Pakistan Journal of Marine Sciences, Vol. 32(1), 01-61, 2023.

A REVIEW OF AQUATIC TOXICOLOGY INVESTIGATIONS IN TURKISH WATERS

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ABSTRACT: Aquatic toxicity studies have been conducted for many years, and their importance has been understood for some time. The need for aquatic toxicity studies arises from the widespread use of chemicals in many different industries, such as agriculture, manufacturing, and energy production. These chemicals can enter aquatic environments through various means, including runoff from fields, discharges from factories, and spills or leaks from storage tanks or pipelines. Once in the aquatic environment, these chemicals can have harmful effects on aquatic life, including fish, crustaceans, molluscs, and algae. By conducting aquatic toxicity studies, researchers can gain a better understanding of the potential harmful effects of chemicals on aquatic life and ecosystems and can inform decisions about their use and regulation to protect the environment. This review summarizes the available aquatic toxicity studies in Turkish waters.

KEYWORDS: Toxicology, water, sediment, lethal concentration, effective concentrations, bio-monitors

INTRODUCTION

Today, in parallel with increasing population density, developing industry and technology, the types, sources and amounts of pollutants are also increasing. In a very general sense, we can divide pollutants into groups such as metals, petroleum hydrocarbons, chlorinated hydrocarbons, pesticides, radioactive substances, microplastics. There are many different sources of pollutants in aquatic ecosystems. Some of the most common sources of pollutants include agricultural and industrial runoff, sewage and wastewater discharge, and the release of chemicals and other substances from factories and power plants (Bat *et al*., 2018). Additionally, pollutants can enter aquatic ecosystems through the atmosphere, through the soil, and through direct human activities such as boating and fishing. In general, any activity or process that introduces harmful substances into the aquatic environment can be a source of pollution in aquatic ecosystems. Some of these pollutants, such as metals, which can remain in aquatic environments for a long time and can be taken up and accumulated by biota, have a lethal effect at high concentrations, although they are necessary for the metabolism of organisms at low concentrations. Studies on toxicology and pollution have thus always been current. These pollutants, which originate on land, enter lakes and the sea either directly or via rivers and the atmosphere, where they harm the biota over the course of short or long periods of time. Greater harm can be avoided by taking the necessary precautions, especially in terms of health, if these effects can be predicted in advance. The effects of pollutants on organisms can be ascertained using a variety of techniques

and methods. The pollution experiments performed in the lab under conditions resembling the ambient environment are one of these methods and are arguably the most significant. The negative effects of pollutants can be identified, and the appropriate protective measures can be taken by assessing the results obtained at the conclusion of these experiments.

There have been many events that have shown or attracted people's attention to aquatic toxicity studies. Some examples of such events include:

Spills or leaks of chemicals into aquatic environments: Spills or leaks of chemicals into aquatic environments, such as oil spills or chemical spills from factories, can have immediate and visible effects on aquatic life and ecosystems. These events can attract public attention and can highlight the need for aquatic toxicity studies to understand the potential impacts of chemicals on the environment.

Environmental disasters: Environmental disasters, such as algal blooms or fish kills, can also draw attention to the importance of aquatic toxicity studies. These events can be caused by a range of factors, including pollutants or other chemicals in the water, and can have serious consequences for aquatic life and ecosystems. By conducting aquatic toxicity studies, researchers can gain a better understanding of the factors that contribute to these events and can develop strategies to prevent or mitigate their impacts.

Increased awareness of environmental issues: In recent years, there has been increased public awareness of environmental issues, including the effects of chemicals on aquatic life and ecosystems. This has led to greater interest in aquatic toxicity studies, as people seek to understand the potential impacts of chemicals on the environment and to take action to protect aquatic environments.

History of aquatic toxicity studies: The beginning of his toxicological experiment's dates to Aristotle's first experiment by placing them in sea water to observe the reactions of freshwater organisms. Until the beginning of the 1800s, physiologists studied the effect of a substance on a living thing just for the sake of curiosity. In these years, with the development of organic chemistry, people obtained different chemical substances by synthesis and the concept of "Toxicology" emerged with the effect of these substances on living organisms (Walker *et al*., 1996). Next, biologists observed the difference between groups of organisms living in streams where various waste materials reach and do not reach. The term ecotoxicology which was derived from the words ecology and toxicology was first proposed by Truhaut in June 1969 during a meeting of an ad-hoc Committee of the International Council of Scientific Unions in Stockholm. The introduction of the new term stated a growing treat regarding the effects of environmental chemicals on species other than humans (Truhaut, 1977). Since the mid-1900s, some researchers have confronted fish with these substances to determine the effects of industrial waste before it reaches streams, thus demonstrating the importance of pollution experiments. Early studies focused on the immediate or acute effects of chemicals on aquatic organisms, such as changes in behaviour or mortality (see review Bat, 2005). As our understanding of the potential impacts of chemicals on aquatic environments grew, toxicity studies began to focus on the long-term effects of chemicals on aquatic organisms and ecosystems. In the latter half of the 20th century, the development of new analytical techniques and the growth of environmental awareness led to an increasing focus on the ecotoxicological approach to studying the harmful effects of chemicals on the

environment. Today, aquatic toxicity studies continue to play an important role in understanding the potential impacts of chemicals on aquatic life and ecosystems, and in informing decisions about the use and regulation of chemicals to protect the environment.

Truhaut (1977) pointed out that the study of the negative effects of environmental chemical pollution on the various ecosystem components, for which man is largely responsible, assumes enormous significance in the context of biological equilibria. However, it is difficult to say which countries are leading in aquatic toxicity studies, as there are many different countries conducting research in this field. However, some countries with a strong tradition of research in aquatic toxicology include the United States, Canada, the United Kingdom, and European countries such as Germany, and France. There are several existing protocols for conducting aquatic toxicity studies. These protocols are typically published by organizations such as the United States Environmental Protection Agency (EPA) or the Organization for Economic Cooperation and Development (OECD)and provide a framework for conducting aquatic toxicity studies in a standardized and consistent manner. These countries have a long history of studying the harmful effects of chemicals on aquatic life and ecosystems and have developed a range of methods and approaches for assessing the potential toxicity of chemicals. In 1965-1978, the US Department of the Interior, Fish and Wildlife Service, for example, conducted 1,587 acute toxicity tests on 271 chemicals against 28 species of fish and 30 species of invertebrates (Johnson and Finley, 1980). Additionally, these countries often have strong regulatory frameworks for controlling the use and discharge of chemicals into aquatic environments and use the results of aquatic toxicity studies to inform these regulations. The US EPA, Environment Canada (EC), and the American Society for Testing and Materials (ASTM) have developed and published standard guides on how to conduct acute toxicity tests for pelagic and benthic species for both freshwater and marine invertebrates, fish and algae (Stephan, 1975; Standard Methods for the Examination of Water and Wastewater, 1976; US Environmental Protection Agency, 1982; Porcella, 1983; Swartz, 1985a,b; Series Environmental Protection, 1990a, b; American Society for Testing and Materials, 1990 and 1991; U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, 1991; Environment Canada, and Canada Environmental Protection Directorate, 1992; Environment Canada, 1997; Scroggins, 1999; Series Environmental Protection, 2007). By following these protocols, researchers can ensure that their aquatic toxicity studies are reliable and accurate, and that the results are comparable across different studies.

In Türkiye, with the enactment of the “Environmental Law” in 1983, the General Directorate of Environment was founded. The Ministry of Environment was established in 1991, following the implementation of the "Water Pollution Control Regulation" in 1988 (Official Gazette of the Republic of Türkiye, 1988). In the ongoing process, the measures taken in the field of water were put into practice and towards the end of the 90s, with the effect of Türkiye's candidacy to the European Union (EU), water resources; Efforts to manage them in a holistic way in terms of quantity, quality and ecological have started. The responsible and relevant institutions of toxicological studies in Türkiye are the Ministry of Forestry and Water Affairs, the Ministry of Environment, Urbanization and Climate Change, the Ministry of Food, Agriculture and Livestock, and Universities and Research Institutes. Aquatic toxicological studies are mostly carried out in universities.

Definition and importance of aquatic toxicity: The term "toxic" refers to the harmful or poisonous nature of a substance, and different substances can be toxic at different levels and in different ways. Additionally, the toxicity of a substance can depends on various factors, such as the dose, the route of exposure, and the individual's susceptibility to the substance. Therefore, it is not necessarily possible to determine a precise number of toxic substances.

Aquatic toxicology is the study of the harmful effects of chemicals on aquatic organisms, such as fish, crustaceans, molluscs, polychaetes, and algae. This field of study focuses on understanding how chemicals can enter aquatic environments and what their effects are on different species of aquatic life. Aquatic toxicologists may study the mechanisms by which chemicals cause harm to aquatic organisms, as well as the ways in which aquatic organisms can be exposed to these chemicals. Additionally, aquatic toxicologists may study to develop methods for predicting and assessing the potential aquatic toxicity of chemicals, as well as methods for mitigating the negative effects of toxic chemicals on aquatic ecosystems. The importance of aquatic toxicity studies has been recognized for many years, and it is important to monitor aquatic toxicity and take steps to reduce pollution to protect aquatic life and maintain healthy ecosystems.

Objectives of aquatic toxicity: Aquatic toxicity tests are experiments to determine the effects of one or more pollutants on one or more organisms (Marking, 1985; Phipps and Holcombe, 1985). The purpose of a test in a freshwater or saltwater environment is to determine the presence of one or more substances in that environment, as well as the effect of wastewater or environmental conditions on aquatic organisms, alone or in combination (Rand *et al*.,1995). Aquatic toxicity tests are typically conducted using a variety of different aquatic organisms, such as fish, crustaceans, and algae using a variety of different chemicals, including both naturally occurring substances and synthetic chemicals. Bioindicator species used in a toxicity test will depend on the goals of the study and the types of chemicals being tested. For example, a toxicity test may use a naturally occurring chemical such as a toxin produced by a microorganism, or a synthetic chemical such as a pesticide, heavy metal, or industrial pollutant. The choice of chemicals used in a toxicity test can also be influenced by factors such as the availability of the chemicals and their potential effects on the aquatic organisms being tested. In general, aquatic toxicity tests are designed to evaluate the potential harmful effects of a wide range of chemicals on aquatic ecosystems (Cairns and Mount, 1990).

The duration of aquatic toxicity tests can vary depending on several factors, such as the specific goals of the study and the types of chemicals and aquatic organisms being used. In general, aquatic toxicity tests are conducted over a period ranging from several hours to several days. For example, a short-term toxicity test may be conducted over a period of hours or days, while a long-term toxicity test may be conducted over a period of weeks or months. The specific duration of an aquatic toxicity test will depend on the specific goals of the study and the type of data that the researchers are trying to collect. Usually the 96-hour period is most appropriate (Niță *et al*., 2022).

The answers sought in aquatic toxicological studies are as follows:

To determine the effects of human-made pollutants on the entire hydrosphere, which can be considered important today.

Determining whether any substance is lethal for the organism, and if so, at what concentration it is lethal.

Determination of the effects of pollutants on these organisms when organisms are faced with sublethal concentrations of any pollutant during their entire life or part of their life.

Finding out which wastes are most toxic and under what conditions.

Determining which organism is most susceptible.

Determining whether the toxicity changes when the mean foreign matter enters

Determination of how much the receiver system is affected.

Determination of the short-term effects of different discharges.

To determine the concentrations of a pollutant in a population under controlled conditions that produce generally harmful effects.

Types of aquatic toxicity tests: Aquatic toxicity studies are typically designed and conducted according to a set of criteria that are intended to ensure the reliability and validity of the results. These criteria may include the use of standardized test methods and protocols, the use of appropriate control groups and statistical analysis, and the use of multiple species of aquatic organisms to represent a range of potential effects. Additionally, aquatic toxicity studies may consider factors such as the potential for chemical exposure through different pathways (such as through the water, sediment or through the food chain), and the potential for long-term effects on the health of aquatic ecosystems (Swartz, *et al*., 1979, 1982; DeWitt *et al*., 1989; McLeay and Sprague, 1990; Burton, 1991; Burton and Scott, 1992; Luoma and Ho, 1993; Ingersoll,1995). It is also important to consider factors such as the temperature and pH of the water, the availability of oxygen, and the presence of other chemicals or contaminants that may affect the test results. By following these criteria, aquatic toxicity studies can provide valuable information about the potential harmful effects of chemicals on aquatic life. Additionally, it is important to carefully design and conduct the toxicity study to ensure that the results are reliable and accurate. This may involve following standardized test methods and protocols, using appropriate control groups and statistical analysis, and using multiple species of aquatic organisms to represent a range of potential effects (Finney, 1971; Falco and Moraski, 1989; Forbes and Forbes, 1994; Environment Canada, and Environmental Technology Centre (Canada). Method Development and Application Section, 2005).

Aquatic toxicity studies typically seek to measure a range of indicators to assess the potential harmful effects of chemicals on aquatic organisms and ecosystems. These indicators may include changes in behaviour, growth, or reproduction in the aquatic organisms being tested, as well as changes in the overall health and functioning of the aquatic ecosystem. In some cases, aquatic toxicity studies may also measure indicators of chemical exposure, such as the concentration of the chemical in the water or in the tissues of the aquatic organisms. By measuring a range of indicators, aquatic toxicity studies can provide a comprehensive assessment of the potential harmful effects of chemicals on aquatic life and ecosystems.

Aquatic toxicity studies can be carried out using a variety of different methods and approaches, depending on the specific goals of the study and the types of chemicals and aquatic organisms being tested. Some common types of aquatic toxicity studies include (Bat *et al*., 1998-1999a):

Acute toxicity tests: These studies are conducted over a short period of time (usually less than 96 hours) to evaluate the immediate effects of a chemical on aquatic organisms.

Static renewal method: The static renewal method is a common method for conducting aquatic toxicity studies. In this method, a fixed volume of test water is used, and the chemical being tested is added to the water. The aquatic organisms are then placed in the water, and their response to the chemical is observed over a set period.

Flow-through method: The flow-through method is like the static renewal method, but in this case, the test water is continuously replenished, and the chemical being tested is added to the water at a known rate. This method allows for a more realistic simulation of conditions in the natural environment but is more complex to set up and conduct than the static renewal method.

Bioaccumulation studies: Bioaccumulation studies are a type of aquatic toxicity study that focuses on the accumulation of chemicals in the tissues of aquatic organisms. In these studies, the aquatic organisms are exposed to the chemical being tested, and the concentration of the chemical in their tissues is measured over time. This can provide valuable information about the potential effects of the chemical on the overall health and functioning of the aquatic organisms.

Chronic toxicity tests: These studies are conducted over a longer period (usually several weeks or months) to evaluate the long-term effects of a chemical on aquatic organisms.

Biodegradation studies: These studies measure the rate at which a chemical is broken down or transformed in the environment.

Ecological toxicity studies: These studies evaluate the potential impacts of a chemical on the overall health and functioning of an aquatic ecosystem.

Appropriate control groups and statistical analysis: Aquatic toxicity studies often include control groups and statistical analysis to provide a reference for comparing the effects of the chemical being tested. This can help to ensure that the observed effects are due to the chemical, and not to other factors such as natural variation or experimental error.

Multiple species of aquatic organisms: Aquatic toxicity studies often use multiple species of aquatic organisms to represent a range of potential effects. This can help to provide a more comprehensive assessment of the potential toxicity of the chemical being tested.

