Journal of Elementology ISSN 1644-2296

Żeber-Dzikowska I., Bąk-Badowska J., Gietka M., Gworek B., Wróblewska I., Łuszczki J.J. 2022.
Importance of water, its quality and proper management as a challenge in environmental education.
J. Elem., 27(1): 47-57. DOI: 10.5601/jelem.2022.27.1.2227

RECEIVED: 27 November 2021
ACCEPTED: 8 January 2022

REVIEW PAPER

IMPORTANCE OF WATER, ITS QUALITY AND PROPER MANAGEMENT AS A CHALLENGE IN ENVIRONMENTAL EDUCATION*

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Abstract

Being the most widespread stable chemical compound in the natural environment, water constitutes one of the main elements of living organisms. By actively participating in the metabolism, water enables metabolic conversion, constitutes a component part of cells and tissues, and is involved in the autosomal transport. Water has a wide range of applications. Some of those are the life needs, economy, agriculture or recreation. As a common and natural good, it is fundamental to life. However, it may be life-threatening as well. Despite the existing legal regulations, studies provide evidence that water can be polluted with chemical substances which pose a serious health threat. The aim of the study is to show the influence of changes in water quality caused by chemical pollution as well as threats to health and life which these entail. The method employed in the study was the bibliometric approach, to help investigate environmental water pollution by chemical substances and its effects on health for the period 2011-2021. A literature review was carried out searching through the PubMed and Google scholar databases, taking into account articles in English and Polish. The criterion of thematic classification was implemented to carry out the analysis of bibliographic data. The analyzed

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* Source of financing: The project is financed from the Research Fund of the Jan Kochanowski University in Kielce, which is intended to support the continuity and development of the university's scientific research.

articles reveal continued interest in environmental water pollution and its influence on health. In conclusion, water is a chemical compound that is essential to life and to the normal course of the processes occurring in the organism. Hence, good quality of water is crucial. Water contaminated with chemical substances may have negative effects on health. Taking into consideration adverse health effects, it is advisable to constantly monitor the quality of water which is intended for consumption, also in the context of emerging chemical pollution (for instance, active substances in pharmaceuticals).

Keywords: water, contamination, environment pollution, health, education.

INTRODUCTION

Industrialization as well as chemicalization of everyday life have contributed to the global pollution with chemical substances that are detrimental to human health. Water as the primary element of the environment has been affected as well. W. H. Auden, an English poet and author, wrote: "Thousands have lived without love, not one without water." For that reason, concerns about water resources and water quality should not be perceived as an end in itself but rather as a means to any future development.

It is estimated that 97% of the world's water resources is saltwater contained in seas and oceans. Freshwater contributes to only 3% of the planet's water resources. Glaciers alone hold about 70% of the world's freshwater. Groundwater constitutes almost 30% of the world's freshwater and provides the global population with 25% - 40% of drinking water. The rest of the freshwater resources on the Earth are deep ocean waters, rivers and lakes. Rivers and the atmosphere store no more than 0.0012% of global water reserves. This leaves only 0.5%-1% of the world's water resources for municipal, agricultural, and industrial purposes (Cosgrove, Loucks 2015, Richey et al. 2015, Postigo, Barceló 2015).

Given the significant global population growth, it will be crucial for the environmental health and the ecology to protect and sustain the available water resources. It is estimated that by 2030 two billion people shall migrate to urban areas which will create a significant water demand as well as cause its deterioration with organic contaminants (EOCs). Pollution of surface and groundwater with chemical substances, which stems from the development of industry, poor agriculture management and lack of accurate environmental protection (for instance in the case of waste disposal), is one of the major threats to the access to freshwater (Beegum et al. 2020, Chmielewski et al. 2020*a*, Mishra et al. 2021).

Water, the resource essential for human life, is subject to various types of anthropogenic pollution, which may be detrimental to said life. It is estimated that up to 80% of all illnesses are somehow related to the quality of freshwater. Ultimately, the issue of biological water pollution had been broadened to include chemical pollution as well. The chemical water pollu-

tion not only alters its pH but also loads it with alien gases, elements (for instance heavy metals) and organic compounds, some of which may cause dangerous mutagenic or cariogenic effects. Some studies examine chemical substances which cause health problems after having been introduced to the organism. This presents a challenge for environmental health and, more broadly, to public health in terms of access to safe water (Kłos 2016, Mohiuddin 2019, Adilov et al. 2021, Chmielewski et al. 2021).

