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THE IMPACT OF PESTICIDES ON OCCUPATIONAL HEALTH, THE HEALTH OF THE GENERAL POPULATION, AND THE ENVIRONMENT

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ABSTRACT

According to Food and Agriculture Organization (FAO) of the United Nations pesticide means any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or, controlling any pest, or regulating plant growth. However, it is known that the increasing food demands of the world population necessarily mean the increasing use of pesticides in agriculture, forestry and other activities. Today, a huge number of chemical substances are used as pesticides, and their use inevitably leads to negative consequences for human health and the environment. The goal of our research was to analyze the impact of pesticides on occupational health, the health of the general population and the environment. A research performed in May 2022 included documents, and data from scholarly literature, and relevant literature from medical journals, the electronic databases Pubmed, data of European Commission, International Labour Organization, World Health Organization (WHO), and content on the website that deals with the topic of the final paper. Authors paid special attention to the legal regulation of the use of pesticides in the Republic of Srpska and Bosnia and Herzegovina (B&H). Also, authors analyzed the international regulations related to pesticides. About 63 of them were analyzed, but 38 of them were included in the systematic review. Most of the selected documents show that production, use, and exposure to pesticides lead to the occurrence of occupational diseases, accidental poisoning of the population, as well as environmental pollution. The analysis suggests that permanent control of the production and use of pesticides through legislation is needed, in order to achieve the best possible protection against these agents.

Keywords: *pesticides, occupational diseases, environmental pollution.*

INTRODUCTION

The term pesticide is derived from the Latin words *pestis*, which means plague, and *occidere*, which means to kill. Since ancient times, people have faced various diseases and had great economic losses due to various pests. Also, since ancient

times people have faced various diseases and had great economic losses due to various pests, which is why they found different ways to control them. Even the ancient Romans used sulfur to protect the vine grape. During the17th century, nicotine was widely used to protect plants in France. The "pesticide revolution" involves the use of DDT insecticide since the 1940s, when this pesticide was first used in southern Italy against mosquitoes (Savić, 1997).

The types of exposure to pesticides are dermal, inhalation, and ingestion. The most frequent route for occupational exposure is dermal. A high percentage of pesticides can be absorbed across intact human skin because of their high lipid solubility. Inhalation exposure derives from the aerosols during the process of application and some inadequate proceedings in agriculture. Ingestion occurs in low percentages when the users eat, smoke, or drink in places that contain pesticides or if they do not wash their hands after usage of pesticides. The active substances that structure pesticides are very different, so there are several divisions of pesticides. They are most often divided according to purpose, chemical composition, toxicity and mechanism of action (FAO, 2014).

Classification of Pesticide (Bulat, 2014):

Pesticides according to purpose

- Insecticides – insects;
- Herbicides – plants:
- Rodenticides – rodents (rats & mice);
- Bactericides – bacteria;
- Fungicides – fungi;
- Larvicides – larvae.

Pesticides according to the chemical composition

- Organophosphate: Most organophosphates are insecticides (malathion, parathion, chlorofos, etc.).
- Carbamate (carbaril,bendiocarb).
- Organochlorine insecticides: (DDT, chlordane, and toxaphene).
- Pyrethroid: These are a synthetic version of pyrethrin, a naturally occurring pesticide, found in flower.
- Sulfonylurea herbicides: The sulfonylureas herbicides have been commercialized for weed control such as: sulfosulfuron, rimsulfuron, nicosulfuron, nicosulfuron,ethoxysulfuron, azimsulfuron, and amidosulfuron.
- Biopesticides: The biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals.

Insecticides, as one of the most commonly used groups of pesticides, can be divided into natural and synthetic, whereby synthetics are divided into organic and inorganic, while natural pesticides are divided into plant-based and mineral oil-based pesticides (Figure 1), (Kaur et al.,2019).

