, 2018

The compounds with an asterisk (*) are found in soil samples, and those with a plus sign (+) are herbicides reported in water.

Table 1.
Occurrence of herbicides in soil and water samples.

4. Health effects on agricultural workers

Occupational health hazards usually refer to the materials and processes that have the potential to cause injury, sickness, and impaired health and affect the well-being and efficiency among workers. Occupational diseases may occur long after being exposed to occupational hazards, such as air contaminants and chemical, biological, physical, and ergonomic hazards, including psychosocial factors as well [5]. In agricultural trade, workers are exposed to numerous agricultural environment aerosols, including herbicides.

People who have been exposed to herbicides occupationally, or by eating foods or liquids containing herbicide residue, or for that matter inhaled herbicide-contaminated air, have experience a broad range of chronic health effects, including impaired neurobehavioral function (e.g., cognitive and behavioral disorders), Alzheimer's and Parkinson's diseases, hormone disruption, asthma, allergies, hypersensitivity, obesity, diabetes, hepatic lesions, kidney failure, multiple sclerosis, and cancer [3, 23–25].

4.1 Neurobehavioral problems

Many studies related to the occupational herbicide exposure of agricultural workers exist. Neurobehavioral symptoms among participants appear to be associated with cumulative exposure [26]. Pesticide poisoning and suicides are very high in developing countries and rural environments. Suicides influenced by pesticides have been largely reported among agricultural workers; evidence exists that indicates that pesticides induce such behavior [25, 27]. Some organophosphates, for example, paraquat and glyphosate, inhibit the cholinesterase activity in the nervous system, whereby this irreversible inhibition can produce cerebral damage such that cholinergic neurons are injured and can be responsible for neuropsychiatric and neurobehavioral disorders, including memory, cognitive, mental, emotional, motor, and sensory deficits [28].

It has long been established that Alzheimer's development is exacerbated from occupational exposure to organophosphates. Chin-Chan [29] determined that the risk of Alzheimer's is higher in those who have had occupational contact. The herbicides induce oxidative stress which in turn produces the activation of calpains and then caspases, a known link to Parkinson's disease [30].

4.2 Hormone disruption

The inhibition of acetylcholinesterase in the hypothalamus after organophosphate exposure alters the secretion rate of gonadotropin-releasing hormone by affecting the secretion of pituitary hormones that stimulate the gonads (gonadotrophic hormones), including folio-stimulating and luteinizing hormones. The relationship between exposure to pesticides and anomalies in the functional structure of the seminal cells was checked [31].

A relationship between hypothyroidism and the use of organochlorine insecticides, fungicides, and herbicides has been found [32]. The organophosphates, by themselves, are capable of interfering with endocrine function by inhibiting the binding of thyroid hormones to their corresponding receptors.

4.3 Respiratory and immune diseases

Occupational exposure to pesticides can represent a serious risk to the respiratory system. Spirometry was performed in workers occupationally exposed to pesticides in various developing countries and revealed a significant decrease in the lung function parameters [33]. Another study evaluated the association between allergic and non-allergic wheeze and pesticides and found significant differences than implicate organophosphates and pyrethroids that are commonly used in agricultural and residential settings with adverse respiratory effects [34].

The organophosphates can affect the immune response, including the production of antibodies and of interleukin 2, T-cell proliferation, decrease of CD5 cells, increase of CD26 and autoantibodies, alteration of Th1/Th2 cytokines, inhibition of NK cells and the lymphocyte-activated killer cells, and the cytotoxic activity of the T lymphocytes. The oxidative stress can be produced by a wide range of factors among which the pesticides are found [35]. In this sense, Simoniello [36] showed that agricultural workers of the Pampas region in Argentina exposed to pesticide mixtures presented modifications in the oxidative equilibrium and enzymatic alterations.

4.4 Metabolic complications

It has been shown that there is an association between exposure to pesticides and a high incidence of metabolic syndrome, insulin resistance, and diabetes. The pesticides affect the cellular metabolism of carbohydrates and lipids and can lead to insulin resistance and alterations in glucose homeostasis [37]. Organochloride compounds are persistent and remain in the body for a long period. The presence of multiple chlorine atoms in its structure increases its lipophilicity and results in accumulation in adipose tissue. Several studies have explored the possible relationship between the concentration of organochlorides and obesity [38].

Organochlorides are associated with peripheral arterial disease, particularly in people suffering from obesity, the idea being that dioxins are supported after binding to AhR and induce inflammation, hypertension, and arteriosclerosis [39].