The threat of water scarcity is one of the main issues which modern society faces. Among the reasons for the scarcity of water, we may enumerate population growth, development of industry, global warming, excessive exploitation of water or simply its waste.

Among the most frequent reasons for water pollution are: (1) crude oil contamination, waste oils (2) urbanization (3) domestic sewage, population growth, (4) heavy metal, plastics and polythene, (5) radioactive waste, (6) global warming, flooding, (7) atmospheric depositing, (8) toxic waste disposal, (9) industrial waste, municipal waste, animal wastes, (10) pesticides, herbicides and fertilizers (Chmielewski et al. 2016, Meng et al. 2017, Chmielewski et al. 2019, 2019*a*, 2020, 2020*a*, 2020*b*, 2020*c*, 2020*d*).

Polluted water poses a threat to both humans and the natural environment. Water pollution causes the limitation of exploited resources, higher cost of water treatment for humans and the environment and poses a danger for human life, fauna and flora. Hence, it is important to maintain a high quality of water and protect the resources. The poor condition of numerous bodies of water has become more visible. Humans are the most vulnerable to water pollution. Numerous studies have shown that heavy metals, organic compounds, pharmaceuticals and hormones found in sewage are being drained away to rivers and seas. As a consequence, they leak into living organisms found in these waters becoming at the same time an energy source and a threat for a human being (Pal et al. 2014, Bhandari et al. 2015, Burri et al. 2019, De França et al. 2019, Gworek et al. 2019, Ochwanowska et al. 2019, Gworek et al. 2020, Chmielewski et al. 2020*c*, 2021).

The pollution of ecosystems with heavy metals

The pollution of the atmosphere is one of the elements of matter circulation and it influences the environment in a complex way. Along with waste, the atmospheric pollution is deposited in surface and groundwater which leads to their pollution. Waste deposited in the bodies of water (rivers, lakes and seas) is often characterized by a elevated content of some trace elements. Many of those are a consequence of inadequate draining of the industrial and urban runoff. Another cause of water pollution is inadequate waste disposal in landfills (leachate) or fires breaking in waste dumps. Studies show that the pollution of water with heavy metals has either a natural source (for instance a volcanic eruption) or an anthropogenic source (Zhang et al. 2018, Barone et al. 2020, Chmielewski et al. 2020*a*, Bandala et al. 2021).

Research shows cases of pollution of water and sediments with heavy metals, such as Al, As, Fe, Cr, Zn, Ni, Mn, Cu, Pb, Cd, Hg (Bąk et al. 2014, Perliceusz et al. 2015, Szydłowski et al. 2017, Tytła, Kostecki 2019).

Pollution of aquatic ecosystems with persistent organic pollutants (POPs)

The pollution of water with POPs, which include organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), hexabromocyclododecanes (HBCDs), and perfluoroalkyl substances (PFASs), has either direct (disposal of waste water containing POPs, drainage of the plant protection products from the fields, leakage from transformers and capacitors, landfills) or indirect causes (from the contaminated atmosphere). Generally, due to their physiochemical properties (poor water solubility), OCPs and PCBs are mainly detected in sediments, while PBDEs and HBCDs are found in sediments and soils. PFASs, which characteristically have higher solubility, are mainly detected in the hydrosphere (Meng et al. 2017, Chmielewski et al. 2020, 2020*a*).

