Emerging Contaminants and Public Health: Environmental Risk and Innovative Controls

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Review Article

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ABSTRACT

An estimated 12.6 million people died as a result of living or working in an unhealthy environment in 2012 – nearly 1 in 4 of total global deaths, according to new estimates from WHO. Environmental risk factors, such as air, water and soil pollution, chemical exposures, climate change, and ultraviolet radiation, contribute to more than 100 diseases and injuries. The growing challenges and negative impacts of emerging contaminates posing risk in human health and the environmental ecosystem in recent decades especially in groundwater, surface water, municipal wastewater, drinking water, and food sources has raised an alarming concern globally. Regardless of the numerous risks identified and associated with emerging contaminates, it is believed that not much work is done in terms of research, policies and strategies. The efficient and cost-effective solutions are yet to be deployed at scale.

This review has made recommendations base on literature review that can be adopted, improved on to help develop a more adoptive innovative treatment technology to manage emerging contaminates.

Keywords: Contaminants; Environment; Water; Ecosystem

INTRODUCTION

An estimated 12.6 million people died as a result of living or working in an unhealthy environment in 2012 nearly 1 in 4 of total global deaths, according to new estimates from WHO. Environmental risk factors, such as air, water and soil pollution, chemical exposures, climate change, and ultraviolet radiation, contribute to more than 100 diseases and injuries. The growing challenges and negative impacts of emerging contaminates posing risk in human health and the environmental ecosystem in recent decades especially in groundwater, surface

Hybrid Ceramic Membrane Filtration (HCMF): Polymeric membranes are widely used in water treatment to remove pathogens, particles and organics from surface, ground, and process and filter backwash water. However, ceramic membranes are much more resilient, outperforming polymeric membranes even under extreme conditions (e.g. temperature, pH and chemicals). LCC assessments based on case studies also show that HCMF have lower operational costs than polymeric membranes, though implementation costs were higher for HCMF. In order to improve cost effectiveness, several alterations to the ceramic membrane modules have already been tested and successfully applied within the DEMEAU project. For example, by combining several membranes into one vessel, fewer valves, and therefore steel, are needed. In addition, an improved bottom plate has helped to enhance its durability, making the technology more resilient during backwashing, particularly in the long-term.

Automated Neural Net Control Systems (ANCS): Automated Neural Net Control Systems (ANCS) are computer-based, process optimization systems that use tailored mathematical algorithms, with applications in drinking water processing and supply, urban drainage systems, and activated sludge reactors in wastewater treatment plants. In the drinking water industry, ANCS technology is usually applied as an add-on to optimize membrane filtration, and thus is widely applicable. Within DEMEAU, marked improvements in filtration and enhancements in process productivity (of about 4% to 15%) has made ANCS particularly lucrative as an add-on for existing membrane filtration plants in Europe to increase their increasing environmental and economic sustainability [13].

However, several barriers to widespread uptake still exist for ANCS. Life cycle assessments have revealed that a certain degree of complexity is necessary in order for ANCS to be cost-effective. Consequently, larger plants are more cost-effective than smaller plants. Similarly, as maintenance is a necessary aspect of the technology, ANCS is more cost-effective at larger scales. As a result, understanding the extent and costs of maintenance required for the plant is an important aspect to account for prior to implementation.

Advanced Oxidation Techniques (AOT): Oxidation techniques have a long tradition for use in disinfecting drinking and wastewater, however, its benefits for use in removing emerging pollutants have only recently come to light. Results from pilot plants and the first full-scale application using post-ozonation produced removal rates greater than 80% for many emerging pollutants. Within DEMEAU, researchers, utilities and SMEs are testing a combination of various oxidation processes (including O3, O3/ H_2O_2, UV/H_2O_2) as well as different post- treatment applications, such as sand filtration or biological activated carbon filtration.

Due to the collaborative character of DEMEAU, the project is actively facilitating a safe environment for utilities and SMEs to experiment and apply this innovative technology in a full-scale drinking water plant. The results have been promising: one oxidation reactor developed by a Dutch SME projects significant energy reductions. In fact, the SME estimates 30%-40% less energy consumption with its oxidation reactor as compared to conventional reactors using UV/H_2O_2 processes.

Bioassays: Current mainstream water monitoring strategies rely exclusively on chemical analysis. However, chemical analysis only identifies specific, targeted compounds with no information on the biological effects of the pollutants. Bioassays address this gap in monitoring strategies, and hold the potential to serve as an additional, complementary technology to chemical analysis. Because bioassays measure the biological effects of single compounds present in water samples, they are particularly useful for application in assessing the harmful effects of complex mixtures of unknown pollutants. As a result, bioassays have the potential to widen the scope of water quality monitoring and can

Photo-fenton: Photo-Fenton processes have been used in a wide variety of CECs degradation of various scales and modes of operations. The majority of the photo Fenton processes uses lower energy UV wavelengths and even solar-powered systems. Degradation time also varies from 10–180 min, depending on the compounds being degraded. Most of the investigations using photo-Fenton processes focus on the removal of target compounds spiked in synthetic matrices at laboratory scale and pilot scales with a good degree of degradation of between 80%–90% of CECs.