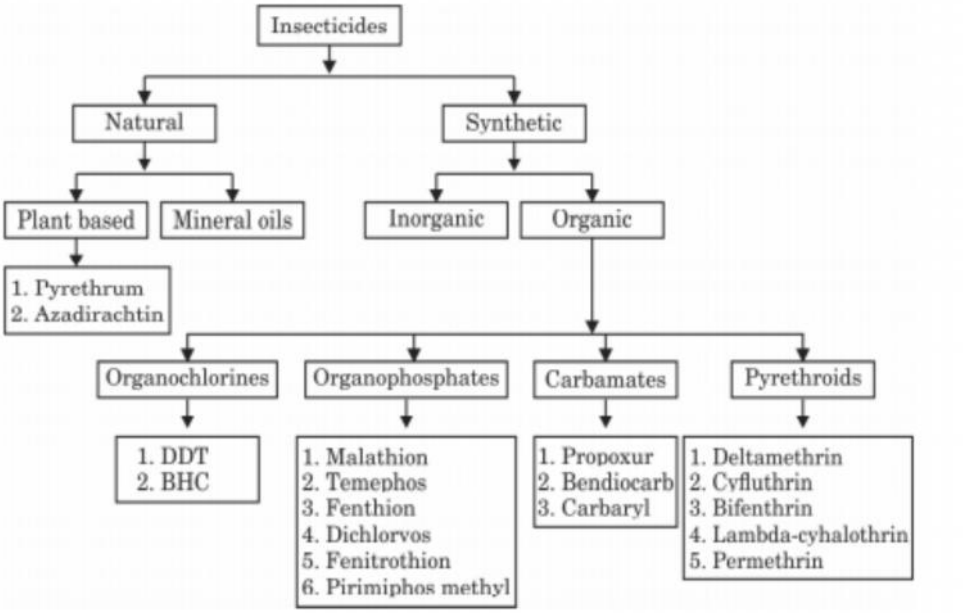

Figure 1. Classification of pesticide

*Source: Kaur et al. (2019).

Toxicity characterization of pesticide indicates that the most of them are related to at least one health effect according to databases of EPA, IARC, and WHO. Some of these effects are: acute and chronic poisoining, carcinogenic, endocrine and reproductive damages. Toxicity of a pesticide refers to the ability of it to produce its harmful effects. These effects may occur from slight symptoms to severe symptoms like convulsions or death. Pesticides cause reversible or irreversible damage. Toxicity of pesticide work by altering normal body functions. Toxicity can be classified into two types as acute and chronic. Acute toxicity with systemic damage may be a result of exposure to relatively large amounts of the pesticide. Chronic toxicity is result of effects produced by long-term, and low-level exposure to pesticides (Relf, 1996).

Acute toxicity of a pesticide is determined by subjecting laboratory animals to different dosages or concentrations of the active ingredient. Tests are also conducted to assess the impact through the skin, through inhalation, and orally. Test results are then used to classify pesticides into one of four toxicity categories (Table 1), (WHO, 2010).

Table 1. Acute toxicity of pesticides according to WHO classification

Class	Classification	LD_{50} for the rat (mg/kg b.w.)			
		Oral		Dermal	
		Solids	Liquids	Solids	Liquids
Ia	Extremely hazardous	<5	<20	<10	<40
Ib	Highly hazardous	5-50	20-200	10-100	40-400
II	Moderately hazardous	50-500	200-2,000	100-1,000	4004,000
III	Slightly hazardous	>501	>2,001	>1,001	>4,001
U	Unlike to present acute hazard	>2,000	>3,000	–	–

Source: WHO. International Code of Conduct on the Distribution and Use of Pesticides: Guidelines for the Registration of Pesticides. World Health Organization; Rome, Italy: 2010.

According to EPA: Toxicity Category I–All pesticide products shall bear on the front panel the signal word "Danger." If the product is assigned a Toxicity Category I on the basis of its oral, inhalation, or dermal toxicity, the word "Poison" shall appear in red on a contrasting background colour, and the skull and crossbones shall appear in immediate proximity to the word "Poison."
Toxicity Category II – All pesticide products shall bear on the front panel the signal word "Warning." Toxicity Category III – All pesticide products shall bear on the front panel the signal word "Caution." Toxicity Category IV – All pesticide products shall bear on the front panel the signal word "Caution" (Table 2.) (EPA, 2009).

Table 2. Acute toxicity of pesticides according to the EPA classification.

