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A mini-review on Pollution of water resources: causes and consequences

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Abstract

Water is an indispensable resource for the continuation of life on planet earth and is one of the major challenges of the 21st century. However, it is threatened daily by pollution of all kinds. In order to better understand the issues related to water pollution, several points have been developed in this mini review article (definition of water pollution, distribution and importance of water, different types of water pollution, their origins and consequences).

Keywords: Water pollution, micropollutants,

1. Introduction

By pollution of surface watersit means the harmful alteration of water caused by the addition of substances that can change its quality, aesthetic appearance and use for human purposes (Sharma and Bhattacharya, 2016). According to Chaouki (2017), water pollution can be considered to be anyunfavourable modification of physical, chemical or biological properties, or any discharge of liquid, gaseous or solid substances into water in such a way as to create a nuisance or make the water unsafe for use.This degradation of water quality can affect not only human health but also the health of aquatic or terrestrial ecosystems directly dependent on aquatic ecosystems or lead to damage to physical assets (Yagouba, 2005). In fact, disturbances to aquatic ecosystems due to pollution affect the viability of aquatic biodiversity. The literature indicates that pollution of aquatic resources can lead to various types of nuisance: increasing the mortality of certain animal or plant species to the point of sometimes causing them to disappear, or altering their physiological capacities (Yenny, 2012; Yagouba, 2005).

In addition, the use of polluted water can be the cause of the high prevalence of water and water-borne diseases (dysentery, typhoid, cholera, skin diseases such as scabies, etc.) in humans. Some authors have reported that mortality related to polluted water is very high, especially among children. Furthermore, toxic substances contained in polluted water can be stored by cultivated plants of which subsequent consumption can cause digestive diseases, liver and kidney damages (Kambole, 2003; Key et al., 2004; Pritchard et al., 2008; Atibu et al., 2013; Mubedi et al., 2013; Tshibanda et al., 2014).Notwithstanding the ecological and health effects, water pollution can have economic and social effects: reduction in the quantity of usable water resources, increase in the cost of treatment for drinking water purification or of water transport when more distant resources have to be used, slowing down the industrial progress knowing that industrial activities require good quality water, hindering the exploitation of aquatic environments for leisure or fish farming activities, alteration of the quality of life due to the depreciation of the polluted site, contamination of agricultural products, etc. (Yagouba, 2005).

Today, many water resources are polluted. Estimates show that just over half of the world's freshwater reserves are polluted and this situation is explained by several factors like demographic growth, urbanization, industrial and agricultural development. Contrary to the developed world where surface waters are relatively well conserved (implementation of treatment systems), surface waters in developing countries are the receptacle of various types of anthropogenic pollutants such as organic waste, toxic metals, pathogenic or antimicrobial resistant bacteria, untreated effluents resulting from industrial, agricultural and urban activities. (Tshibanda et al., 2014; Wanga et al., 2015; Laffite et al., 2016).

According to Laffite et al. (2016), rivers and lakes in developing countries are reservoirs of different types of pollutants (medical products, metals, resistance genes, antibiotic-resistant bacteria) that are discharged into water ecosystems via hospital, agricultural, municipal and urban effluents. Other sources indicate that 95% of domestic wastewater and more than 75% of industrial discharges end up in surface and groundwater in developing countries.In view of the increasing pollution of the world's water reserves, the control and monitoring of the quality of surface and groundwater is of particular interest in order to preserve the health of the population and ecosystems as well as the safety of the biodiversity (Ouali et al., 2010).

The purpose of this review is to identify data highlighting the distribution of water around the world, the importance of this vital resource, and the causes and effects of water pollution on the environment and human health. This scientific information is useful for scientists, organizations or stakeholdersworking in the field of water chemistry and microbiology, health or the environment.

2. Distribution of water around the globe: importance

In order to understand the impact of surface water pollution, it should first be noted that the distribution of these resources on a global scale, their role in socio-economic development and in the functioning of ecosystems.

