Plant Archives Vol. 20 Supplement 1, 2020 pp. 1607-1618 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

BIOINDICATORS OF PESTICIDES POLLUTION IN THE AQUATIC ENVIRONMENT : A REVIEW

Hind I. AL-Khazraji*, Baraa M. Thakir and Sawsan A.K. EL-Hadeeti

Department of Plant protection, College of Agricultural Engineering Sciences, University of Baghdad, Iraq

Abstract

The aquatic environment is of vital and economic importance that is unique to other environments as it is rich in many living resources and wealth. Due to the growing concern about the pollution of the environment with various chemicals, especially the aquatic environment and the accompanying adverse effects on humans and animals. Generally, today there is a growing interest in the scientific community and international agencies to monitor and evaluate environmental pollution. Furthermore, the aquatic environment suffers from multiple forms of pollution, the most important of which is pollution caused by the excessive and incorrect use of agricultural pesticides. This has increased at present due to the lack of guidance, environmental awareness and health control, which causes the deterioration of water quality and thus impact on living organisms and moving through the food chain down to the human. Many methods have been used as indicators of environmental pollution and one of these important bioindicators is the use of living organisms as one of the indicators of environmental pollution. In fact, this indicator plays main role in controlling changes and improving risk assessment and management and laying the foundations and limits allowed to improve the quality of environmental measurements and mitigation of pollution effects on environment.

Key words: Bioindicators, pesticides, Aquatic ecology, Aquatic toxicology, pollution.

Introduction

A large number of pollutants such as metals, chemicals and waste accumulate annually and pollutants cause environmental problems that lead to the imbalance of the natural system, among these pesticide chemicals, which are defined as any substance or combination of substances used to control destructive pests such as insects and pathogens. In order to increase productivity and improve the quality of productive crops, the use of pesticides and fertilizers in agriculture has become necessary and common throughout the world to achieve the increase required to keep pace with the increase happening in the world population. Therefore, there was a major development in the chemical pesticide industry in the 20th century, accompanied by various techniques in its use against various agricultural and veterinary pests, these pesticides, which belong to different chemical groups, were able to control a wide range of insect pests and thereby minimize the losses that causing agricultural production to a minimum. It has become an effective and rapid means of combating various pests in addition to the achievements of pesticides in the field of public health by eliminating many thousands of animals carrying some dangerous diseases for humans and animals. However, many of these pesticides have had a detrimental effect on organisms living in environments where they have been used, such as their impact on human health and non-target organisms and the impact on environmental ecosystems, such as the contamination of streams, rivers and lakes as a result of the flow of chemicals into nearby waters (Ishaaya, 2001, Shukla *et al*., 2010, FAO, 2013). After World War II, global production of pesticides increased, rising from about 500,000 ton/a in the 1950s to more than 3 million ton/a at the beginning of the 21st century (Tilman *et al*., 2002). Al-Ghozi *et al*., (2011) indicated in a study conducted in Basra governorate that the amount of insecticides used for agricultural pest control and veterinary purposes from 2000-2006 occupies the largest space among the types of pesticides used. The total number of insecticides was 288,956 (kg/L), while the amount of fungicides was 87,532 (kg/L), herbicides

****Author for correspondence :*** E-mail: hindaa2007@yahoo.com

8,654 (kg/L) and rodenticides 6,474 (kg/L). Moreover, (FAOSTAT, 2018) also reported that the most environmentally applied pesticides were herbicides by 49%, fungicides and bactericides by 27% and insecticides by 19%. In order to reduce the problems caused by these pesticides, great efforts have been made during the last three decades of the last century and continue to this day to find pesticides with Selective qualities that work on certain chemical and physiological aspects of insects. For example, the use of insect growth regulators that affect In the activities of growth, development, reproduction or the use of environmentally friendly pesticides such as the use of plant extracts and bio-pesticides (Dhadialla *et al*., 1998, Ali and Ahmed, 2009, AL-khazraji *et al*., 2016). These collections of modern pesticides are characterized by their low toxicity to humans and some of them are characterized by their high specialization, in addition to characterized by high degradation thus, be less harmful to the natural enemies of insects. Therefore, manifests their importance by the possibility of being used in the integrated pest management (Moulton *et al*., 2002, Pineda *et al*., 2007).

Water ecosystems are extremely complex environments and any simple change to the ecosystem can be a barrier to the balance of the entire system. The problem of pollution of aquatic ecosystems occurs globally and the United States Environmental Protection Agency confirms that pollution from agricultural runoff has contributed mainly to 70% of pollution in U.S. streams and rivers. As a result of current farming practices with irrigation systems that cause the flow of chemicals, silt and animal waste (Dodds and Whiles, 2010, Horrigan *et al*., 2002). The risk of pesticide contamination is due to its easy transport with surface and ground water, as well as its ability to accumulate in sediments, which facilitates its transmission during the aquatic food chain. Then, its accumulation in aquatic organisms such as large benthic vertebrates, plants, Mollusca and fish makes their risk increase with regard to the environment and human health (Boran *et al*., 2007, Khan *et al*., 2007). The results of many studies indicated the effect of pesticides on living organisms in the aquatic environment, as they were observed in the cells of aquatic organisms, where they accumulate little concentrations in many types of fish and their effect extends to the human being who eats these organisms as a food source. Since it is considered the main consumer of fish (Pan and Dutta, 2000, WHO, 1990). (He *et al*., 2008) also noted that pesticides have a high capacity for bio concentration in fish, shellfish and invertebrates.

Aquatic Toxicity knows the field that is interested in studying and evaluating the impact of chemicals and other human influences on aquatic organisms from the cellular level to the ecosystem level (Nikinmaa, 2014). Common tests in this area are Acute Toxicity and Chronic Toxicity tests. Hydrotoxicity tests are carried out using organisms that are highly sensitive to pollutants and are easily treated laboratory (EPA, 2011). Impacts on an organism or the environmental level are usually an indicator of early warning of potential impacts on human health. Therefore, the world is going to use these organisms to assess environmental pollution with so-called bioindicators or biomonitoring. Aquatic environments are the final fate of any chemical that enters the environment and aquatic organisms are able to detect the negative effects of undetected chemicals by employing standard chemical techniques, due to the ease of breeding these organisms laboratory being small, life-cycle Short, which makes it suitable. Since living organisms react with the overload of these dangerous substances, they change their vital functions, which called bioindicator organisms or these substances accumulate within their tissues and are called living organisms with a cumulative bioindicators. Where this type of response may occur through changes in the benefit of society such as influencing the performance of invertebrates or reducing the rates of death or reproductive or perhaps the effect for long periods through genetic selection (Al-Dory, 2001, Van der Oost *et al.,* 2003, Diener *et al.,* 2004, Hader and Erzinge, 2016).

Pesticides

Pesticides are defined as any natural or synthetic biochemical substance that control pests, which reduce their numbers or prevent their reproduction and increase their numbers. Pesticides are classified based on several concepts, WHO (2005) is divided into:

Insecticides

Acaricides

Rodenticides

Molluscicides

Nematicides

Fungicides

Herbicides

Divided by Chemical Composition into

Inorganic pesticides

Naturally organics

Synthetic organics

Classification Based on Mode of Entry into

Systemic pesticides

Non-systemic (Contact) pesticides

Stomach poisoning and stomach toxicants

Fumigants

Repellents

Srivastava *et al*., (2018). In table 1 Classify pesticides depending on the pest to be controlled and depending on the method and time of effect and according to their chemical Structure.