Class	Signal words	Acute toxicity to rat		
		Oral LD_{50} (mg/kg)	Dermal LD_{50} (mg/kg)	Inhalation LC_{50} (mg/L)
I	DANGER	<50	<200	<0.2
II	WARNING	50-500	200-2,000	0.2-2.0
III	CAUTION	500-5000	2,000-20,000	2.0-20
IV	CAUTION (optional)	>5,000	>20,000	>20

Source: EPA *Registering Pesticides* 2009. Available online: http://www.epa.gov/pesticides/regulating/re-gistering/index.htm

The purpose of this paper is to present and discuss adverse effects of pesticides on human health and the environment, as well as their impact on occupational health.

MATERIAL AND METHODS

A research was performed in May 2022, and the article is based on a systematic review of all documents, and data from scholarly literature, relevant literature from medical journals, the electronic databases Pubmed, data of European Commission, International Labour Organization, World Health Organization, and content on the website that deals with the topic of the final paper. We paid special attention to the legal regulation of the use of pesticides in the Republic of Srpska, and B&H. Also, we analyzed the international regulations related to pesticides. About 63 of them were analyzed, but 38 of them were included in the systematic review.

RESULTS AND DISCUSSION

The risk of pesticides to human health has been investigated since the 1970s. Most of the early works was conducted in the USA after 1980s, with rapid growth in the number of studies in the 1990s. Although the use of pesticides is necessary in many human activities, these chemical substances can have very serious consequences on human health. However, pesticide overuse and pollution have increased. Global pesticide use has continued growth to 4.1 million tonnes per year in 2017, an increase of nearly 80% from 1990. (FAO, 2019). Currently, around two million tonnes are used per year on a global basis, most of which are herbicides (50%), followed by insecticides (30%), fungicides (18%) and other types such as rodenticides and nematicides (Sharma et al., 2019).

According to the other studies, herbicides (over 40%), insecticides (over 30%), and fungicides (over 20%) are used the most, while other pesticides are used to a slightly lesser extent. The major pesticides for human poisonings were highly toxic organophosphorus pesticides, which accounted for 86.02% of the total cases (Zhang et al., 2011).

Professional exposure to pesticides is seen in workers who work on the formulation of pesticides, agricultural workers who work on pesticide application, as well as employees in agricultural pharmacies and warehouses. The most exposures and poisoning occur in workers involved in agricultural operations such are: mixing, loading, applying, and flagging. Mixers and loaders are exposed to high concentration of pesticide because the leaking or poorly equipment may fail and produce overexposures with any type of device including the closed mixing-loading system. Workers who work on the processes of disinsection and pest control can also be victims of pesticide poisoning. Poisoning by pesticides is severe public health problem. Probably, the occupational exposure is the most common source of exposure that results in unintentional acute intoxication. The most important route to occupational route is dermal which occurs by contamination of clothing, damaged skin, and sweat. All of these factors are common in agricultural work that forces absorption through the skin. The use of personal protective equipment can be useful for exposed workers. In occupational occasions, poisoning with organophosphates, and carbamates are rather frequent. They can easily penetrate through the skin, the respiratory tract or through ingestion. The clinical

manifestations of poisoning by these pesticides reflect the organs where the acetylcholine is the transmitter of nerve impulses. The exposed workers have the clinical sings and symptoms such as: miosis, diarrhea, urination, excitation, lacrimation, bronchorrhea, pulmonary oedema. Usually, the cause of death in acute poisoning is respiratory failure. Chronic health effects in exposed workers are: carcinogenicity, neurobehavioral effects, teratogenicity and skin effects. Organochlorine insecticides have acute and subacute clinical forms in occupational poisoning. These pesticides produces a picture of generalized CNS excitability and dysfunction. The symptoms and sings of poisoning are: dizziness, headache, confusion, weakness, convulsions and coma. The most mentioned chronic effect of chronic poisoning by organochlorine insecticides is cancer, especially breast cancer, and prostate cancer (O'Malley, 2014).

Pesticides can contaminate soil, water, air, and plants. United Nations Environment Programme (UNEP) estimated that pesticides intoxicate at least 3 million agriculture workers in less-developed countries and at the minimum 300,000 workers in the United State. The Academy of Sciences mentioned that pesticide residues in food cause approximately 4.000-20.000 cancer cases annually in the United States (Miller & Spoolman,2016).

The Occupational Safety and Health Administration (OSHA) regulates and enforces worker protection standards to ensure that employers provide a safe working environment for employees and ensure that workers receive personal protection equipment when handling pesticides. According to World Health Organization, each year, about 3,000,000 cases of pesticide poisoning and 220.000 deaths are reported in developing countries (Lah, 2011).