Lethal concentration (LC_{50}) and effective concentration (EC_{50}) are two commonly used measures in aquatic toxicity studies. LC_{50} refers to the concentration of a chemical that is lethal to 50% of the aquatic organisms in a study, while EC_{50} refers to the concentration of a chemical that produces a specified effect in 50% of the organisms in a study. These measures are often preferred in aquatic toxicity studies because they provide a clear and concise summary of the toxic effects of a chemical on aquatic organisms. By calculating the LC_{50} or EC_{50} of a chemical, researchers can quickly and easily determine its potential toxicity to aquatic life. Additionally, these measures are commonly used in regulatory contexts, such as in setting environmental standards or in assessing the safety of chemicals for use in aquatic environments.

Observations of aquatic organisms: In many aquatic toxicity studies, the effects of the chemical being tested are observed directly on the aquatic organisms being studied.

This can include monitoring the behaviour, growth, and reproduction of the organisms, as well as looking for signs of stress or other adverse effects. If the aquatic organisms show little or no signs of harm, then the results of the study may be considered healthy.

Measurements of chemical concentrations: In some aquatic toxicity studies, the concentration of the chemical being tested in the water is measured over time. If the concentration of the chemical remains low, and does not exceed certain thresholds or standards, then the results of the study may be considered healthy.

Dietary exposure: In some cases, chemicals that are harmful to aquatic life and ecosystems may also be harmful to human beings if they are ingested through the diet. For example, if fish and other aquatic organisms are contaminated with chemicals, and these contaminated organisms are then eaten by human beings, the chemicals may enter the human body and cause harm. To interpret the results of aquatic toxicity studies for human health, it is necessary to consider the potential for dietary exposure to the chemicals being tested.

Water contamination: In other cases, chemicals that are harmful to aquatic life and ecosystems may also be harmful to human beings if they enter the water supply and contaminate the water that is used for drinking, cooking, and other purposes. To interpret the results of aquatic toxicity studies for human health, it is necessary to consider the potential for water contamination by the chemicals being tested.

Single chemical studies: In single chemical studies, a single chemical is tested to determine its effects on aquatic life and ecosystems. This approach has the advantage of simplicity, as it focuses on the effects of a single chemical and can provide a clear and concise assessment of its potential toxicity. However, single chemical studies may not provide a complete picture of the potential impacts of chemicals on aquatic environments, as many aquatic environments are exposed to multiple chemicals simultaneously.

Multiple chemical studies: In multiple chemical studies, multiple chemicals are tested together to determine their combined effects on aquatic life and ecosystems. This approach has the advantage of providing a more comprehensive assessment of the potential impacts of chemicals on aquatic environments, as it considers the effects of multiple chemicals acting together. However, multiple chemical studies can be more complex and challenging to conduct, as they require the use of multiple test chemicals and the analysis of the combined effects of these chemicals on aquatic organisms.

Other pathways: There may also be other pathways by which chemicals that are harmful to aquatic life and ecosystems can enter the human body and cause harm. For example, chemicals that are released into the air through industrial processes or other sources can be inhaled by human beings and can cause harm.

Statistical analysis: In many aquatic toxicity studies, statistical analysis is used to compare the effects of the chemical being tested on the aquatic organisms with the effects of a control group of organisms that have not been exposed to the chemical. If the differences between the two groups are small and not statistically significant, then the results of the study may be considered healthy.

Chemicals or substances used in aquatic toxicity studies: A wide variety of chemicals and other substances are used in aquatic toxicity studies, including both natural and synthetic chemicals, as well as mixtures of chemicals. Some common examples of chemicals used in aquatic toxicity studies include heavy metals, such as cadmium, lead

and mercury, pesticides, herbicides, other industrial chemicals and microplastics. In addition, aquatic toxicity studies may also use complex mixtures of chemicals, such as wastewater effluent or sediment samples, to evaluate the potential toxicity of these mixtures to aquatic organisms. The specific chemicals and substances used in aquatic toxicity studies can vary depending on the research question and the objectives of the study.

A toxic substance is a substance that is harmful or poisonous to living organisms. It can cause adverse health effects, including death, when ingested, or absorbed through the skin or gills. The degree of toxicity of a substance can vary depending on the dose, the route of exposure, and the individual's susceptibility to the substance. Some examples of toxic substances include heavy metals, pesticides, and certain chemicals.

Heavy metals are chemical elements that have a high atomic weight and a density at least 5 times greater than that of water. Examples of heavy metals include cadmium, lead, mercury, copper, and zinc. These elements are called "heavy" because they are denser and have a higher atomic weight than most other elements. Heavy metals can be naturally occurring or man-made, and they can be found in the environment in various forms, such as in sediment or water. Heavy metals are often used in aquatic toxicity tests because they are known to be toxic to aquatic organisms, such as fish and other aquatic life. These substances can enter aquatic environments through a variety of sources, such as industrial discharges, agricultural runoff, or natural weathering of rocks and minerals. Once in the water, heavy metals can accumulate in the tissues of aquatic organisms, leading to a variety of negative health effects, such as damage to the nervous system, the kidneys, or the liver. Therefore, aquatic toxicity tests are conducted to determine the potential harmful effects of heavy metals on aquatic ecosystems and to develop strategies for mitigating their negative impacts (Bat *et al*., 1998-1999b).

Aquatic toxicity studies are often conducted to evaluate the potential harmful effects of pesticides on aquatic ecosystems. Pesticides are chemicals that are used to control pests, such as insects, weeds, or fungi, but they can also be toxic to non-target organisms, such as aquatic life. Aquatic toxicity studies are used to assess the potential effects of pesticides on aquatic species, such as fish, crustaceans, and algae, and to develop strategies for mitigating their negative impacts on aquatic environments. These studies may involve exposing aquatic organisms to different concentrations of a pesticide and measuring its effects on the organisms over a period. Pesticides are commonly used in aquatic toxicity studies because they are widely used in agriculture and can potentially enter aquatic environments through runoff or other means.

Insecticides are chemicals that are used to control or kill insects. In aquatic toxicity studies, the role of insecticides is to assess the potential hazard effects of these chemicals on aquatic life and ecosystems. This can involve exposing aquatic organisms to different concentrations of insecticides, and then measuring the effects of these exposures on the health and behaviour of the organisms. The results of these studies can help to identify the potential risks of insecticides to ecosystems.

Detergents are chemicals that are used to clean and remove dirt and stains from surfaces. In aquatic toxicity studies, the role of detergents is to assess the potential harmful effects of these chemicals on aquatic life and ecosystems. This can involve

exposing aquatic organisms to different concentrations of detergents, and then measuring the effects of these exposures on the health and behaviour of the organisms.

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that are found naturally in the environment but can also be released because of human activities, such as burning fossil fuels and wood. In aquatic toxicity studies, the role of PAHs is to assess the potential harmful effects of these chemicals on biota. This can involve exposing aquatic organisms to different concentrations of PAHs, and then measuring the effects of these exposures on the health and behaviour of the organisms.

Industrial chemicals: Industrial chemicals, such as solvents and detergents, are often used in aquatic toxicity studies because they are commonly found in aquatic environments and can have harmful effects on aquatic life.

Pharmaceuticals: Pharmaceuticals, such as antibiotics and hormones, are increasingly being studied in aquatic toxicity studies because of concerns about their potential impacts on aquatic ecosystems.

Microplastics are often used in aquatic toxicity studies. Microplastics are tiny plastic particles that are less than 5 mm in size and are found in many aquatic environments. Because of their small size, microplastics can be ingested by a wide range of aquatic organisms and can have harmful effects on their health and the overall functioning of aquatic ecosystems. As a result, microplastics are an important topic of study in aquatic toxicity research.

Advantages: Using microplastics in aquatic toxicity studies has several advantages. For example, microplastics are widely present in aquatic environments, so studying their effects can provide valuable information about the potential impacts of these particles on aquatic life and ecosystems. Additionally, microplastics are small and easily ingested by aquatic organisms, which can make it easier to detect their effects at low concentrations.

Disadvantages: There are also some disadvantages to using microplastics in aquatic toxicity studies. For example, microplastics can be difficult to detect and quantify in the laboratory, which can make it challenging to accurately measure their effects on aquatic organisms. Additionally, the effects of microplastics on aquatic organisms can vary depending on factors such as the type of microplastic, the size of the particles, and the species of aquatic organism.

Groups of organisms mostly used in aquatic toxicity studies: Both marine and freshwater organisms are commonly used in aquatic toxicity studies. The specific organisms used in a study will depend on the goals of the study and the types of chemicals being tested. In some cases, marine organisms may be more appropriate for the study, because they are more ecologically relevant to the marine environment, or because they are more sensitive to the effects of the chemical being tested. Marine organisms are those that live in the sea and include a wide range of species such as fish, crustaceans, molluscs, polychaetes, algae, and marine plants. These species are also often used in aquatic toxicity studies because they are ecologically relevant to the marine environment and can provide valuable information about the potential effects of chemicals on marine ecosystems. Additionally, many marine species are sensitive to the harmful effects of chemicals, which makes them useful for detecting the toxic effects of chemicals at low concentrations. Some common marine organisms used in aquatic toxicity studies include fish, crustaceans (such as shrimp or crabs), molluscs (such as clams or oysters), polychaetes, and marine algae. In other cases, freshwater organisms may be more

appropriate, because they are more readily available, or because they are better suited to the test conditions. Ultimately, the choice of organisms for an aquatic toxicity study will depend on a range of factors, including the specific goals of the study and the characteristics of the chemical being tested.

When conducting aquatic toxicity tests, it is important to choose the appropriate species of aquatic organisms for the study. Aquatic toxicity studies can use a wide range of aquatic organisms, including fish, invertebrates, algae, and other aquatic plants and animals. Each of these organisms has its own advantages and disadvantages for use in aquatic toxicity studies. The specific species used in a study will depend on the goals of the study and the types of chemicals being tested. Some key factors to consider when selecting species for aquatic toxicity tests include:

Ecological relevance: The species used in the study should be ecologically relevant to the aquatic environment being studied and should be representative of the types of organisms that may be affected by the chemical being tested.

Knowledge their biology in advance: It is important to know the biology of the experimental organisms well so that the obtained data can be evaluated in a healthy way. Information on the biology of these organisms can be obtained either from the literature or from pre-experimental observations.

Sensitivity: The species used in the study should be sensitive to the chemical being tested, so that the effects of the chemical can be accurately measured. Generally, organisms are more sensitive to pollutants in the young stages of their life (egg, larva, juvenile) than in the adult stages. Therefore, it will be advantageous to use young stages of economically important organisms in experiments.

Appropriate size: Generally, the test organisms should be small so that they can be placed in sufficient numbers in the test vessels and therefore the obtained data can be evaluated statistically. If possible, they should be of the same length, age and sex.

Availability: The species used in the study should be readily available, to facilitate the conduct of the study. On the other hand, organisms to be used in experiments should be easily and adequately obtained from the area to be researched, and organisms should not be damaged during collection.

Suitability: The species used in the study should be suitable for the test conditions, including factors such as temperature, pH, and the presence of other chemicals or contaminants.

Salinity tolerance: It is useful to use species that can live in wide salinity limits (euryhaline) in experiments. Because these species can live without being affected by wide salinity changes.

Surviving in laboratory conditions: Organisms must be able to live in laboratory conditions for a long time and in good health.

Species of organisms: Experimental organisms should represent various groups. For example, algae, annelids, crustaceans, molluscs, and fish. Because the sensitivity of each organism group to pollutants is different.

Level of the organism in the food chain: Especially in bioaccumulation experiments, organisms from different levels of the food chain should be selected. For example, primary producers (phytoplankton), herbivores, those that feed on sediment particles, such as carnivores.

Economic importance of the organism: The organism to be selected must be economically important in the region. For example, macroalgae, crustaceans, molluscs, and fish.

By carefully selecting the appropriate organisms for an aquatic toxicity study, researchers can ensure that the study is reliable and accurate, and that the results provide valuable information about the potential harmful effects of chemicals on aquatic environments.

Aquatic toxicity refers to the harmful effects of chemicals on aquatic organisms, such as fish and other aquatic life. It is important to study aquatic toxicity because aquatic ecosystems are important to the health of the environment and to human health. Chemicals that are toxic to aquatic life can have negative effects on the food chain and on the overall health of the ecosystem. Additionally, toxic chemicals can be harmful to humans who meet contaminated water, either through drinking or through recreational activities such as swimming or fishing. For these reasons, it is important to understand the potential aquatic toxicity of chemicals and to take steps to prevent or mitigate their negative effects. For example, fish are often used in aquatic toxicity tests because they are a common and ecologically important group of aquatic organisms, and because they are sensitive to many different types of chemicals. However, fish can be difficult and expensive to maintain in a laboratory setting, and their responses to chemicals can vary depending on factors such as the species of fish and the specific chemical being tested. The choice of organisms used in a toxicity test can also be influenced by factors such as the availability of the organisms and their suitability for the test conditions.

Invertebrates, such as crustaceans, molluscs, and polychaetes are also commonly used in aquatic toxicity studies. They are often more readily available and less expensive to maintain in the laboratory than fish and can provide valuable information about the effects of chemicals on non-vertebrate aquatic organisms. However, invertebrates can be less sensitive to some chemicals than fish, which can make it more difficult to detect the effects of these chemicals.

Crustaceans, which are a group of aquatic animals that includes crabs, lobsters, and shrimp, are often used in toxicity studies because they are relatively easy to maintain in the laboratory and they can provide useful information about the potential toxicity of a substance. Crustaceans are considered a good bioindicator organism for toxicity studies because they are sensitive to a range of chemicals.

Molluscs, which are a group of invertebrates that includes snails, slugs, mussels, and clams, are often used in toxicity studies because they are relatively easy to maintain in the laboratory and they can provide useful information about the potential toxicity of a substance. Molluscs are considered a good model organism for toxicity studies because they are widely distributed in a variety of aquatic environments, they have a simple anatomy and physiology, and they accumulate of chemicals. In addition, molluscs are often used in toxicity studies because they are an important part of the food chain in many aquatic ecosystems.

Polychaetes, which are a group of segmented worms, are often used in toxicity studies because they are relatively easy and inexpensive to maintain in the laboratory and they can provide useful information about the potential toxicity of a substance. Polychaetes are wanted organism for toxicity studies, so the effects of a toxic substance

on polychaetes can provide insight into the potential effects on other species in the ecosystem (Bat and Kurt, 2020).

Algae are a group of aquatic organisms that are commonly used in aquatic toxicology studies because they are relatively easy to maintain in the laboratory and they can provide useful information about the potential toxicity of a substance. Algae are considered a good model organism for toxicity studies because they have a simple anatomy and physiology, they are widely distributed in a variety of aquatic environments, and they are sensitive to a range of chemicals. In addition, algae are often used in toxicity studies because they are an important part of the food chain in many aquatic ecosystems, so the effects of a toxic substance on algae can provide insight into the potential effects on other species in the ecosystem.

The importance of using algae in aquatic toxicology studies is that they can provide valuable information about the potential risks of toxic substances to aquatic ecosystems and the species that depend on them. By understanding the effects of toxic substances on algae, researchers and regulatory agencies can evaluate the potential risks to other aquatic species and take appropriate actions to protect the environment and public health. Additionally, the use of algae in toxicity studies can help to identify the mechanisms by which toxic substances exert their effects, which can provide important insights into their toxicology and inform the development of risk assessment models and other tools for evaluating the potential risks of toxic substances.