Pollution of the aquatic environment

It refers to changes in the biotic and non-biotic elements of the aquatic environment in terms of quantitative and qualitative terms or is defined as processes leading to a change in all or parts of the chemical, physical and biological properties of water. These changes have negative effects on the volume of available natural resources, making aquatic environments unfit for human use or the living aquatic organisms in which they live. The issue of water pollution with pesticides is of great interest for its wide use and in large quantities. Moreover, it has a great impact on aquatic ecosystems, especially on aquatic organisms that not targeted by the control process through its impact on the relationships of organisms with each other and the loss of biodiversity. Many researchers pointed to the negative effects of pesticides on organisms in aquatic environments, such as reduced reproduction in aquatic birds, weakened immune system and cancer formation due to the accumulation of toxins in the fat layer. As well as, their effect on carbohydrate representation and blood ratios in fish (Cengiz and Unlü, 2003, Ishihara *et al*., 2003, Lveda *et al*., 2004). (Malev *et al*., 2012) noted that the algae community was influenced by as a result of its stunted growth due to the use of pesticides. In California, the use of pesticides, especially imidacloprid and thiamethoxam, led to decline in four frogs of California frogs (Mason *et al*., 2013). Some compounds used as pesticides such as polychlorinated biphenyls (PCB's) are estrogenic and anti-estrogenic contaminants that affect fish reproduction and cause endocrine disorders (Banaee, 2013). Finally, pesticides such as chlorpyrifos and carbaryl have reduced the number of salmon in the Pacific Ocean due to changing feeding behavior through loss of prey (Macneale *et al*., 2014). (Shaaban and Al-Malah, 1993) reported that there are several ways for pesticides to get into water as follows: Direct spraying of pesticides to pests living in water, such as spraying ponds and swamps to control mosquitoes and bushes in irrigation canals and lakes. Secondly, washing residues of pesticides from agricultural lands with rain water and irrigation. Moreover, aerial spraying operations, such as the use of agricultural aviation to control pests in the forest or large areas planted, leading to the fall of a huge amount of pesticides in the streams, rivers and swamps. As well as, disposal of pesticides by factories in sewage and river water, as some factories use pesticides in their work, which leads to contain the waste of these factors on large quantities of pesticides and Swears are the place where most materials are treated with pesticides, especially slow degradation. As well as, Cattle ponds, which are used to immerse animals to combat external parasites. Finally, dust and rain.

Schäfer *et al*., (2011) shows in table 2, the results of field studies of the last two decades of the effects of pesticides use on different organisms in aquatic environments.

Aquatic toxicology

Aquatic toxicology a science that studies the effects of synthetic chemical material, other natural substances and human activities on aquatic organisms and at different levels of regulation (from subcellular to individual, communities and ecosystems). These effects may include death or survival, changes in behavior, growth, development, tissue synthesis, reproduction, induction or inhibition of enzymatic activity or changes in relative abundance and physiological status of specific species. It is a wide-ranging science that combines Toxicology, Aquatic ecology and Aquatic chemistry, as well as it's include the study of freshwater and marine water (Nikinmaa, 2014). The study of the toxicity of the aquatic environment plays a very important role in understanding the impact of human activities on aquatic ecosystems and helps to protect and maintain the health of the aquatic ecosystem by predicting and assessing the impact (Moiseenko, 2008). Aqueous toxicity tests are necessary to detect and assess the potential toxic effects of chemicals on aquatic organisms, particularly at relatively low exposure concentrations. Water toxicity tests provide a database that can be used to assess the risks associated with the chemical, organism and exposure conditions (Rand, 1995). Toxicity is defined as any biological change in an organism and the response of a population resulting from exposure to dose or a successive dose of chemical agents over a period of time (OEDC, 1981).

Aquatic toxicity tests (Assay)

Aquatic toxicity tests are used to prepare quantitative and qualitative data on the negative and harmful effects of any toxic substance on aquatic organisms. These tests can be used to assess the potential for harm to the aquatic environment and to employ a database, which is used to assess risks associated with toxic substances and can be carried out in the field or laboratory. Field tests indicate the exposure of several species of organisms, while

Table 1: Pesticides classifications (Srivastava *et al.,* 2018).

By Target		By Mode or Time of Action		By Chemical Structure
Type	**Target**	**Type**	**Action**	
Bactericide (sanitizers or disinfectants)	Bacteria	Contact	Kills by contact with pest	Pesticides can be either organic or inorganic chemicals, mostoftoday's pesticides are organic.
Defoliant	Crop foliage	Eradicant	Effective after infection by pathogens	Today's pesticides are organic.
Fungicides	Fungi	Non selective	Toxic to both crop and weed	
Herbicides	Weeds	Post emergence	Effective when applied after crop and weed emergence	Commonly used inorganic pesticides include copper based fungicides. lime-sulfur used to control fungi and mites, boric acid used for cockroach control and sulfamate herbicides.
Insecticides	Insects	Post emergence	Effective when applied after planting and before crop or weed emergence	
Maticides (acaricides)	Mites and ticks	Preplant	Effective when applied prior to planting	
Molluscicide	Slugs and snails	Protectants	Effective when applied before pathogen infects plants	
Nematicides	Nematodes	Selective	Toxic only to weed	Organic insecticides can either be natural (usually extracted from plants and bacteria) or synthetic. Most pesticides used today arte synthetic organic chemicals. They can be grouped into chemical families based on their structure.
Plant to growth regulation	Crop growth processes		Toxic to all vegetation	
Rodenticides	Rodents	Stomach poison	Kills animal pests after ingestion	
Wood preservative	Wood destroying organisms	Systemic	Transported through crop or pest following absorption	

laboratory tests indicate the exposure of one species of organisms. A dose-response relationship is usually used in a sigmoidal curve. Toxicity tests are based on several factors, including the type of chemical material and the differences in organisms, including differences in metabolic rate, genetic factors, feeding method, age, sex and health status of organisms (Rand and Petrocelli, 1985). The effect criteria for the toxic substance or the end point of the test are defined as the symptoms or effects that can be relied upon to determine that there is a negative or harmful effect of chemicals. One of the most important end points of the test is that animal movement stops, as the heartbeat stops leading to their death (Ostrander, 2005). These criteria are used as the end of the test for easy calculation and monitoring (Newman, 2014). Some types of toxicity tests include.

Acute toxicity tests

This test is based on sudden and short-term exposure (hours or days) to high concentrations of toxic substances, which produces direct effects. The importance of test is to calculate the effect of chemicals in the biological activity, to be toxic or non-toxic and calculate the degree of the resulting biological response. The animal death is usually counted as the end of the test and the test is incorrect if the mortality ratio of test animals in the control group is greater than 10%. The results of acute toxicity tests in aquaculture are measured by the term LC50 (Median lethal concentration), which is the concentration of the toxic substance responsible for the death of half of the organisms exposed to the toxic substance (Banaee, 2013).

Chronic toxicity tests

These are long-term tests (weeks, months, or years depending on the age of the test animal, that is, no more than 10% of the age) in which organisms are exposed to a chemical material over and over again with few concentrations (Newman, 2014). These chronic tests are considered complete life cycle tests, which cover the time of a whole generation or reproductive life cycle, chronic tests are not accurate if the mortality in the control sample exceeds 20%. The main purpose of these tests is to calculate the continuous exposure of the chemical pollutant concentrations expected to be present in the aquatic environment, The results of this test are recorded at the no observed effects level (NOEL) or at the lowest observed effects level (LOEL). Accordingly, acute and

Table 2: Pesticides effects on the different groups of organisms under field or field-relevant conditions (Schäfer *et al*., 2011).

