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REVIEW PAPER

Presence of pharmaceuticals in the aquatic environment – an underestimated threat to environmental health and a challenge for education*

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Abstract

The presence of pharmaceuticals in the environment, also through the use of veterinary drugs, is a significant environmental health problem. Pharmaceuticals are constantly discharged with wastewater into the environment. As biologically active substances designed to act in low concentrations, they are used in medicine and veterinary medicine. The main sources of their occurrence in the environment include their production, medicinal use, improper disposal and excretion by both humans and animals. Due to their tendency to bioaccumulate, they pose a threat to all levels of trophic chains in the environment. Purpose of the study: The purpose of this paper is to present issues related to the presence of pharmaceuticals in the environment in the context of environmental health and environmental education. Research methods: Studies, including epidemiological ones, on the risk of adverse health effects associated with the presence of pharmaceuticals in the environment were reviewed. The literature review covering the years 2013-2022 was conducted by searching PubMed, Scopus and Google Scholar databases, and included studies focusing on the identification of pharmaceuticals and possible adverse health effects. Results: The presence of pharmaceuticals in water poses real risks, including those related to hormonal imbalance in human and animal bodies, or the emergence of antibiotic-resistant bacteria. Conclusions: The presence of pharmaceuticals in the aquatic environment is a global problem. Therefore, there is a need to develop wastewater treatment technologies to effectively eliminate these compounds from water and wastewater. It is also necessary take educational measures.

Keywords: pharmaceuticals, aquatic environment, ecotoxicology, environmental hazards, health

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INTRODUCTION

Poland is one of the least water-abundant countries in Europe, constantly struggling with water shortages, which is why the concern for water quality and purity of the discharged wastewater weighs extremely high (Canales et al. 2020, Pińskwar et al. 2020, Żeber-Dzikowska et al. 2022).

The pharmaceutical industry belongs to the fastest-growing economic sectors in the world. Available data confirm that the global pharmaceutical market made a profit of $1.2 trillion in 2018, $100 billion more than in 2017 (Zhu et al. 2021). By 2022, the pharmaceutical market had been experiencing a significant growth for over two decades, and pharmaceutical revenues worldwide (the value of the global pharmaceutical market) reached $1.482 trillion (Statista 2023). As the European Federation of Pharmaceutical Industries and Associations (EFPIA) shows, the pharmaceutical industry is one of the most prosperous industries in the world (EFPIA 2022). The value of the pharmaceutical market in Europe is estimated at €220,200 million (Lacorte et al. 2021).

In 2020, the value of the pharmaceutical market in Poland, including the pharmacy segment, hospitals and mail order sales, was estimated at about PLN 38.3 billion. The value of pharmaceuticals produced in Poland in 2020 was about PLN 11.5 billion (Obłąkowska, Bartoszewicz 2022). On the other hand, data from the Statistics Poland (Polish abbreviation: GUS) confirm that the value of pharmaceutical products sold in Poland in 2020, divided into basic pharmaceutical substances, medicines and other pharmaceutical products, increased by 5.4% as compared to 2019, and amounted to 11,455,121.5 (in thousands of PLN) – GUS (2020).

As the data presented by the Statistics Poland confirm, 425 million prescriptions were issued for patients in Poland in 2021 (GUS 2021). In the United States alone, more than 3 billion prescriptions are issued annually (Vatovec et al. 2017).

Data regarding the number of the prescriptions issued for veterinary drugs are not available. In agricultural practice, a wide range of pharmaceuticals and personal care products (PPCPs) are used in large-scale animal husbandry. In the recent years, production of veterinary pharmaceuticals has increased significantly due to their use in aquaculture and livestock farming for prevention and treatment of fish and livestock diseases (Wang, Wang 2016). Antibiotics (β-lactams, sulfonamides, tetracyclines), steroidal and non-steroidal anti-inflammatory drugs and dietary supplements are widely used. Hormones and estrogens (e.g. oxytocin, steroids, ergonovine, progesterone, prostaglandins) are applied in reproduction of animals. Increased milk and meat production requires the use of hormonal growth implants, subtherapeutic antibiotics, bovine somatotropin, etc. (Patel et al. 2019). Ingestion of PPCPs from animal husbandry can be more problematic as human excrements are subjected to wastewater treatment processes whereas animal excreta are not.