In fact, water is the most precious natural resource on our planet because without it, life on earth would not be possible. Surface water represents about 3/4 of the earth's surface and includes oceans, seas, lakes, rivers, etc. Sea water, which accounts for about 97% of all the world's water supply, is salty and undrinkable. Drinking water (lakes, rivers, etc.), on the other hand, is a scarce resource and represents only 2.8% of the world's total water. The majority of freshwater reserves are located in the polar regions in the form of ice (2.15%), in the underground with groundwater (0.63%) and in lakes, rivers as well as streams (0.019%). The lowest percentage of freshwater is found in the atmosphere (only 0.001%) (Belghiti et al., 2013). This predicts that the amount of freshwater that humans can easily retrieve is therefore extremely low since it is very expensive to make freshwater from seawater (seawater desalination) (Belghiti et al., 2013).

Several authors reported that freshwater ecosystems are natural compartments necessary for the continuity of life and are essential for various activities such as municipal drinking water supply, industry, agriculture, recreation, etc. (Belghiti et al., 2013). They are therefore indispensable for socio-economic development, as water is involved in the manufacture of most consumer products (Simpi et al., 2011; Sari, 2014).

3. Different types of surface water pollution and environmental and health effects

Numerous studies reported that surface water pollution results from different sources: physical (thermal, radioactive and mechanical pollution), chemical, microbiological and anthropogenic activities are the main causes of this pollution (Kambole 2003; Key et al. 2004; Pritchard et al. 2008; Mubedi et al. 2013; Atibu et al. 2013; Tshibanda et al. 2014).

3.1. Physical pollution

The physical origin of pollution refers mainly to thermal, radioactive and mechanical pollution of water.

Thermal pollution is due to the rise in temperature. It is the consequence of the discharge into the aquatic environment (rivers, coastal waters) of considerable quantities of water used for cooling, especially during the production of electrical energy by thermal or nuclear power stations. This form of pollution is the cause of the decrease in dissolved oxygen content, the acceleration of biodegradation and the proliferation of germs in aquatic ecosystems. It follows that, at equal load, an increase in temperature favours the harmful effects of pollution (Chaouki, 2017). Moreover, Yagouba (2005) asserted that aquatic organisms are more sensitive to temperature changes than those in terrestrial environments. Others have reported that the excessive rise in river water temperature, especially during periods of low flow (low water level), can modify the biological balance of the water with regard to fish species . Moreover, radioactive pollution is the one that worries the population the most, it is by far the lowest. This concern is linked in particular to a lack of knowledge of the different types of radiation and their dangerousness. Alpha radiation is stopped by a sheet of paper and can pose a problem if a radioelement emitting this type of radiation is ingested whilebeta radiation and especially gamma radiation are very dangerous and might cause health problems while exposed to without ingestion or inhalation.

Radiation emitters (^{226}Radon, ^{234}Uranium, ^{238}Uranium, etc.) are generally of natural origin and may be present in the undergroundwater of specific geographical areas such as granite areas (Brittany, Massif Central and Vosges) for radon. Beta emitters are generally associated with human activities (^{90}Strontium, ^{134}Cesium, ^{131}Iodine) and radiocontamination can come from deliberate or accidental water spills, or from atmospheric fallout such as Iodine in the event of a nuclear accident. Most radioelements are easily absorbed on particles (water sediments, sewage plant sludge, etc.). Aquatic organisms (fish, mollusks, crustaceans) are likely to accumulate certain radioelements, creating contamination of the food chain. As for gamma radiation emitters, used mainly in diagnostics by nuclear medicine departments, their use is strictly regulated and their discharge is prohibited (Pravalie, 2014). These substances are most often used in nuclear medicine and in the energy industry. Studies carried out on radioactive pollution of aquatic ecosystems show the manifestation of the biomagnification of certain radioelements on the aquatic biocenosis (Pravalie, 2014).