Effects level	Bacteria, protozoa and fungi	Phytoplankton and benthic algae	Macrophytes	Macro invertebrates and zooplankton	Fish	Amphibians
Suborga-nismal (S)	-	Genetic changes (Kasai and Hanazato, 1995)	Increase Glutathione-S-transferase and chlorophyll ratio (Amaya-Chavez *et al*., 2006)	p-nitrophenylac-etate esterase, Glutathione-S-transferase and Acetylcholin esterase inhibition (Bonzini *et al*., 2008)	Acetylcholine esterase inhibition (Sturm *et al*., 2007)	Alteration of receptor binding and cell signalling (Venturino *et al*., 2003, Marcogliese *et al*., 2009)
Individual (I)	Decrease in bacterial activity (Widenfalk *et al*., 2004)	Decline in photosynthesis and mortality (Knauert *et al*., 2008. Abrantes *et al*., 2008)	Decline in frond area and weight, and mortality (Coors *et al*., 2006, Solomon *et al*., 1996)	Feeding depression and mortality (Lopes *et al*., 2007)	Mortality (Pablo and Hyne, 2009)	Increase in parasite susceptibility and mortality (Rohr *et al*., 2008, Relyea *et al*., 2005)
Population decline (P)	(Leboulanger *et al*., 2009)	(Seguin *et al*., 2002)	Sobrero *et al*., 2007)	(Schulz, 2004, Liess and Schulz,1999)	(Gormley *et al*., 2005)	(Vonesh and Kraus, 2009)
Community: change in composition (C)	(Widenfalk *et al*., 2008, Pesce *et al*., 2008)	(Seguin *et al*., 2002, Knauert *et al*., 2009)	(Mohr *et al*., 2007)	(Liess *et al*., 2008)	(Gormley *et al*., 2005)	
Associated Ecosystem processes (E)	Inhibition of microbial mineralisation (Garcia-Ortega *et al*., 2006)	Reduction in pH and O_2 (Jüttner *et al*., 1995)	Decrease in nutrient level, pH and carbonate cycle (Mohr *et al*., 2007, wendt-Rasch *et al.,* 2003)	Inhibition of organic matter decomposition and decrease of energy transfer (Hanazato and Takayuki, 1997)	-	-
Frequency of reported effects	I, P, C, E: low	S: low I,P,C,E: medium	E,C,S: Low P,I: medium	High for all levels, except E: low	S: high I: medium P,C: Low	P: medium S,I: high
Clear evidence from field studies	No field studies, only mesocosm (except one field study on C)	No field studies, only mesocosm	Not for E,C,S level	All levels	All levels	For S,P,I

chronic toxicity tests, therefore, differ according to the time required for testing, cost and results.

The Fate of Pesticide in the Environment

There are many factors that affect the pesticides stability and activity in the environment, including photodegradation, chemical degradation and microbial degradation. Degradation rate depends on pesticide chemistry, as well as on environmental conditions. Soil temperature and pH in soil and water, microbial activity and other soil properties may affect pesticide stability. Fig. 1, shows the processes that lead to the transfer of pesticides and their fate in the soil, after spraying pesticides and access to the soil, it exposed to many chemical, physical and biological processes, including absorption, desorption, volatilization, runoff and leaching. These processes lead to the transfer of pesticides from the plant to the soil and transport from soil to water or air (Arias-Estevez *et al*., 2008). Herbicides may reach water bodies directly by spraying the pesticide spray on water bodies to control water weed, or indirectly through certain processes such as agricultural wastewater, spraying spray erosion, filtration and run-off operations on or below the surface of the earth or runoff with groundwater into rivers

(Schulz, 2001, Battaglin *et al*., 2003). Regular and frequent use of pesticides as well as high pesticide resistance to degradation causes the presence of pesticides at significant concentrations in water bodies (Beketov and Liess, 2008).

Bioindicators

Defined as organisms or biological processes that can be used to identify and measure the effects of pollutants on the environment. Before selecting an organism as a bioindicator, its physiological and behavioral changes must be properly studied and these changes vary from one organism to another and are used to detect changes in the environmental health of the ecosystem. (Kumar *et al.,* 2012) pointed out that the important way to understand the complex interaction between environmental factors and the organism's response and resistance to the death one, is the use of bioindicators that express the overall environmental safety of water from the biological, physical and chemical aspects. Aquatic ecosystems are a repository of a large number of chemical environmental pollutants, that can assess their risks to aquatic organisms based on a large number of community-level testing. Which is a complex and long process accompanied by many variables at the level of society or at the level of chemical contaminant. Most research is therefore has tended to use bio communities is almost in control to produce reliable results at intervals appropriate to the movement of the polluter through the environment and commensurate with the life cycle of that organism. Then it is necessary to study the impact of this pollutant in any detail of the life of that organism and it is therefore necessary to develop or find living organisms in the water which have a high capacity and sensitivity to environmental pollutants (Barros *et al*., 2007, Bayona *et al*., 2014). These organisms include:

Plankton

Defined as a group of organisms living in fresh and saltwater and have the ability to swim in a water column and are divided into phytoplankton and zooplankton (Pionthovski *et al*., 2003). Water flea *Daphnia magna* is a small organism species that lives in fresh water and have a great importance, as it occupies a biology position in the food web and it also represents a link between the primary producer and the secondary consumer (AL-Ghashami, 2004). It is a primary consumer and feeds on phytoplankton the primary producer, which in turn is a good food for the rest of the large invertebrates and fish and in this location it transfers the energy from the producer to the consumer. Thus, any damage to this type of organism will eventually result in damage to the fisheries. Daphnia magna was also used as a bio indicator to identify water quality (Zawisza *et al*., 2016). Water flea lives in temperate and stagnant waters, such as in ponds, water's canals and lakes and are rarely found in rivers (Barnes, 1987, Weider and Hebert, 1987). The main mechanism by which water fleas feed is filtering of particles (Freyer, 1991). As it has specialized devices for the process of filtering and represented of the thoracic appendixes, that generate water currents near the chest opening in the shield and allow the collection and digestion of single-celled algae, bacteria and decomposed organic materials, it is the detritivore. It is considered to be a primary consumer and contributes to the transfer of energy to the secondary consumers, It has an important role in the food chain (Dodson and Frey, 1991, Zawisza *et al*., 2016). Several studies have been conducted to assess the water flea sensitivity to chemical pesticides, including (Jemec *et al*., 2007) study to determine the chronic effects of a number of chemical pesticides on the reproductive capacity of water flea *D. magna*. The

