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**Review Article**

# Sources and Toxicological impacts of Surface Water Pollution on Fish in Egypt

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## Abstract

Egypt has been listed as one of the most popular nations which are menaced through lack of water by the year 2025 due to overpopulation. The great deposition of highly polluted domestic and industrial effluents into its water ways, made a continuous and prompt damage to its surface and groundwater. The River Nile represents about 97% of Egypt's water resources; however winter rain and nonrenewable groundwater aquifers are also comprised. In Egypt, the main source of pollution is industrial wastes that are poured directly into the main water sources or through the municipal system. On the other hand, the pollution of the Mediterranean coast of Alexandria is mainly due to the discharge of wastes of industrial plants into the sea via Lake Marriott. The provincial populations have little or even no entry to drainage systems or wastewater treatment facilities and they rely only on theelimination of wastewater at the site of their production or collection. In the Delta region, drainage water is reused for irrigation after mixing with Nile water, while in Upper Egypt drainage water is disposed into the River Nile. Fertilizers and pesticides have been used on a wide range after the constructions of High Dam which resulted in weed flourishing which blocks the waterways, and provides habitats for Bilharzia snails. Egyptian fish aquaria exposed to toxicity due to water pollution from chemical plants and sewage pipes. Heavy metal pollution of Egyptian water is primarily produced by industrial and agricultural discharges. Other sources also include: coal and oil combustion, phosphate fertilizers, plastics and pesticides. Recently, the consumption of contaminated fish has been the possible cause of heavy metal poisoning in human. The aim of this review is to disclose the fundamental origin of water pollution in Egypt, and to elucidate the side effects of this pollution on fish.

**Key words:** Water pollution, Pesticides, Heavy metals, Fish, Egyptian water resources.

## Introduction

Water is the key component to life existence as well as sustained nations and societies, as all activities of human beings depend on water, such as agriculture, industry, domestic and recreational activities, etc. [1]. Unfortunately, it is proposed that by 2025, 2.7 billion humans will be facing water scarcity globally [2], which might be a threat to the existence of life on earth. This subsequently renders the conservation of water and elimination of water polluting sources on a priority basis. The requirements of water have been increased owing to the industrialization and expanding populations. The additional supply is commonly fulfilled by the well water or nearest available surface water. It may lead to incomplete treatment and substandard supply of drinking water [3].

Water pollution refers to changing of the chemical and physical characteristics of water from a beneficial state to one that is hazardous to organisms depending on water for their well-being [4]. Globally, industrial waste water represents the principal source of water pollution. The Uprising increase in modern industries, agriculture urbanization, tourism and human activities are the main sources for chemical pollution to both, aquatic environment and its coexisting ecosystems [5]. The developing countries are facing severe

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environmental deterioration which continuously polluting water [6]. This might be due to natural activities including floods, sliding of mud, or volcanoes, but most of the activities contributing to water pollution are anthropogenic in nature, rendering water unusable [7].

Water pollution in Egypt is mainly due to the chemical and industrial processes. Because of discharging the industrial effluents and animal wastes into streams and rivers by factories and manufacturers in Egypt, several environmental and health problems were developed. Heavy metals have great awareness due to their accumulation, toxicity [8] and bio magnification [9] in the aquatic ecosystems**.**

Water pollution is categorized into a wide range of sources, including pesticides, organic waste products, fertilizers, heavy metals, and habitat modification.

## 1. Pesticides

### 1.1 Pesticides and water pollution

The term pesticide is a complex expression used for those chemicals used to resist, mitigate, deter, repel, prevent and destroy pests [10-11]. Air, water, and soil are contaminated with pesticides which may be due to its application in all the three media such as their direct application for controlling vectors, agricultural weeds, as well as aquatic flora. The accumulation of pesticides in soil and water is due to their escape with drainage, leakage via soil and transportation via air [12-14].

Pesticides cause several impacts of on water and those are related to the main ingredient and the existed impurities in the pesticide formulation. Furthermore, the added ingredients which are mixed with the main principal chemical compound (extenders, wetting agents, preservatives, diluents, emulsifiers, buffers, or solvents and adhesives), that is formed during microbial or photochemical degradation of the active ingredient [4].

