



Environmental and Human Health Problems Associated with Hospital Wastewater Management in Zimbabwe

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Abstract

Purpose of the Review Wastewater is a term used to describe water that has undergone degradation in quality owing to anthropogenic activities or natural processes. Wastewater encompasses liquid waste originating from academic institutions, households, agricultural sector, industries, mines and hospitals. Hospital wastewater contains potentially hazardous substances including residues of pharmaceuticals, radioisotopes, detergents and pathogens, with detrimental impacts to the environment and human health. Nevertheless, studies related to hospital waste management are limited in Africa, particularly in Southern Africa. This research offers an overview of aspects surrounding hospital wastewater in Southern Africa, focusing on Zimbabwe. Already published and grey literature was reviewed to compile the paper.

Recent Findings Number of patients, nature of medical services offered and hospital size influences generation of hospital wastewater. Partially and non-treated hospital wastewater is managed together with municipal wastewater. Management of hospital wastewater is impeded by shortage of resources, lack of co-ordination among responsible authorities and ineffective legal framework enforcement, among other challenges. Inappropriate hospital wastewater management results in environmental contamination, causing human ailments.

Summary Attainment of sustainable hospital wastewater management requires clearly defined and enforced legislation, collaboration of accountable stakeholders, sufficient resources and enhanced awareness of involved stakeholders. Application of technologies that uphold recycling and reuse of wastewater is essential to reach Sustainable Development Goals, Zimbabwe Vision 2030 and National Development Strategy 1 targets, particularly those dealing with environmental protection while upholding human health.

Keywords Hospital Wastewater · Management Strategies · Environmental Risks · Health Risks · Zimbabwe

Introduction

Globally, rapid population growth, industrialisation and service provision have led to a significant increase in the generation of wastewater, which is causing detrimental environmental health impacts [1••, 2••]. Wastewater is a product of various anthropogenic activities, although natural processes can affect water quality negatively. Wastewater comprises liquid generated from households, industries, commercial premises, mines, agricultural activities and institutions [2••, 3••]. Nevertheless, wastewater from hospitals has the

potential to cause the most detrimental impacts to the environment and humans, since it contain pathogens and heavy metals [4••, 5••]. As a result, the management and environmental health impact of hospital wastewater is becoming an issue of concern in developed and developing nations. In developed countries, more sophisticated approaches include converting hospital wastewater into biogas and fertilizer [6••]. This signifies that developed countries are applying hospital wastewater management strategies that support circular economy. The scenario differs in developing regions like Africa where management of wastewater, including hospital wastewater, puts much emphasis on wastewater disposal [7••, 8••]. In Southern Africa, inadequate management of hospital wastewater can be attributed to socio-economic and political challenges, and poses negative impacts to terrestrial, aquatic, atmospheric ecosystems and human health [9, 10] and Zimbabwe is not exempted [11, 12].

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Proper management of hospital wastewater is rare in Southern Africa and is surrounded by various questions related to sustainable development goals (SDGs). In the Zimbabwean context, inappropriate management is highly ascribed to limited resources, inadequate infrastructure, lack of awareness and low enforcement of legislation and policies [13••]. Inappropriate management of wastewater from various sources, including hospitals, offers opportunity for hazardous materials, namely antibiotics, anti-inflammatory drugs, heavy metals, solvents, disinfectants, cytostatic agents, anaesthetics and detergents, to reach the natural ecosystem [14, 15••]. This implies that hospital wastewater has the potential to spread organic pollutants that persist in the environment for a long time and cause ailments to humans since the pollutants can accumulate in the food chain. Indiscriminate disposal of hospital wastewater plays an important role in dissemination of antibiotic-resistant bacteria into the surrounding environment, including natural and artificial water sources. Mismanagement of hospital wastewater also triggers the occurrence of gastrointestinal diseases, and according to Shabani et al. [16] and Jerie et al. [17] Zimbabwe is struggling with diseases like cholera, typhoid, dysentery and diarrhoea due to improper waste management.