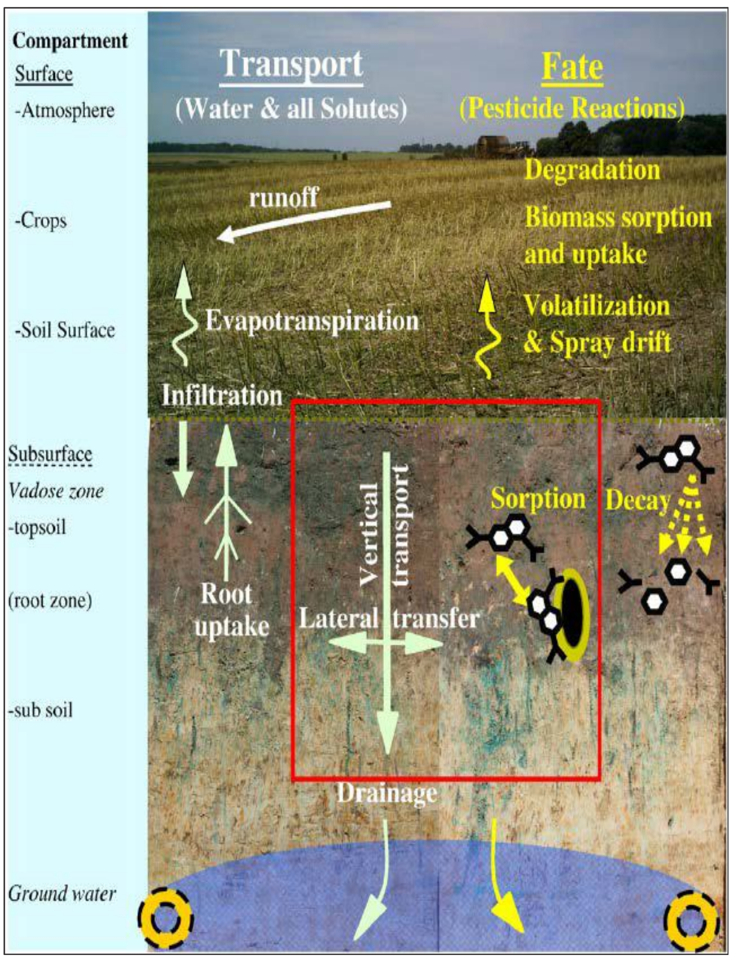

Fig. 1: Processes governing pesticide fate and transport in agricultural structured soils (Köhne *et al*., 2009b).

results showed that diazinon pesticide was more effective than Imidacloprid and Confidor SL 200. (Thakir, 2017) indicated that the sensitivity of *D. magna* to the Roundup Ultra Glyphosate and 2,4-D, different concentrations of the two herbicides caused a decrease in the average females ages and a decrease in the number of eggs / brood depending on the concentration used for the two herbicides.

Algae

Are an organisms or thallophytic non flowering plants, rootless, stems and leaves. Some are composed of one cell, while the others are multicellular, characterized by possessing chlorophyll dye, live in different environments, including fresh and salty water and in the soil and between rocks and bark, Algae is a primary producers and an important and essential food source for many food webs in the oceans and fresh water. It is also an important and regulated source of oxygen levels, so the toxic effects of pesticides and chemical compounds on algae have later effects on higher nutritional levels of the food chain (Fleming and Haselkorn, 1973, Russel, 1973, Starks *et al*., 1981, Hu *et al*., 2003). Algae have been widely used in many countries of the world in biological monitoring programs to assess water quality and detect the presence of pollution or not, which is environmentally important group in most aquatic ecosystems. Its totals and variations have been adopted to determine the quality of aquatic systems as they are responsive to changes in physical and chemical properties of water sources and its appearance, absence and density depend on biology and non-biology factors of water. what makes it valuable indicators of short-term effects is its rapid reproduction and its short life cycle (Komala *et al*., 2013). (Debenest *et al*., 2008, 2010, Sjollema *et al*., 2014) showed that algae groups are sensitive to certain pollutants and to environmental disturbances and that chemical materials stimulate growth inhibition and genetic toxicity in microalgae, so the presence or absence of a particular organism or plant in the ecosystem represent important evidence about the environmental health. (Chamsi *et al*., 2019) indicated that when testing the effect of nine herbicides, one metabolite and one safener individually and in mixtures on the growth for a group of algae. The results showed the sensitivity of *Nitzschia palea*, *Navicula pelliculosa*, the diatoms to the atrazine pesticide, desethylatrazine and the safener benoxacor, while green algae, *Desmodesmus subspicatus,* were more sensitive to iodosulfuron-methyl-sodium compared to atrazine and metabolite when used that pesticides alone.

Mollusca

Mollusca play an important role in the ecosystem and food chain, as they are a food source for fish, invertebrates and herbivores, it recycles nutrients by converting organic matter that found in different degrees of decomposition into concentrated food from which benthic fish benefit (Barker, 2001). Consequently, it is important to assess their effects on a large number of chemical materials to which it's exposed, as adverse effects on Mollusca may affect the function of the ecosystem and the groups of species below them in the food chain. Mollusca are one of the most widely used aquatic organisms in environmental monitoring programs in aquatic systems. It plays an important role in the biological purification of sea water from various types of pollutants such as pesticides, heavy metals, organic materials, etc. Its absorption of chemical pesticides by the diffusion through the surfaces of biofilms by water or sediment or through food (Norbriga, 2002). The toxic effects of pesticides in snails include behavioral change, growth reduction, effects on immune system and effects on reproduction. In addition to physiological, histological and biochemical effects (Carson, 1962). However, toxicity tests by exposing the organisms such as snails to toxic substances at different concentrations and for a certain period of time and the response time of the organisms is either reflective, such as the effect on growth, reproduction and behavior or the mortality ratios. Thus, it can determine the concentration that kills 50% of the experimental organisms within a specified period of time called LC50 (AL-Yaseri *et al*., 2009). In this field (Serrano *et al*., 1995) pointed out the effect of a group of organophosphorus pesticides which are (dimethoate, methidathion, chlorfenvinphos, chlorpyrifos and phosmet) on two species of Molluscs (*Mytilus galloprovincialis* and *Venus gallina*). The analysis results of pesticide residues in the soft tissues of Mollusca showed that pesticides can be concentrated in their bodies within short periods of time. The levels of the two pesticides methidathion, chlorpyrifos in Mollusca depend on their concentration in water. It was also found to be somewhat related to mortality ratios in *M. galloprovincialis* and as to *V. gallina*, pesticides were concentrated in their tissues over short periods of time without any toxic effects that can be observed after 96 hours. The researchers noted that the bio concentration of pesticide residues could lead to serious risks on public health because of the consumption of these contaminated organisms. (Mane *et al*., 2012) indicated that the acute toxicity of Thiodan (Endosulfan 35% EC) on the respiratory rate of freshwater lamellibranch Mollusca *Lamellidens corrianus*, as the pesticide caused a decrease in Mollusca respiration rate after 0, 24, 48, 72 and 96 hours of treatment.

Fish

The study and use of fish as environmental bioindicators of water pollution began in many countries at the beginning of the twentieth century, which they are biological factors for water quality as they are the last link in the food chain. In addition to its sensitivity to pollution and possessing some special advantages as indicators of the health of freshwater ecosystems, including biodiversity and ease of determining their numbers and health and behavioral status and being very visible and valuable elements, which is easy to deal with in the water system. As well as, most fish species have a long shelf life and can reflect current and long-term water quality and the proven classification of fish helped biologists reduce time and effort in identifying samples in this field (Simon, 1999). Kanaanani (1995) explained the effect of Nogos and Diazinon on *Gambusia affinis* fishes as the pesticides caused inefficiency of the glander to perform its function by increasing the speed of the cover glander and increasing the concentration of the pesticide and the exposure period. The fish's inability to take the dissolved oxygen may be due to the acute concentrations of pesticides that cause changes in the composition of the tissues of the worm, which damage the respiratory plates and reduce the movement of the wrap cap by the lack of functional effectiveness (Omoregie and Ufodike, 1991). (Andrade *et al*., 2004) indicated the use of two species of mullet and sea catfish in the Tramandai and Mampituba rivers in the State of Rio Grande do Sul, southern Brazil, as bioindicators for detecting and evaluating the genotoxic effects of pollutants and seasonal variation of genetic toxicity from chemical pollutants (industrial wastes, agricultural pollutants and wastewater). The results of the two-year study when comparing chemical pollutants and physical changes in rivers to genetic toxicity data indicated that there may be some association between hydrocarbons, minerals, pH, water temperature and level of damaged cells observed in mullet and sea catfish in Tramandai and Mampituba estuaries.