### 1.2 Negative impacts of water pollution by pesticides creates negative impacts

#### 1.2.1 Residues of pesticides in water

Pesticide residues are believed to be the key component of pollution [15]. All over the world, many types of pesticides are employed to cope with various pests and are designed in different ratios as herbicides (15%), fungicides (1.46%) and insecticides (80%) [11].

Pesticides lead to water bodies mainly through sediments (inorganic substrate), Algae, hydrophytes, and vascular branches or litter and moss (organic substances) [14- 16]. Pesticides can be cycled among different media such as water, non-target plants, and animals, wetlands, atmosphere and soil [17-19]. In water bodies, pesticides are found in higher concentration in stationary water while in sediments with negligible levels. The pesticides present in the water bodies pose a serious threat to the lives of aquatic organisms, as well as alter their regular life activities such as swimming, fitness, and species to species interaction [20].

Organochlorine compounds (OCPs) were found in high concentrations in about23 sediment specimens gathered from Alexandria Harbor, Egypt as persistent concentrations. The authors found that polychlorinated biphenyls (PCBs) concentrations ranged from 0.9 to 1210 ng/g with 4 to 7 Cl-substituted biphenyls being the most prevalent PCBs congeners [21].

In a study about the levels of Organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) samples that were estimated in sediment gathered from 34 locations in Lake Qarun, Egypt. The study concluded that ɤ-HCH, endrin and chlordanes would be more concerned OCP species for the ecotoxicological risk in Lake Qarun [22].

Many authors estimated the distribution pattern of organochlorine residues in the Mediterranean Sea water (Egypt). They found that the concentration of total OCPs in surface sediments ranged from 0.11 to 50.73 with a mean of 14.52 ng/g dry weight [23].

In a recent study, it was found that HCHs, cyclodienes, DDTs, PCB concentrations in sediments of the Red Sea coast, Egypt were much lower than those recorded by the international organization [24].

### 1.2.2. Impacts of pesticides on marine life

### 1.2.2. a. Impacts on fish behavior

The survival of fish communities is indirectly affected by altering the plankton communities, which is a food source for different species of fish [25]. The presence of pesticides in water bodies altered the fish behavior [26]. Pesticides render the fish habitat unsuitable and adversely affect their escape behavior and locomotion, hence expose them to predators [27]. Pesticides also affect the predations/competition and life history of different fish taxa [28-29]. These indirect effects are considered as more severe and dangerous for the fish population than direct ones [30].

Sub-lethal concentrations of pesticides lead to diverse effects in fish. These changes may be in the behavior of the fish like disrupted schooling behavior, equilibrium loss, jerky movements, color change, erratic swimming, adapting vertical position, bottom sinking, jumping, motionlessness, sluggishness, hyper or hypo-excitability and increase in opercular beats, etc. These behavioral changes are observed in different fish species including *Cirrhinusmrigala, Channapunctatus, Clariasbatrachus, Labeorohita, Oreochromis mossambicus, Torputitora, Cyprinuscarpio,* and *Catlacatla* etc. [31-38]. Pesticides exposure also alters the swimming speed and growth of the fish.

### 1.2.2. b. Impacts on fish reproduction

So far, scientific literature has evidenced toxicological influence in the form of reproductive abnormalities among various living beings. For example, pesticide exposure led to reproductive dysfunction in *Salmosalar*, *Salmotrutta* and *Mystusvitattus* [39-40], and reduced fertility in *Pseudosidaramose*. The Physiological disturbance is also observed in some fish species [41]. Different studies also revealed the developmental toxicological effects of pesticides in fish [42-43]. Pesticides including dichlorvos, diazinon, carbufuran, endosulfan, and malathion, atrazine, and deltamethrin led to pathological toxicity in different organs of the fish including gills, kidney, liver, and muscles.

The pathological effects were necrosis, orientation loss of plates, cytoplasm granularity, cells shrinkage, oocytes increase, damage to collecting duct, follicular cells degeneration, nuclear materials shrinkage, vacuolation, change in the size of tubular line, nuclear pycnotic alterations, glomerulus degeneration, and rupturing of epithelial lining in *Glossogobiusgiuris*, *Gambusiaaffinis*, *L. rohita*, *Corydoraspaleatus*, *Lepomismacrochirus*, *C. carpiocommunis*, *C. punctatus*, *O. niloticus*, *C. mrigala*, *Aphaniusdispar*, *Glossogobiusgiuris*, *Macrobrachium malcolmsonii*, *O. mossambicus* and *Heteropneustes fossilis* [44-54].