5. Implications of herbicides on health problems in people who live in agricultural rural areas

The use of herbicides is uncontrolled in many developing countries. Herbicides can cause toxic effects on agricultural workers' health, both by their direct and indirect action (inhalation, dermal or oral exposure) [10]. Long-term and acute occupational exposure to herbicide among agricultural workers produces a charge or a cost to the countries [40]; the study of Buendía [41] reports that the average cost per patient intoxicated by paraquat exceeds that of various chronic diseases prevalent in Colombia. The social and economic impact on health could contribute significantly to the global public health problem. The increased morbidity includes lower quality of life and functional status.

The Organisation for Economic Co-operation and Development (OECD) offers "the Index for a Better Life" which measures people's quality of life and compares it among countries, based on the personalized management of the priorities of each individual [42]. In developing countries increase the poverty of the population, due to the low remuneration, for example, in the research of Cely-Andrade [43] reports that in mining zones exist the worst quality of life-related to health than agricultural areas, however the mining works are better paid, although economic growth does not accurately represent human well-being, the economic dimension is a key dimension of rural prosperity and farmers consider that economic resources increase the chances of improving their quality of life.

Reference	Method	Participants and precedence	Reported concentrations in urine
[38]	ELISA	Agricultural workers in Costa Rica	6.3 μg/24 h of paraquat
[44]	HPLC–MS/MS	Students in Thailand	2,4-D
[45]	ELISA	Children in Nicaragua	0.9 μg/g Cr 2,4-D
[46]	LC–MS/MS	Agricultural workers in Croatia	0.3 to 8.0 μg/g Cr atrazine
[47]	HPLC-ESI-MS	Farmer family in France	9.5 μg/L glyphosate
[48]	LC–MS/MS	Agricultural workers in a rural area from Italy	2.94 μg/L TBA
[21]	ELISA	Farmers from Mexico	0.47 μg/L glyphosate
[49]	MS	Pregnant women from Ghana	0.46 μg/L 2,4-D
[50]	MS	Pregnant women in rural zones of the USA	3.40 ng/mL glyphosate
[51]	HPLC–MS/MS	Amenity horticulturists in Ireland	7.4 μg L^{-1} glyphosate
[52]	ELISA	Farmers in Sri Lanka	0–2.1 mg/g Cr paraquat 48–353 mg/g Cr Glyphosate
[53]	LC-MS/MS	Farmers in the USA	4.04 ppb
[54]	MS/MS	Children and teenagers in Mexico	2.63 μg/mL glyphosate

Table 2.
Analysis studies of herbicides in urine from people living in rural areas.

The monitoring of human groups exposed to chemical agents with the potential to cause damage to the organism is aimed at preserving health and quality of life especially of those populations that are at high risk. Many studies of the exposure of herbicides in agricultural workers exist; one of the most common, biomonitoring, is searching the chemicals in the urine of the people living in agricultural areas. In **Table 2** the most recent studies about the concentrations of herbicides in people from rural areas are shown.

Herbicide exposure is a current problem in public health, especially in developing countries mainly for the following reasons: the main cause of work accidents in agriculture is neglect of safety requirements (28.9%) [55]; workers do not have training for use herbicides and do not use the appropriate personal protective equipment (PPE) for the preparation, application, transportation, and storage [56]. On the other hand, herbicide regulations are less strict or inexistent in developing countries [57], and these chemicals are used by tons because they replace the manual tasks, increasing productive capacity and significantly lowering production costs [10].

6. Damaged environment: How to rehabilitate it?

The use of pesticides to produce food, both to feed local populations and for exportation, should comply with good agricultural practices regardless of the economic status of a country. Farmers should limit the amount of pesticide used to the minimum necessary to protect their crops [5]. One approach is the large-scale implementation of precision agriculture that utilizes remote sensing and responds in real time to crop resource requirements and to weather and climatic conditions. Also, with the cost being such an important factor in consumer choices, policymakers can seek a market-based solution for modifying consumption patterns by better incorporating the true environmental costs to produce a food item [2].

The sustainable rise includes improving agricultural yields while at the same time abating environmental impacts. Relative to scenarios, less-extreme changes toward reducing meat consumption, waste, and the demand for nonfood agricultural products could greatly reduce the environmental impacts of the food system [58]. A few years ago, the agri-environmental scheme (AES) options were rising; these were established as effective strategies to evading contamination peaks when weed burden is high, whereas more demanding AES options guarantee an overall reduction in herbicide use, even during relatively easy farming years in which less weed pressure is experienced [59].