Crustaceans

Crustaceans are among the most organisms that are characterized by diversity in terms of form, life and variety of species and include many arthropods, such as Crabs, Lobster, Shrimp, Crayfish and Wood Lice. It live in different environments on the Earth's surface, whether in the sea or deserts or mountains and more metazoan located on the surface of the earth, crustaceans are an important nutrient for invertebrates and fish and is one of the important elements in the food system, therefore, has an important role in the ecosystem. It is an important link between benthic and pelagic organisms, fish and birds. One of its organisms is grass shrimp, which has an important role in the transfer of energy from the lowest levels of the food chain represented by the product and the decomposer to the highest levels of the food chain and is an important nutrient for many fish and crab (Anderson, 1985). Several studies have confirmed the use of grass shrimp as a bioindicator of pollution in aquatic environments, which is one of the most sensitive crustaceans to many pesticides, including fenvalerate, endrin, DDT, azinphosmethyl, parathion, endosulfan and malathion (Schimmel *et al*., 1977, Anderson, 1985, Scott *et al*. 1987). (Hatakeyama and Sugaya, 1989) indicated that when testing the sensitivity of freshwater shrimp and Paratya compressa improvisa against five species of pesticides and five herbicides, compared to two species of Cladocera, *Daphnia magna* and *Moina macrocopa*. The results showed that shrimp were more sensitive to pesticides, especially fenitrothion and fenthion, compared to Cladocera and it was also found that shrimp more sensitive to herbicides as LC50 values were less than two to eight times compared to the two species of Cladocera. (Kumar *et al*., 2010) showed the sensitivity of the freshwater shrimp *Paratya australiensis* to several types of pesticides after 96 hours of exposure. The results showed that cypermethrin is the most toxic pesticide for shrimp, then chlorpyrifos, carbaryl, dimethoate, fenarimol and diuron. (Webb, 2011) conducted several tests to determine whether *Palaemonetes australis euryh*aline shrimp was a suitable species for use as a bioindicator of the organisms health in estuarine biota in Australia, then the results observed that this species of crustaceans is biologically effective and suitable for laboratory and field studies.

Conclusions

Despite the large and effective role played by chemical pesticides of various types, but pesticides today constitute one of the elements of pollution in the environment, so more attention should be paid to them and the issuance of instructions and legislation that limit the randomly using of pesticides. Moreover, the lack of regulatory control in many countries over market pesticides, especially in developing countries, has led to an increase in the problem of environmental pollution. There are many methods that can be taken to reduce the problem of pesticide pollution, especially pollution of the aquatic environment, in the forefront is raising awareness among farmers of the dangers of pesticides and the risks of environmental pollution and the use of safe methods. As well as, environmentally friendly agricultural practices such as the use of plant extracts, organic agriculture as a means of reducing the use of pesticides, the application of biological controls such as the adoption of biological control using parasites and predators, the use of attractants and repellents. As well as, requiring factories to establish special units to treat water containing many contaminants, including pesticides to reduce and remove those contaminants before they reach rivers and streams, drainage of spray liquids and bathtub used to control parasites on animals away from crops, waterways and groundwater sources. This is due to the danger of pesticides leaking into humans, animals and aquatic life. Finally, further studies are needed in this aspect to prevent organisms from being exposed to damage that play a biological role in maintaining the ecosystem.

References

Abrantes, N., R. Pereira, A. Soares and F. Goncalves (2008). Evaluation of the ecotoxicological impact of the pesticide Lasso ® on nontarget freshwater species, through leaching from nearby agricultural fields, using Terrestrial Model Ecosystems. *Water Air and Soil Pollut*., **192:** 211-220.

AL-Dory, M.G. (2001). Comparative study of the benthic invertebrates of Diyala River and some of its branches. *Ibn Al Haytham Journal of Pure and Applied Sciences*., **14(4b):** 1-10.

Ali, H. I. and R.F. Ahmed (2009). Effects of some insect growth regulators and bio-insecticide (Abamectin) in reproductive potential of the cotton leaf worm. *The Iraqi Journal of Agricultural Sciences*., **40(3):** 98-107.

AL-Ghashami, W.M.A. (2004). Effect of some heavy elements on the growth of water flea *Daphnia magna* (Straus). Thesis of M.Sc. College of Science for Women. University of Baghdad. 108.

AL-Ghazzi, K.W.M., L.J.M. Al-Anbar, H.M.G Al-Mayah, J.H.A. Al-Malki, A.J.N. Hamad and A.A.K. Juma (2011). Study on natural and abnormal use of pesticides in the rivers and marshes of Basra province. *Journal of Babylon University Pure and Applied Sciences*., **1(19):** 139-147.

AL-Khazraji, H. I., R.F. Ahmed and R.S. Al-Jorany (2016). Effect of feeding treatment with some extracts of black pepper on some biological aspects of cotton leaf worm. *The Iraqi Journal of Agricultural Sciences*., **47(3):** 856-864.

AL-Yasiri, S.T.L., A.A. Hantoush and A.M. Nasser (2009). Short-term toxicity of Basra crude oil in freshwater snails *Lymnaea euricularia* (Linn.1758) From Shatt al-Arab- Iraq. *Journal of Basrah Research*., **5(1):** 1-8.

Amaya-Chavez, A., L. Martinez-Tabche, E. Lopez-Lopez and M. Galar-Martinez (2006). Methyl parathion toxicity to and removal efficiency by *Typha latifolia* in water and artificial sediments. *Chemosphere*., **63:** 1124-1129.

Andrade, V.M., J.D. Silva, F.R. Silva, V.D. Heuser, J.F. Dias, M.L. Yoneama and T.R. Freitas (2004). Fish as bioindicators to assess the effects of pollution in two southern Brazilian rivers using the Comet assay and micronucleus test. *Environ. Mol. Mutagen*., **44(5):** 459-68.

Anderson, G. (1985). Species profile: life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico) grass shrimp. U.S. Fish Wildl. *Serv. Biol. Rep*., **82(11.35)**, U.S. Army Corps of Engineers, TR EL-82-4. 19.

Arias-Estévez, M., E. López-Periago, E. Martínez-Carballo, J. Simal-Gándara, J.C. Mejuto and L. García-Río (2008). The mobility and degradation of pesticides in soils and the pollution of groundwater Pesticides, Anthropogenic Activities and the Health of our Environment resources. Agriculture, *Ecosystems and Environment*., **123:** 247-260.

Banaee, M. (2013). Physiological dysfunction in fish after insecticides exposure. *I.N.T.E.C.H.,* chapter 4.

Barker, G.M. (2001). The Biology of Terrestrial Molluscs. 1st ed. CABI Publishing.

Barnes, R.D. (1987). Invertebrate zoology (No. Ed. 5). WB Saunders company.

Barros, L.S.S., L.A. Amaral and C.S. Lorenzon (2007). *Daphnia magna* bio-indicator of pollution from poultry and pig abattoir Effluents. *Rev. Bras. Saúde Prod. An*., **8(3):** 217-228.