### 1.2.2. C. Impacts on fish hematology

Hematological effects including anemias, neutropenia, lymphocytopenia, decreased R.B.Cs. count, etc., of blood parameters related to pesticide toxicity were observed in *T. putitora*, *O. niloticus*, *O. mossambicus*, *C. punctatus*, *C. batrachus*, *C. carpio*, *Puntiusticto* and *Onchorhynchusmykiss* [55 – 66].

### 1.2.2. d. Impacts on fish enzymes

Exposure to pesticides led to changes in the activities of different enzymes such as citrate synthase (CS), glucose 6-phosphate phosphate dehydrogenase (G6-PDH), lactate dehydrogenase (LDH), L-Keto acid glutaminaseand in the brain, gills, liver and muscles of *C. batrachus* and *L. rohita* [67-70]. Pesticide exposure led to AChE (acetylcholine esterase) inhibition in different fish species including *O. massambicus*, *L. rohita*, *C. carpio*, and *Leporinuso btusidens*, *Jenynsia multidentata* and *Odontesthes hatcheri* etc., leading to neurotoxicity [71-73]. Pesticide exposure altered the feeding biology of *Puntius stigma*, and *Oryzias carnaticus* [74-75], as well as led to endocrine disruption in *O. mykiss* and *L. rohita* [76- 77].

Pesticides altered the activities of different enzymes of the antioxidant enzyme system including glutathione-s-transferase, glutathione reductase, superoxide dismutase, lipid peroxidase, peroxidase and catalase in *T. Putitora*, *C. gariepinus*, *L. macrochirus*, *Hoplias malabaricus*, *O. niloticus*,*L. rohita*, *O. hatcheri and J. multidentata* [78-84].

Pesticides exposure led to immunotoxicity in some fish species by reducing the phagocytosis, the number of granulocytes, lymphocytes, and leukocytes, inhibiting proliferation of B, T and screening cells (antibody) and ultimately decreasing the resistance of fish to infections and diseases **[85-90].** Exposure to pesticides led to changes in proximate composition of C. *carpio, H. fossilis, C. gariepinus, Colisafasciatus, C. batrachus, O. niloticus, Puntiusticto*, and *L. rohita* via increase in cholesterol and ascorbic acid or decrease in protein, albumin and glycogen [91-99].

### 1.2.2. e. Genotoxic impact of pesticides in fish

Pesticides exposure led to genotoxicity in *L. rohita*, *C. mrigala* and *C. auratus* [100-101]. Pesticide exposure induced carcinogenic, mutagenic and genotoxic effects in fish and altered the genetic material like mediation of centromeric gaps, attenuations, stubbed arms of chromosomes, extra fragments, pycnosis, chromatid breaks and gaps, etc., consequent alteration of DNA replication, ultimately leading to cell proliferation and mutations [102].

## 2. Heavy metals

Heavy metal pollution sources of Egyptian water are mainly the agriculture drainage, sewage disposal, pesticides in water and industrial effluents and fertilizers **[103-104]**. Heavy metals are frequently released from human- made activities and natural sources into the aquatic ecosystems and accumulated in fish which situated at the top of the food chain and can accumulate large amounts of heavy metals [105].

To our knowledge, heavy metals delivered many unfavorable health effects. However, the vulnerability to heavy metal is common and persistent and even increasing in some parts of the world, mostly in rural districts. Metals are divided into two major classes: the first one is the essentials that function a proper role inside the body, while others like lead, cadmium and arsenic are not essentials and may be toxic [106].

### 2.1. Heavy metals and water pollution

Industrial effluents and metal industry constitute a real threat to the aquatic ecosystems. It represents about 50% of the total waste discharges and [107]. Serious concerns were found due to the presence of heavy metals in waterproducing serious influences on plant and animal life. Lead, cadmium and many other elements cause extreme toxicity at even trace levels [108]. Recent studies have shown that the natural habitat of fish and other marine organism which is exposed to human activities are under ecological pressure [109].