However, the sheer number of prescriptions issued for people indicates the scale of the problem of environmental pollution with pharmaceuticals and – as a result – also the associated risks for both humans and the environment. The increase in drug consumption translates into an increase in environmental pollution with medicinal substances and their degradation products (Kümmerer et al. 2014).

Noticeable medical progress, in both diagnostics and treatment, has contributed to development in pharmacotherapy, and thus an increase in the use of drugs. This increase constitutes a response to the prevalence of numerous diseases and ailments in the modern world that medicine and veterinary medicine are trying to cope with. This is also the cause of the presence of pharmaceuticals and their derivatives of varying types, concentrations and effects in the environment.

Pharmaceuticals are chemical compounds with a variety of chemical structures that demonstrate multi-dimensional biological effects on living organisms. The literature confirms that pyridine-based ring systems are among the most widely used heterocyclic compounds in the field of drug design, primarily because of their profound effect on pharmacological activity, which has led to the discovery of numerous broad-spectrum therapeutic agents. In the Food and Drug Administration (FDA) database, there are 95 approved pharmaceuticals that stem from pyridine or dihydropyridine, for example isoniazid and ethionamide (tuberculosis), delavirdine (HIV/AIDS), abiraterone acetate (prostate cancer), tacrine (Alzheimer's), ciclopirox (ringworm and athlete's foot), crizotinib (cancer), nifedipine (Raynaud's syndrome and premature birth), piroxicam (NSAID for arthritis), nilvadipine (hypertension), roflumilast (COPD), pyridostigmine (myasthenia gravis) and many more (Ling et al. 2021).

Nearly 4,000 different pharmacologically active substances are available on the global market as human and animal drugs, with the annual global consumption estimated at around 100,000 tons per year (Patel et al. 2019). Among these drugs, non-steroidal anti-inflammatory and analgesics, antibiotics, hormonal agents, lipid-regulating drugs, anti-epileptic drugs, β-blockers, antidepressants, hormones and steroids, diuretics, lipid regulators and others dominate in terms of quantity (Patel et al. 2019, Rogowska et al. 2019, Lacorte et al. 2021).

Pharmaceuticals are most generally classified as biologically active chemical compounds that are mainly applied in medicine and veterinary medicine. They belong to xenobiotics of anthropogenic origin, referred to in the literature as Pharmaceuticals and Personal Care Products (PPCPs). The group of PPCPs also includes food supplements and nutritional supplements (the so-called nutraceuticals) and various types of cosmetics (shampoos, UV blockers, toilet waters and antiseptics). PPCPs constitute the compounds with various physicochemical properties, often with complex chemical structures, which often hinders their detection and removal from the environment (Koszowska et al. 2015, Gworek et al. 2019).

The interest in the occurrence of PPCPs in the environment mainly results from the concerns about possible toxicological risks and consequences of human exposure through drinking water, development of antibiotic-resistant bacteria as well as toxicity and genotoxicity of aquatic organisms, e.g. fish (Kümmerer et al. 2014, Cizmas et al. 2015, Khan, Nicell 2015, Ebele et al. 2017, Gworek et al. 2019, Zainab et al. 2020, Dietrich et al. 2022).

The primary routes for PPCPs to enter the environment are presented in Figure 1 (Overturf et al. 2015).

