WATER RESEARCH COMMISSION

WORKING PAPER

Emerging substances of concern in water environments

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Summary

Water pollution by chemicals is a severe worldwide problem that needs to be urgently addressed. The sound management of chemicals and the importance of ensuring a sustained access to safe water have been recognised as an integral part of sustainable development, as stated in the United Nations' 2030 Agenda for Sustainable Development. Recently, there has been increasing concern over the presence of so-called emerging substances of concern (ESOC) within the aquatic ecosystem. The presence of these ESOCs into the aquatic environment has been increasingly associated with the discharge of poorly treated waste and wastewaters resulting from industrial, agricultural or municipal activities. In the past, regulators have solved legacy water quality challenges by imposing stricter regulations and/or standards. However, the enforcement of such regulations has proven to be challenging for most countries worldwide, mainly due to the fragmentation of related policies. However, managing the risks associated with ESOCs requires a shift from the conventional approach towards a more integrated and coordinated approach as means of ensuring sound chemicals management and attainment of a number of related sustainable development goals (SDGS). Strengthening water quality governance and ensuring that all water users are aware of their responsibility for the protection of water resources and risks are adequately managed is also vital. Finally, there is a need to put in place the required resources for supporting the implementation of ESOCs management strategies.

1 Introduction

The current water quality challenges confronting the world are unparalleled, as they are complex and dynamic in nature, calling for fundamental shifts in the way we use, manage, and even think about water. The declining quality and availability of usable water resources is an issue of global concern with potential to cause detriment to socio-economic development, ecosystems and human health. Both natural/environmental and anthropogenic activities are a common cause for the deterioration of quality in water resources. The water quality situation in South Africa is more intense, by nature of it being a water scarce country, where, in many cases the pollutant load reaching the receiving water resources exceeds their assimilative capacity. In addition, future projections indicate that climate change impacts related to climate variability, extreme weather events and changing rainfall seasonality could further worsen the water quality/quantity situation in South Africa [1].

Recently, there has been increasing concern over the presence of so-called emerging substances of concern (ESOC) within the aquatic ecosystem. ESOCs can be defined as substances, both of chemical or biological nature or of natural or synthetic origin, that have been detected in the environment, but which are currently not included in routine monitoring programmes and whose fate, behaviour and (eco)toxicological effects are not well understood. Emerging environmental substances of concern are not necessarily new chemicals, but have often long been present in the environment, only their presence and health effects are only now being investigated [2]. For the purposes of this paper, the "Emerging substances of concern" term has been adopted as an all-inclusive phrase to capture all the different connotations. In the context of the definition adopted in this paper, ESOCs can be categorised as follows; (i) global organic contaminants; (ii) pharmaceuticals and personal care products; (iii) endocrine disrupting compounds (EDCs); (iv) nanoparticles; (v) industrial chemicals (new and recently recognized); and (vi) biological metabolites and toxins, as well as emerging pathogens [3].

The presence of these substances in aquatic environmental systems such as wastewater, surface water, groundwater and drinking water presents a new water quality challenge and adds more pressure to the world's water resources with still unknown long-term effects on human health and ecosystems [4]. Thus, addressing water quality challenges due to the presence of ESOCs in water requires a shift from the traditional and fragmented sectoral approach to water quality management to a more integrated and coordinated approach as part of one urban water cycle, ensuring that all water users are aware of their responsibility for the protection of water resources and are accountable for the impacts. This paper presents a synopsis of the current scientific understanding, with regards to the sources, occurrence, fate and behaviour of ESOCs within the environment, as well as current efforts in managing these. Finally, key insights for a conceptual framework ESOCs surveillance within the environment, approaches and tools for toxicity and water quality assessment, as well as requirements for further research to inform institutional alignment and policies with respect to ESOCs as a base for integrated and sustainable water resource management are proposed.

2 Sources, fate and behaviour of ESOCs within the aquatic environment

Entry of these substances into aquatic environment has been perpetuated by the increase in the development of new (some known and others unknown) personal and household care products, industrial, agricultural and pharmaceutical substances, whose wastes are potentially discharged into the environment [4] (Figure 1).