Taken into consideration, fish are the most susceptible organisms in the aquatic ecosystem to toxic substances that is accumulated in water [110]. Fish usually accumulate heavy metals in their bodies either directly through daily water consumption or through the gills, skin, and digestive tract [111]. Eventually, human health is exposed to risk through fish intake as fish is a main ingredientin human food**[112]**. Therefore, heavy metals accumulation in water and eventually fish has been a great worldwide problem; not only due to bad fish health concerns, but also due to the human health risks associated with fish consumption [113].

**Water pollution by heavy metals creates negative impacts as follows:**

### 2.1.1. Residues of heavy metals in water

In the aquatic ecosystem, heavy metals are the most important form of pollution due to their bioaccumulation by marine organisms [114]. The metabolic processes inside the living body usually need some trace elements, which are assimilated by marine organisms. Although, these living organisms form complexes with organic substances that can result in concentrations up to 1000 times higher than their assimilation and fixation in tissues and so, these metals become toxic to organisms [115].

In the aquatic ecosystem, water, suspended solids, sediments and biota are the main environmental components where trace elements are divided [116]. Sediment contamination is considered the major environmental problems in ecosystems. The pollution status of the environment is properly assessed through sediment analysis [117]. Generally, the variations in metals concentration in water are depending on several factors as climate, soil type, pH, redox potential and dilution capacity [118].

A previous study analyzed the most environmental metals including; Pb, Cd, Ni, Co, Cu, and Zn in twenty five samples which were collected from both water and surficial bottom sediments of El-Manzala Lake. The study displayed that Cd caused a serious pollution due to the massive use of phosphate fertilizers. The mean Cd content in the area of the study was 17.5 ppm, which is about 36 fold the Maximum Permissible Limit (MPL=0.5 ppm) of soil. The major concentration of Cd is 22.3 ppm, which is more than 45 fold the MPL. Cadmium is more mobile in aquatic environments than most other heavy metals. The areas around Port Said and El-Serw drain show marked pollution by most of the studied heavy metals. The main reason for such pollution is the industrial activities and agricultural drains [119].

The main origin of Ni pollution in water was evaluated. Domestic wastewater effluents were found to be the major source, where, the drinking water and acidic beverages may dissolve Ni from pipes. Also, the advancement in industrialization progress increases the Ni discharge into the environment, where many nickel compounds are introduced in the commercialand industrial uses. It was found that water samples was greater than the authorized concentration for drinking water (20 µg $L^{-1}$) in the studied human- made activities impact points and reached 33.1 µg $L^{-1}$ at the River Nile [120].

Iron concentration in fresh water was estimated [121]. The study concluded that iron concentration in water is managed by flow and redox conditions, the type and amount of dissolved organic matter and water pH. The results of the study deduced that Fe concentrations overstepped the aquatic life guidelines [122] where the anthropogenic activities in the Nile River have led to high concentrations of iron into its streams.

The water quality in El-Max fish farm was evaluated [123]. The results depicted the strong association between Zn and Cd in fish farm water. The highest concentration of heavy metals Cd and Zn exerted adverse biological effects.

### 2.1.2. Impacts of heavy metals on marine life

Heavy metals can affect negatively on the growth rates, physiological functions, mortality and reproduction in fish [124].

### 2.1.3. a. Impacts on fish growth

Growth and maturation of fish larvae and juveniles is very fast. In the water polluted with heavy metals, fish growth may be inhibited. Inhibition of growth is one of the most distinct symptoms of metal toxicity on fish larvae. Therefore, environmental pollution is indicated by fish body length and mass [125].

### 2.1.2. b. Impacts on fish behavior

The data of many authors indicated that heavy metals reduce survival and growth of fish larvae [126-127]. Also, behavioral abnormalities such as impaired locomotors attitude resulting in increased susceptibility to predators were evident [128]. Also, fish behaviors may be changed by some heavy metals like Zinc (Zn). The main identified changes due to Zn include balance disorders, confused swimming, air guzzling, periods of dormancy and death [126].

Behavioral abnormalities like loss of equilibrium, jerky body movements, rolling, mucous secretion over the body, rapid opercular movements, difficulty in breathing and lethargic hyperactivity, erratic swimming, swallowing of air, rotations, convulsions and accelerated ventilation with rapid arrhythmic mouth movements after the exposure to several elements( Cd, Pb, Hg, Cu) in various fish species as *Tilapia mossambica*, *Eutroplusmaculatus*, *Salvalinusfontinallis*, *Salmogairdneri*, and *Clariasbatrachus*[127-131].