Other aquatic organisms: There are many other aquatic organisms that can be used in aquatic toxicity studies, including aquatic plants and other aquatic animals such as amphibians and reptiles. These organisms can provide valuable information about the effects of chemicals on different parts of aquatic ecosystems but may be less widely studied or less well-understood than fish, invertebrates, or algae.

Toxicological studies in Turkish marine waters: Toxicological studies on marine organisms are somewhat less. When Tables 1-4 are examined, it is seen that studies on biota collected from the Black Sea are mostly seen. The Black Sea is a large body of water that is home to a diverse array of marine life, including many species of fish, crustaceans, molluscs, and polychaetes. Some of these species are used in aquatic toxicity studies to evaluate the potential harmful effects of chemicals on the Black Sea and its marine ecosystems.

The interaction between water, sediment, and living organisms is a complex and dynamic process that plays a critical role in the health and functioning of aquatic ecosystems. Water and sediment provide the physical and chemical conditions that support the growth and reproduction of aquatic plants and animals, and living organisms, in turn, can influence the composition and characteristics of the water and sediment. This interaction can be determined through a variety of methods, including chemical and biological analysis of water and sediment samples, monitoring of water quality parameters, and observations of the behaviour and distribution of aquatic organisms.

Sediment toxicity studies: Sediment aquatic toxicity studies are studies that focus on the potential effects of chemicals on the sediments at the bottom of aquatic environments. Sediment aquatic toxicity studies can help to improve our understanding of the fate of chemicals in aquatic environments. By assessing the potential effects of chemicals on sediment-dwelling organisms, these studies can provide information about

the mechanisms by which chemicals can enter and be retained in sediments and can help to identify the factors that can affect the movement and persistence of chemicals such heavy metals in aquatic environments (Bat, 2005).

Water toxicity studies: In many aquatic toxicity studies, the concentration of the chemical in the water is measured over time. As such, one of the most important questions to ask in these studies is what the concentrations of the chemical are, and how these concentrations vary over time.

Toxicity studies on Fish: Aquatic toxicity studies in Türkiye were mostly carried out in fish species. In this review, 97 studies on fish were found between 1998 and 2022.In these studies, 30 different species of fish were used, of which 5 were marine fish and 25 were freshwater fish. Most of the *Oreochromis niloticus* (Linnaeus, 1758) species were used as test organisms in the studies. The following effects were investigated in toxicity studies on fish species (Table 1).

- LC_{10}, LC_{50}, LC_{90}, IC_{50}, EC_{50}, accumulation and elimination in different tissues and organs, behavioural changes, oxidative stress, toxic effects antioxidant responses, genotoxic effects,
- Effects on blood parameters and blood ion level,
- Effects on serum biochemistry, sera glucose, protein, cholesterol concentrations and haematocrit levels,
- Effect on tissue histopathology, toxic serum proteins liver,
- Effect of EDTA on metal accumulation,
- Effects on glycogen level, serum glucose level, total protein amount in liver,
- Effects of cadmium on levels of sera aspartate aminotransferase, alanine aminotransferase and glucose,
- Alterations in reduced glutathione, catalase, and proteins electrophoretic patterns,
- Na/K ion levels in gill tissue,
- Protective effects of antioxidant compounds in the liver and kidney,
- The toxic effect molecular and morphologic alterations in stress-associated genes and damage of DNA,
- Micronucleus test, nuclear abnormalities
- Non-specific immune system, phagocytosis, respiratory burst and lysozyme activity, and specific growth rate,
- Antioxidative role of selenium against the toxic effect,
- Effects of carbosulfan on erythrocyte acetylcholinesterase (AChE) activities,
- Pro-oxidant potency of clothianidin,
- Biological effects of ulexite, oxidative DNA damage toxicity damage,
- Changes in erythrocyte morphology,
- Effects of pH on the mortality and accumulation,
- The alteration of haematocrit and plasma glucose level as secondary stress indicators,
- Effects of erythrocyte antioxidant systems,
- Na,K-ATPase activity,
- The protective effect of calcium on aluminium toxicity,

- Protective effect of zeolite Determination of Na,K-ATPase activity and ion levels in the tissues exposure to salinity and cadmium,
- Protective effect of selenium against mercury-induced toxicity on haematological and biochemical parameters,
- Effect of ATPases and AChE activities in the brain,
- Effects on ion (Na^+ , K^+ , Ca^{++} and Mg^{++}) levels, and
- Preservative effect of humid acid.

The following substances were used as toxicants:

- Cu, Zn, Pb, Cd, Ni, Ca, Se,Hg, Cr, Ag, Al, and Tl,
- $CuSO_4$, $CdCl_2$, $CoCI_2$, $HgCl_2$, $CdSO_4$, $KMnO_4$, $HgCl_2$,
- Zn nanoparticles, CuO nanoparticles, TiO_2 nanoparticles, Al(III) and Al_2O_3 nanoparticules, Ni and Ni nanoparticles, Magnetic nanoparticles (α-Fe2O3, β-Fe2O3 NPs),
- Atrazine, Gesaprim, Bisphenol S (BPS), Esbiothrin, Tribenuron-Methyl, Imazamox, Trimethoprim-Sulfamethoxazole (TMP-SMX), Lambda-cyhalothrin, Carbosulfan, Propineb, Benomyl, Linearalkylbenzenesulphonate (LAS), Clothianidin (E)-1-(2-chloro-1,3-thiazol-5-ylmethyl)- 3-methyl2-nitroguanidine, 2,4-dichlorophenoxy, aceticacid, Cypermethrin, Alpha-cypermethrin, Fenitrothion, Deltamethrin, Cyfluthrin, Dodine, Dimethoate, Formaldehyde, di-n-butylphthalate (DBP),
- petroleum refinery and chromium processing plant effluents, crude oil, and
- N-Acetylcysteine (NAC), alpha-lipoicacid (LA), Taurine (TAU), Curcumin (CUR), Zeolite, EDTA, Aspirin.

Toxicity studies on Aquatic Invertebrate:

Crustacea: Aquatic toxicological studies with crustaceans started in 1998 and a total of 26 literatures were reviewed until 2022 (Table 2). Of these studies, 17 are on freshwater and 9 on marine species.In these studies, carried out on 16 different species, *Daphnia magna* species was used most frequently. In only two of the studies, water and sediment combined tests were established. Studies were generally carried out with static and semi-static experiments. Studies have investigated LC_{50}, EC_{50}, $LD(LT)_{50}$, accumulation, oxidative stress parameters, accumulation in tissues and effects on protein and glycogen levels, effect of different temperatures. As toxicants in these studies, Cd, Zn, Cu, Pb, Cr (IV), sodium lauryl sulphate, potassium dichromate, lead acetate, TiO_2 and $AgTiO_2$ nanoparticles, nanoparticles (AgNPs) and *Paeonia kesrouanensis* (J.Thiébaut) J.Thiébaut, perfluoro octane sulfonate (PFOS), extracts, fenitrothion, malathion chlorpyrifos, propylparaben (PP), pozzolanic cement (contained SiO_2, CaO, Al_2O_3, and Fe_2O_3), lanthanum oxide nanoparticles (La_2O_3 NP), triclosan and 2,4-dichlorophenol, imidacloprid and acetamiprid, ZnO NP + $ZnCl_2$ were used. It has been determined that *Astacus leptodactylus* (Eschscholtz, 1823) (Sarıkaya *et al*., 2011), *Gammarus pulex* (Linnaeus, 1758) (Guven *et al*., 1999), *Hyale crassipes* (Heller, 1866) (Bat *et al*., 2018) species have the potential to be used as test species for toxicity studies.

Table 1. Toxicity test on fish (Fw: Freshwater; Sw: Seawater; W: Water; St: Static, h: hour; d: day).

Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Anguilla anguilla	Fw	15-d, 30-d	W + S W + Semi - St	Effects of lead on Sera glucose, protein, cholesterol concentrations and on haematocrit levels	Pb	No mortality was observed during the experiments. Sera glucose and protein levels showed a linear increase and a decrease respectively under the effect of lead. Lead concentrations 0.12 ppm lead did not cause any variation in haematocrit level, while 0.06 ppm lead increased it compared to control.	Çiftçi *et al*., 2008
Argyrosomus regius	Fw	30-d	W + Semi - St	Accumulation	Cu, Cd	The accumulation of copper and cadmium in the tissues increased considerably and the difference was significant. The accumulation in both metals was mostly in the liver followed by gill and muscle tissue.	Özen and Pak, 2020
Capoeta capoeta	Fw	96-h	W + St	Effects on some blood parameters	Cypermethrin	Cypermethrin decreased haemoglobin and haematocrit values, but sediment increased.	Atamanalp and Cengiz, 2002
Capoeta capoeta	Fw	10-d	W	Effect on tissue histopathology and toxic serum proteins	Cobalt II Chloride ($CoCI_2$)	Thinning in various protein types were observed in experimental groups in comparison to the control group. These thinning were more in the group that 1 mg/L $CoCl_2$ applied. In addition, formation of a 32.4 kD new protein band was observed in the group that 1 mg/L was applied; and 33.3 kD, 30.6 kD, and 28.2 kD new protein bands were observed in the group that 2 mg/L $CoCl_2$ applied. In histopathological evaluations, an increase in the level of degeneration was observed in the livers and intestines tissues of the experimental fish groups in parallel to the increase of the dose.	Bayram *et al*., 2010
Carassius auratus	Fw	2-d, 4-d, 6-d	W	Genotoxic effects	Atrazine and Gesaprim	Fish were exposed to 5, 10 and 15 µg/L atrazine and to its commercial formulation for 2, 4 and 6 days. Ethyl methane sulfonate (EMS) at a single dose of 5 mg/L was used as positive control. The result of the study revealed significant increases in the frequencies of micronuclei and DNA strand breaks in erythrocytes of *C. auratus*, following exposure to commercial formulation of atrazine and thus demonstrated the genotoxic potential of this pesticide on fish.	Cavas, 2011
Carassius auratus	Fw	21-d	W	Toxic effects on gonad and visceral organs	Bisphenol S (BPS)	Fishes treated with different concentrations (0, 100 and 500 µg/L) of BPS were tested for a duration of 21-days.	Nane *et al*., 2021

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
						In gills, BPS caused hyperaemia, oedema, epithelial desquamation, and necrosis. Kidney lesions included necrosis and melano-macrophage infiltrations. BPS stress caused hyperaemia and inflammatory cell infiltrations in livers. The study results revealed that BPS causes degenerative changes in various visceral organs of *C.auratus* and severity of histopathological changes were dose related.	
Carassius auratus	Fw	5-d	W + St	Effects of exposure of low and high concentrations nanoparticles	(TiO_2 NPs)	Accumulation of TiO_2 NPs increased from 42.71 to 110.68 ppb in the intestine and from 4.10 to 9.86 ppb in the gills of the goldfish with increasing exposure dose from 10 to 100 mg/L TiO_2 NPs. No significant accumulation in the muscle and brain of the fish was detected. Malondialdehyde as a biomarker of lipid oxidation was detected in the liver of the goldfish.	Ates *et al.*, 2013
Carassius carassius	Fw	10-d	W + St	Effect on liver total protein amount	Cu, Cd	The total protein levels of liver tissue increased with increasing Cu doses, while the effect of Cd was determined with higher doses. The highest protein level was determined as 0.5-0.5 ppm in Cu-Cd interaction. The increase in total protein concentration in the metabolically active liver can be explained by the increase in the synthesis of metallothionein and non-metallothionein proteins in these tissues, depending on the level of Cd accumulation.	Güner, 2008
Clarias gariepinus	Fw	96-h	W + St	LC_{50}	Cr	Test solutions were made by using an appropriate amount of Cr+6. According to the results, 96h-LC_{50} was determined as 288 mg/L of *C. gariepinus*.	Dural *et al.*, 2005
Clarias gariepinus	Fw	7-d, 15-d, 30-d	W + Semi - St	EDTA on lead accumulation in tissues	Pb and EDTA	No mortality was observed in fish over the time periods of the experiments. The presence of lead increased the metal accumulation in the tissues was determined between the tissues in the order of gill > kidney > liver > brain > muscle. The effect of lead together with EDTA was reduced lead accumulation in tissues and organs when compared to the effect of lead only.	Karayakar *et al.*, 2021a
Clarias lazera	Fw	7-d, 15-d, 30-d	W + Semi - St	Effects on glycogen level and serum glucose level in liver and muscle tissues	Cu	Cu concentrations caused significant alterations in the carbohydrate metabolism of *C. lazera* by effecting tissue glycogen and sera glucose levels during the exposure periods studied.	Arslan *et al*., 2006

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Ctenopharyngodon idellus	Fw	96-h	W + St	LC_{50} and behavioural changes	$CdSO_4$	The LC_{50} value for grass carp species was calculated as 9.42 mg/L. *C. idellus* individuals displayed various behavioural changes when subjected to different cadmium sulphate concentrations.	Yorulmazlar and Gül, 2003
Cyprinus carpio	Fw	15-d	W + Semi - St	Accumulation of metals in liver, gill, and muscle tissues	Cu, Zn	Except the zinc accumulation in gill tissues under the exposure of copper-zinc interaction, the highest copper and zinc accumulation were measured in the liver whereas the accumulation of copper and zinc in the muscle tissues were the lowest. When exposed to the mixture concentrations of copper and zinc, both the copper and zinc accumulation rates in tissue and different organs were found to be lower than those measured when exposed to individual metal concentrations	Cicik, 2003
Cyprinus carpio	Fw	1-d, 3-d, 15-d, 30-d	W + Semi - St	Effects of cadmium on levels of sera aspartate aminotransferase, alanine aminotransferase and glucose	Cd	Sera aminotransferase and glucose levels in Cd exposed animals are varied compared with control on short term exposure, but the levels returned to normal on prolonged exposure. A 50% decrease was observed in sera glucose levels in day 30 compared with the levels in day 1 in all concentrations of cadmium tested	Karataş *et al.*, 2005
Cyprinus carpio *Carassius gibelio* *Corydoras paleatus*	Fw	21-d	W	Genotoxicity tests	Cu, Cd and Cr	Results indicated the formation of micronuclei and binuclei in fish cells caused by their exposure to cadmium, copper and chromium, thus verifying results obtained earlier on mammals, which indicated that these heavy metals have cytotoxic and genotoxic effects	Cavas *et al.*, 2005
Cyprinus carpio	Fw	7-d,15-d, 30-d	W + Semi - St	Effects of haematocrit levels and erythrocyte numbers	Cr^{+6}	No mortality was observed during the experiments. haematocrit levels and erythrocyte numbers increased under the effect of metal on day 15. Haematocrit levels and erythrocyte numbers decreased by increasing exposure periods except at 0.5 ppm chromium.	Çiftçi *et al.*, 2010
Cyprinus carpio	Fw	10-d, 20-d	W + Semi - St	Alterations in reduced glutathione, catalase and proteins electrophoretic patterns	Cu	Cu caused stress in fish gills and an acclimation with induction of reduced glutathione, catalase, medium molecular weight proteins and high molecular weight proteins, which were important in the protection against metal damage, was observed.	Fırat and Kargın, 2010b