Exposure of the general population to pesticides occurs through eating food and drinking water contaminated with pesticides. Non-occupational exposure is from residues in food, air and drinking water, and generally involves low doses and it is chronic. The risk to human health from many studies is mentioned as a result of pesticide use in or around the home. Individuals can be exposed during the preparation and application of pesticides, whereas delayed exposure can occur through inhalation of residual air concentrations or exposure to residues found on surfaces, clothing, bedding, dust, discarded pesticide containers. Accidental poisoning with pesticides in the home is a possible from pesticide use around the house or garden (Davis et al.,1992).

The significant amount of pesticide residues can be found in daily food, including: water, fruits, juices, fish, meat. Additionally, it is mentioned that washing and peeling cannot remove completely the residues of pesticides (Nicolopoulou-Stamati et al., 2016). According to WHO more than 4 million people are poisoned by pesticides each year in the world, of these, at least a million people are hospitalized (Raven, 2011).

Organochlorines pesticides are substances that are classified as persistent organic pollutants because of their long-term environmental persistence. Due to their high persistence, low aqueous solubility, low polarity and lipid solubility, organochlorine pesticides are more dangerous to humans, plants, animals and the

atmosphere. They are stable chemical substances that can attach to soil and air, and have been identified as chronic exposure agents for animals and humans. The example of a major organochlorine pesticide with structure chemical name and toxicity is Dichlorodiphenyltrichloroethane (DDT) (Kedari, 2020).

In 1940s DDT was used as the first modern synthetic insecticide to control insect in agriculture, housing, institutes and to combat insect-borne human diseases (EPA, 2012). According to many studies the widespread use of DDT was signed as a very toxic substance to humans, and environment. Investigations showed that DDT was a reproductive toxic with increasing evidence of its adverse effects (Longnecker et al, 2005). Also the results of the other studies showed that high level of DDT was detected in food of animal origin, vegetable, fruit, soil and water (Dogheim et al, 1996). DDT was also signed as one of 12 restricted persistent organic pollutants in the world from the international agreement Stockholm Convention 2001 (WHO, 2011).

In one study by USA researchers in cooperation with Canadian provinces, conducted in Canadian provinces, pesticides were commonly found in water consumed by populations. Groundwater was found to have residues of 39 pesticides and their degradation products. Residues of pesticides that are "severely restricted" because of their serious effects on human health were also found in significant quantities in the water sources. Residues enter the water supply as they are leached from the soil into groundwater after home, lawn, roadway, and agriculture spraying (Zahm,1998).

The pesticides can enter the body through skin, eyes, digestive system, and respiratory system. Pesticides can be toxic to humans and animals. The important source of exposure to pesticides is diet. Variations in dietary more concentrated with certain foods high in pesticides may also have outcomes such as neurological, behavioral, endocrinological, and oncological. Anyone who uses pesticides or is present when pesticides are used is at risk for dangerous exposure. The findings suggest that the consumption of eggs and meat is also a significant source of exposure to the majority of organochlorine chemicals studied (Mc Connell et al, 1993).

In our work, we also investigated key legal international and domestic regulations about the use and transport of pesticide. Also, we mentioned some results that indicate the hazards of the pesticides related to health of general population, as well as environmental pollution. Some results are related to professional exposure to pesticide, and professional diseases due to pesticides.

Some of the most important documents are:

- *Rotterdam Convention*. It entered into force on 23 February 2004. Its aims are to: (1) promote shared responsibility and cooperation in the international trade of certain hazardous chemicals in order to protect human health and the environment; and (2) contribute to the environmentally sound use of certain hazardous chemicals information exchange about their characteristics, establishment of a national decision-making process on their import and export and dissemination

of these decisions to the Parties of the Convention (Rotterdam Convention, 2003).