### 2.1.2. c. Impacts on fish reproduction

It is well established that many chemicals, both natural and man-made, may adversely affect wildlife, including decrease in fertility, disrupted hormone secretion or reproductive histopathology. Damaged ovarian follicles were observed in female mussels exposed to tetrabromodiphenyl ether [132].

A reduced gonad size with delayed sexual maturity in perch exposed to leachate from Swedish refuse dumps. Also, ovarian growth inhibition, reduction of egg weight and increased atresia, were depicted in white perch in areas polluted with domestic and industrial effluents. The discrimination of gonads and development of salmon were affected by sewage effluents [133]. Fish living in Bizerta lagoon, downstream of anthropogenic pollution have been found to exhibit an array of altered features in their reproductive development, including sperm abnormality and ovarian atresia [134].

The impact of diluted levels of polluted seawater from the Egyptian Mediterranean coast on reproductive, toxicological and hematological characteristics of *Siganus rivulatus* was investigated. Contaminated water has a harmful effect on gonads differentiation, changed endocrine haemostasis, and testosterone and progesterone levels reduction in females. While in male, progesterone level increased. Necrosis of spermatogenic cells and atresia of developing oocytes are pronounced at levels of 10 and 15 ml $L^{-1}$ polluted seawater [135].

### 2.1.2. d. Impacts on fish hemopoietic system

The damage and changes of the hemopoietic system of fish is mainly due to water- borne pollutants [136]. Several previous studies [137-139] investigated the sub- lethal effect of some heavy metals (Pb, Cd, and Cu) on *Siganusrivulatus*. The results were concluded in some changes in the morphology of the R.B.Cs such as tear drop- like cells, acanthocytes, and sickle cells. [140] found that R.B.Cs of *Clariaslazera* poisoned with lead were deteriorated, as clumping of chromatin material and disintegration of their cellular and nuclear membrane. It was examined that the exposure of Indian carp *Caltacalt*a to copper [141]. The results were concluding in shrinkage of the configuration of the red blood cells with slight anisocytosis and an inclination to overlap. It was found that upon the exposure of *Tilapia nilotica*to sub-lethal concentration of copper resulted in significant increase in erythrocyte count and haemoglobin content was observed [142].

### 2.1.2. e. Impacts on fish musculature

The tissue of greatest concern regarding heavy metal accumulation, from human standpoint, is the musculature. Most of the heavy metals bio- accumulates poorly in fish musculature only in the heavily contaminated environment [143].

the influence of the heavy metal pollution in the Lake Mariuot on some musculature biochemical constituents of *Oreochromis niloticus* fish was studied [143]. The study results showed a significant elevation in the lead, cadmium, copper, zinc and iron levels in musculature comparing with reference fish collected from a relatively clean aquaculture. The fish musculature protein, lipid, calcium, phosphorus and the amino acids, methionine, lysine and cystine concentrations were significantly decreased**.** The accumulation of heavy metals in *Oreochromisniloticus* fish followed the order: Mn>Zn>Pb>Cu. The highest levels of the heavy metals were found in the intestine and the lowest was found in the muscles [144]. Cu concentrations in the muscle of fish were below the maximum permissible limit, however, Mn, Pb and Zn exceeded the permissible limits. Total proteins, total lipids and activities of ALT and AST were significantly lower in the muscles of the studied fish from the River Nile in Egypt.

### 2.1.2. f. Impacts on immune system of fish

Phagocyte activity of fish macrophages has been inhibited by Lead, mercury and cadmium and so the cell mediated immune response has been an inhibited. The humoral immune response also affected due to these metals which is manifested by low levels of antibodies and high mortality rates in fish exposed to these metals than in the control fish after experimental infection by *Pseudomonas flourscens*. Immune response by these metals provides opportunities for the entry of pathogens and developing of many diseases in fish [145]. Heavy metals take great attention and special importance due to their increased toxic effects on fish as they affect live, growth, development and reproduction [145-146].