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Cyprinus carpio	Fw	7-d, 15-d, 30-d	W + Semi - St	Accumulation of chromium (VI) in tissues of effect on protein and glycogen levels	Cr (IV)	In *C. carpio*, except for the effect of 0.5 ppm concentration of Cr for a period of 15 and 30 days, the increase in the ambient concentration of the metal decreased the liver total protein level statistically significantly compared to the control. It is possible that the increase in liver protein level of *C. carpio* under the influence of the determined time and concentrations of Cr may be due to the increase in the synthesis of metal-binding proteins.	Çiftçi and Cicik, 2011
Clarias gariepinus						In all tissues examined in *C. gariepinus*, the increase in the ambient concentration of Cr in a given time increased the metal accumulation. Chromium accumulation in the tissues of the fish increased due to the increase in the exposure time. Tissue protein and glycogen levels were found to be decreased.	
Oreochromis niloticus						No mortality was observed during exposure. Cr accumulation increased with increasing metal concentrations and exposure periods in the muscle, gill, liver and the hepatopancreas tissues. Tissue accumulation of Cr can be explained by detoxification mechanisms and changes in protein and glycogen levels might be due to metabolic and physiological changes caused by the metal.	
Cyprinus carpio	Fw	96-h	W + St	Accumulation and oxidative stress	*N*-Acetylcysteine (NAC), alpha-lipoicacid (LA), Taurine (TAU), Curcumin (CUR) and Cd	All substances lowered Cd levels (LA=NAC>TAU=CUR). Cd increased SOD activity, but CAT activity declined, regardless of antioxidant treatment. Treatment with CUR induced GPx activity. Treatment with TAU lowered Cd due to higher total glutathione (tGSH). The most effective substances on lipid peroxidation were LA and NAC due to a greater Cd-lowering potential.	Sevgiler *et al.*, 2011
Cyprinus carpio	Fw	24, 48, 72-h, 96 h	W + St	LC_{50}	Esbiothrin	On the basis of the 96 h LC_{50} data from U.S. EPA ecotox database (32 lg/L) two sublethal exposure concentrations (5 and 10 lg/L) were used together with ethyl methane sulfonate (EMS) (5 mg/L) as positive control The fish showed behavioural changes at the higher dose.	Selvi *et al.*, 2011

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Cyprinus carpio	Fw	20-d	W + Semi - St	Effect in blood ion level	Cu, Pb	Blood serum Na^+ levels decreased after periods tested at exposure to Cu while increasing at exposure Pb. Cu concentrations blood serum K^+ levels increased while decreased with effect of Pb concentrations after 10 and 20 days of exposure. Blood serums ionize Ca^{++} levels decreased at exposure to Cu while increasing at exposure to Pb after periods tested. Blood serum Cl^- levels while increasing at Cu exposure; it was seen that decreasing at Pb exposure.	Çoğun and Kargın, 2013
Oreochromis niloticus						Blood serum Na^+ levels decreased after periods tested at exposure to copper while increasing at exposure lead. *O. niloticus*blood serum K^+ levels increased with effect of Cu and Pb concentrations. Ionize Ca^{++}levels of blood serum in *O. niloticus*decreased at high concentrations of Cu and in all the concentrations of Pb. In all the concentration of Cu and Pb and periods tested, blood serum Mg^+ levels decreased in *O. niloticus.* Blood serum Cl^- levels while increasing at copper exposure; it was seen that decreasing at lead exposure.	
Cyprinus carpio	Fw	4-h Hg / 15-d Aspirin	W	Effect of aspirin on mercury toxicity	Aspirin, Hg	Increases in blood parameters were observed depending on the increases in mercury concentration. Statistically significant variations were observed in blood parameters of the fish, which were made exposed to mercury at the same concentrations after they had been interacting with aspirin, compared to blood parameters of the fish, which were made exposed directly to mercury. It was found that aspirin has caused significant increases in especially the levels of serum aspartate aminotransferase and alanine aminotransferase and significant decreases in cortisol and glucose levels among to blood parameters. It was concluded that aspirin alters the toxic effect of mercury.	Polat and Dal, 2013
Cyprinus carpio	Fw	10-d, 20-d, 30-d	W	Accumulation and Na/K ion levels in gill tissue	Cu	The 30th day, all of the fish died under the effect of 1.0 mg/L concentration of Cu. Cu accumulation in the gill tissue of *C.carpio* increased with increasing concentrations of copper in the medium and with increasing periods of exposure. In all conditions tested in *C. carpio*, Cu caused a decrease in gill tissue Na^+ and K^+ levels.	Çoğun and Kargın, 2020

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Cyprinus carpio	Fw	7-d, 15-d, 30-d	W + Semi - St	Effects of EDTA on zinc accumulation in tissues	Zn	No mortality occurred in fish under the exposure times and concentrations with solutions containing Zn only and Zn combined with EDTA. The exposure to both Zn alone and Zn combined with EDTA significantly increased metal accumulation in the tissues and organs as compared to the control, and gill> liver> muscle accumulation relationship was found among the tissues. The results obtained showed that EDTA reduced Zn accumulation in the gill, liver, and muscle tissues when compared to the effect of Zn only	Karayakar *et al.*, 2021b
Cyprinus carpio	Fw	96-h	W	Protective effects of antioxidant compounds in the liver and kidney	Cd, Cr	Compared to control, all levels were significantly higher in Cd- and Cr-exposed fish, save for the *N*-Acetylcysteine cotreated fish. Compared to fish exposed to Cd or Cr alone, cotreatment with *N*-Acetylcysteine reduced liver Cd and Cr levels by 65.9 and 50.0%, respectively. Other antioxidants showed no significant effect on liver Cd and Cr. Even though Cd and Cr are model toxicants, our study did not demonstrate the well-known pro-oxidative effect of Cd, while Cr showed only a weak pro-oxidative action in the liver and kidney of common carp	Karaytuğ *et al.*, 2011
Danio rerio	Fw	96-h	W	LC_{50}	Ni and Ni Nanoparticules (NPs)	Acute toxicity of Ni in fish exposed to Ni(II) was higher (96-h LC_{50} = 32.6 mg/L) than for fish exposed to Ni-NPs (96-h LC_{50} = 122.2 mg/L). indicated that while Ni-NPs induced gene expression (presumably by the release of Ni ions), the differences in concentration relationships of gene expression between Ni-NPs and Ni(II) suggest that factors in addition to the release of Ni ions from Ni-NPs influence acute toxicity of Ni-NPs.	Boran and Şaffak, 2018
Danio rerio	Fw	48-h, 72-h, 96-h	W	The toxic effect molecular and morphologic	CuO NPs	The results showed that CuO NPs was not able to enter into the zebrafish embryos/larvae tissues but caused an increased the mortality rate, a delayed hatching, and a decreased heartbeat rate. Moreover, CuO NPs caused several types of abnormalities such as head and tail malformations, vertebral deformities, yolk sac oedema, and pericardial oedema.	Aksakal and Ciltas, 2019

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Danio rerio	Fw	72-h, 96-h	W	LC_{50}, alterations in stress-associated genes and damage of DNA	Al(III) and Al_2O_3-NPs	Genotoxic effects of Al(III) and Al_2O_3-NPs were evaluated. The lethal concentrations that cause death of 50% (LC_{50}) of zebrafish larvae when exposed to 0–50 mg/L Al(III) and 0-500 mg/L Al_2O_3-NPs were 3.26 ± 0.38 and 130.19 ± 5.59 mg/L, respectively, for 96 h. A concentration-dependent increase was observed in the genotoxicity in cells of larvae exposed to Al(III) and Al_2O_3-NPs for 96 h. DNA damage was more severe in larvae exposed to Al(III) (41.0% tail) than that of Al_2O_3-NPs (21.8% tail). A complex induction of stress-associated genes was observed in fish and this induction was not directly related to the concentrations of Al(III) and Al_2O_3-NPs, although a significant induction was detected in mt2 gene of larvae exposed to Al(III) and Al_2O_3-NPs relative to control group.	Boran and Şaffak, 2020
Danio rerio	Fw	96-h	W	Toxic effects on liver tissue	Tribenuron-Methyl	In conclusion, Tribenuron-Methyl showed a detrimental effect on liver tissue enzyme activities and lipid peroxidation levels of zebrafish.	Kayhan *et al.*, 2020
Danio rerio	Fw	24-h, 48-h, 72-h, 96-h	W	Genotoxic effect and blood cells in vivo using the micronucleus method	Imazamox	At the highest concentration (12 mg/L), it was observed that all fish died in all treatment periods. According to 24, 48 and 96 h treatment results; compared to the negative control, it was determined that the micronucleus frequency increased as the concentration increased.	Rasgele *et al*., 2022
Dicentrarchus labrax *Sparus aurata*	Sw	1-h, 24-h, 48-h	W	Physiological stress and innate immune response	Trimetoprim-Sulfametoksazol (TMP-SMX)	Ceruloplasmin (Cp) were measured soon after treatment and following 24 and 48 h in normal sea water for recovery. Treatment with TMP-SMX in both gilthead sea bream and sea bass led to an increase in plasma cortisol and glucose and which requires more than 48-h period for regaining homeostasis	Yıldız and Altunay, 2011
Gambusia affinis	Fw	14-d	W + Semi - St	Micronucleus Test, Nuclear Abnormalities and Accumulation o	Cu, Cd	Cu accumulation was increased compared to their singly (0.1 ppm) exposed concentrations. Micronucleus and nuclear abnormality analysis tests revealed that, although Cu and Cd did not significantly increase micronuclei frequency, nuclear abnormalities were significantly induced compared to control groups.	Güner and Muranlı, 2011

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Gambusia affinis	Fw	96-h	W + St	LC_{50}	Lambda-cyhalotrin	The 96-h LC_{50} value for mosquito fish was estimated as 1.107 µg/L.	Güner, 2009
Gambusıa holbrookı	Fw	48-h, 72-h, 96-h	W	LC_{50}	Ni	Acute toxicity of Ni was determined by the probit analysis method and 96-h lethal dose test result was 16.811 mg/L for *G. holbrooki*. During acute and chronic toxicity experiments, some behavioural change in concentration, water column distribution, clustering and mobility and some physical changes such as blood supply to the gills and blackening of the outer epithelial tissue were observed in test animals.	Dumlu and Güner, 2020
Gobius niger	Sw	25-d	W + Semi - St	Effects of erythrocyte structure	Cd	An increase on the number of immature and degenerated erythrocytes has been observed. Ovoid shape of nuclei seen in normal erythrocytes has been changed to spherical shape and the cell membrane became echinoid. Moreover, hypochromic anaemia, fragmented erythrocyte structure, and an increase on the number of micronuclei were observed.	Katalay and Parlak, 2004
Leuciscus cephalus	Fw	96-h	W	LC_{50}	$HgCl_2$	The 96-h LC50 value of mercury-II-chloride ($HgCl_2.H_2O$) on *L. cephalus*was found to be 0.55 mg/L (0.53-0.57). There were significant changes observed in the behaviour of the fish as the concentration of the toxic compound increased	Gül *et al*., 2004
Leuciscus cephalus	Fw	10-d	W	Tissue histopathology and serum protein expression	$CdSO_4$	Microscopic examination revealed degeneration in the secondary lamellar epithelia, hydropic degeneration and necrosis in chloride cells of the fish gill in $CdSO_4$ given groups. Hydropic degeneration and necrosis were also observed in light to severe levels in the liver depending on the groups. It was concluded that $CdSO_4$ has toxic effects on the expression of serum proteins and causes degenerative changes on gill and liver morphology in *L. cephalus*.	Yılmaz *et al*., 2011
Liza saliens	Sw		W	IC_{50}	Al and Tl	The IC_{50} values of $AlCl_3$ and $TlCl_3$ were estimated to be 34 µM and 3 µM, respectively. The Lineweaver–Burk plot and Dixon plot revealed that both metal ions noncompetitively inhibited the purified mullet cytochrome P450 reductase.	Bozcaarmutlu, 2007

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Onchorhyncus mykiss	Fw	30-d	W	Accumulation of Zn in liver and muscle tissues	Zn	The concentrations of zinc in the muscle tissues of rainbow trout were 14.22 (control), 41.05, 45.03, 56.73, 61.44 and 72.53 µg/g dry weight, exposed to 0 (control), 0.1, 0.5, 1, 5 and 10 mg/L Zn levels, whereas those in the liver of the fish were 46.53 (control), 155.24, 186.43, 239.51, 261.49, 398.88 µg/g dry weight, respectively. The accumulation of Zn in the tissue and organs increased with increasing metal concentrations.	Gündoğdu *et al.*, 2009
Onchorhyncus mykiss	Fw	14-d	W + Semi - St	Effects on the vital organs	Carbosulfan, Propineb, Benomyl	Fish exposed to sublethal concentrations of pesticides did not show any abnormality such as restlessness, convulsions, respiration rate, excessive mucus, swimming and balance compared to control groups. No fish died in concentrations of carbosulfan, propineb and benomyl during the sublethal toxicity tests. The most important lesions were determined in the highest concentrations of pesticides while few lesions were observed in lower concentrations. Fish gills exposed to the pesticides had lamellar fusion, lamellar hyperplasia, epithelial lifting, vacuolization, epithelial necrosis, hypertrophy, sloughing of epithelium. Also lamellar swellings were presented in fish gills exposed carbosulfan and benomyl.	Çapkın *et al.*, 2010
Onchorhyncus mykiss	Fw	54-d	W	non-specific immune system, phagocytosis, respiratory burst and lyzosyme activity, and specific growth rate	Linear alkylbenzene sulphonate (LAS)	No significant reductions were observed in the extra-intracellular respiratory burst and lysozyme activities after exposure to LAS at any of the concentrations tested. The final body weight in fish groups exposed to the LAS were found to be significantly lower than in the control. The results of this study showed sublethal doses (0.2–0.4 mg/l) of LAS caused to statistically insignificant suppression of non-specific immune system mechanisms excluding phagocytosis in fish at laboratory conditions.	Bakırel *et al.*, 2005
Oncorhynchus mykiss	Fw	7-d	W	Antioxidative role of selenium against the toxic effect	Cd, Cr, Se	The activities of catalase, glutathione peroxidase and superoxide dismutase in the tissues of fish exposed to the stress of Cd^{+2} and Cr+3 were significantly lower than the control groups. Meanwhile, the closer values to the control groups were obtained in selenium-added groups (Cr^{+3} + Se^{+4}, Cd^{+2} + Se^{+4}). For the level of malondialdehyde, the last production of lipid peroxidation showed increases in the groups exposed to the metal stress, whereas significant decreases were obtained in selenium-applied groups. the negative effects occurring in the biochemical parameters of the applied groups exposed to the toxicity of heavy metal were significantly eliminated as a result of selenium treatment.	Talas *et al.*, 2008