3.2. Chemical pollution

This kind of pollution results from the introduction into water of chemical pollutants like heavy metals (chromium, copper, zinc, lead, cadmium, nickel, arsenic, aluminium, tin, manganese, mercury), hydrocarbons, fertilizers, pesticides, fungicides, herbicides, insecticides, or various types of waste from industrial, medical, scientific, livestock or crop activities (excrement, manure, slurry, plant health products, etc.) or the washing of the atmosphere (acid rain) or the leaching of road soils and any impermeable surface (roads, railways, car parks, built surfaces) (Tchounmou et al, 2012).

Chemicals such as nitrates, phosphates, herbicides and pesticides are widely used in agriculture. They are dumped into fields and then end up in ground and surface water. Similarly, chemical supplements administered to animals on farms are a source of water pollution (Tchounmou et al, 2012).While certain mineral elements are naturally present in water and are essential for the development of life, an imbalance of these same elements causes plant growth to be disrupted or physiological disorders in animals. Others, such as heavy metals and pesticides, have the unfortunate property of accumulating in certain living tissues (bioaccumulation) and constitute deferred pollution for species at the end of the food chain. The presence of heavy metals and pesticides is amplified by anthropogenic activities, including industrialization and agriculture (Sigg et al., 2000). Yagouba (2005) asserted that heavy metals or pesticides accumulate in organisms and concentrate in certain tissues or organs at doses sometimes much higher than those measured in water. In fact, metals and pesticides are not or only slightly biodegradable; they are therefore not transformed or eliminated naturally by aquatic organisms (self-purification). Hence, their adsorption on suspended matter and their accumulation in aquatic ecosystems (sediments in certain river or coastal areas) and the intoxication of aquatic organisms (Sigg et al., 2000; Yagouba, 2005; Doumont et al., 2006). This accumulation along the food chain can have more or less serious effects on human health.Keck et al. (2010) reported that mercury is transformed, on suspended matter and in sediments, into methylmercury by bacterial action. This compound, which is more fat soluble, readily crosses biological membranes, accumulates in aquatic organisms, and reaches increasingly higher concentrations as it moves up the food chain.Gaudreau et al. (1998) reported that metals cause respiratory, digestive, nervous or skin disorders. Arsenic, nickel and chromium are considered carcinogenic. The neurotoxic action of lead or carcinogenicity of arsenic and chromium has also been reported by Doumont et al. (2006).It has also been reported that metals and metalloids play a key role in changes in the structure of plant and animal populations that result in "biodiversity loss". They have been implicated in cases of death and inhibition of growth or reproduction of aquatic and terrestrial animals (Nagajyoti et al. 2010). As for pesticides, their reprotoxic (malformations, sterility, reproductive disorders), mutagenic and carcinogenic effects have been reported; they are also responsible for neurological disorders (Doumont et al., 2006).However, certain nitrogenous (nitrates, nitrites) or phosphorus pollutants are responsible for the eutrophication of aquatic environments by excess of plant nutrients (algae) and leading to the axphixia of environments. This can reduce the fish biological qualities of an aquatic ecosystem. Ammonia and nitrite are considered toxic to aquatic fauna. Furthermore, nitrates poison blood in infants by blocking haemoglobin preventing oxygen transport; nitrates promote the formation of methaemoglobin; infants and pregnant women are also vulnerable to methaemoglobinaemia. More than 2000 cases of methaemoglobinaemiahave been reported and most of these involved infants under 3 months of age who consumed water contaminated with more than 25 mg of nitrates.Methaemoglobinaemia is not the only risk associated with the presence of nitrates in drinking water. Potential risks of carcinogenicity and teratogenicity are also associated with the ingestion of nitrates/nitrites via the formation of nitrosamines and nitrosamides, which are distinguished as N-nitroso compounds. Approximately, 80% of the nitrosamines and almost all the nitrosamides studied have been shown to be carcinogenic in several animal species. Several studies have shown that mortality rates from cancer (gastric and prostate) increase with nitrate exposure levels. Other epidemiological investigations have established a particularly strong correlation between exposure to nitrates in drinking water and the incidence of gastric cancerThe literature indicates that nitrites are the cause of long-term cancers in adults when associated with certain pesticides (Gaudreau et al., 1998; Doumont et al., 2006; Koné et al., 2009; Laurent, 2012).