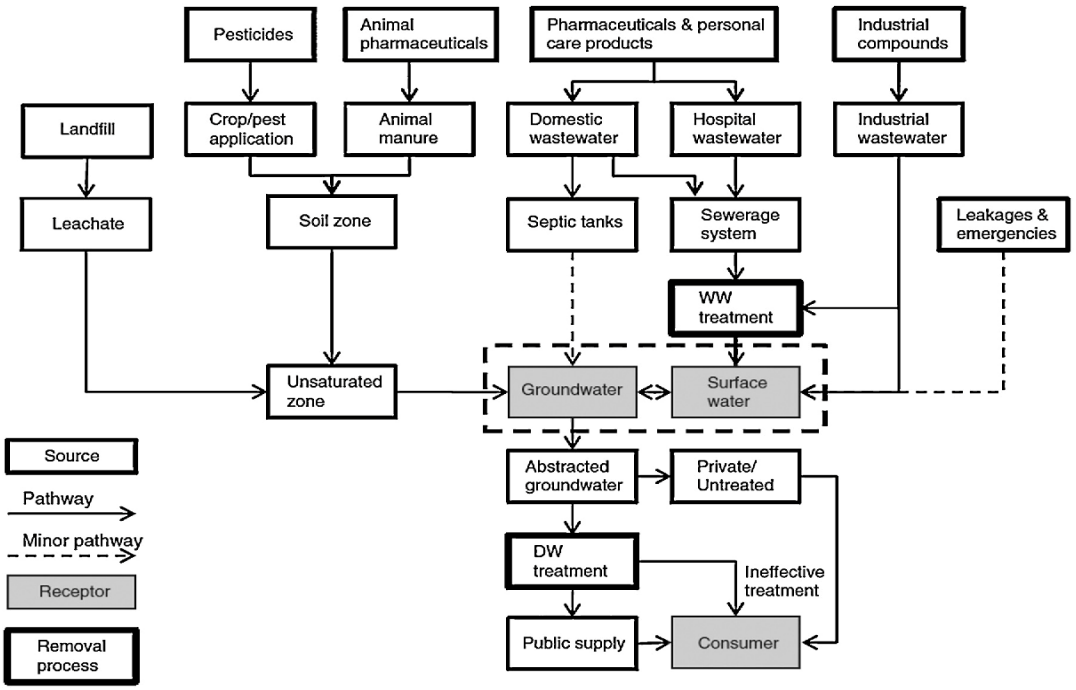

Figure 1: Sources and the flow pathways of emerging substances of concern into the aquatic environment [4].

Once within the aquatic environment, the extent of the contaminant transport is determined by their respective chemical properties, which dictate their fate and behaviour, i.e. persistence, bioavailability (speciation), i.e. whether it remains bioavailable for accumulation by humans and aquatic life or it interacts with soil and sediment particles. In this regard, there is need to strengthen research aimed developing and testing modelling approaches for predicting fate and behaviour of CECs within the aquatic environment as part of risk management. Alongside studies for determining the presence, fate and behaviour of ESOCs within the aquatic environment, a fair amount of work has been done on establishing the adverse health effects due to exposure to ESOCs, especially those with particular chemical structures and properties, which interfere with endocrine system. Thesecontaminants, denoted endocrine disrupting compounds (EDCs) constitutes a large class of ESOCs, but are poorly inventoried and regulated, and there is a general lack of information on their occurrence, fate and impact in the environment. Apart from EDCs, other ESOCs, such as fire-retardants, heavy metals (cadmium, lead or mercury), etc, have been shown to also impact the endocrine systems [5]. Based on research done thus, there is evidence that selected emerging contaminants could affect human and environmental health.

3 Synopsis of current practices in ESOCs management in water

In response to the increasing concern over the presence and risks of ESOCs, the Water Research Commission has funded numerous studies aimed at establishing their presence and environmental and human health impacts over the past two decades [6]. As noted in the current SDGs, poor water quality has a potential to cause detriment to socio-economic development, ecosystems and human health. To date, a significant number of chemicals of emerging concern (CECs), from both point and diffuse pollution sources have been detected within the aquatic environment in South Africa [7] and other parts of the world [8] These chemicals and their mixtures may pose a risk to ecosystems and raise concerns for environmental and human health when the contaminated water is used for drinking water production, irrigation, fishing and recreation. This

is because these are chemicals that are not adequately monitored and regulated, and their fate, behaviour and ecotoxicological effects are often not well understood. Similarly, the emergence and detection of a host waterborne pathogens, such as *Vibrio cholerae* O139, enterohaemorrhagic *Escherichia coli* (*E. coli* O157:H7), chlorine-resistant Cryptosporidium, hepatitis viruses (including hepatitis E virus), *Campylobacter jejuni*, microsporidia, cyclospora, *Yersinia enterocolitica*, calciviruses and environmental bacteria like Mycobacterium spp, aeromonads, *Legionella pneumophila*, etc, constitute a major health hazard in both developed and developing nations [9].