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Oncorhynchus mykiss	Fw	5-d, 5-d, 30-d	W + Semi - St	Haematological, biochemical, and behavioural responses	Dimethoate	The glucose concentration showed an ascending pattern that proved to be positively correlated with duration. The protein concentration declined in higher dimethoate concentrations following 15 and 30 days. Negative and significant correlation was detected between glucose and protein concentrations. The fish showed remarkable behavioural abnormality such as loss of balance, erratic swimming, and convulsion. Dimethoate exerts its toxic action even in sublethal concentrations and haematological parameters and abnormal behaviour may be sensitive indicators to evaluate pesticide intoxication.	Doğan and Can, 2011
Oncorhynchus mykiss	Fw	96-h	W + Semi - St	LC_{10}, LC_{50}, LC_{90}	Formaldehyde	Experiment concentrations which were 0.05, 0.10, 0.15, 0.20 ml/L, the 96-hour LC10, LC50, LC90 values of Formaldehyde on *O. mykiss* frys was found as 0.05±0.01, 0.09±0.01 and 0.13±0.02 ml/L, respectively. Relationship with formaldehyde and dead fish numbers were observed positive-strong. The increase in the toxic reagent concentration caused respiratory difficulties, tremors, imbalanced swimming patterns and sudden jerks in frys.	Özgür *et al.*, 2011
Oncorhynchus mykiss	Fw	60-d	Stream system	Effects of carbosulfan on erythrocyte acetylcholinesterase (AChE) activities	Carbosulfan	Changes in enzyme activity of rainbow trout was statistically significant. Increase of inhibition rate on AChE activity was up to 3rd week. Inhibition rates of AChE was determined as 41.32 % and it was determined that change onenzyme activity affected fish behaviour	Çapkın, 2011
Oncorhynchus mykiss	Fw	48-h, 96-h	W	Bioaccumulation levels and histological alterations	Dodine	Neither of the applied dodine doses resulted in killing 50% of the total individuals in the experimental groups. 48 hours after doses, behaviours such as instability, anomaly in swimming or sudden jumping movements were observed. Histological results of the study showed deteriorations of the radiological pattern of hepatocytes, sinusoidal dilatations, haemorrhages, oedemas, mononuclear cell infiltrations, vascular congestions, hyperplasia and hypertrophy in liver, gill and muscle tissues. Accumulation of dodine in tissues correlated with increase of dose. The maximum level of active substance accumulation in tissues were measured 96 hours after application of 1 mg/L dodine dose -in order- in gills, muscles and liver.	Büyüksoylu *et al.*, 2022

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Onchorhyncus mykiss	Fw	7-d, 14-d, 21-d	W	Pro-oxidant potency of clothianidin	Clothianidin (E)-1-(2-chloro-1,3-thiazol-5-ylmethyl)- 3-methyl2-nitroguanidine	Clothianidin inhibited the activity of acetylcholinesterase (AChE) and lowered tissue protein levels. Heart tissue weight increased, while that of spleen decreased significantly. The effects were time- and concentration-dependent. What raises particular concern is the inhibition of AChE in the trout, even though clothianidin is claimed to be selective for insect receptors. Increased antioxidant activity in response to oxidative stress was clearly insufficient to keep malondialdehyde and protein carbonyl at normal levels, which evidences the pro-oxidant potency of the insecticide.	Fakhereddin and Doğan, 2021
Onchorhyncus mykiss		48-h, 96-h	W	Biological effects of ulexite, oxidative DNA damage toxicity damage	Magnetic nanoparticles (Fe_3O_4 MNPs)	The brain tissues were taken at the 48th and 96th hours of the trial period, the effects on neurotoxic, pro-inflammatory cytokine genes, antioxidant immune system, DNA and apoptosis mechanisms were analysed. In the present study, it was determined that acetylcholinesterase activity and brain-derived neurotrophic factor level in the brain tissue decreased over time in the Fe_3O_4-MNPs group compared to the control, and ulexite (UX) tried to depress this inhibition. It was determined that Fe3O4-MNPs caused stress in *O. mykiss* and UX exhibited a positive effect on this stress management	Ucar *et al.*, 2022
Oreochromis mossambicus	Fw	14-d	W + Semi - St	Changes in erythrocyte morphology	Pb	The important changes in the treatment groups exposed to medium and high lead concentrations were shown than the control group. Medium and high doses of lead red blood cell nucleus area, an important reduction in the length and width compared to the control, while the width of the cell cytoplasmic space and the control group showed a significant increase. It was concluded that increasing lead concentrations might cause hypertrophy, anisocytosis and cariopicnosis in erythrocyte cell morphology of *O.mossambicus*.	Kaya and Akbulut, 2012
Oreochromis niloticus	Fw	30-d	W + Semi - St	Accumulation in different size	Cu, Cd	The results show that Cu has a positive relationship with size while Cd has a negative or independent relationship with size *O. niloticus*. The difference in metal content between small and large animals may be due to differences in their metabolic activity and thus metal metabolism.	Çoğun *et al.*, 2003

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Oreochromis niloticus	Fw	30-d	W + Semi - St	Effects of different concentrations of mixture on the accumulation	Cu, Cu+Cd	Accumulation of Cu in the tissues and organs increased with increasing concentrations of Cu and with longer exposure periods. Cu accumulation associated with Cu + Cd mixtures in the gill, liver, kidney and muscle tissues varied with the concentration, exposure period and tissue type. Cu accumulated most in the liver and least accumulated in the muscle tissue. While Cu + Cd mixture had a decreasing effect on the accumulation of Cu in kidney, gill and liver tissues at 1, 7 and 15 days, it had an increasing effect on the 30th day.	Sağlamtimur and Cicik, 2003
Oreochromis niloticus	Fw	30-d	W + Semi - St	Effects of pH on the mortality and accumulation	Cu	In all pH levels, tissue accumulation of copper increased with increasing concentrations of Cu in the medium at a given exposure period. In all pH values tested, highest levels of Cu were found in the liver of *O. niloticus*, followed by the gills and muscle tissues. Accumulation of copper in all tissues were higher at pH 5.5 compared with the other pH values in all the conditions tested.	Çogun and Kargın, 2004
Oreochromis niloticus	Fw	15-d	W + Semi - St	Accumulation tissue and organ	Cu, Cd	The highest cadmium accumulation was found as 55.92 µg Cd/g (dry weight) in gill tissues of fish, in the exposition of cadmium solution only. Fish exposed to Cu-Cd mixture, however, accumulated more cadmium in their kidney tissue (27.02 µg Cd/g dry weight). The lowest cadmium accumulation was in muscle tissue being 1.64 µg Cd/g (dry weight) in Cd only and 1.65 µg Cd/g (dry weight) in Cd+Cu treatments. Although, copper treatment decreased the cadmium accumulation in all the tissues except the muscle tissue, when compared with the effects of cadmium only treatments, the highest decrease was found as 77% in the liver tissue.	Sağlamtimur *et al*., 2004
Oreochromis niloticus	Fw	7-d, 15-d	W + Semi - St	Accumulation tissue and organ	Pb, Cd	At the end of 15 days, the highest amount of Pb and Cd was found in kidney tissue, and the lowest accumulation was in muscle tissue. Cd accumulation in tissues and organs, respectively; kidney>liver>spleen>gill>muscle and Pb; kidney>gill>liver>spleen>muscle. The mixture of Pb and Cd increased the accumulation of Cd in kidney and liver, while it increased the accumulation of Pb in liver, gill and muscle tissue.	Cicik *et al*., 2004

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Oreochromis niloticus	Fw	48-h, 72-h	W + St	LC_{50}	Cyfluthrin	The 48 and 72 h LC_{50} value of cyfluthrin in tilapia fry were found as 25.82 and 21.07 g/L in the present work, respectively, and here we report cyfluthrin to be highly toxic to fish.	Benli, 2005
Oreochromis niloticus	Fw	48-h	St	LC_{50}	(2,4-dichlorophenoxy) acetic acid (2,4-D)	48 h LC_{50} value for Nile tilapia larvae and adults were found to be 28.23 mg/L and 86.90 mg/L, respectively in a static bioassay test system. 95% lower and upper confidence limits for the LC_{50} were 22.55–32.98 and 80.67–92.80 mg/L, respectively. Water temperature was 24 ± 1 ◦C. Behavioural changes of both tilapia life forms were examined for various herbicide concentrations.	Sarikaya and Selvi, 2005
Oreochromis niloticus	Fw	48-h	W + St	LC_{50}	Deltamethrin	All fish, exposed to 5 g/L deltamethrin revealed severe morphological alterations in the gills and liver. In the gill's hyperaemia, fusion of secondary lamellae and telangiectasis were observed; whereas hydropic degenerations in liver were observed in all examined fish. The results are significant for reporting acute deltamethrin toxicity in terms of behavioural and histopathological changes: Deltamethrin is highly toxic to fingerling.	Yıldırım *et al*., 2006
Oreochromis niloticus	Fw	7-d, 28-d	W + Semi - St	Antioxidant responses and metal accumulation	Zn, Cd and Zn + Cd	Concentration of metals in the tissues of fish exposed to the Zn + Cd combination were significantly lower than in fish exposed to the single metal. The highest metal accumulation was observed in the liver. Exposure to the heavy metals affected the antioxidant parameters in the tissues, with both glutathione (GSH) level and glucose-6-phosphate dehydrogenase (G6PD) activity in the gill and liver being increased under Zn, Cd and Zn + Cd exposures, especially in their higher concentrations. These increases in the antioxidant responses were higher with the Cd alone, and in combination with Zn, than with Zn alone. Furthermore, GSH level and G6PD activity increased with increasing exposure period only for Cd alone, and in Cd combination with Zn. The results indicate that *O. niloticus* resisted oxidative stress induced by heavy metal exposure by antioxidant mechanisms.	Fırat *et al.*, 2008

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Oreochromis niloticus	Fw	1-h, 96-h	W + Semi - St	The alteration of haematocrit and plasma glucose level as secondary stress indicators	Fenitrothion	After 1 and 96 h exposed to fenitrothion haematocrit values were declined significantly. Plasma glucose levels were increased significantly in both sampling periods; however, time and concentration dependent changes were shown at the concentrations of 50 and 100 µg/L haematocrit values were declined. Considering the parameters measured in this study Nile tilapia appeared to exhibit a stress response to sublethal fenitrothion concentrations.	Karasu Benli and Gülen, 2009
Oreochromis niloticus	Fw	30-d	W + Semi - St	Alterations in ion levels (Na^{+}, K^{+}, Ca^{+2}, Mg^{+2})	Cu^{+2}, Cd^{+2}, Cr^{+6}, Ag+ and Zn^{+2},	Except for Ag^{+}, none of the metals killed the fish within 30 days. Silver killed all the fish within 16 days. Ion levels in the tissues were altered by metal exposure, the general tendency being a decrease in Na^{+} and K^{+} levels and an increase in Mg^{2+} and Ca^{2+} levels. Acute exposure to heavy metals seemed to be more effective in altering ion levels of the tissues than chronic exposure. Na+ was the most affected ion while Mg^{2+} was the least affected. Results of this study emphasize that ion levels in the tissues of *O. niloticus*can be altered by heavy metals, both in acute and chronic exposures.	Atlı and Canlı, 2010
Oreochromis niloticus	Fw	7-d, 28-d	W + Semi - St	Biochemical alterations in the serum	Zn, Cd	Alkaline phosphatase activity was elevated at both exposure periods. No changes in activities of lactate dehydrogenase and lipase were observed in response to single or combined Zn and Cd exposure at 7 days while they increased at 28 days. Fish exposed to metals showed a decrease in cholinesterase activity at 7 days followed by a return to control levels at the end of the exposure period. The individual and combined effects of metals caused a decline in levels of Na^{+}, Cl^{-}, and Ca^{2+}, especially at 28 days. K^{+} level increased at 7 days but it returned to control levels with increasing duration of exposure	Fırat and Kargın, 2010a
Oreochromis niloticus	Fw	7-d, 28-d	W + Semi - St	Protein intensity changes in the haemoglobin and plasma electrophoretic patterns	Zn, Cd	The protein intensity in haemoglobins (three bands for haemoglobin Hb1, Hb2, Hb3) of fish following Zn, Cd, and Zn + Cd exposures decreased in Hb1, whereas it increased in Hb3. There was increasing level of the metals in the whole blood with increasing concentrations of metals in the exposure medium and with increasing duration of exposure.	Fırat and Kargın, 2010c

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Oreochromis niloticus	Fw	14-d	W + Semi - St	Effects of serum biochemistry	Zn, Cd and Zn + Cd	Zn+Cd, concentrations of these metals in their serum were lower than in fish exposed to individual metals. İncreased Alanine Aminotransferase activity of fish exposed to Cd was higher compared with the Zn and Zn+Cd groups, respectively. The decreased cholesterol level was higher in the Cd alone, and for Cd in combination with Zn, than in Zn alone at 14 days. Zn or Cd levels increased in the blood serum of fish exposed to metals individually or in combination. When fish were exposed to the mixtures of Zn+Cd, concentrations of these metals in their serum were lower than in fish exposed to individual metals.	Fırat and Kargın, 2010d
Oreochromis niloticus	Fw	7-d, 14-d	W + Semi - St	Effects of erythrocyte antioxidant systems	Zn, Cd and Zn + Cd	Erythrocyte GSH level and CAT and G6PD enzyme activities increased in response to single and combined Zn and Cd exposure. The elevation observed in the CAT activity was higher in the Cd alone, and in combination with Zn, than in Zn alone. Exposure to metals (alone and in mixture) resulted in elevation of Zn and Cd levels in the blood. Concentration of metals in the blood of fish exposed to the Zn + Cd combination was lower than in fish exposed to the single metal.	Fırat and Kargın, 2010e
Oreochromis niloticus	Fw	4-d, 21-d	W + Semi - St	Serum biochemistry effects	Cypermethrin , Cu, Pb	All serum biochemical parameters of fish-treated pesticide were higher than those in fish exposed to metals.	Fırat *et al.*, 2011
Oreochromis niloticus	Fw	0-d, 1-d, 3-d, 7-d, 14-d	W + Semi - St	Na,K-ATPase activity and increased salinity	Cd, Salinity+Cd	Salinity+Cd combine exposures decreased Na^+/K^+ - ATPase activity in 2 ppt medium in the gill while the activity increased at 8 ppt medium. Na^+/K^+ -ATPase activity in the intestine decreased in relation to salinity increase, though there was no significant decrease in the kidney. Mg^{2+}-ATPase and Ca^{2+} -ATPase activities showed a declining trend with the increase in salinity. Cd accumulation in the tissues decreased as the salinity of medium increased, though accumulation in the gill increased regardless of salinity increase at the longest exposure period.	Kulaç *et al.*, 2012
Oreochromis niloticus	Fw	7-d, 14-d, 21-d	W + Semi - St	The protective effect of calcium on aluminium toxicity	Al, Ca and Al + Ca	Al accumulation exposure tissues highest accumulation occurred in the kidney followed by gill, liver and muscle. In all exposure period, accumulation of Al in whole tissues of *O. niloticus* decreased in the presence of calcium. In both mixed exposure (Al+Ca) concentrations, significantly reduced the accumulation of Al in the kidney, gill and liver of *O. niloticus*	Çoğun and Uras, 2012