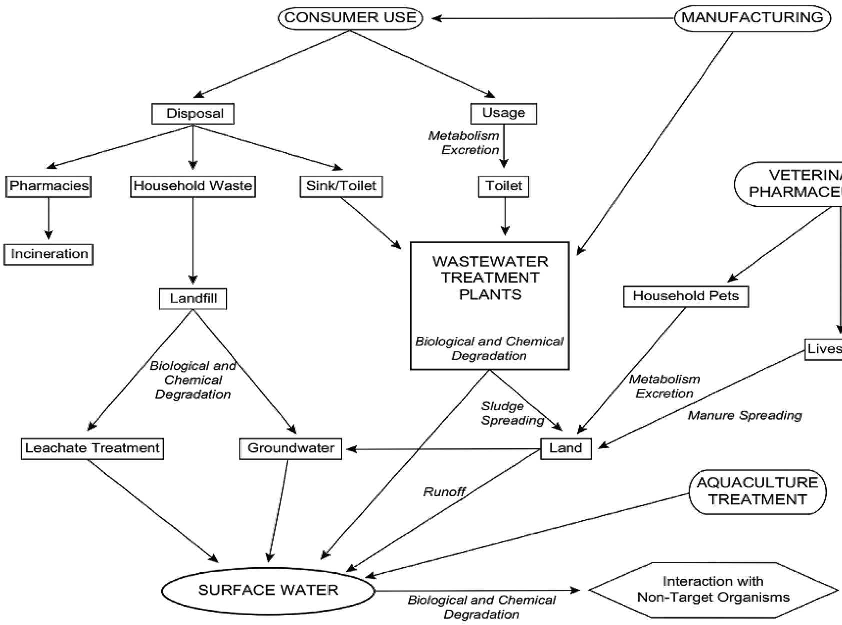

Fig. 1. Major routes of entry of PPCPs into the environment (Overturf et al. 2015)

IMPACT OF PPCPS ON THE ENVIROMENT

As a result of the increased consumption of PPCPs, the environment is becoming more and more polluted with pharmaceutical substances and products of their degradation (Wilkinson et al. 2022). The main reason for the presence of PPCPs in the aquatic environment is their regular excretion, both in an unchanged form or as metabolites, by humans and animals. A considerable part of unconsumed PPCPs before their expiration date is disposed with the exclusion of their proper disposal process (e.g. in households, veterinary surgeries, healthcare or social welfare facilities), reaching toilets and sinks or directly municipal landfills as waste (Jureczko, Kalka 2019).

As the studies concerning surface waters (lakes, rivers, streams, estuaries, seas and oceans) show, PPCPs belong to a group of compounds that are detected in trace amounts all over the world, including Antarctica (Patel et al. 2019, Perfetti-Bolaño et al. 2022, Wilkinson et al. 2022). In Poland, the presence of PPCPs has been confirmed not only in the waters of large rivers, but also in medium-sized rivers and even small rivers (Ślósarczyk et al. 2021).

Data on quantities of wastewater discharged in Poland through sewerage networks in years 2015-2020 are contained in Table 1, whereas amounts of wastewater containing pharmaceuticals generated in healthcare and social welfare facilities in years 2017-2021 are presented in Table 2, both on the basis of information issued by Statistics Poland (the Polish Central Statistical Office) – GUS (2021*a*).

Table 1

Treated and untreated wastewater discharged through sewage network in 2015-2020

Specification	2015	2016	2017	2018	2019	2020
		in cubic hectometres				
Municipal wastewater requiring treatment	1 258	1 290	1317	1330	1 343	1 344
Treated	1 254	1 289	1316	1329	1 337	1 334
Mechanically	0.4	0.4	0.4	0.4	0.3	0.3
Biologically	189.9	189.9	207.6	200.5	202.0	210.3
With increased biogene removal	1 064	1 064	1 108	1 128	1 134	1 123
Untreated wastewater	4.1	1.2	1.0	1.6	6.7	10.4

The source: collated by the authors, based on data of Statistics Poland (GUS 2021*a*)

Table 2

Treated and untreated industrial wastewater by sections of Polish Classification of Activities in 2017-2021

Specification	Year	Discharged wastewater	Of which wastewater requiring treatment discharged directly into the ground		
			total	treated	untreated
			in cubic hectometres		
Human health and social work ctivities	2017				
	2018	10.3	1.3	1.2	0.1
	2019	9.9	1.2	1.2	0.1
	2020	8.8	1.0	1.0	0.0
	2021	8.8	1.0	1.0	0.0

The source: collated by the authors, based on data of Statistics Poland (GUS 2021*a*)

PPCPs enter the environment from various sources, of which the most common ones include wastewater from pharmaceutical manufacturing factories, municipal wastewater from hospitals, long-term care facilities, veterinary clinics and households.