According to Laurent (2012), the risk of eutrophication by phosphorus appears at low doses for thresholds close to 0.035 to 0.1 mg.L^{-1} in total phosphorus. The pollution by phytosanitary products (insecticides, fungicides and herbicides) used in agriculture causes respiratory, genital, mutagenic, immune, neurological, cardiovascular or carcinogenic problems in humans and different ecosystems suffer from the effects of these products. Pesticides disturb the soil's microfauna and microflora and can reduce its fertility (reduction in the number of earthworms). Insect populations decline, birds are affected in particular by seeds treated with organochlorine pesticides. Mammalian predators suffer particularly with degeneration of the sexual organs. Fish are very affected, the lethal doses of many molecules on fish are close to 10 µg.L^{-1} (Laurent, 2012).Regarding ammonia, excessive levels can cause several adverse effects, including: hyperexcitability, increased respiratory activity and oxygen consumption, and increased heart rate. Various sub-lethal effects may also occur: reduced hatching success, reduced growth rate and development.

In addition, many compounds, organochlorinated (DDT, PCBs, etc.), or substances widely present in wastewater treatment plant effluents, such as degradation products of polyethoxylatedalkylphenol detergents or phthalates, have been recognized as being able to induce endocrine disruption in male fish. In situ studies downstream of sewage treatment plant discharge points have shown evidence of estrogenic disorders in male trout exposed to effluents from polluted water treatment plants (DWTPs) in relation to contamination of the environment by alkylphenols and/or estrogens (Jobling et al., 1996; Tyler et al., 1996; Harries et al., 1997; Flammarion et al., 2000).Several organochlorine compounds possess immunosuppressive properties that are manifested by a strong decrease in resistance to bacterial and viral infections in humans or by an increase in the incidence of allergies and cancers. However, there is little research on immunotoxicology that can rigorously demonstrate the impact of exposure to pollutants on the human immune system. Moreover, research highlighting the effect of the cocktail of chemical compounds found in aquatic ecosystems on aquatic biodiversity or on human health is poor. It should be noted that chlorinated solvents, dioxins, polycyclic aromatic hydrocarbons are carcinogenic (Doumont et al., 2006).Some chemical pollutants act synergistically (cocktail effect). In the environment or in human exposure patterns, it is very difficult to assess these synergistic effects because the number of combinations of micropollutants is almost infinite. There is currently no methodology or certified, robust, cost-effective and robust tool that can simply and effectively quantify all the risks associated with complex mixtures of molecules (Gavrilescu et al., 2015).

3.3. Organic pollution

Organic pollution results from the introduction of fermentable, i.e. biodegradable, organic matter.This pollution is by far the first cause of pollution of water resources (FAO, 2017). Sources of organic pollution are the following: household waste, black water (from toilets, containing faeces and urine), agricultural wastewater (from livestock farming, including manure and slurry, rich in nitrogenous organic matter but including some compounds, such as nitrates), industrial effluents (paper mills, tanneries, slaughterhouses, dairies, oil mills, sugar mills, etc.) and wastewater discharged (effluents) from collective facilities, such as hospitals, schools, shops, hotels and restaurants (Yagouba, 2005).Organic pollution has several effects on the environment. It asphyxiates the environment by consuming dissolved oxygen and stimulates the excessive production of plants and algae or seaweed (eutrophication, dystrophication) or promotes the accumulation of sludge and the development of organisms that are pathogenic to humans. The asphysification of the environment can promote the death of fish and other aquatic organisms (Hauxwell et al., 2001; Yagouba, 2005). Dystrophicationis often linked to excessive nitrate and phosphate intake. In addition, phosphates contained in household detergents have dangerous effects on the environment. (Rodier, 1996; Manahan, 2000).

Cases of pollution by nutrients, especially nitrogen and phosphorus, due to natural and/or anthropogenic causes, generate disruptions in biogeochemical cycles. The result is an undesirable accumulation of sometimes toxic intermediates of these cycles, which can lead to an ecological imbalance depending on their chemical form and concentration (Féray, 2000).Some synthetic organic molecules are poorly or not at all biodegradable by aquatic micro-organisms. They will therefore persist in the receiving environment and may bioaccumulate along the trophic chain.