Sewage sludge containing (among others) POPs, which in agriculture is utilized as a fertilizer and soil amendment in podsolic and degraded soil owing to its abundance of nutrients, becomes the source of pollution. Given the hydrophobicity of the POPs, they tend to shift from the liquid form to one of greater hydrophobicity, for example by bioaccumulation. In this process, POPs accumulate in tissues and organs of living organisms. They may shift through sorption as well. Then they bind with particles of sediments or suspensions found in water. Poor aqueous solubility of POPs, as well as strong absorption of organic matter particles, determine its stability in aquatic ecosystems, in particular in sediments. As a result of chemical and biochemical processes, a share of POPs contained in sediments may be subject to desorption to water. Consequently, they may become accessible to living organisms. Although sewage sludge improves the quality of soil, studies have shown that sludge also contains toxic organic compounds such as POPs, with mutagenic, carcinogenic, immunotoxin and reproductive effects on living organisms (Urbaniak et al. 2016, Meng et al. 2017, Chmielewski et al. 2020, 2020*e*, 2020*f,* Nguyen et al. 2020 Hu et al. 2021,).

Chemicals in the water and their health effects

Groundwater is the fundamental source of water supply. In view of potential health effects of polluted water, pollution of groundwater with organic chemical substances is the subject of various research projects (Postigo, Barceló 2015).

Chemical pollution found in water normally does not cause immediate and severe effects on human health. For that reason, they are of secondary importance compared to microbiological pollution, which is the still

main cause of morbidity and mortality due to exposure to polluted water (Villanueva et al. 2014).

The health effects caused by the chemical substances found in water arise from a prolonged period of the consumption of polluted water. The pollution with heavy metals or carcinogenic substances is of particular importance (Shakoor et al. 2015).

The ways in which chemical substances penetrate the environment are closely connected with the origin of these substances. Chemical pollutants are present in the atmosphere, water, and soil. Potential sources of dioxins polluting aquatic ecosystems are industry and agriculture. Due to the poor aqueous solubility of dioxins, they adsorb on the surface of particles suspended in water and sink with them to the bottom of the water body. Dioxins are considered detrimental to human health due to their toxicity as well as prolonged periods of accumulation in an organism (Chmielewski et al. 2020).

Polycyclic aromatic hydrocarbons (PAHs) accumulate in sediments, where their decay is additionally inhibited by the shortage of oxygen. PAHs are also present in the groundwater. They penetrate through splayed drainage layers of soil, polluting the sources of drinkable water. Their carcinogenic and mutagenic effects on health had been shown in studies (Raza et al. 2018, Adeniji et al. 2019, Chmielewski et al. 2020*e*).

MATERIAL AND METHODS

An analysis has been made of articles from fields of medicine and biological sciences, obtained from PubMed, an online English database of the National Library of Medicine, National Institutes of Health, Bethesda, MD, USA (http://www.ncbi.nlm.nih.gov/PubMed), and dedicated to issues of the relationship between the pollution of water with chemical substances and health effects. In addition, a review of the literature published by the PubMed, Scopus and Google Scholar databases between the years 2011 and 2021 has been carried out. Advanced search was conducted by using keywords or a combination of keywords: water pollution, chemical water pollution, heavy metals in water, organic water pollution, health effects of polluted water and by using the limitation to a period of 2011-2021.

Opinions, conference materials, letters to the editors, chapters of books and notes from conferences and trainings were not included in the review and were excluded from the analysis.

RESULTS AND DISCUSSION

The analysis showed that the PubMed database between 2011 and 2021 gathered 168,997 publications (as of 12.11.2021) concerning water quality in the context of environmental health. Table 1 shows a quantitative list

Table 1

Publications about water pollution and its influence on health in years 2011-2021

Year of publication	Number of publications based on the search of the key terms					
	water pollution	chemical water pollution	heavy metals in water	organic water pollution	health effects of polluted water	total
2011	3,122	1,922	4,338	582	295	**10,259**
2012	3,484	2,030	4,663	635	323	**11,135**
2013	3,631	2,014	4,953	675	366	**11,639**
2014	3,943	2,126	5,180	828	463	**12,540**
2015	4,433	2,267	5,321	890	537	**13,448**
2016	4,998	2,663	5,314	1,065	706	**14,746**
2017	5,314	2,712	5,273	1,133	753	**15,185**
2018	6,407	3,229	5,824	1,460	932	**17,852**
2019	7,414	3,873	6,631	1,689	1,044	**20,651**
2020	8,450	4,245	6,952	1,848	1,254	**22,749**
2021	7,484	3,512	4,995	1,646	1,156	**18,793**
Total	**58,680**	**30,593**	**59,444**	**12,451**	**7,829**	**168,997**

of publications about water pollution and its influence on health in the analyzed timeframe. Among 168,997 (100%) of publications, articles on water pollution constituted 34.7% of all the publications, papers on chemical water pollution made up 18.1% of all the publications, those about heavy metals in water represented 35.2% of all the publications; 7.4% of all the articles dealt with organic water pollution whereas articles on health effects of polluted water constituted 4.6% of all the publications.