Battaglin, W.A., E.M. Thurman, S.J. Kalkhoff and S.D. Porter (2003). Herbicides and transformation products in surface waters of the midwestern United States. *J. of the Ame. Water Res. Assoc*., **39:** 743-756.

Bayona, Y., A. Roucaute, M. Roucaute, C. Gorzerino, K. Cailleaud, L. Lagadic, A. Bassères and T. Caquet (2014). Secondary production of freshwater zooplankton communities exposed to a fungicide and to a petroleum distillate in outdoor pond mesocosms. *Environmental Toxicology and Chemistry*., **(9):** 1-11.

Beketov, M.A. and M. Liess (2008). Potential of 11 pesticides to initiate downstream drift of stream macroinvertebrates. Archives of environ. *Contam. and Toxicol*., **55:** 247-253.

Bonzini, S., A. Finizio, E. Berra, M. Forcella, P. Parenti and M. Vighi (2008). Effects of river pollution on the colonisation of artificial substrates by macrozoobenthos. *Aquat Toxicol.,* **89:** 1-10.

Boran, M., I. Altinok, E. Capkin, H. Karacam and V. Bicer (2007). Acute toxicity of Carbaryl, Methiocarb and Carbosulfan to the Rainbow Trout (*Oncorhynchus mykiss*) and Guppy (*Poecilia reticulate*). *Turk. Journal Vent. Anim. Sci*., **31(1):** 39-45.

Carson, R. (1962). Silent spring. Houghton Mifflin publishers, Boston, USA. 368.

Cengiz, E.I. and E. Ünlü (2003). Histopathology of gills in mosquitofish (*Gambusia affinis*) after long-term exposure to sublethal concentrations of malathion. *J. Environ. Sci. Health B.,* **38:** 581-589.

Chamsi, O., E. Pinelli, B. Faucon, A. Perrault, L. Lacroix, J.M. Sanchez-Perez and J.Y. Charcosset (2019). Effects of herbicide mixtures on freshwater microalgae with the potential effect of a safener. *Ann. Limnol. Int. J. Lim*., **55(3):** 1-9.

Coors, A., J. Kuckelkorn, M. Hammers-Wirtz and T. Strauss (2006). Application of in-situ bioassays with macrophytes in aquatic mesocosm studies. *Ecotoxicology*., **15:** 583-591.

Diener, L.C., P.M. Schulte, D.G Dixon and B.M. Greenberg (2004). Optimization of differential display polymerase chain reaction as a bioindicator for the cladoceran *Daphnia magna*. *Environmental Toxicology*.,**19(3):** 179-190.

Dhadialla, T.S., G.R. Carlson and D.P. Le (1998). New insecticides with ecdysteroidal and juvenile hormone activity. *Annul. Rev. Entomol*., **43:** 545-569.

Debenest, T., J. Silvestre, M. Coste, F. Delmas and E. Pinelli (2008). Herbicide effects on freshwater benthic diatoms: induction of nucleus alterations and silica cell wall abnormalities. *Aquat Toxicol.,* **88:** 88-94.

Debenest, T., J. Silvestre, M. Coste and E. Pinelli (2010). Effects of pesticides on freshwater diatoms. *Rev Environ Contam Toxicol*., **203:** 87-103.

Dodds, W. and M. Whiles (2010). Freshwater ecology: Concepts and environmental applications of limnology (2nd ed.). Burlington, MA: Academic Press.

Dodson, S.I. and D.G. Frey (1991). Cladoceran and other Branchiopoda. 723-786 In Thorp: JH and AP Covich (eds.). Ecology and classification of North American freshwater invertebrates.

EPA (2001). Environmental Protection Agency. Parameters of Water Quality, Interpretation and Standard. ISBN 1-84096-015-3. Ireland.

FAO (2013). Pesticides as water pollutants in Control of Water Pollution from Agriculture.Food and Agriculture Organization of the United Nations.

FAOSTAT (2018). Food and Agriculture Organization (FAO) of the United Nations (Internet). Available from: ftp://ftp.fao.org/FAOSTAT (Accessed: 19 Sep. 2018).

Fleming, H. and R. Haselkorn (1973). Differentiation in *Nostoc muscorum*-nitrogenase is synthesized in heterocyst. *Proc. Nalt. Acad. Sci*., **70:** 2727-2731.

Freyer, H.D. (1991). Seasonal variation of 15N/14N ratios in atmospheric nitrate species. *Tellus. B*., **43(1):** 30-44.

Garcia-Ortega, S., P.J. Holliman and D.L. Jones (2006). Toxicology and fate of Pestanal® and commercial propetamphos formulations in river and estuarine sediment. *Sci. Total Environ*., **366:** 826-836.

Gormley, K.L., K.L. Teather and D.L. Guignion (2005). Changes in salmonid communities associated with pesticide runoff events. *Ecotoxicology*., **14:** 671-678.

Häder, D.P. and G.S. Erzinger (2016). Daphniatox-Online monitoring of aquatic pollution and toxic substances. *Chemosphere*., **167:** 228-235.

Hanazato, T. and T. Takayuki (1997). Pesticide effects on structure of zooplankton community and functioning of lake ecosystems. *Acta. Hydrobiol. Sinica*., **21:** 22-28.

Hatakeyama, S. and Y. Sugaya (1989). A freshwater shrimp (*Paratya compressa improvisa*) as a sensitive test organism to pesticides. *Environ. Pollut.,* **59:** 325-36.

He, L.M., J. Troiano, A. Wang and K. Goh (2008). Environmental Chemistry, Ecotoxicity and Fate of Lambda-Cyhalothrin. Whitacre, D.M. ed., *Reviews of Environmental Contamination and Toxicology*., **195:** 71-91.

Horrigan, L., R.S. Lawrence and P. Walker (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health Perspectives*., **110(5):** 445-456.

Hu, C.X., Y.D. Liu, B.S. Paulsen, D. Petersen and D. Klaveness (2003). Extracellular carbohydrate polymers from five desert soil algae with different cohesion in the stabilization of fine sand grain, *Carbohydrate Polymers*., **5:** 33-42.

Ishaaya, I. (2001). Biochemical sites of insecticide Action and Resistance. Springer, Berlin. 239-252.

Ishihara, A., N. Nishiyama, S. Sugiyama and K. Yamauchi (2003). The effects of endocrine disrupting chemicals on thyroid hormone binding to Japanese quail transthyretin and thyroid hormone receptor. *Gen. Comp. Endocrinol*., **134:** 36-43.

Jemec , A., T. Tisler, D. Drobne, K. Sepcic, D. Fournier and P. Trebse (2007). Commercial liquid formulation and diazinon to non-target arthropod, the micro crustacean *Daphnia magn*. *Chemosphere*., **68(8):**1408-1418.

Jüttner, I., A. Peither, J.P. Lay, A. Kettrup and S.J. Ormerod (1995). An outdoor mesocosm study to assess ecotoxicological effects of atrazine on a natural plankton community. *Arch Environ Contam Toxicol*., **29:** 435-441.

Kanaanani, S.M. (1995). Effect of water hardness and salinity on the toxicity of two pesticides of *Gambusia affinis* (Baird and Girard). *Mesopotamian Journal of Marine Science*., **15(1):**105-117.

Kasai, F. and T. Hanazato (1995). Genetic Changes in phytoplankton communities exposed to the herbicide simetryn in outdoor experimental ponds. *Arch. Environ. Contam. Toxicol.*, **28:** 154-160.