3.4. Microbiological pollution

Microbiological pollution of surface water is linked to increased microbial load. This pollution develops in conjunction with organic pollution, which encourages the proliferation of germs of human or animal origin, some of which are highly pathogenic. Yet, organic waste, in particular excrement, contains pathogenic germs (viruses, faecal coliforms, streptococci, enterococci, *Escherichia coli, Pseudomonas aeruginosa, Giardia lambia, Entamoeba coli* and other parasites) carried by water. These germs can cause diseases as serious as cholera, typhoid, dysentery, etc. (Emoke et al., 2013). Viruses (poliovirus-type enteroviruses, coxsackies and echoviruses, hepatitis A viruses, corona and rotaviruses, Norwalk viruses and associated) responsible, depending on the case, for gastroenteritis, hepatitis or neuro-meningeal syndromes, are generally more persistent in the environment and more resistant to disinfection treatments than bacteria. In addition, parasites such as *Giardia lamblia* and *Cryptosporidium parvum* are considered to be formidable pathogens, especially for immunocompromised subjects; their cysts are also particularly resistant in the environment and to disinfectants. Some microscopic algae can also proliferate in the aquatic environment and create problems for drinking water through their toxins(Huang and Shih, 2015).

In general, coliforms and *Escherichia coli* in particular are considered to be the preferred indicators of microbiological water pollution (Tshibanda et al., 2014; Chevalier, 2016; Mindele, 2016), their presence predicts the presence of other enteropathogens. According to Isnard (2017), enterococci, unlike thermo-tolerant coliforms, including *E. coli*, are characterized by their particular adaptability to different environmental conditions, hence their presence in different ecological niches (wastewater, freshwater, seawater and soil). Numerous studies have revealed the existence of strains of enterococci resistant to the disinfecting agents used for the microbiological treatment of water or strains involved in various infections (Diallo, 2013; chevalier, 2016; Isnard, 2017). Other studies have also reported that aquatic ecosystems in general and freshwater (rivers, streams, lakes, etc.) in particular are reservoirs of pathogenic and/or antibiotic-resistant bacteria and antibiotic resistance genes. Water ecosystems are believed to contribute significantly to the cycles of dissemination of antimicrobial resistance genes through horizontal transfer mechanisms (Rysz and Alvarez, 2004; Pruden et al., 2006; Poté et al., 2008; Knapp et al., 2012;Bréchet et al., 2014; Czekalski et al., 2014; Laffite et al., 2016). Antibiotic-resistant bacteria can travel far and to the most remote locations. Antimicrobial resistance has now passed the stage of rarity and almost exclusive presence in hospitals (Yuo et al., 2014).

3.5. Micropollutants

The term "micropollutants" refers to a set of substances, whether mineral (metals and metalloids) or organic (hydrocarbons, benzene derivatives, polychlorinated biphenyls or PCBs, phthalates, bisphenols, organochlorines, pesticides, biocides, detergents, drug residues, etc.) which, even at very low concentrations, of the order of µg/L or ng/L, can be toxic and cause harm in aquatic environments.Briand et al. (2018), defined micropollutants as a set of substances that originate at least in part from human activities and that have proven or suspected adverse effects even at the low concentrations (ng/L to µg/L) at which they are present in the environment. Micropollutantsare considered new or emerging pollutants. Their appearance is not new; the phenomenon is accelerating with the constant evolution of analytical methods, which are efficient and make it possible to detect pollutants even at low doses. In addition to their toxicity, they are persistent and/or bioaccumulative. There is no fixed list including all micropollutants, as this list evolves as knowledge of the effects of the substances studied evolves. Some authors group micropollutants according to their uses: plasticizers, detergents, pesticides, biocides; pharmaceuticals (Gavrilescu et al., 2014).