The analysis showed a positive trend in the number of publications since the year 2011, except the year 2021, when the number of publications decreased. This was probably a result of the COVID-19 pandemic and a consequent decline in the number of conducted studies. Nevertheless, despite the constant growth in the number of publications (authored by scientists throughout the world) about water pollution and its influence on health, the area directly linked to water pollution and its influence on health constitutes only 4.6% of all the studies. In contrast, the problems of heavy metals in water were a significant issue, discussed in 35.2% of all the articles. 34.7% of all

the articles were dedicated to the question of chemical water pollution. It may be due to the fact that the health effects of exposure to heavy metals and organic compounds are already widely known. It is well known that health largely depends on the environmental factors and exposure to risk factors (Barouki et al. 2012, Chmielewski et al. 2015, Ali et al. 2019, Chmielewski et al. 2017, 2020, 2020*c*, 2020*e*, 2020*f*, 2021).

Since 2016, a significant increase in the scholarly interest in health effects of polluted water can be observed. The analysis of the trends in publications proved that the problem of heavy metals in water constantly raises significant interest.

The research shows that health disorders linked to the exposure to chemical substances, also found in water, may lead to heart diseases, obesity, type 2 diabetes, some cancers or dysfunctions of the reproductive, neurocognitive and immune systems (Barouki et al. 2012).

As part of their research on the impact of polluted oceans on health, Landrigan et al. showed that contaminated seafood, from water polluted with methylmercury and PCB, consumed by a mother during pregnancy may negatively affect the fetus and further development of the child, causing a higher incidence of damage to the developing brain, lower IQ and higher risk of autism, ADHD and other learning impairments in children. Adults exposed to methylmercury increases the risk of developing cardiovascular illnesses and dementia. Purposefully produced chemicals such as phthalates, bisphenol A, flame retardants and perfluorinated chemicals, many of which spread into the sea with plastic waste, may cause endocrine signaling disorders, reduce fertility among males, cause damage to the nervous system and increase the risk of cancer (Landrigan et al. 2020).

The toxic equivalency (TEQ) carried out for benzo(a)pyrene (BaP) and dibenz[a,h]anthracene (DiahA) showed a possible threat of cancer in people at risk of exposure to marine sediments (Adeniji et al. 2019).

In their study, Kasonga et al. raise the issue of potential health effects resulting from the pollution of surface waters with chemical substances (including pharmaceuticals and personal hygiene products, organic pollution, and heavy metals), which disrupt the hormonal balance (EDCs). They show that even at low concentrations in a given body of water, chronic exposure to EDCs may have detrimental health effects on human health. EDCs may disrupt the functioning of hormones in the organism, cause problems with the reproductive system and the thyroid, while Alzheimer's, cancer and obesity are some of the main effects of EDCs in people (Kasonga et al. 2021).

CONCLUSIONS

Water is one of the key substances with influence on human health. On the one hand, it is essential to life; on the other hand, it may be a carrier of chemical substances which influence water's properties and assimilability of water-contained compounds.

The assessment of a health risk related to the consumption of water is an essential, multi-stage process that contributes to any evaluation of health effects caused by potential exposure of humans to chemical substances.

The constant global growth and the development of industries have increased the water demand. More economical water management as well as greater attention to water quality, both locally and globally, are the best way to counteract the threat of global water scarcity.

Educational efforts should be taken to raise awareness about the importance and role of water in the environment. It is also necessary to educate the public about the negative effects of anthropogenic activity and pollution on human health.

Conflict of interest

The authors declare no potential conflict of interest concerning the authorship and/or publication of this article.

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