Routine water quality monitoring for tracking the entry of ESOCs into the aquatic environment, managing the risks thereof, including adoption of appropriate water treatment technologies and imposing and enforcement of related water quality regulations, has proven to be challenging for most countries worldwide. This is because of their large numbers of contaminants that have detected to date. To put this into perspective, more than 100 million chemical substances are currently registered in the Chemical Abstracts Service (CAS) and about 4000 new ones are registered every day [10] and this number is expected to continue to increase exponentially, presenting a significant cost and analytical challenges for their monitoring and regulation in water resources.

Furthermore, the current water quality monitoring and assessment regimes fail to characterize the likelihood that complex mixtures of chemicals affect water quality. The uncertainty associated with their presence, sources, environmental fate, behaviour and transport adds further complexities in determining associated health risks. Establishing water quality regulations for ESOCs requires an understanding of the risks, and in this instance, the lack of toxicological studies that give direct information on the adverse health effects is a major limitation. Therefore, in the interest of protecting public and environmental health, it is necessary that alternative approaches for ESOC management, involving controlling pollution from the source, routine water quality screening and surveillance, as well as the use of effects-based methods as a proxy for water quality risk assessment.

4 Recommendations

4.1 Institutionalising the management of chemicals in the environment

Chemicals are part of everyday life, and the chemicals sector contributes a sizeable portion to the economy. However, if not properly managed, they may end up in the environment, posing a human health risk. In 2006, a Strategic Approach to International Chemicals Management (SAICM), a global multi-sectoral and multi-stakeholder policy framework, was adopted by a number of stakeholders (including governments, intergovernmental and non-governmental organizations) as means for fostering the sound management of chemicals throughout their life cycle [11]. SAICM supports the achievement of the 2020 goal agreed at the 2002 Johannesburg World Summit on Sustainable Development, which envisages that all chemicals are produced and used in ways that minimize significant adverse impacts on the environment and human health by the year 2020.

Due to its importance, the sound management of chemicals and related wastes is also specified as a target in a number of the UN Sustainable Development Goals, including:

- SDG 3 on Good Health and Well-being, where Target 3.9 relates to reducing deaths and illnesses from hazardous chemicals),
- SDG 6 on Clean Water and Sanitation, specifically Target 6.3, which aims to improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials,

- SDG 12 on Sustainable Consumption and Production, where Target 12.4 is aimed at achieving the environmentally sound management of chemicals and wastes, and reducing their release to minimize adverse impacts on human health and the environment.

Given the different SDGs, it is likely that their implementation and reporting resides in different government departments (or ministries), highlighting a clear need for an integrated approach. For example, Sustainable Development Goal (SDG) 6 concerns ensuring the availability and sustainable management of water and sanitation for all, and is implemented within the Department of Water and Sanitation. The six 'outcome-oriented targets' under this SDG include: safe and affordable drinking water; end open defecation and provide access to sanitation and hygiene, improve water quality, wastewater treatment and safe reuse, increase water-use efficiency and ensure freshwater supplies, implement integrated water resources management (IWRM), protect and restore water-related ecosystems [12]. SDG target 6.3, which specifically relates to chemicals management cannot be achieved independently, i.e. without the others (i.e. SDG targets 3.9 and 12.4). In this case, it might be worthwhile to strengthen already existing governmental efforts on chemicals management, for example – current multilateral environmental agreements (MEAs) on chemicals and waste, such as Stockholm convention, Rotterdam convention, Basel convention, etc. In the case of South Africa, strengthening the implementation of chemicals and wastes policies within the Department of Environment, Fisheries and Forestry, as the overall custodian of the environment would be necessary.