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Oreochromis niloticus	Fw	10-d, 20-d, 30-d	W + Semi - static test	Effect of zeolite on reduction of lead toxicity	Pb, Zeolite and Pb+zeolite	Pb accumulation increased with increasing concentrations of Pb in the medium and with increasing periods of exposure tissues studied. All tissues lead accumulation was found to be statistically significant in the 0.1 and 1.0 mg/L of lead concentrations at 10, 20 and 30 days. Highest accumulation occurred in the kidney followed by gill, liver and muscle. In all exposure period, accumulation of lead in whole tissues of *O. niloticus* decreased in the presence of zeolite. In both mixed exposure (Pb+zeolite) concentrations, zeolite significantly reduced the accumulation of lead in the kidney and liver of *O. niloticus*.	Çoğun and Şahin, 2012
Oreochromis niloticus	Fw	14-d	W + Semi - st	Determination of Na,K-ATPase activity and ion levels in the tissues exposure to salinity and cadmium	Cd, metal+salt	Enzyme activity varied depending upon salinity, tissue, and exposure duration. Na^+ /K^+ -ATPase activity changed in fish exposed to both metal and salinity in relation to exposure conditions and duration. In salinity alone group, the declining trend in enzyme activity was observed, whereas there was increasing trend in the metal+salt mixture group. There was no significant metal accumulation in salinity alone group, though there were some increases in the metal+salt mixture group, despite few decreases. There were also alterations in ion levels regarding exposure conditions, general trend being as decreases.	Kulaç and Canlı, 2012
Oreochromis niloticus	Fw	7-d, 14-d	W + Semi - st	Protective effect of selenium against mercury-induced toxicity on haematological and biochemical parameters	Hg, Se	Hg alone resulted in decreases in red blood cell, white blood cell, haemoglobin, haematocrit values, and cholinesterase activity while it increased in alanine aminotransferase and aspartate aminotransferase activities and cortisol and glucose levels. Se, in combination with Hg, partially or totally caused an alleviation for the toxic effect of Hg on the above mentioned haematological and biochemical parameters. The results of our study showed that Se has a protective effect against toxicity induced by Hg.	Çoğun *et al.*, 2012

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Oreochromis niloticus	Fw	30-d, 60-d	W	Effects of chronic exposure nanoparticles	α-Fe_2O_3 and β-Fe_2O_3 NPs	The organs, including gills, liver, kidney, intestine, brain, spleen, and muscle tissue of the fish were analysed to determine the accumulation, physiological distribution and elimination of the Fe_2O_3 NPs. Largest accumulation occurred in spleen followed by intestine, kidney, liver, gills, brain and muscle tissue. Fish exposed to -Fe_2O_3 NPs possessed significantly higher Fe in all organs. Accumulation in spleen was fast and independent of NP concentration reaching to maximum levels by the end of the first sampling period (30th day). Fe levels in gills and brain reflect more dissolved Fe accumulation from metastable Fe_2O_3 polymorph.	Ates *et al*., 2016
Oreochromis niloticus	Fw	24-h, 96-h		LC_{50} and Genotoxicity	di-n-butyl phthalate (DBP)	The results showed that mean micronucleus (MN) frequencies in both DBP and ethyl methane-sulfonate (EMS, positive control for MN bioassay) groups were significantly different with respect to control and solvent control groups, in both exposure scenarios. When analysing nuclear abnormalities, the frequency of notched nuclei was significantly different, but the frequencies of other subtypes did not change. The 96-h exposure led to an increase in the mean frequencies of notched nuclei, and also caused significant differences between MN frequencies in all groups.	Karasu Benli *et al*., 2016
Oreochromis niloticus	Fw	4-d, 21-d	W	LC_{50} and protective effect of zeolite	Hg and Zeolite	It was determined increases in activities of serum enzymes of *O. niloticus*were higher in the mercury alone than mercury zeolite mixture and zeolite partially or totally played a protective role against the toxic effect of Hg.	Fırat and İnandı, 2016
Oreochromis niloticus	Fw	7-d, 21-d	W	Accumulation in tissues	Hg	Hg accumulation in tested all tissues elevated with increasing exposure periods with increasing medium concentrations of Hg. Highest accumulation occurred in the gill followed by liver and muscle.	Fırat and Kargın, 2016
Oreochromis niloticus	Fw	7, 14 d	semi-static	Accumulation in tissue and histo-pathological changes	Zinc Nanoparticles (Zn NPs)	The results indicated that exposure to Zn NPs could lead to disturbances in blood biochemistry and cause histopathological injuries in the tissues of *O. niloticus*	Kaya *et al*., 2016
Oreochromis niloticus	Fw	3-d, 30-d		Effect of ATPases and AChE activities in the brain	Hg^{2+} and Ni^{2+}	The exposures, activities of ATPase (Total-ATPase, Na^+/K^+ -ATPase and Mg^{2+} -ATPase) and erythrocyte acetylcholinesterase (AChE) were measured in the brain. There were changes upon Hg^{2+} and Ni^{2+} effects depending on the Ca^{2+} concentration though low dependence on Ca^{2+} exposure alone. Decreased activities were recorded after acute metal exposures even at high Ca^{2+} concentration.	Atli, 2018

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Oreochromis niloticus	Fw	10-d, 20-d, 30-d	W	Effects of Copper on ion (Na+ , K+ , Ca++ and Mg++) levels and accumulation in muscle tissues	Cu	It was determined that copper accumulation in *O. niloticus* muscle tissue increased at all ambient concentrations and with prolonged exposure time. When the ion levels under the influence of Cu in *O. niloticus* muscle tissue were examined, there was no change in sodium level in the tested environment concentrations and durations, while it caused an increase in magnesium level and a decrease in potassium and calcium levels.	Çoğun and Kargın, 2021
Oreochromis niloticus	Fw	4-d, 21-d	W	Hemotoxic effects by measuring haematological and blood oxidative stress biomarkers	Copper oxide nanoparticles (CuO-NPs) and Copper sulphate ($CuSO_4$)	The results demonstrates that CuO-NPs and $CuSO_4$ for *O. niloticus* have similar hemotoxic effects, however, CuO-NPs are slightly more toxic than $CuSO_4$ regarding haematological changes and oxidative stress observed.	Fırat *et al*., 2021
Oreochromis niloticus	Fw	3-d, 6-d, 9-d	W	Genotoxic effects of effluents using the micronucleus	petroleum refinery and a chromium processing plant effluent	The results showed that both effluents had genotoxic potential. On the other hand, the level of genetic damage induced by petroleum refinery effluent was considerably higher than that of chromium processing plant effluent. Nuclear abnormalities other than micronuclei, such as blebbed and lobed nuclei, may also be used as indicators of genotoxic damage.	Cavas and ErgeneGözukara, 2005
Oreochromis niloticus	Fw	10-d, 20-d, 30-d	W	Effect of lead on ion levels of gill tissue	Pb	Ion concentrations of *O. niloticus* gill tissues (10, 20 and 30 days in concentrations of 0.1, 05 and 1.0 m/L Pb) Na^+, K^+, Ca^{++} and Mg^{++} levels were affected by Pb. Pb concentrations caused an increase in Na+, Ca++ and Mg++ ion levels, but caused a decreased in K+ ion levels. In this study, *O. niloticus* was found to be an organism sensitive to metal contamination due to Pb influences of ion levels.	Çoğun and Kargın, 2019
Pelvicachromis pulcher	Fw	96-h	W	Effects of water-soluble fractions of crude oil on the intestine and liver	Crude Oil	Several histological alterations such as prominent ulceration, desquamation, lymphocyte infiltration and necrosis, were noted for the intestinal tissue of the crude oil exposed animals when compared with controls. The liver was also shown marked deformative changes identified as steatosis, haemorrhage, dilatation of sinusoids and pronounced hepatocellular degeneration which was specially characterized pyknotic and karyorrhectic nuclei. It was concluded that the water-soluble fractions of crude oil was drastically effected both of the tissues studied, as expected.	Önen *et al*., 2011

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Poecilia reticulata	Fw	96-h	W + St	LC_{50} and the effect of behaviour	$CdCl^2$	The LC_{50} were 29.3 and 31.7 mg/L, 95% lower and upper confidence limits respectively. The water temperature was kept between 21 and 23 °C. The behavioural changes observed in fish were, swimming in imbalanced manner, capsizing, attaching to the surface, difficulty in breathing and gathering around the ventilation filter	Yılmaz *et al.*, 2004b
Poecilia reticulata	Fw	96-h	W + St	LC_{50}	Alpha-cypermethrin	Data obtained from the alpha-cypermethrin investigation were evaluated by the use of probit analysis statistical method and the 96-h LC50 value for guppy was estimated as 9.43 lg/l.	Yılmaz *et al.*, 2004a
Poecilia reticulata	Fw	96-h	W + St	LC_{50}	Fenitrothion	Behavioural changes at each fenitrothion concentration were observed for the individual fish. The 96 h LC_{50} value for guppy was estimated as 3.28 mg/L.	Sarıkaya *et al.*, 2007
Poecilia reticulata	Fw	96-h	W + St	LC_{50} andEC_{50}	Potassium Permanganate ($KMnO_4$)	The 96 h LC_{50} and EC_{50} were determined as 0.674 mg/L (95% CI 0.506 to 0.878) and 0.786 mg/L(95% CI 0.558-1.101). During the experiment, depending on the concentration, some side effects of potassium permanganate on fish such as fast-moving, uncontrolled swimming, to escape out of the water, perpendicular movement to the water surface, irregular swimming and fast breathing action were observed.	Aslantürk and Çetinkaya, 2014
Salmo coruhensis	Fw	30-d	W	LC_{50}, accumulation tissues in the hard and soft water medium	$HgCl_2$	Mercury accumulation in the tissues of the fish treated mercuric chloride at low concentration (0.05 mg/L) were as 0.105 mg/kg in the soft water, while as 0.062 mg/kg in the hard water medium. On the other hand, mercury accumulation in the tissues of the fish treated mercuric chloride at high concentration (0.5 mg/L) were as 0.628 mg/kg in the soft water while as 0.193 mg/kg in the hard water medium. Heavy metal accumulation in the tissues were more in the soft water than the hard water medium and the mercury accumulation in the fish tissues at the high level concentrations of mercuric chloride (0.5 mg/L) in soft water medium exceed to the maximum acceptable mercury value according to Turkish Food Regulations	Verep *et al.*, 2018

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Salmo trutta fario	Fw	7-d	W	Preservative effect of humid acid	Cd	The alterations at the electrolyte levels were analysed at the end of the experiment. The parameters were evaluated according to the species and treatment. The differences at Sodium (Na), Magnesium (Mg), Phosphor (P) and Chlorine (Cl) were not significant for statically at the Calcium (Ca) was not.	Uçar *et al.*, 2012
Salmo trutta fario	Fw	7-d	W	Investigation of humid acid effects versus cadmium toxicity on haematologicalparameters	Cd	At the end of the trial period, change of haematological parameters; haemoglobin, haematocrit, erythrocyte, mean corpuscular haemoglobin (MCH), mean cell volume (MCV) and mean corpuscular haemoglobin concentration (MCHC) were observed. Statistical analyses showed that the differences in all values but RBC, haematocrit, platelet counts, MCV and MCH were important.	Alak *et al.*, 2012
Solea solea	Sw	60-d	W+ weekly renew	LC_{50}	Zn	The levels of Zn accumulated in edible tissues and gills of *S. solea* correlated well to exposure concentrations and the greater the uptake. Significant accumulations were observed in muscle Zn levels at the 0.5 mg/L treatment in comparison to controls.	Baki *et al.*, 2015
Tilapia nilotica	Fw	30-d, 60-d	W + Semi - St	Accumulation in the spleen, brain, and muscle tissues	Cu, Zn and Cu+Zn	No mortality was observed during the exposure to of Cu, Zn and Cu+Zn mixtures over 60 days In both cases (alone and mixture) the highest levels of Zn and Cu were accumulated in the spleen, whereas accumulation was the lowest in the brain. Accumulation of a metal in the tissues decreased in the presence of the other metal.	Karakoç and Kargın, 1999
Tilapia nilotica	Fw	10-d (exposure) 15-d, 30-d (elimination)	W + Semi - St	Interactions during accumulation and elimination	Zn, Cd	The highest level of Cd was observed in the liver, and Zn in the gills. Significant Cd and Zn excretion was seen in the gills, but no significant changes were found in the muscles. Cd excretion was observed in the liver of fish exposed to Cd+Zn, but it was not found in fish exposed only to Cd.	Kargın and Çoğun, 1999
Tilapia nilotica	Fw	30-d	W + Semi - St	Effects of salinity on the accumulation of copper in liver, gill and muscle tissues	Cu	The highest levels of copper were found in the liver and the lowest values in the muscle tissue in a given NaCl and metal concentration. Accumulation of copper in the liver tissue, however, increased with increasing copper concentrations in the medium in all salt concentrations. The increase of the NaCl concentration in the medium, significantly reduced the accumulation of copper in the liver, gill and muscle tissues of *T. nilotica*, at all copper concentrations	Karakoç, 1999

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Tilapia nilotica	Fw	7-d,14-d	W + Semi - St	Effects of copper on the levels of manganese, ıron and zinc in gill and liver tissues	Cu	The element levels of liver tissues were affected from the copper more than those of gill tissues. However, there was a significant statistical difference between the iron levels of gill tissues at 14 day and the zinc level of gill tissues at 7 day under 4 ppm concentration. In conclusion, copper caused an increase on the element levels of manganese, iron and zinc in liver tissues.	Kalay *et al.*, 2003
Tilapia nilotica	Fw	60-d	W + Semi - St	Effect of cadmium accumulation on total protein levels	Cd	Cd accumulation was higher in the gill, liver and kidney tissues. Cd primarily accumulated in liver tissue where metalloproteins (MT) are synthetized, while accumulation in kidney tissue exceeded the liver levels with increasing exposure periods. The total protein levels of the liver and kidney tissues rose with increasing cadmium accumulation. The Cd accumulation and total protein levels decreased, however, on day 60 compared with the previous periods.	Kalay and Erdem, 2003
Tilapia zilli	Fw	10-d (exposure) 30-d (elimination)	W + Semi - St	Elimination of metals	Cu, Zn, Pb, Cd	After a 30-day elimination period, the levels of Cd, Pb and Cu in the gills decreased 21.5, 3.02 and 7.37 times, respectively. Cd and Cu were not eliminated from the liver. On the contrary, the levels increased during the elimination period. Pb was the only metal that was eliminated to a significant extent from the liver. Elimination of the metals also showed considerable differences in terms of both the tissues and the metals. The elimination levels of Cd and Cu from the gills were higher than the elimination level of Pb, while the opposite was true for the liver.	Kalay and Canlı, 2000
Tilapia zilli	Fw	1-d, 7-d, 15-d, 30-d	W + Semi - St	Accumulation in the gill, liver, kidney and brain tissues	Pb	Accumulation of lead in tissues increased with increasing concentrations of Pb in the experimental medium and with increasing time of experiment. The ratios of total Pb in the tissues were 15.47, 6.10, 52.87 and 25.56% in the gill, liver, kidney and brain respectively (Kidney > Brain > Gill > Liver). The high level of Pb accumulation in the kidney tissue may be explained by the fact that this tissue contains Pb combining proteins, and a high level of metal is disposed of with the aid of kidney tissue.	Karataş and Kalay, 2002
Tinca tinca	Fw	96-h	W + Semi - St	LC_{50}	Cu, Zn	The 96 h LC_{50} values for Zn and Cu were found as 20.79 (%95 confidence intervals; 17.39-23.98) ve 1.13 (%95 confidence intervals; 1.06-1.20) mg/L, respectively.	Ergönül and Altındağ, 2011

Table 2. Toxicity test on aquatic invertebrate (Fw: Freshwater; Sw: Seawater; W: Water; Sed: Sediment; St: Static, h: hour; d: day).

Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
CRUSTACEA							
Artemia nauplii	Sw	6-h, 24-h	W	LC_{50}	Sodium lauryl sulfate, Potassium dichromate	Six hours after the exposure of instar I to SLS, LC50 value was observed to be between 75 and 87mg/l.	Toğulga, 1998
Artemia parthenogenetica	Fw	24-h	W	Uptake of heavy metal and ultrastructural changes	Lead acetate	Numerous vesicles of variable size discontinuities of the basal lamina were seen a lot of vesicles cells. The shrinkage in nucleolus and irregular density of chromatin were observed. Degenerated mitochondria dilation of endoplasmic reticulum and cytoplasmic vacuolization were observed. The lead acetate exposure may cause some ultrastructural changes on midgut in *A. parthenogenetica.*	Kutlu *et al.*, 2008
Artemia salina	Sw	24-h, 48-h, 72-h, 96-h	W	LC_{50}	TiO_2 and $AgTiO_2$ NPs	$AgTiO_2$ (43.0 nm) was found to be more toxic to nauplii compared to TiO_2 (44.1 nm). TiO_2 concentrations of 381.60 and 18.77 mg/L resulted in killing of 50 % of the nauplii after shorter (24 h) and longer exposure times (96 h), respectively. LC_{50} values for 24 h and 96 h, the $AgTiO_2$ concentrations were 23.03 and 0.79 mg/L, respectively. Depending on exposure time, $AgTiO_2$ was 17–39 times more toxic than TiO_2.	Ozkan *et al.*, 2016
Artemia salina	Sw	24-h, 48-h, 72-h	W	LC_{50}	NPs (AgNPs) and *Paeonia kesrouanensis*extracts	The survival rate of organisms decreased with increasing b-AgNPs concentration and time. At the end of the 72nd hour, while the survival ratio in the control group was 97%, it was calculated as 91%, 86%, 79%, 73%, 68%, and 63% at 0.2, 1, 5, 10, 25 and 50 mg/L, respectively. The LC50 value of b-AgNPs was found as 102 mg/L.	Unal *et al.*, 2022
Astacus leptodactylus	Fw	24-h, 48-h		acute toxicity and exposure on hemolymph nitrite, total hemocyte counts, hemolymph glucose	Nitrite sodium chloride	The 48-h acute toxicity was within 22-70 mg/L. Environmental chloride (100 mg/L chloride) increased the 48-h toxicity of nitrite to a range of 31-80 mg/L with environmental chloride nitrite exposure did not cause elevation of hemolymph glucose. Hemolymph nitrite accumulation was found to be closely related to the decrease in total hemocyte counts and increase in hemolymph glucose.	Yildiz andBenli, 2004

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Astacus leptodactylus	Fw	21-d	W + St	LC_{50} and accumulation	Cd	The accumulation was found to be 118.33, 661.63, 39.47 and 3.77 mg/L in hepatopancreas> gill> exoskeleton> abdominal muscles, respectively. At the end of the study, it was concluded that the crayfish rapidly eliminated (excreted) cadmium.	Guner, 2010
Astacus leptodactylus	Fw	48-h, 96-h, 7-d, 21-d	W + Semi - St	LC_{50}	Perfluoro octane sulfonate (PFOS)	The 96 h LC_{50} value was determined as 48.81 mg/L (34.19–63.68 mg/L) with Probit analysis. The sublethal experimental design was formed into four groups solvent control (DMSO, dimethyl sulfoxide), non-treated control group, and 1/10 (5 mg/L) and 1/ 100 (0.5 mg/L) of 96 h LC_{50} of PFOS, and crayfish were exposed for 48 h, 7 d, and 21 d under laboratory conditions	Belek *et al*., 2022
Astacus leptodactylus	Fw	96-h	W	LC_{50} and oxidative stress parameters	Fenitrothion	The LC_{50} were 9.45 to 25.01 µg/L. 24-h malondialdehyde (MDA) levels of hepatopancreas decreased at 5,10, and 20µg/L of fenitrothion doses.	Sarıkaya *et al*., 2011
Callinectes sapidus	Sw	30-d	W + Semi - St	Accumulation in tissues and effects on protein and glycogen levels	Cr (IV)	No mortality was observed in the examined species under the influence of the determined time and ambient concentrations of chromium. Chromium accumulation in the examined muscle, gill, liver and hepatopancreas tissues increased due to the increase in the ambient concentration and exposure time of the metal. Total protein level and glycogen level decreased with increasing media concentration and exposure time.	Çiftçi and Cicik, 2011
Daphnia magna	Fw	24-h, 48-h	W	EC_{50}	Malathion	24h EC_{50}; 0.8 for technical malathion and 0.11 for commercial malathion 48 hours EC_{50}; 0.028 ppm for technical malathion, 0.11 and 0.003 ppm for commercial malathion.	Rassoulzadega and Akyurtlaklı, 2002
Daphnia magna	Fw	24-h, 48-h	W	LC_{50}	Chlorpyrifos	According to the toxicity results of water samples 0.01, 0.02, 0.04, 0.06, 0.08, 0.10 and 0.12 µg/L chlorpyrifos, an increase in toxicity reaching 45% was observed as the concentration of chlorpyrifos increased. Toxicity increases especially after 0.06 µg/L concentration, and the immobility percentage of *D. magna* at 0.12 µg/L concentration increases to 15% at the end of 24 hours and up to 45% at the end of 48 hours.	Ekmekyapar *et al*., 2014

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Daphnia magna	Fw	24-h, 48-h, 72 h	W + St	LC_{50}	ZnO NP + $ZnCl_2$	The highest toxicity was found at 72 hours of the mixture (ZnO NP+ZnCl2) and the lowest toxicity was found at 24 hours of $ZnCl_2$. When the overall acute toxicity results were considered, ZnO NP was determined to be more toxic than $ZnCl_2$ and mixtures were determined to be more toxic than these two pollutants alone. When the results of time-dependent acute toxicity were evaluated, toxicity was found to increase with increasing time for all three experimental groups (ZnO NP, $ZnCl_2$ and ZnO NP+$ZnCl_2$).	Ergen, 2017
Daphnia magna	Fw	24-h, 48-h	W	LC_{50}	Propylparaben (PP)	PP concentrations of 100 µM and above were found to be highly toxic to *D. magna*. LC_{50} values were found to be 58 µM and 49.3 µM for 24- and 48-hour exposures, respectively.	Bereketlioğlu, 2021
Daphnia magna & Gammarus komareki	Fw	24-h	W	LC_{50}	Pozzolanic Cement (contained SiO_2, CaO, Al_2O_3, and Fe_2O_3)	The LC_{50} in *D. magna* species was calculated as 118.57 mg/L in 24-h, while in *G. komareki* individuals, it was 197.25 mg/L. The results of the experiment indicated that *D. magna* was more sensitive to cement toxicity than *G. komareki*.	Er and Kayış, 2022
Daphnia magna	Fw	48-h	W	EC_{50} and LD_{50}	Lanthanum oxide nanoparticules (La_2O_3 NP)	No significant toxic effects were observed on *D. magna* at concentrations of 250 mg/L or less, and considerable toxic effects were noted in higher concentrations $EC_{50,}$ 500 mg/L; LD_{50},1000 mg/L.	Balusamy *et al.*, 2015
Daphnia magna	Fw	24-h, 48-h, 72 h	W	EC_{50} and LD_{50}	Triclosan and 2, 4-dichlorophenol	EC_{50} concentration value was 0.2 mg/L and LD_{50} concentration value was 1 mg/L for triclosan treated daphnids in 24 h, respectively. The no observed effect level and low observed effect level were calculated at 1 mg/L and 5 mg/L for 2,4-dichlorophenol, respectively. The EC_{50} and LD_{50} concentration value were 5 mg/L and 10 mg/L for 2,4-dichlorophenol treated daphnids in 24 h.	Taştan *et al*., 2017
Daphnia pulex	Fw	24, 48 h	W	LC_{50}	NaCl	effect of salinity, as observed from the 24- and 48-h LC50 values and survival results. Molecular findings provided antagonism at even lower salt concentrations, for which antagonism was not evident with organismal data. The single effect of increasing salinity resulted in increased mortality, decreased fecundity, and slower somatic growth in Daphnia, despite their acclimation to salinity. Daphnia do not have any physiological mechanisms to buffer the	Bezirci *et al*., 2012

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Species	Habi-tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Diogenes pugilator	Sw	96-h	W + Sed	LC_{50}	Zn, Cu	96-h Zn LC_{50} with sediment; 19 (16.8-21.2) mg/L, without sediment; 6.5 (4.3-7.7) mg/L. 96-h Cu LC_{50} with sediment; 4.1(3.35-4.85) mg/L, without sediment; 2 (1.35-2.35) mg/L.	Bat *et al.*, 1998
Echinogammarus solivii	Sw	96-h	W + St	LC_{50}	Zn, Cu, Pb	96-h LC_{50} is 0.25 mg/L for Cu, 1.30 mg/L for Zn, 0.62 mg/L for Pb. The most toxic metal was copper, followed by lead and then zinc.	Bat *et al.*, 1999a
Gammarus kischineffensis	Fw	48-h, 72-h, 96-h	W + Semi - St	LC_{50}	Imidacloprid and Acetamiprid	The LC_{50} for Acetamipride was 1.687 and 0.517 µ/ L for 72- and 96-h, respectively. The LC_{50} values for Imdacloprid at 48-, 72- and 96-h were determined as 9764.4, 4546.7 and 1560.9 µg/L.	Demirci, 2018
Gammarus pulex	Fw	96-h	W + St	LC_{50}	Cu	LC50 values at 24, 48, 72 and 96 h were calculated to be 0.2, 0.17, 0.12 and 0.1 ppm, respectively.	Güven *et al.*, 1999
Gammarus pulex	Fw	96-h	W + St	LC_{50}	Cu, Zn, Pb	The LC50 values of copper, zinc and lead for *G. pulexpulex* species were found to be between 0.028-0.080, 5.2-12.1 and 11.2 -23.2 mg/L, respectively. The most toxic metal for these species was copper, followed by zinc and then lead.	Bat *et al.*, 2000
Gammarus pulex	Fw	96-h	W	LC_{50} and effect of different temperatures	Cd	LC50 values were found to be; 51.79±1.2 µg/L for 10ºC, 47.67 ± 0.6 µg/L for 14ºC and 33.93±0.6 µg/L for 18ºC. LC50 values were found to decrease due to the increase in temperature.	Serdar *et al.*, 2019
Hyale crassipes	Sw	24-h, 48-h, 72-h, 96-h	W + St	LC_{50}	Cu, Cd, Zn	Cu was more toxic than Cd and Zn for *H. crassipes* and the 96-h LC50 values of Cd and Zn were about 3.83 and 8.87 fold higher than Cu, respectively. Zn was found to be least toxic. Cu was more toxic than Cd and Zn.	Bat *et al.*, 2018
Idotea baltica	Sw	20-d	W + St	LT_{50}	Zn, Cu, Pb	Survival rate decreased with increasing concentrations of Zn, Cu and Pb. Zn has been found to be more toxic than Cu and Pb. The least toxic of these metals tested is Pb.	Bat *et al.*, 1999b
Palaemon adspersus	Sw	4-d, 30-d	W + St	LC_{50} and LT_{50}	Cu, Pb	96 hours LC_{50} Cu: 16c (12-21) mg/L, Pb: 68 (55-74) mg/l. Copper was more toxic than lead for *P. adspersus*,	Bat *et al.*, 2001b

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Palaemon adspersus	Sw	4-d,10-d	W + Sed + St	LC_{50}	Cd	The 96-h LC_{50} value was 0.14 mg/L for Cd. The 10 days bioassays were conducted with nominal concentrations of 0, 0.05, 0.1, 0.5, 1.0, 5.0, 10.0 and 20.0 mg/L for Cd. Mortality increased in parallel with the increase in concentrations of Cd on Zoea – I stage of *P. adspersus* and time of exposure. The toxicity rate of the organism is concentration-dependent. All organisms except the control group died at the end of 10 days. Less than 25% of the animals survived at the 5 days of the exposure to concentrations of 0.5 mg/kg Cd or more. Only 20% of the organisms survived at the 7 days of the exposure to concentrations of 0.1 mg/kg Cd or less in seawater with clean sediment.	Bat *et al*., 2017
Palaemon elegans	Sw	96-h	W + St	LC_{50}	Zn, Cu, Pb	The LC_{50} values of for: Cu: 2.52 mg/L, Zn: 12.3 mg/L, Pb: 5.88 mg/L. The results indicated that Cu was more toxic to the species followed by Pb and Zn.	Bat *et al*., 1999a
Sphaeroma serratum	Sw	96-h	W + St	LC_{50}	Zn, Cu, Pb	The LC_{50} values of for: Cu: 1.98 mg/L, Zn: 6.12 mg/L, Pb: 4.61 mg/L. The results indicated that Cu was more toxic to the species followed by Pb and Zn.	Bat *et al*., 1999a
MOLLUSCA							
Dreissena polymorpha	Fw	24-h, 96-h	W	LC_{50}	Gadolinium	*D. polymorpha* was exposed to three non-lethal Gd concentrations (1/20, 1/10 and 1/5 LC_{50} values) for a period of 24 and 96 hours under controlled conditions. The LC_{50} value was determined to be 332.20 mg/L.	Serdar *et al*., 2021
Mytilus galloprovincialis	Sw	13-d +11-d	W + Semi - St	Accumulation and removal	Cr	Cr (VI); The descending order was gill< muscle< gonad< hepatopancreas< foot < byssus. Cr (III) compounds in various tissues and organs were shown in descending order as mantle< muscle< foot< gonad< gills< hepatopancreas< byssus. these results it can be concluded that accumulation of Cr (VI) was higher than that of Cr (III).	Parlak *et al*., 1999
Mytilus galloprovincialis	Sw	96-h, 28-d	W+ Sed + St + Semi - St	LC_{50}	Cu, Pb, Zn	Survival decreased with increasing concentrations of Cu, Pb and Zn but the survival in seawater with dissolved Cu, Pb and Zn was higher in the presence of sediment than without sediment.	Bat *et al*., 2013

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Physa acuta	Fw	10-d, 20-d, 30-d	W	Histopathological observations, destructive effects in the body tissues	$CuSO_4$	The snails were exposed to different sublethal concentrations of $CuSO_4$ (0.05 mg/L, 0.1 mg/L and 0.2 mg/L) periods of 10, 20 and 30 days. The relationship between $CuSO_4$ concentration and mortality rate in snails was positive (R^2=0.94). The histopathological examinations revealed that $CuSO_4$ caused significant histopathological changes in all the tissues of the snail. The severity of these lesions in tissues increased with increasing $CuSO_4$ concentration and duration of exposure.	Otludil and Ayaz, 2020
Unio crassus	Fw	21-d	W	Accumulation	Pb (II) acetate	The lowest and highest lead II acetate accumulation level on samples are measured 0.013±0.00 mg/kg and 0.119±0.01 mg/kg in the control group, respectively. The lowest and highest lead II acetate accumulation level 0.564±0.01 mg/kg and 1.811±0.01 mg/kg in the second group, respectively. The lowest and highest lead II acetate accumulation level 0.439±0.02 mg/kg and 5.217±0.05 mg/kg in the third group, respectively. At the end of essay, *U. crassus* samples no death was observed.	Kobaza *et al.*, 2021
Unio delicatus	Fw	24-h, 48-h	W	Hemocyte parameters	Cyfluthrin (Pesticide)	Compared to the control group, the total hemocyte counts of the experimental groups were found to increase in 24h and decrease in 48h significantly ($p<0.05$). In the examination of hemocyte morphologies, granular, semi granular, and hyalinocyte cells were observed. Similar values of differential hemocyte counts were found both 24 and 48h exposure times.	Arslan, 2022
Unio elongatuluseucirrus	Fw	1-h, 24-h, 48-h, 72-h, 96-h	W+ Semi - St	LC_{50} (LC_{10-90})	Deltamethrin	The 1, 24, 48, 72 and 96 h LC_{50} values of deltamethrin for freshwater mussels were determined as 10.07, 8.99, 8.09, 7.30 and 6.60 mg/L, respectively. There were significant differences in LC_{10-90} values obtained for different times of exposure.	Köprücü and Şeker, 2008
Unio terminalis	Fw	96-h		LC_{50} and accumulation	Cu	The 96 h LC_{50} value of copper to this species was determined as 4.65 ppm Cu. Total body accumulation of copper were 56 µg Cu/g d.w., 77µg Cu/g d.w. and 28µg Cu/g d.w. for 1.0, 2.0 and 4.0 ppm Cu exposures respectively after 96 hours. Copper levels were significantly higher in animals exposed to copper compared with the control.	Ay *et al.*, 2014