Notable publications describing the effects of chemical structures on the efficiency of photo/Fenton-based systems are summarized above. Recent innovation with magnetic carbon-based heterogeneous composites addresses the reusability and separation of conventional heterogeneous catalysts. Alani et al., [18] reported that the photocatalytic performance of the magnetic catalyst remains relatively high even after 5 consecutive uses.

The recent innovation of the use of solar-assisted Fenton, raceway pond reactors, shows promising results for the degradation of CECs. This reactor configuration requires less energy input due to the use of solar energy and also shows a high degree of degradation. The height of the race pond bed seems to contribute significantly to the degradation performance of CECs. More recently, alternative and cheaper ligands such as NTA are also being test bedded against conventional EDDS ligands. At present, the study of this reactor is still in its infancy stage and hence has the potential to be developed further.

Photo catalysis: Photo catalysis uses solar energy/UV lamps with a catalyst and has been used in a wide variety of CECs degradation of various scales and modes of operations. The majority of the photo catalysis processes utilize both lower energy UV wavelengths and even solar energy. Degradation time also varies from 10–180 min, depending on the compounds being degraded. Most of the investigations using photo catalysis processes have been focused on the removal of target compounds spiked in synthetic matrices at a laboratory scale with a good degree of degradation of between 80%-90% of CECs. Various types of photo catalysts such as Titanium Dioxide (TiO_2), Zinc Oxide (ZnO), Tungsten Trioxide (WO_3), and Graphitic Carbon Nitrides (g-C3N4) have been explored.

The degradation rate of CECs by photo catalysis is found to be closely related to their molecular structures. Eskandarian, et al. found that decomposition kinetics of CECs by TiO_2 photocatalytic followed the order: sulfamethoxazole > diclofenac >ibuprofen>acetaminophen. Sulfamethoxazole is highly reactive due to the NH group in its chemical structure. Ibuprofen could be decomposed *via* rearrangement of the acidic group, followed by decarboxylation reaction and dehydrogenation. However, it is less flexible in degradation sites due to its molecular structure. Degradation of acetaminophen is the most difficult of the four compounds. The mechanism involved the removal of the amide group (CH3CONH), formation of phenoxy radical that will react with superoxide radical. In another study, [20]Alverez–Corena. et al, found the decreasing trend of UV/TiO_2 degradation kinetics for 5 CECs: Gemfibrozil > 17β estradiol > N-nitrosodimethylamine (NDMA) > 1,4-dioxane > tris-2-chloroethyl phosphate (TCEP). The high degradation for gemfibrozil could be attributed to the presence of a deprotonated carboxyl group in its structure which can enhance its adsorption capacity on the photocatalyst surface. N-NO bond in NDMA could act as an electron donor to the TiO_2 surfaces. C-O bonds in 1,4-dioxane could be served as hydrogen bond acceptors for dipolar attractions [21-23]. TCEP is without ionizable functional groups in its structure. In addition, a high pKa of 14.86 of its leaving group 2-chloroethanol and higher dipole moment makes it difficult to be removed. Hence, TCEP showed the slowest degradation rate.

innovative solutions-oriented technologies, while also providing an incentive for technology developers to generate innovations.

There are economic barriers and associated risks. As mentioned previously, SMEs and water utilities often cannot bear the burden posed by such economic barriers. Because innovation in the water sector is often fraught with uncertainty, it requires a very specific environment for actors to be willing to engage and also be successful.

Increase research in these areas, to identify more innovative approached and technology to treat emerging contaminants that posing high risk to human and the environment.

It is believed that the adoption of this recommendation will not only help identify solutions to emerging contaminates but also go a long way to reduce the risk to humans and the environment.

DECLARATIONS

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Ethics approval

The authors declare that the submitted manuscript is original. The authors also acknowledge that the current research has been conducted ethically and the final shape of the research has been agreed upon by all authors. The authors declare that this manuscript does not involve researching humans or animals.

Conflicts of interest/Competing interests

The authors declare no conflicts of interests/competing interests.

Authors' contributions

Ebenezer John Atsugah: Conceptualization, Methodology, Investigation, Supervision, Writing- Original draft preparation, Validation, Writing- Reviewing and Editing. Samuel Jerry Cobbina: Data curation, Validation, Writing- Reviewing and Editing. Abdul-Wahab Tahiru: Methodology, Investigation, Writing- Reviewing and Editing.

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