Within the context of promoting good environmental management, controlling pollution at source and waste minimisation provides an opportunity to be environmentally responsible. In this instance, strengthening the enforcement of the "Polluter Pays Principle", one of the well-known and widely accepted environmental policy principles, can be used to address environmental pollution. Furthermore, preventing pollution by reducing and eliminating the generation of hazardous waste at the source is an important consideration. In this regard, more research is needed for the development of products that use non-hazardous material and/or technologies that utilize other source reduction approaches. In order to strengthen this component in developing countries, it is necessary that more efforts are directed towards establishment and institutionalisation of routine environmental surveillance and/or inventory programs.

Similar to many other governments, South Africa has adopted both the Strategic Approach to International Chemicals (SAICM) and UN's 2030 Agenda for Sustainable Development. Through the Department of Environment, Fisheries and Forestry, efforts are underway to strengthen the country's institutional approach towards sound management of chemicals and wastes. Currently, the management of chemicals in South Africa is fragmented, with different policies and regulations spread within different government departments, and this situation is not unique for South Africa. Thus, current efforts by the DEFF for developing of a national (unifying) policy framework and spearheading a coordinated approach for sound chemicals management is a step in the right direction in ensuring institutional alignment, accountability, attainment of SDGs, and ultimately minimising the impacts of chemicals on the environment and human health.

4.2 Strengthening the implementation of an integrated water quality governance model

Water resources are an important component of sustainable development, thus most problems related to water quantity and quality require coordinated national and regional solutions. In this regard, it is important that there is multilateral cooperation for the attainment of environmental management principles and developmental goals, as means for solving complex water quality challenges due to the presence of ESOCs.

Moreover, such solutions should also incorporate a wide range of social, ecological and economic factors in order to account for the roles and responsibilities of human activities on water quality management. Apart from having the right policies in place, active water quality surveillance is yet a fundamental tool in the management of freshwater resources.

In the developed world, forensic approaches are increasingly being applied as part of an early warning strategy for water quality changes, as means for chemical pollution control and to enforce compliance to environmental quality regulations [13]. In South Africa, an integrated water quality management model has been adopted, however, there is need to strengthen the implementation of this model, in order to give impetus to the national water quality monitoring programs established under the National Water Act (Act 36 of 1998), as well as to balance the need for water to achieve developmental needs as well as those for maintaining a healthy environment.

4.3 Strengthening capacity for water quality analysis and research

Tracking the emergence of new pollutants into the environment requires the use of rapid and highly sensitive analytical technologies. Thus, improvements in laboratory analytical methods are necessary for the timeous and accurate identification of these substances, also aiding risk management. Additionally, there is a need to improve and harmonise methods for sampling and analysis for a number of ESOCs, in order to be able to compare and extract meaningful information from analyses. For example, methods for microplastics analysis are still at its infancy, requiring further research and harmonisation. As environmental risk cannot be meaningfully assessed for the vast majority of ESOCs, there has been an increased research interest towards the use of effect-based methods (EBMs) complemented by chemical screening and/or impact modelling for water quality risk assessment and establishment of health-based targets for water quality for different uses [14]. The main goal of water quality risk assessment is protecting human, as well as that of ecological communities in the aquatic environment. Thus, adoption of effect-based methods as part of a risk based approach may serve as an alternative method for assessing the cumulative risks from combined exposures to several stressors, including mixtures of ESOCs.

5 Concluding remarks

It is almost inevitable that small amounts of ESOCs, which are manufactured to protect human health, improve consumer goods, or optimize agricultural production, are unintentionally released into the aquatic environment. Therefore, it is important that more effort is directed towards establishing a water quality surveillance program in order to track the emergence of new pollutants and their sources, estimate the loads within the environment as part of toxicity assessment. Research, development and innovation is also critical for supporting the management of risks associated to exposure to ESOCs, as well as for informing policy and decision making on water quality regulations. ESOCs have been addressed in a number of WRC projects commissioned as part of the Water Quality and Health Programme. WRC reports cited below can be downloaded by accessing the WRC's knowledge hub at http://www.wrc.org.za/. Current initiatives under the WRC's Water Quality and Health Programme include: development of a knowledge hub on ESOCs, tracking the occurrences, sources and levels of ESOCs and strengthening capacity for risk assessment (including the use of effect-based methods as a proxy) and management.

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