There was significant ($P < 0.01$) difference in WBCs of fish collected from the different studied sites along Borollus Lake. Moreover, fish collected from the western and eastern sites of the lake had a significant increase in WBCs count, than that of fish collected from El-Boughaz opening. The reported leukocytosis in this study may be due to elevated leukocyte mobilization to conserve the body against infections in metals-affected tissue [147]. The elevation in the number of WBCs of fish was suggested to be due to alteration in defense mechanism to manage the highly toxic and the bioaccumulated heavy metals in fish organs as reported by [148-151].

**2.1.2. f. Impacts on fish antioxidant enzymes**

Heavy metals are recognized to decrease the antioxidant enzymes activities of (e.g. superoxide dismutase, Catalase**)** [152]. Heavy metal give rise to oxidative stress that is manifested by redox cycling and interaction with organic pollutants contribute to from aquatic pollution. Oxidative stress has been identified as a causative agent in a number of pathologies in fish resulting from reactive oxygen species (ROS) [153]. Oxidative stress occurs as a conclusion of excessive reactive oxygen species (ROS) and nitrogen species (RNS) release and it is improved by endogenous antioxidant enzyme activity and exogenous dietary antioxidants [154]. Cells that manage oxidative stress show many alterations due to the effect of ROS on serious structures in the body (lipids, proteins and DNA) [155]. Oxidative stress resulted from pollutants is usually manifested by elevated levels of lipid peroxides (LPO) (products of oxidative damage) and Malonaldehyde (MDA) and subsequent increase in defense enzymes (GSH, SOD activity and CAT ase) in response to the stress [156]or decrease due to overwhelming effect of the pollutants [157].Nitric oxide is a highly unique and ubiquitous signaling molecule which is known to play variable physiological functions including those of adaptation to various stresses. Metal bioaccumulation is found to be in the same line with increased LPO and MDA levels and certain biomarkers of oxidative stress as surrogate bio-indicators of aquatic pollution in *Clarias gariepinus* [158].

**Conclusion**

This review highlights the causes and consequences of the water sources contamination on fish organs in Egypt. There was a strong evidence of a correlation between water contaminants in different fish tissue and those of the surface water of the polluted areas**.** All the aforementioned sources of pollution affect the physicochemical characteristics of the water, sediments and biological components, thus negatively affecting the quality and quantity of fish stocks.

**Conflict of interest**

The authors have no conflict of interest to declare.

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**الملخص العربي**

**المصادر والتأثيرات السمية للتلوث السطحي للمياه على الأسماك في مصر**

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تم تصنيف مصر كواحدة من أكثر البلدان التي يهددها نقص المياه بحلول عام ٢٠٢٥ بسبب الزيادة السكانية. أدى الترسب الكبير للنفايات السائلة المنزلية والصناعية الملوثة في المياه إلى إلحاق ضرر مستمر وسريع بسطحها ومياهها الجوفية. في مصر ، المصدر الرئيسي للتلوث هو النفايات الصناعية ، حيث يتم تصريفها مباشرة في النيل أو من خلال النظام البلدي. من ناحية أخرى ، فإن تلوث البحر الأبيض المتوسط في الإسكندرية يرجع أساسا إلى المصانع الصناعية التي تصرف مياه الصرف الصحي في البحر عن طريق بحيرة ماريوت. كما ان سكان الأرياف لا يتمتعون بإمكانية الوصول إلى شبكات الصرف الصحي أو مرافق معالجة المياه العامة ، بل إنهم لا يحصلون عليها ، ولا يعتمدون إلا على التخلص من المياه المستعملة في نهر النيل في منطقة الدلتا ، يتم إعادة استخدام مياه الصرف للري بعد مزجها بمياه النيل و بعد إنشاء السد العالي ، تم استخدام الأسمدة والمبيدات الحشرية على نطاق واسع مما أدى إلى ازدهار الأعشاب الضارة التي تمنع الممرات المائية ، وتوفر عوائل لقواقع البلهارسيا. تتعرض الأسماك للسمية بسبب تلوث المياه من المصانع الكيماوية وأنابيب الصرف الصحي. وتتمثل المصادر الرئيسية لتلوث المياه المعادن الثقيلة و حرق الفحم والنفط وأسمدة الفوسفات واللدائن ومبيدات الآفات التي يتم القاءها في مياه الانهار والبحار و في الآونة الأخيرة ، لوحظت مخاطر محتملة لتسمم المعادن الثقيلة في الإنسان بسبب استهلاك الأسماك الملوثة