Others group them into 3 categories:

- organic micropollutants: phytosanitary products (pesticides: triazines, organochlorines, organophosphates, substituted ureas, herbicides, fungicides, rodenticides, etc.), pesticides (pesticides: triazines, organochlorines, organophosphates, substituted ureas, herbicides, fungicides, rodenticides, etc.), pesticides (pesticides: triazines, organophosphates, organophosphates, substituted ureas, herbicides, fungicides, rodenticides, etc.), pesticides (pesticides: triazines, organochlorines, organophosphates, substituted ureas, herbicides, fungicides, rodenticides, etc.), pesticides (pesticides: triazines, organophosphates, organophosphates, substituted ureas, herbicides, fungicides, rodenticides, etc.).), hydrocarbons, polychlorinated biphenyls or PCBs, polybrominated biphenyls or PBBs, polychlorinated dibenzodioxins (PCDDs) or dioxins, polychlorinated dibenzofurans (PCDFs), detergents (or surfactants), phthalate esters, various medicinal substances: hormones (oestrogen, testosterone...), antibiotics, anaesthetics, anxiolytics, disinfection by-products (especially chlorination), etc.
- mineralmicropollutants (Cd, Pb, Cr, Hg, As, Cu, Zn, Ni, etc.), and
- organometallicmicropollutants: results from the association of a metal ion with an organic group (Tri, di, Mono Butyltins, etc.).

The contamination of natural aquatic ecosystems by micropollutants is a growing concern that is receiving increasing attention from policy makers and researchers. Several authors have reported that these compounds can harm aquatic organisms and threaten drinking water resources. Although strongly suspected, the health risks associated with chronic exposure to micropollutantsare still poorly documented.Among the effects of these environmental pollutants on exposed organisms are carcinogenic, mutagenic, reprotoxic (toxic to reproduction: sterility, fertility), neurotoxic (disruption of the functioning or development of nerve cells, teratogenic, appearance of birth defects; disturbance of intellectual quotient, and callergenic, immunotoxic (reduced immune protection: infections, allergies) or endocrine disruption and so on.

Some sources report that the main effects observed after exposure to micropollutantsare: free radical formation, altered gene expression, tissue or organ toxicity, endocrine deregulation and mutagenicity. These effects result in the appearance of various pathologies: cancers, immunodeficiency, infertility, growth problems, Alzheimer's disease, malformations in newborns(Agarwal et al., 2006; Hoo et al., 2016). The toxicity of micropollutants depends on several factors such as the type of micropollutant, the dose received and the route of exposure (dietary, inhalation, skin passage).The literature also indicates that micropollutants present in surface waters affect aquatic organisms. For example, feminisation (sex hormone disorders) and developmental inhibition in fish, a significant number of morphological deformities and abnormalities in the reproductive process in invertebrates and early mortality are observed. (Theunis, 2011).

As regards to medicines, once ingested, they are found in the faeces and urine and reach the sewage treatment plants. However, sewage treatment plants do not totally degrade the drugs and some of them end up in rivers and then in the water we drink (Theunis, 2011). Many African countries do not have sewage treatment plants. This predicts a significant pollution of drug residues in the water reserves present in this country. Drugs are consideredmicropollutants for the environment because they were developed with the intention of producing a biological effect on the organism and their presence in aquatic ecosystems is in itself a danger to organisms (Halling-Sorensen et al., 1998).Several scientific studies have revealed the presence of a wide range of pharmaceutical molecules in surface water and/or drinking or tap water. (Rodil et al., 2009; Gros et al., 2009; Pailler et al., 2009; Trenholm et al., 2009). One study showed that drug residues are present at very low doses in surface or groundwater (less than 100 ng/L) and in treated water (less than 50 ng/L).