PPCPs present in the aquatic environment, due to their tendency to bioaccumulate and possible toxicity, constitute a serious threat to all levels of trophic food chains. As biologically active substances designed to act at low concentrations, PPCPs in the aquatic environment may have adverse effects on the non-target organisms that have been non-targeted due to their long-term exposure to a particular substance (Ebele et al. 2017, Gworek et al. 2019). PPCPs, due to their medical properties (e.g. nonsteroidal anti-inflammatory drugs, NSAIDs), may contain aromatic rings that are not easily degradable, which significantly affects their half-life in the environment. Consequently, they may have a considerable impact on the aquatic and terrestrial ecosystems (He et al. 2017). Studies confirm that PPCPs occur in wastewater and river waters at relatively low concentrations (of the order of 10^{-3} - 10^{2} μg dm^{-3}), while their quantity is often sufficient to have a negative influence on living organisms (Mao et al. 2015). Numerous studies have confirmed that PPCPs have been found in the surface water at concentrations ranging from ng L^{-1} to μg L^{-1} (Wu et al. 2015, Roberts et al. 2016), in the groundwater at concentrations ranging from ng L^{-1} to mg L^{-1} (López-Serna et al. 2013), in the sediment at concentrations reaching μg kg^{-1} (Richardson et al. 2005) and in the soil at concentrations up to μg kg^{-1} (Gottschall et al. 2012).

Numerous studies confirm the presence of PPCPs both in the surface water and in drinking water from municipal intakes (Kümmerer et al. 2014, Liang et al. 2015, Marsik et al. 2017, Na et al. 2019, Lacorte et al. 2021, Aydin et al. 2022, HE et al. 2022, Wilkinson et al. 2022). Examples of PPCPs identified in the water are given in Table 3.

PPCPs are designed to be persistent and to act stably in the body. The methods applied to remove PPCPs from wastewater do not provide high treatment efficiency. They generally involve a combination of physical, chemical and biological methods, and pollution removal efficiency varies depending on the applied process, nature of the pollutants and influence of the external factors. Unfortunately, even wastewater treatment plants using microbiological processes to remove nitrogen compounds, phosphorus and other organic pollutants as a rule do not cope with pharmaceuticals and therefore a large percentage of these substances enter water bodies, posing a real threat to human health and water-dwelling organisms (Cizmas et al. 2015, Bernhard et al. 2017, Ebele et al. 2017, Gworek et al. 2019, Liu et al. 2020, Żeber-Dzikowska et al. 2022).

Table 3

Examples of PPCPs detected in wastewater and aquatic environments

Substance	Analytical sampling site	The range of recorded concentrations	Literature
Ibuprofen (CAS-15687-27-1) Naproxen (CAS-22204-53-1) Diclofenac (CAS-15307-86-5) Ketoprofen (CAS-22071-15-4) Indomethacin (CAS-53-86-1)	Elbe River, Czech Republic	3210 (ng L^{-1}) 1423.8 (ng L^{-1}) 1080 (ng L^{-1}) 929.8 (ng L^{-1}) 69.3 (ng L^{-1})	Marsik et al. (2017)
Carbamazepine (CAS-298-46-4) Sulfamethoxazole (CAS-723-46-6) Naproxen (CAS-22204-53-1) Clarithromycin (CAS-81103-11-9)	surface water of the Yeongsan River, Republic of Korea	0.2067 (µg L^{-1}) 0.1132 (µg L^{-1}) 0.0516 (µg L^{-1}) 0.0427 (µg L^{-1})	Na et al. (2019)
The analysis of 43 drugs (were analgesic and anti-pyretic drugs such as acetylsalicylic acid, paracetamol, ibuprofen; antibiotics such as amoxicillin and sulfamethoxazole; compounds for the treatment of neuropathies as gabapentin, trazodone and valsartan; pharmaceuticals for the treatment of diabetes (vildagliptin) and anticancer drugs) consumed by the elderly.	samples were collected from 6 senior residences located in north-east Spain, in south of France and Portugal	main compounds detected at the high µg L^{-1}	Lacorte et al. (2021)
Clarithromycin (CAS-81103-11-9) Azithromycin (CAS-83905-01-5)	urban wastewater treatment plant in Konya, Turkey	1496 (µg kg^{-1} dm)	Aydin et al. (2022)