Khan, I.A.T., Z.P. Riazuddin and M. Ahmed (2007). Multi-residue determination of organophosphorus pesticides and synthetic pyrethroid in wheat. *Int. J. Agri. Biol*., **9:** 905-908.

Knauert, S., B. Escher, H. Singer, J. Hollender and K. Knauer (2008). Mixture toxicity of three photosystem II inhibitors (atrazine, isoproturon and diuron) toward photosynthesis of freshwater phytoplankton studied in outdoor mesocosms. *Environ. Sci. Technol*., **42:** 6424-6430.

Knauert, S., U. Dawo, J. Hollender, U. Hommen and K. Knauer (2009). Effects of photosystem II inhibitors and their mixture on freshwater phytoplankton succession in outdoor mesocosms. *Environ Toxicol Chem*., **28:** 836-845.

Köhne, J.M., S. Köhne and J. Šimùnek (2009b). A review of model applications for structured soils: b) Pesticide transport. *Journal of Contaminant Hydrology*., **104:**36-60.

Komala, H.P., L. Nanjundaswamy and P.A.G. Devi (2013). An assessment of Plankton diversity and abundance of Arkavathi River with reference to pollution. Advances in Applied. *J. Science Research*., **4(2):** 320-324.

Kumar, A., R.S. Correll, S. Grocke and C. Bajet (2010). Toxicity of selected pesticides to freshwater shrimp, *Paratya australiensis* (Decapoda: Atyidae): Use of time series acute toxicity data to predict chronic lethality. *Ecotoxicology and Environmental Safety*., **73(3):** 360-369.

Kumar, R.N., R. Solanki and J.I. Kumar (2012). Spatial variation in phytoplankton diversity in the Sabarmate river at Ahmedabad .Gujarta, India. *J. Enviro. Sci*., **6:** 13-28.

Leboulanger, C., M. Bouvy, M. Pagano, R.A. Dufour, P. Got and P. Cecchi (2009). Responses of planktonic microorganisms from tropical reservoirs to paraquat and deltamethrin exposure. *Arch Environ Contam Toxicol*., **56:** 39-51.

Liess, M. and R. Schulz (1999). Linking insecticide contamination and population response in an agricultural stream. *Environ Toxicol Chem.,* **18:** 1948-1955.

Liess, M., R.B. Schäfer and C.A. Schriever (2008). The footprint of pesticide stress in communities-species traits reveal community effects of toxicants. *Sci Total Environ*., **406:** 484-490.

Lopes, I., M. Moreira-Santos, E.M. da Silva, J.P. Sousa, L. Guilhermino, A.M. Soares and R. Ribeiro (2007). In situ assays with tropical cladocerans to evaluate edge-of-field pesticide runoff toxicity. *Chemosphere*., **67:** 2250-2256.

Lveda, M.S.S., J.J. Wiebe, D.C. Honeyfield, H.R. Rauschenberger, J.P. Hinterkopf, W.E. Johnson and T.S. Gross (2004). Organochlorine Pesticides and Thiamine in Eggs of *Largemouth Bass* and *American alligators* and Their Relationship with Early Life-stage Mortality. *Journal of Wildlife Diseases.,* **40(4):** 782-786.

Macneale, K.H., J.A. Spromberg, D.H. Baldwin and N.L. Scholz (2014). A modeled comparison of direct and food web-mediated impacts of common pesticides on pacific salmon. *Plos. One*., **9(3):** e92436: 1- 13.

Malev, O., R.S. Klobucar, E. Fabbretti and P. Trebse (2012). Comparative toxicity of imidacloprid and its transformation product 6-chloronicotinic acid to non-target aquatic organisms: Microalgae *Desmodesmus subspicatus* and amphipod *Gammarus fossarum*. *Pesticide Biochemistry and Physiology*., **104:** 178-186.

Mane, B. U., V.S. Kamble and K.R. Rao (2012). Effect of Acute Toxicity of Organochlorine Pesticide on Respiration in Lamellibranch Mollusc *Lamellidens corrianus* During Winter Season. *American-Eurasian Journal of Toxicological Sciences*., **4(3):** 151-153.

Marcogliese, D.J., K.C. King, H.M. Salo, M. Fournier, P. Brousseau, P. Spear, L. Champoux, J.D. McLaughlin and M. Boily (2009). Combined effects of agricultural activity and parasites on biomarkers in the bullfrog, Rana catasbeiana. *Aquat Toxicol*., **91:** 126-134.

Mason, R., H. Tennekes, F. Sanchez-Bayo and P. Jepsen (2013). Immune Suppression by Neonicotinoid Insecticides at the Root of Global Wildlife Declines. *J. Environmental Immunology and Toxicology*., **1:** 3-12.

Moiseenko, T.I. (2008). Aquatic ecotoxicology: theoretical principles and practical application. *Water Resources.,* **35(5):** 530-541.

Mohr, S., R. Berghahn, M. Feibicke, S. Meinecke, T. Ottenströer, I. Schmiedling, R. Schmiediche and R. Schmidt (2007). Effects of the herbicide metazachlor on macrophytes and ecosystem function in freshwater pond and stream mesocosms. *Aquat Toxicol*., **82:** 73-84.

Moulton, K., A. Pepper, K. Jansson and J. Dennehy (2002). Proactive management of beet armyworm (Lepidoptera: Noctuidae) resistance to the tebufenozide and methoxyfenozide: baseline monitoring, risk assessment and isolation of resistance. *J. Econ. Entomol*., **95:** 414-424.

Norbriga, M.L. (2002). Larval delta smelt diet composition and feeling incidence: environmental and ontogenetic influences. *California Fish and Game*., **88:**149-164.

Newman, M.C. (2014). Fundamentals of ecotoxicology: the science of Pollution, 4th Edition. CRC press. 680.

Nikinmaa, M. (2014). An Introduction to aquatic toxicology. Elsevier. 253.

OECD (1981). Organization for Economic Cooperation and Development. Guideline for testing of chemicals. "Daphnia sp"., Acute Immobilisation Test and Reproduction Test. Paris, France.

Omoregie, E and E.B.C. Ufodike (1991). Histopathology of Oreochromis niloticus exposed to Actellic 25 EC. *J. Aqua. Sci.,* **6:**13-17.

Ostrander, G. K. (2005). Techniques in aquatic toxicology (Vol.2). CRC Press.788.

Pablo, F. and R.V. Hyne (2009). Endosulfan application to a stream mesocosm: studies on fate, uptake into passive samplers and caged toxicity test with the fish *M. ambigua*. *Arch. Environ. Contam. Toxicol*., **56:** 525-535.

Pan, G. and H. Dutta (2000). Diazinon induced changes in the serum proteins of largemouth bass, Micropterus salmoides. *Bull. Environ. Contam. Toxicol*., **64:** 287-293.

Pesce, S., C. Fajon, C. Bardot, F. Bonnemoy, C. Portelli and J. Bohatier (2008). Longitudinal changes in microbial planktonic communities of a French river in relation to pesticide and nutrient inputs. *Aquat Toxicol*., **86:** 352-360.

Pineda, S., S. Marcela-Ines and G. Smagghe (2007). Lethal and Sublethal effects of Methoxyfenozide and Spinosad on *Spodoptera littoralis* (Lepidoptera: Noctuidae). *J. Econ. Entomol*., **100(3):** 773-780.