- *Stockholm Convention on Persistent Organic Pollutants* (EPA, 2021).
- *Regulation (EC) N. 396/2005* of the European Parliament and of the Council of 23 February 2005on maximum residue levels of pesticides in or on food and feed of plant and animal origin.
  - ✓ Key points: High and consistent level of consumer protection across EU
  - ✓ Community harmonised MRLs
  - ✓ Consumer risk assessment reviewed by EFSA (*Regulation (EC) N. 396/2005* of the European Parliament, 2005).
- Directive 2009/128/EC of the European Parliament and of the Council on the sustainable use of pesticides, (the "Directive"), was adopted on 21 October 2009 as part of the 2006 Thematic Strategy on the sustainable use of pesticides. The Directive provides for a range of actions to achieve a sustainable use of pesticides in the European Union by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of Integrated Pest Management (IPM) and of alternative approaches or techniques, such as non-chemical alternatives to pesticides (Directive 2009/128/EC, 2009).
- Regulation (EU) No 649/2012 of the European Parliament and of the Council of 4 July 2012 concerning the export and import of hazardous chemicals (recast) Text with EEA relevance (Regulation EU № 649, 2012).

In the Republic of Srpska, pesticide poisoning refers to jobs and workplaces where exposure to pesticides exists, and where there is evidence of the intensity and duration of the exposure. The clinical picture of poisoning with specific damage to two organs or organ systems is taken into account as an occupational disease. In that case, occupational pesticide poisoning is on the List of occupational diseases of the Republic of Srpska, and the insured person has certain rights to free treatment, the possibility of professional rehabilitation, as well as the possibility of early retirement (List of occupational diseases, 2018).

With the aim to support the elimination and reduction of the release of persistent organic pollutants (POPs) into the environment, the United Nations member states signed the Stockholm Convention in 2001. Bosnia and Herzegovina (B&H) ratified this Convention in 2010, thus, the country should meet its requirements, which include avoiding the use of hazardous POPs by shifting to safer alternatives and removing old supplies and equipment containing these substances. According to Food Safety Agency of Bosnia and Herzegovina, there was research about the pesticide residues measured in the food products analysed by the national competent authorities. Pesticide residues resulting from the use of plant protection products on crops that are used for food or feed production may pose a risk factor for public health (EFSA, 2021). The chemical monitoring data collected and

published by EFSA include the analytical results provided by EU Member States, Iceland, Norway and three pre-accession countries: Bosnia-Herzegovina, Montenegro and North Macedonia (Food Safety Agency of Bosnia and Herzegovina, 2021),

In Bosnia and Herzegovina, a comprehensive legal framework was adopted, which defines the rules for the approval of active substances used in plant protection products, the use of plant protection products, and prescribes the maximum permitted amounts of pesticide residues in and on food. In order to ensure a high level of consumer protection, the permitted limits, the so-called "maximum permitted amount" or "MRL" (Ordinance on maximum levels of pesticide residues in and on food and feed of plant and animal origin, 2017) which is harmonized with Regulation (EC) 396/2005 as well as Law on Phytopharmaceutical Products of BiH. Pesticide residue in foods can be present in many products and can lead to many health damages. In B&H was conducted study that investigated pesticide residue in foods, and the result was that about 27% of total samples contained pesticide residues above the quantification level (Tomović et al., 2021). These data may be a signal to relevant institutions in B&H to promote better legal regulation in the field of protection from pesticides.

CONCLUSION

Pesticides have very important role for global food security, but the importance of that contribution can cause harm to human health and environment. It is known that the use of pesticides causes long-term severe negative effects on human health and the environment. Many studies have been concerned the problems with use of pesticides. Many pesticides are banned or restricted due their negative impacts, as outlined in Regulation (EC) No 1107/2009 and Regulation (EC) No 396/2005 in EU, but some pesticide companies headquartered within the EU export large amounts of pesticides banned for use to developing countries where regulations regarding their use are less strict. This problem is concerned by the some regulation bodies of UN and European Commission. The most of pesticides are hazardous if misused, and have the potential to seriously damage human health as well as environment. Pesticides are the significant factor of professional diseases due to their production or use. The protection of the people and environment from pesticides must be the priority of all international institutions that are included in this problem in terms of pesticide risk reduction, the use of high-risk pesticides, as well as the promotion of integrated pest management.

In our research the most of the selected documents shows that production, use and exposure to pesticides leads to the occurrence of occupational diseases, accidental poisoning of the population, as well as environmental pollution. The analysis suggests that permanent control of the production and use of pesticides through legislation is needed, in order to achieve the best possible protection against these agents.

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