THREATS TO THE ENVIRONMENT FROM PPCPS

Pollution of the surface water with PPCPs poses a number of threats to aquatic ecosystems. This is due to the fact that they are not completely removed by wastewater treatment plants, which results in their release into the environment with treated water (Bernhard et al. 2017). This state of affairs raises concerns about destruction of the ecosystem due to their untargeted action. Even low concentrations of PPCPs may produce antibiotic-resistant bacterial strains that threaten environmental ecosystems (Zhang et al. 2014, Jendrzejewska, Karwowska 2018). There is a higher risk for aquatic organisms due to their multi-generational and continuous exposure to PPCPs (Srain et al. 2021).

Comparison of sensitivity of various systematic groups has shown that planktonic green algae and cyanobacteria are more sensitive than bacteria to effects of non-steroidal anti-inflammatory drugs (NSAIDs). The acute and chronic effects of NSAIDs on invertebrates and vertebrates are more or less known and can be attributed to the non-specific inhibition of cyclooxygenase enzymes (Bacsi et al. 2016).

Active compounds included in PPCPs pose a threat to the ecosystem through their continuous accumulation, their toxic and persistent nature as well as possibility of development of drug-resistant microbial strains (Pal 2018). For example, diclofenac and carbamazepine accumulate in the tissues of *Carassius carassius* and as a result they may interfere with the biochemical functions of fish and lead to tissue damage (Nkoom et al. 2020).

On the basis of conducted studies of ten target pharmaceuticals in drinking water sources and tap water in a city in the middle course of the Yangtze River, including erythromycin (ERY), roxithromycin (RTM), ciprofloxacin (CPX), ofloxacin (OFX), sulfadiazine (SDZ), sulfamethoxazole (SMX), oxytetracycline (OTC), tetracycline (TC), ibuprofen (IBF), and naproxen (NPX), He et al. showed that individual pharmaceuticals in drinking water supplies posed a negligible risk to invertebrates and fish, but ERY, CPX, OFX, and SMX posed a high risk to algae (He et al. 2022).

β-diketone antibiotics (DKAs) may lead to environmental biological resistance that contributes to severe liver and kidney toxicity as well as neurotoxicity in fish. The results of the conducted studies have confirmed that exposure to DKAs at trace levels influences various cellular and biological processes in *Danio rerio* (Yin et al. 2014).

The presence of PPCPs in the water is dangerous to aquatic organisms, including fish, since these substances are characterized by high toxicity. PPCPs may have influence on the aquatic organisms even at ng L^{-1} or μg L^{-1} levels. Potential effects of PPCPs include disruption of physiological processes, reproductive damage, changes in mating behaviour, cytopathological damage, endocrine function effects, genotoxicity and mutagenic effects. There is evidence that PPCPs are not only physiologically toxic to aquatic organisms, but they also exhibit long-term bioaccumulation and may pose a threat to the ecosystem (Bernhard et al. 2017, Gworek et al. 2019, Wang et al. 2021, Dietrich et al. 2022). It is known that the adverse effects of the antibiotics found in the water, e.g. quinolones, sulfonamides, tetracyclines and macrolides, cause damage to the developmental, cardiovascular and metabolic systems as well as altering antioxidant and immune responses in fish (Yang et al. 2020). NSAIDs influence vertebrate species, particularly fish, even at low concentrations (Bernhard et al. 2017). Antibiotics used in fish farming impair general physiological functions, nutritional metabolism and affect negatively their immune systems (Limbu et al. 2018) .

Selected PPCPs causing toxicity in fish are presented in Table 4.