Piontkovski, S.A., M.R. Landry, Z.Z. Finenko, A.V. Kovalev, R. Williams, C.P. Gallienne and V.N. Nikolsky (2003). Plankton communities of the South Atlantic anticyclonic gyre. *Oceanologica Acta*., **26(3):** 255-268.

Rand, G.M. and S.R. Petrocelli (1985). Fundamentals of aquatic toxicology: methods and applications. F.M.C. Corp., Princeton, NJ.

Rand, G.M. (1995). Fundamentals of aquatic toxicology: effects, environmental fate and risk assessment. CRC Press. 1125.

Relyea, R.A., N.M. Schoeppner and J.T. Hoverman (2005). Pesticides and amphibians: the importance of community context. *Ecol Appl*., **15:** 1125-1134.

Rohr, J.R., A.M. Schotthoefer, T.R. Raffel, H.J. Carrick, N. Halstead, J.T. Hoverman, C.M. Johnson, L.B. Johnson, C. Lieske, M.D. Piwoni, P.K. Schoff and V.R. Beasley (2008). Agrochemicals increase trematode infections in a declining amphibian species. *Nature.,* **455:** 1235-1250

Russell, E.W. (1973). Soil conditions and plant growth, 10th edition, Longman, London. 849.

Schäfer, R. B., P.J. Van Den Brink and M. Liess (2011). Impacts of Pesticides on Freshwater Ecosystems. Chapter 6. Ecological impacts of toxic chemicals, Publisher: Bentham. 111-137.

Schimmel, S.C., J.M. Patrick and A. Wilson (1977). Acute toxicity to and bioconcentration of endosulfan by estuarine animals. In: Mayer F, Hamelink J, editors. Aquatic Toxicology and Hazard Evaluation. ASTM STP 634. Philadelphia, PA: American Society for Testing and Materials. 241-252.

Scott, G., D. Baughman, A. Trim and J. Dee (1987). Lethal and sublethal effects of insecticides commonly found in nonpoint source agricultural runoff to estuarine fish and shellfish. In: Vernberg W, Calabrese A, Thurberg F, Vernberg F, editors. Pollution physiology of estuarine organisms. Columbia, SC: University of South Carolina Press. 251-274.

Schulz, R. (2001). Comparison of spray drift-and runoff-related input of azinphos-methyl and endosulfan from fruit orchards into the Lourens River, South Africa. *Chemosphere*., **45(4):** 543-551.

Schulz, R. (2004). Field studies on exposure, effects and risk mitigation of aquatic nonpoint-source insecticide pollution: a review. *J. Environ Qual*., **33:** 419-448.

Serrano, R., F. Hernández, J.B. Peña, V. Dosda and J. Canales (1995). Toxicity and bioconcentration of selected organophosphorus pesticides in *Mytilus galloprovincialis* and *Venus gallina. Archives of Environmental Contamination and Toxicology*., **29(3):** 284-290.

Seguin, F., F. Le Bihan, C. Leboulanger and A. Berard (2002). A risk assessment of pollution: induction of atrazine tolerance in phytoplankton communities in freshwater outdoor mesocosms, using chlorophyll fluorescence as an endpoint. *Water Res*., **36:** 3227-3236.

Shaaban, O. and N.M. Al-Mallah (1993). Pesticides. Dar Al-kutub for printing and publishing. University of Al Mosul. 520.

Shukla, K.P., N.K. Singh and S. Sharmam (2010). Bioremediation: Developments, Current Practices and Perspectives. *Genetic Engineering and Biotechnology Journal*., In Press.

Simon, T.P. (1999). Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Boca Raton, Florida.

Sjollema, S.B., G. Martínezgarcía, H.G. Van Der Geest, M.H.S. Kraak, P. Booij, A.D. Vethaak and W. Admiraal (2014). Hazard and risk of herbicides for marine microalgae. *Environ Pollut*., **187:** 106-111.

Solomon, K.R., D.B. Baker and R.P. Richards (1996). Ecological risk assessment of atrazine in North American surface waters. *Environ Toxicol Chem*., **15:** 31-76.

Srivastava, A., N.K. Jangid, M. Srivastava and M. Srivastava (2018). Pesticides as Water Pollutants. Chapter 1. Handbook of Research on The Adverse Effects of Pesticide Pollution in Aquatic Ecosystems. IGI GLOBAL:1-19.

Sobrero, C., M.L. Martin and A. Ronco (2007). Phytotoxicity of the Roundup® Max herbicide on the non-target species *Lemna gibba* in field and laboratory studies. *Hydrobiologia*., **17:** 31-39.

Starks, T.L., L.E. Shubert and F.R. Trainor (1981). Ecology of soil algae: a review. *Phycologia*., **20:** 65-80.

Sturm, A., T.S. Radau, T. Hahn and R. Schulz (2007). Inhibition of rainbow trout acetylcholinesterase by aqueous and suspended particle-associated organophosphorous insecticides. *Chemosphere*., **68:** 605-612.

Thakir, B.M. (2017). Toxicity of Herbicides Roundup Ultra Glyphosate and Amin Salts of 2,4-D on Some Biological Aspects of Females of *Daphnia manga* Straus 1820. Thesis of M.Sc. College of Science for Women. University of Baghdad. 122.

Tilman, D., K.G. Cassman, P.A. Matson, R. Naylor and S. Polasky (2002). Agricultural sustainability and intensive production practices. *Nature*., **418:** 671-677.

Van der Oost, R., J. Beyer and N.P. Vermeulen (2003). Fish bioaccumulation and biomarkers in environmental risk assessment: a review. *Environmental toxicology and pharmacology*., **13(2):** 57-149.

Venturino, A., E. Rosenbaum, A.C. De Castro, O.L. Anguiano, L. Gauna, T.F. De Schroeder and A.M.P. De D'Angelo (2003). Biomarkers of effect in toads and frogs. *Biomarkers*., **8:** 167-186.

Vonesh, J.R. and J.M. Kraus (2009). Pesticide alters habitat selection and aquatic community composition. *Oecologia.,* **160:** 379-385.

Webb, D. (2011). Freshwater shrimp (*Palaemonetes australis*) as a potential bioindicator of crustacean health. *Environ. Monit. Assess*., **178(1-4):** 537-544.

Wendt-Rasch, L., P. Pirzadeh and P. Woin (2003). Effects of metsulfuron methyl and cypermethrin exposure on freshwater model ecosystems. *Aquat Toxicol*., **63:** 243-256.

Weider, L.J. and P.D. Hebert (1987). Ecological and Physiological Differentiation Among Low Artic Clones of Daphnia Pulex. *Ecology.,* **68(1):** 188-198.

WHO (1990). Cyhalothrin, Environmental Health Criteria, 99, Geneva, Switzerland.

WHO (World Health Organization) (2005). Dept. of Mental Health and Substance Abuse. Mental health atlas 2005. World Health Organization .

Widenfalk, A., J.M. Svensson and W. Goedkoop (2004). Effects of the pesticides captan, deltamethrin, isoproturon and pirimicarb on the microbial community of a freshwater sediment. *Environ Toxicol Chem*., **23:** 1920-1927.

Widenfalk, A., S. Bertilsson, I. Sundh and W. Goedkoop (2008). Effects of pesticides on community composition and activity of sediment microbes - responses at various levels of microbial community organization. *Environ Pollut*., **152:** 576-584.

Zawisza, E., I. Zawiska and A. Correa-Metrio (2016). Cladocera Community Composition as a Function of Physicochemical and Morphological Parameters of Dystrophic Lakes in NE Poland. *Wetlands*., **36(6):** 1131-1142.