Sulfamethoxazole and ibuprofen in hospital sewage sludge have the potential to be absorbed by green crops [18••, 19]. Nevertheless, many consider wastewater as suitable for watering plants, particularly in urban areas where backyard farming is practised [13, 20••]. This is a matter of great importance to people since they consume contaminated food, exposing themselves to internal organs damage and cell growth disturbances. Diseases caused by hazardous substances in hospital wastewater cause acute and chronic health problems that require persistent medical attention. In Southern African nations, not sparing Zimbabwe, municipal wastewater encompassing wastewater from health institutions is partially treated and sometimes finds its way into water sources [21, 22••], and it often contains carbamazepine. Unfortunately, carbamazepine accommodates compounds that affect people's neurological development,

causes the death of aquatic creatures, and is highly linked to rampant algal growth in water sources [23, 24••]. Mismanagement of hospital wastewater widens the gap to attain the requirements of SDGs, particularly life on land, life below water, good health and wellbeing, sustainable cities and communities and clean water and sanitation. In order to suppress numerous health problems, hospital wastewater management in Southern African nations, exemplified by Zimbabwe, should shift from the current paradigm and focus on global sustainable prospects [22, 25]. However, research related to management of hospital wastewater in countries in Africa is low (Fig. 1), particularly in Zimbabwe, since it is among the countries that are not listed in Fig. 1. Therefore, this review paper puts much emphasis on Zimbabwe.

Overview of the Study Area

Zimbabwe (Fig. 2) is a landlocked country located in Southern Africa and is a lower income nation with a population of approximately 15.1 million that grows at 1.5% annually [26]. Zimbabweans are served by various health institutions, including private and public hospitals. Hospital wastewater is projected to increase owing to the exponential growth of people who resort to health institutions for treatment. The estimated number of hospital facilities in Zimbabwe is 214 while the number of primary healthcare facilities is around 1634. A hospital facility is a type of specialist healthcare facility that offers sick or injured people nursing, medical and surgical treatment. Hospitals are fitted with expert personnel, cutting-edge medical equipment and resources to manage emergencies and complicated medical issues. They provide a broad variety of services including operations, critical care units, diagnostic testing and specialised therapies for a range of illnesses. Primary healthcare facilities are the first point of contact for individuals seeking healthcare services. These facilities focus on providing essential and basic healthcare services to the community. Primary healthcare facilities include clinics, health centers, community health centers, and other outpatient settings. Progress

Fig. 1 African countries with documents related to hospital wastewater in SCOPUS database

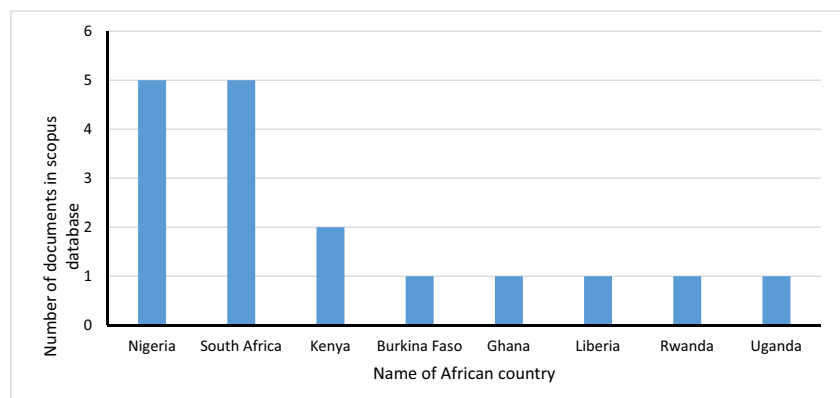




Fig. 2 Map of Zimbabwe

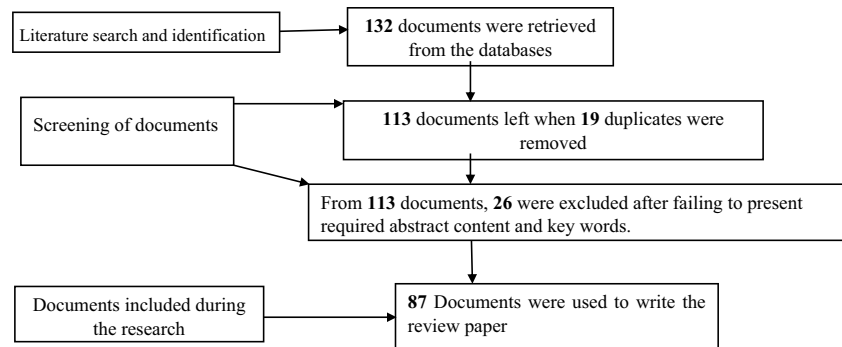
towards sustainable management of hospital wastewater, however, is not matching the increase of health facilities. Gweru, Harare, Bulawayo and Mutare produce about 10.500m³/d, 200.000 m³/d, 34.000m³/d and 30.000m³/d of wastewater respectively [27], not sparing wastewater from hospitals. Most of the existing studies put much emphasis on hospital solid waste management issues, neglecting hospital wastewater, though it also contains hazardous living organisms and pathogens. This scenario is found in most countries in Southern Africa [28••, 29, 30].