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
POLYCHAETA							
Hediste diversicolor	Sw	10-d, 28-d	W + Sed + St	LC_{50}	Zn, Pb	Mortality increased with increasing concentrations of Zn and Pb. Zn was found to be more toxic than Pb. Small individuals are more sensitive to Zn and Pb than large individuals.	Bat *et al*., 2001a
Ophelia bicornis	Sw	24-h, 48-h, 72-h, 96-h	W + St	LC_{50}	Cd	The LC_{50} values for 24, 48, 72 and 96-h with 95% confidence limits were estimated by the Probit method and were found as 26 (22.8-29.4), 18 (15-22), 12 (9.1-14.4) and 7.2 (6.8-7.5) mg/L for Group 1 (15 and 25 mm in length) and 28 (24.6-33.8), 24 (22.4-25.5), 18 (16.1-19) and 8.7 (7.8-9.6) mg/L for Group 2 (26 and 36 mm in length), respectively. Toxicity of Cd was dependent on concentration and exposure time. LC_{50} increased with increasing the length of organisms. Mortality of *O. bicornis* was increased by Cd concentration and exposure.	Bat *et al*., 2019
INSECTA							
Chironomus thummi	Sw	96-h	Sed + St	LC_{50}	Zn, Cu, Pb	The LC_{50} values of Zn,Cu and Pb were found to be 11.2, 19.1 and 14.3 µg/g, respectively. The most toxic metal for this species was Zn, followed by Pb and Cu. The individual weight of organisms increased with increasing concentrations of Zn, Cu and Pb	Bat and Akbulut, 2001

Mollusca: A total of 8 studies were found on the species belonging to the Mollusca group, which started in 1999 and until 2022 (Table 2). In the studies, 7 different species were used, of which 6 were freshwater and 1 was marine. The most used species was *M. galloprovincialis*, and the most frequently studied species was *Unio* sp. In only one of the studies, water and sediment combined tests were established. Studies were generally carried out with static and semi-static experiments. Chemicals whose effects were examined in the studies; Cr, Cu, Pb, Zn, $CuSO_4$, Pb (II) acetate, gadolinium, cyfluthrin, and deltamethrin. The data obtained as a result of the study, LC_{50}, accumulation and removal, histopathological observations, destructive effects in the body tissues, hemocyte parameters (Table 2). It is pointed out that *Physa acuta* (Otludil and Ayaz, 2020) and*Unio crassus* (Kobaza *et al*., 2021) can be used as an indicator mussel in fresh water since it is sensitive to heavy metal pollution.

Polychaeta: Two studies were conducted in this group. In the studies, *Hediste diversicolor* and *Ophelia bicornis* species were used. The LC_{50} values of Zn, and Pb (Bat *et al*., 2001a) for *H. diversicolor* and Cd (Bat *et al*., 2019) for *O. bicornis* were investigated.

Aquatic Insect: Of the Aquatic insect species, the only studied species is *Chironomus thummi* (Table 2). In this study, LC_{50} value was calculated by using Zn, Cu and Pb metals. The most toxic metal for this species was Zn, followed by Pb and Cu (Bat and Akbulut, 2001).

Toxicity studies on Algae: A total of 11 toxicological studies were conducted on algae in Turkish waters between 2001 and 2021 (Table 3). Of the studies carried out on 8 different species, 5 were on macroalgae and 6 were on microalgae and cyanobacteria. Marine algae were used in 5 studies and freshwater algae in 7 studies (Table 3). The most frequently used species were *Lemna minor* in macroalgae and *Dunaliella tertiolecta* in microalgae. In these studies, IC_{25}(inhibition concentration) SC_{20}metal interaction, toxic effects, effects on growth, biomass inhibition, chlorophylls (a -b), (stimulatory concentration),carotenoid, ascorbic acid (AsA), non-protein SH groups and protein, effect of different pH, salinity, and light intensity on metal uptake were investigated. Al, Cu, Pb, Se, Ni, Cd, Cr, phenol and 13 chlorinated phenols, lanthanum oxide nanoparticles (La_2O_3 NP), Triclosan and 2,4-dichlorophenol and dye were used as toxic substances.

Table 3. Toxicity test on algae (Fw: Freshwater; Sw: Seawater; W: Water; St: Static, h: hour; d: day).

Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Dunaliella tertiolecta	Sw	24-h	W	Metal interaction and the effect of pH	Al, Cu, Pb, Se	The accumulation at pH 6.2 is Pb>Al>Cu>Se, pH 8.2 is Pb>Cu>Al>Se. An antagonistic attitude was observed in the Al-Cu interaction, but no significant difference was observed in the Al-Se and Al-Cu interaction.	Saçan and Balcıoğlu, 2001
Spirulina platensis	Fw	96-h	W + St	Effect on growth	Se	It was observed that the increase in the selenium dose (10 mg/L, 20 mg/L, 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L) studied did not make a significant difference. When the decreasing and increasing biomass and growth stages of *S. platensis* were compared.	Yılmaz *et al*., 2007
Dunaliella tertiolecta	Sw	8-d	W	IC_{25}, SC_{20} in different light density	Dye, Se	At high light intensity (76.8 µE/m^2/s);Dye; IC_{25}:52.01±4.64, SC_{20}:27.12±0.74 ;Dye+Se; IC_{25}:60.11±1.17, SC_{20}:35.15±0.58.At low light intensity (38.4 µE/m^2/s);Dye; IC_{25} 53.05±0.25, SC_{20} 28.13±1.61 ;Dye+Se; IC_{25}:46.87±2.45, SC_{20}:22.55±1.62.	Saçan and Özkovalak, 2007
Dunaliella tertiolecta	Sw	24-h, 48-h, 72-h	W	Growth response, IC_{25}, SC_{20}	Pb, Al	The IC_{25} values of lead are 8.43, 7.29, and 6.74 mg L^{-1} for 24, 48, and 72 h, respectively. The corresponding values for aluminium are 30.54, 22.42, and 18.16 mg L^{-1} .The 24-h SC_{20} values for Pb and Al were 1.27–7.5 and 2.23–24.5 mg L^{-1}, respectively. By increasing the exposure time from 24 to 72 h, the average IC_{25} values decreased significantly from 8.43 to 6.74 mg L^{-1} for Pb and from 30.54 to 18.16 mg L^{-1} for Al.	Saçan *et al*., 2007
Lemna gibba & *Lemna minör*	Fw		W	The effect of different pH values on nickel ptake and chlorophyll content	Ni	It was observed that at high pH value (pH = 7), the amount of kl-*a* and kl-*b* increased with increasing pH. In addition, it was determined that the nickel accumulation capacity of *L. minor* was higher than that of *L. gibba*.	Uruç *et al*., 2008
Elodea canadensis	Fw	5-d	W	Effects of Pb on chlorophylls (*a* -*b*), carotenoid, ascorbic acid (AsA), non-protein SH groups and protein	Pb	Pb accumulation in *E. canadensis* tissues increased with increasing metal concentrations. The increases at 1, 10 and 100 mg/L Pb are about 12.0, 44.6 and 71.1 times greater than control, respectively. Contents of chlorophylls, carotenoid and protein were adversely affected by Pb accumulation. Induction of non-protein SH groups and AsA showed that Pb accumulation caused oxidative stress.	Doğan *et al*., 2009

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Species	Habi -tat	Test Duration	Method	Measured	Toxicants	Results	Reference
Spirodela polyrrhiza	Fw	4-d,10-d	W	Effect of salinity on growth and heavy metal accumulation capacity	Cd, Ni	It was observed that linear growth rate (RGR) of the plant decreased at high salinity level (100-200 mM NaCl). However, it was observed that high salt level caused a decrease in cadmium and nickel accumulation in *S. polyrrhiza*.	Leblebici *et al.*, 2011
Dunaliella tertiolecta	Sw	48-h, 72-h, 96-h	W	IC_{50} and IC_{20}	phenol and 13 chlorinated phenols	The IC_{50} and associated confidence intervals for 48- and 96-h did not overlap, which might suggest that the toxicity of phenol and chlorophenols to *D. tertiolecta* tended to decrease between these durations. Algal adaptation to chlorophenols might have a role in rendering these compounds less toxic at the end of a 96-h exposure compared with a 48-h exposure. Based on the IC_{50} values, the least toxic compound was found to be phenol, whereas the most toxic compound was pentachlorophenol regardless of exposure duration or response variable.	Ertürk and Saçan, 2012
Lemna minör	Fw	24-h, 7-d	W	Growth and biomass inhibition	Cu, Cr and Pb	Relatively low absorption capacity was observed for Cu, increasing concentrations of which were associated with significant decreases in growth rate. The 24 h and 7 days absorption rates of Cu, Pb and Cr, and equilibrium occurs within 24 h of metal exposure were not found statistically significant different.	Üçüncü *et al.*, 2013
Chlorella sp.	Fw	24-h, 72-h	W	Growth	Lanthanum oxide nanoparticules (La_2O_3 NP)	The highest growth was attained in the control culture at 0.133 g/L dry weight of microalgal biomass in 24 h. Nanoparticle concentration at 10 mg/L showed no toxic effects on *Chlorella* sp., as the biomass reached 0.130 g/L. At the 1000 mg/L nanoparticle concentration, the lowest biomass was recorded at 0.057 g/L	Balusamy *et al.*, 2015
Chlorella sp. & *Geitlerinema* sp.	Fw	24-h, 72-h	W	Growth and toxic effects	Triclosan and 2,4-dichlorophenol	*Geitlerinema* sp. and *Chlorella* sp. degraded 82.10% and 92.83% of 3.99 mg/L of triclosan at 10 days, respectively. The microalgal growth inhibition assay confirmed absence of toxic effects of triclosan on *Chlorella* sp., even at higher concentration (50 mg/L) after 72 h exposure.	Taştan *et al.*, 2017
Lemna minor	Fw	7-d	W	combined toxic effects of metals on growth inhibition (estimation with model)	Cu, Cd	The models of all test groups were examined, it is possible to say about a general inhibition trend (except for Cd concentrations of 0.2 and 1.6 mg L-1). It has been determined that cubic models give better results than linear and quadratic models and generally form the models closest to the actual inhibition values.	Ustaoğlu *et al.*, 2021

CONCLUSION

The aim of aquatic toxicity studies is to evaluate the potential harmful effects of chemicals on aquatic organisms and ecosystems. These studies are typically conducted to assess the potential toxicity of chemicals that may enter aquatic environments through a variety of sources, such as industrial discharges, agricultural runoff, or natural weathering of rocks and minerals. The results of aquatic toxicity studies can provide valuable information about the potential impacts of these chemicals on aquatic life and can help inform decisions about their use and regulation to protect aquatic ecosystems. The future of toxicity studies is likely to continue to be shaped by the ecotoxicological approach. As our understanding of the complex interactions between chemicals and the environment grows, toxicity studies are likely to become more holistic and integrated and will focus on understanding the potential impacts of chemicals on the overall health and functioning of ecosystems. Additionally, as concerns about the impacts of chemicals on human health and the environment continue to grow, toxicity studies are likely to play an increasingly important role in informing decisions about the use and regulation of chemicals to protect the ecosystem and human health.

Aquatic toxicity experiments have a long history, with the first recorded studies dating back to the early 20th century. These experiments have played a critical role in our understanding of the impacts of toxicants on aquatic ecosystems and the species that depend on them. In the past, aquatic toxicity experiments were often focused on testing the effects of individual toxicants on aquatic organisms. These studies helped to identify the toxic effects of various substances and to establish safe levels of exposure for aquatic species. In recent years, there has been a shift towards more realistic and integrated approaches to aquatic toxicity testing. These approaches often involve testing the effects of multiple toxicants simultaneously or assessing the impacts of toxicants in the context of other stressors, such as climate change or habitat degradation. Looking to the future it is likely that aquatic toxicity experiments will continue to evolve and incorporate new technologies and approaches. For example, there is increasing interest in using computational modelling and machine learning techniques to predict the impacts of toxicants on aquatic organisms, which could help to reduce the need for animal testing.

There are several areas of research in aquatic toxicology that are likely to continue to be important in the future. These include:

Climate change and toxicant exposure: Climate change is likely to affect the distribution and fate of toxicants in aquatic environments. Research is needed to understand the impacts of these changes on aquatic organisms.

Effects of emerging contaminants: There is increasing concern about the impacts of emerging contaminants, such as microplastics, nanomaterials, and pharmaceuticals, on aquatic ecosystems. Research is needed to understand the fate and effects of these substances in the environment.

Ecotoxicogenomics: This is the study of the genetic basis for the sensitivity of aquatic organisms to toxicants. This research can help to identify the mechanisms behind toxicant effects and may help to predict the impacts of toxicants on different species.

Restoration and remediation: Aquatic toxicologists may be involved in efforts to restore damaged aquatic ecosystems or to clean up contaminated sites. This research

could involve developing new methods for removing toxicants from the environment or studying the long-term effects of remediation efforts.

Studies on microplastics accumulating in water, sediment, and biota, which are aquatic ecosystem elements, are increasing day by day. Microplastics have started to be used in aquatic toxicity studies and only two studies have been found in Türkiye (Jovanović *et al*., 2018; Aytan *et al*., 2022). However, it is inevitable that these studies will increase very rapidly in the future. Because microplastics are a major concern in aquatic toxicology due to their potential impacts on aquatic organisms. Aquatic toxicity studies with microplastics are typically conducted to understand the potential impacts of these particles on aquatic organisms. These studies may involve exposing aquatic organisms, such as fish or invertebrates, to different concentrations of microplastics and then measuring any changes in the organisms' physiology, behaviour, or survival. Some of the key questions that aquatic toxicity studies with microplastics may aim to address include:

How do microplastics affect the growth, development, and survival of aquatic organisms?

How do different types and sizes of microplastics affect aquatic organisms differently?

How can the impacts of microplastics on aquatic ecosystems be mitigated or managed?

What are the mechanisms behind the toxic effects of microplastics on aquatic organisms?

What is the environmental fate of microplastics in aquatic ecosystems, and how do they interact with other pollutants or toxicants?

Overall, the future of aquatic toxicology will likely involve a combination of basic and applied research, as well as efforts to translate this research into effective policies and practices that can protect aquatic ecosystems and the species that depend on them. Institutions and organizations involved in aquatic toxicity studies may also be responsible for advising policymakers and regulators on the potential effects of chemicals on aquatic life and ecosystems. This can involve providing information and expert advice on the results of aquatic toxicity studies, as well as making recommendations for the use and regulation of chemicals.

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