There are several strategies for controlling weeds; one of the practices is the manual weeding that depends on the workforce and is one of the main causes of the loss of organic matter in the soil, due to the excess of weeding and constant plows, making the soil lose its fertility. Therefore, low-income farmers require using herbicides; however, they do so in an uncontrolled manner. These types of practices are not sustainable options for the protection of the environment and occupational health. Moss [60] in his analysis points out that there are approximately 16 reasons why farmers prefer the use of herbicides and within them are economic factors due to the reduction of labor and rapidity of results, in addition to the lack of training and technology among other points.

Numerous studies have provided substantial knowledge to obtain these objectives, noting that one of the strategies is the minimum tillage; however, it is critical and requires effective management, since changes and resistance can be induced in the same herbs, in addition to greater involvement of economists, social scientists, and marketing professionals [12, 60].

In this sense, it is necessary to promote solutions that improve biodiversity and its environment, in addition to maintaining agricultural production; **Figure 1** shows the relationship between the diverse strategies necessary for the sustainable control of weeds.

Farmers are always looking for immediate changes to eliminate weeds; herbicides offer these options, compared to nonchemical strategies that take more time.

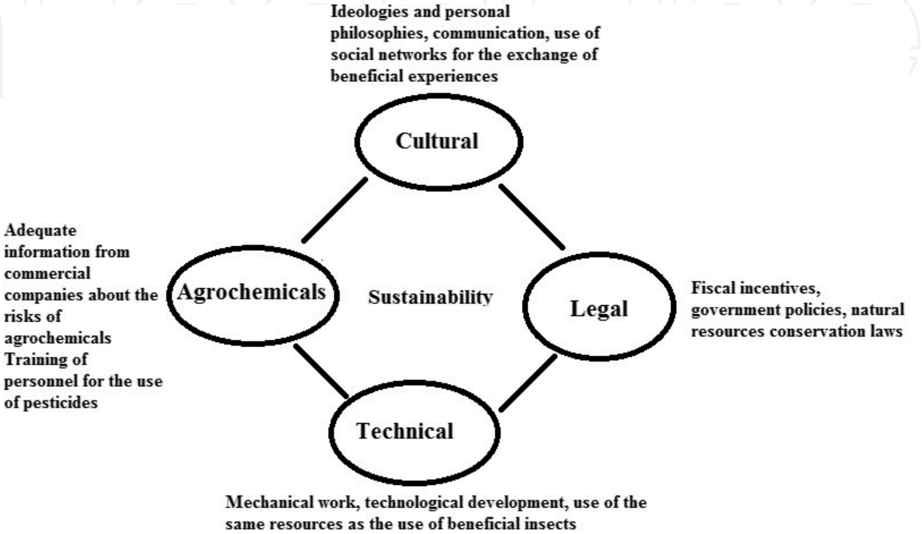

Figure 1.
The main factors that must be involved to achieve sustainable control of the herbs do not benefit the crops.

Some strategies to convince the farmers are to promote crop rotations and field demonstrations, among others, but the most important is to change the farmer mentality which could be achieved by encouraging financial support that could bring about short-term changes [61]; however, attitudinal changes are long-term results that lead to better results.

As was mentioned in Section 3, the global food demand promotes that farmers cannot leave aside the use of herbicides [24]. Consequently, the natural recovery of the soil is not carried out, causing an accumulation of herbicides. This phenomenon is the main factor associated with the development of diseases produced by the chronic exposure of people who work and live in rural areas.

7. Conclusions

The literature analysis indicates that the health problems of agricultural workers are directly related to environmental pollution due to the unsustainable use of herbicides.

Health problems due to the exposure of agricultural workers to herbicides are a major concern, mainly in developing countries. This concern is due to the fact that the use of herbicides in these regions is indiscriminate and the workers have no prior training for their use, so there are no personal protective equipment regulations, and in developing countries there are few or no regulations to address accumulated concentrations in the environment, and there are no regulated biomonitoring in workers.

In rural areas mainly from developing countries, where there are no exists specific standards for their regulations, there is disturbing environmental contamination by herbicides; in these places are reported numerous diseases related to herbicide exposure, which leads to demand in public health services and hence decrease in the workforce, the worker's quality of life, and the growth of the country. That is why herbicide distribution companies should commit to indicate to the users/workers the correct management of the herbicides, including application quantities, as well as, the rigorous use of personal protective equipment.

This research showed that exposure to herbicides by agricultural workers and the environmental contamination with these chemicals are problems that can be solved by enforcing establish regulations in rural zones principally from developing countries.

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Conflicts of interest

The authors declare no conflict of interest.

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