Table 4

Examples of PPCPs causing toxicity in fish

PPCPs	Species fish	Toxicity	References
Ciprofloxacin, ofloxacin, norfloxacin, enrofloxacin	*Danio rerio*	abnormal development and histopathological changes	Yin et al. (2014)
Norfloxacin	*Xiphophorus* Heller	genotoxicity	Liang et al. (2015)
Oxytetracycline	*Oncorhynchus mykiss*	DNA damage and altered activity of anti-oxidant enzyme	Rodrigues et al. (2018)
Oxytetracycline	*Oreochromis niloticu*	DNA damage in erythrocytes and altered microbiota in gut	Limbu et al. (2018)
Erythromycin	*Oncorhynchus mykiss*	oxidative stress and genotoxicity	Rodrigues et al. (2016)
Erythromycin	*Carassius auratus*	altered activity of anti-oxidant enzyme	Liu et al. (2017)
Roxithromycin	*Oreochromis niloticus*	neurotoxicity	Zhang et al. (2018)

THREAT TO HUMAN HEALTH

Chemical water pollutants include PPCPs. An important prerequisite for achieving good water condition, particularly a good ecological status, includes elimination or reduction of discharge of the number of substances that pose a significant threat to waters, of which a significant proportion is formed by PPCPs. Taking into account the threats, organic water contamination with PPCPs that do not undergo biological decomposition by microorganisms or are decomposed to a low degree and therefore are not subject to biological wastewater treatment in municipal and industrial treatment plants is of great importance (Kümmerer et al. 2014, Gworek et al. 2019, Żeber-Dzikowska et al. 2022). Numerous PPCPs are not removed in the existing wastewater treatment plants and enter both groundwater and surface waters. NSAIDs and estrogens (female sex hormones) that are components of contraceptives enter the surface waters (Bernhard et al. 2017, He et al. 2017).

PPCPs are able to enter the environmental system as trace contaminants, at various concentrations. These residues may affect human life in terms of subsequent exposure. Contamination of drinking water with substances belonging to PPCPs will be particularly hazardous for humans (Roccaro et al. 2013, Chmielewski et al. 2021).

As the literature shows, even low concentrations of antibiotics, from nanograms to micrograms per litre, may produce antibiotic-resistant bacterial strains that threaten human health (Zhang et al. 2014, Jendrzejewska, Karwowska 2018).

The above information indicates that PPCPs may pose a serious threat to human health. Taking into consideration the fact that estrogens accumulate in aquatic organisms, they can enter the human body through fish consumption (Dietrich et al. 2022). Excess of these substances (e.g. estrogens) at the levels of contaminants has been linked to breast cancer in women and prostate cancer in men as well as lead to fetal damage (Adeel et al. 2017, Vilela et al. 2018). The presence of pharmacological substances in drinking water, especially for children is equally harmful (Tijani et al. 2016). Anti-cancer drugs applied in chemotherapy, present in natural waters or drinking water that are excreted into wastewater and found in the aquatic environment in the lower rage of μg L^{-1} constitute a threat and predicted concentrations in the environment are often below the action limit determined by European Medicines Agency (EMA) guidelines as they are of mutagenic, teratogenic, embryotoxic and genotoxic nature (Kümmerer et al. 2014, Jureczko, Kalka 2019).

Important risks are posed by antibiotics present in various types of wastewater discharged into the aquatic environment. These include antibiotics used for both human treatment and animal treatment on livestock farms. They may cause antibiotic resistance and, as a result, numerous dangerous health effects in the long-term exposure to consumption of water contaminated with them (Khan, Nicell 2015, Limbu et al. 2018, Sanganyado, Gwenzi 2019, Ben et al. 2020).

The negative health effects related to exposure to drinking water contaminated with PPCPs on the human body have not been fully understood yet. Consequently, households are advised to use filters to improve the quality of drinking water.

THE ROLE OF EDUCATION IN CREATING PUBLIC AWARENESS OF THE MANAGEMENT OF PPCPS

The proper management (disposal) of unused and expired PPCPs behaviour by societies is primarily influenced by their awareness of the impact of the negative impact of these substances on the environment and health.

Taking into account the fact that the consumption of PPCPs is steadily growing, the problem of proper handling of unused and expired PPCPs is also increasing. As the literature shows, PPCPs unused in households are disposed as municipal waste reaching landfills or are discharged into a municipal sewage system. PPCPs are commonly dumped directly into municipal sewer systems and municipal landfills (Tijani et al. 2016, Vatovec et al. 2017).