Recent research has focused on the toxicity of these compounds of pharmaceutical interest. Some authors have reported that the accumulation of micropollutants such as pharmaceuticals (pharmaceutical pollution) such as antibiotics and contributes to the emergence of antibiotic-resistant strains of bacteria. Actually, manufacturers emit significant quantities of antibiotics, which frequently end up in wastewater and mix with effluents from agricultural and human activities, forming an environment conducive to the multiplication of resistant bacteria. These bacteria may in turn exchange or share their genetic characteristics with other bacterial strains either by the horizontal transmission or by the vertical transmission (Larsson et al., 2007; Yuo et al., 2014; AMR, 2015; Ågerstrand et al., 2015). Pollution by antibiotic residues in this way is an unexplored cause of antibiotic resistance.Some sex hormones have effects on aquatic organisms at concentrations below 1µg/L. For example, estradiol, the female sex hormone (and a hormonal marker of aquatic pollution), can alter the sexual characteristics of some fish at concentrations of 20 ng/L.As regards to anti-tumour agents, their mutagenic, carcinogenic and teratogenic properties have been demonstrated and they are considered as the most toxic(Skov et al., 1990).

4. Sources or origins of surface water pollution

There are three main sources of surface and groundwater pollution: industry, agriculture and settlements (domestic pollution, pollution from economic activities, etc.) (Nader et al., 2002; Ghrabi et al., 2002; Battle et al., 2007 ; Yé, 2008;).The pollution of water resources can also result from several other activities. We can mention among others: oil extraction, aquaculture, landfill or wild dumps (polluted soils), maritime transport and ports, construction sites, urban discharges in rainy weather or atmospheric fallout, etc. (Hamatoukour et al., 2010; Nakié, 2011; Bauma, 2017).

Conclusion

Pollution of the world's water supplies has impacts on human health, aquatic and terrestrial ecosystems. The socio-economic life and development of nations and the survival of biodiversity depend on these reserves. Thus, the preservation of various water resources is of paramount importance. Nevertheless, the control of pollution of water resources is not always obvious given the diversity of sources of pollution and contaminants.

Given that the major source of pollution of water resources is human activities, the most decisive action to reduce this scourge lies in changing consumption habits. Moreover, integrated waste management, particularly of micropollutants, which gives responsibility to different stakeholders (industrialists, craftsmen, consumers, communities, scientific and political institutions), is one of the ways to ensure good waste management.

Some pollutants, particularly micropollutants, are difficult to detect and yet have significant consequences. It is necessary to develop not only effective detection techniques but also waste treatment methods that take these contaminants into account.

Other measures, such as the establishment of effective environmental remediation programmes in general, combined with binding legislation, especially in the countries of the South, will enable waste to be collected at source and properly stored and treated. It would also be advisable to :

- Promote the creation of wastewater treatment plants, particularly in the southern countries and/or and to set up in this plant a technology likely to take into account various types of waste including micropollutants;
- Reinforce the control of the use of plant protection products,
- Promote upstream studies on the use of chemical inputs for agriculture,
- Promote the development of biological crop protection techniques (use of bio-pesticides, intercropping practices, etc.), or the use of bio-fertilizers,
- Raise farmers' awareness of the dangers associated with certain substances used in plant protection products and encourage them to choose less harmful products,
- To control and reduce industrial discharges or to raise the awareness of industrialists about environmental problems and the impact of their activities on the sanitation system,
- Promote the introduction of pollutaxes (taxes linked to polluting activities). This consists of applying the polluter pays principle and sanctions to certain industries in order to restrict the use of certain pollutants considered to be ecotoxic or that may harm human health,
- Monitor mining activities and control mining effluents by conducting regular analyses,
- Update research on the toxicology of pollutants in general and micropollutants (drugs, etc.) in particular (found in surface water or beverages) on the health of aquatic and human organisms,
- Promote research aimed at developing tools capable of completely eliminating micropollutants in drinking water,
- Encourage research related to water quality monitoring,
- Raising awareness for a good management of hospital waste and pharmaceutical industries,
- Prohibit the discharge of effluents from pharmaceutical industries into water,
- Raise awareness among manufacturers, prescribers, distributors and consumers about the consequences of pollution by pharmaceutical residues,
- Create specific collection channels for harmful products in order to avoid their discharge into the sewerage system (collection of used batteries, paint residues, solvents, etc.),
- Promote the marketing and use of green products or eco-products, i.e. products that are the least harmful possible from an environmental point of view,

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