In Poland, as presented by studies conducted by Rogowska et al., nearly 68% of the respondents have stated that they usually dispose of expired PPCPs in household trash or flush them down the toilet (Rogowska et al. 2019). Throwing expired PPCPs into the rubbish constitutes a global way of their disposal from households, indicated as the most commonly reported practice reported in various studies conducted in the United States (Vatovec et al. 2017), China (Chung, Brooks 2019), Australia (Bettington et al. 2018), Ireland (Vellinga et al. 2014), Ethiopia (Ayele, Mamu 2018), Romania (Tit et al. 2016), Cyprus (Zorpas et al. 2018), Pakistan (Bashaar et al. 2017), India (Kozak et al. 2016), Malaysia (Fatokun 2014), Nigeria (Banwat et al. 2016), or Israel (Barnett-Itzhaki et al. 2016).

The above data indicate the necessity of undertaking extensive educational efforts to eliminate improper practices of disposal of unused and expired PPCPs from life. This results from the fact that consumer behaviour regarding the disposal of waste PPCPs determines the impact on both the environment and the health of consumers. Although most societies are convinced that PPCPs should never be disposed with the application of the sanitary sewer system (pouring them down the sink or toilet) or by dumping them in the household municipal waste, this behaviour is still common, as indicated by the aforementioned studies.

Current evidence gathered from the conducted studies suggests that patients still lack knowledge about the proper method of disposal of unused and expired PPCPs as well as the environmental impact of improper disposal methods. The most common methods of disposal of PPCPs in the households disposal observed in numerous studies have the potential for causing harmful environmental pollution. Consequently, extensive educational efforts are needed to eliminate these practices (Tijani et al. 2016, Kusturica et al. 2017).

Shaabana et al. in their studies have confirmed that respondents who received the information on proper disposal were more likely to return pharmaceuticals to the pharmacy. Simultaneously, 73% of the respondents stated they had never received such instructions (Shaaban et al. 2018).

The purpose of the broadly-defined education should be to make the public and the authorities aware that the quality of life depends on the state of the environment in which we live, including the proper management of unused and expired PPCPs. Health education programs enshrined in the Ottawa Charter as part of the environmental approach, which – among other things – increase motivation for rational use of the environment by taking into account its impact on health, can be of great importance in this regard (Chmielewski et al. 2020, Żeber-Dzikowska et al. 2022). An example of effective educational activities in the form of an information campaign on the proper use and management of PPCPs can be found in Australia, which has been implementing the Return Unwanted Medicines (RUM) project since 1998. The project stipulates that each citizen may return unwanted PPCPs to any pharmacy. The cost of disposing of PPCPs returned to pharmacies is incurred by the state in cooperation with pharmaceutical companies. The project is accompanied by a large-scale campaign to inform the public about the dangers of improper disposal of PPCPs (RUM).

CONCLUSIONS

Protection of water from pollution should not only be related to rational management of water resources and restoration of the water environment to the condition required by law, but to prevention of pollution as well. Prevention of water pollution should become an important type of the protective measures in the context of environmental health.

Taking into account the unquestionable benefits that PPCPs bring to modern medicine, potential strategies for mitigating their environmental impact must include health and environmental education. The measures aiming at the implementation of the above should focus on prevention, reduction and management of PPCPs. They should also include the proper management of unused and expired PPCPs through their proper disposal, and ensure effectiveness of wastewater treatment of their presence. However, it should be remembered that these activities should take place without compromising their effectiveness and availability as well as affordability of PPCPs.

PPCPs are becoming an increasing threat to the environment as they are continuously discharged with industrial and municipal wastewater. As biologically active substances designed to act at low concentrations, PPCPs may have adverse effects on so-called non-target organisms in the environment and due to their tendency to bioaccumulate they are a serious threat to all levels of trophic food chains, potentially to human health as well.

There is a need for implementation of the wastewater treatment procedures at healthcare and social welfare facilities as well as pharmaceutical plants that have been identified as point sources of contamination with PPCPs.

Environmental health education concerning the problematic disposal of PPCPs is of key importance. It is necessary to build awareness of the public about their proper disposal. Guidelines for safe disposal and implementation of the organized method of collecting unused and expired PPCPs are required.

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