Methodology

Relevant published journal articles, papers, books, book chapters and dissertations were retrieved from various academic databases such as PubMed, Scopus, Web of Science, Google Scholar, ResearchGate and Academia.edu. Grey literature, like official reports, were retrieved from recognised government institutions among other organisations websites. In order to expedite the literature retrieval process key search

terms utilised encompass “hospital wastewater”, “hospital wastewater composition”, “hospital wastewater management”, “Zimbabwe” and “environmental health impacts of hospital wastewater”. Boolean operators such as “and”, “or”, quotation marks” and “parenthesis” were used to combine search terms, refine searches and narrow down the results. Appropriateness of documents was determined by abstract content, and key words, namely hospital wastewater, management strategies, management strategies, environmental risks, health risks and Zimbabwe. Only documents written in English were included. 132 documents were retrieved from authentic databases. However, 19 duplicates documents were removed after screening, leaving suitable documents at 113. After screening considering relevant key words and abstract content 26 documents were excluded. Consequently, 87 documents were utilised to write the review paper since they meet the inclusion criteria requirements. To lessen burden in identifying and screening of secondary data sources, PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) was adopted and is illustrated by Fig. 3.

Fig. 3 Flow chart showing article selection and number of documents used



Results and Discussion

Generation and Composition of Hospital Wastewater in Zimbabwe

Zimbabwe's population has been growing over the years as demonstrated by a 2022 census [26], leading to an increased demand for healthcare services [11, 12]. More healthcare facilities have been established to cater for the growing population, leading to an increase of wastewater generated from hospitals. In Zimbabwe, Malawi, Tanzania, Botswana and Kenya composition of hospital wastewater varies depending on type of healthcare facility, patient demographics and nature of health services offered [31–33, 34••]. Therefore, drivers of hospital wastewater increase in Zimbabwe are similar to other countries in Southern Africa. Larger hospitals like the Parirenyatwa group of hospitals, Mpilo hospital and Gweru Provincial hospital accommodate more patients and tend to produce higher volumes of wastewater than Holy Cross and ST Theresa hospitals in Chirumanzu district. The rate of hospital wastewater generation fluctuates throughout the day due to peak periods when healthcare activities are more intensive [1••, 35].

Hospital wastewater is generated from various sources and activities, including patient care activities and diagnostic procedures [30, 36]. Composition and characteristics of hospital wastewater varies depending on the specific activities and services provided to the patients by the health facility. Patient care activities comprise bathing, diagnostic procedures, and showering, among other personal hygiene practices of patients. Wastewater composed of a variety of substances, such as detergents and body fluids, has the potential to change colour and accumulate persistent organic pollutants [37••, 38]. Diagnostic activities like laboratory testing, medical imaging and radiology examinations performed at hospitals generate wastewater that may contain chemicals, contrast agents and radioactive materials among other hazardous substances [39, 40••]. Healthcare facilities are among sources of infectious materials such as blood, urine, faeces and other bodily fluids that may contain bacteria, viruses, parasites, or fungi [11, 12, 41]. This entails

that hospital wastewater generated by private and public hospitals in Zimbabwe contains numerous pathogens and substances with the potential to cause various human ailments, including diarrhoeal diseases. This highlights the need to manage wastewater from rural and urban hospitals appropriately.

Certain medical procedures like surgeries involve the use of heated fluids or solutions resulting in generation of warm wastewater. Autoclaves are commonly used to sterilise surgical instruments and they operate at high temperatures, translating to generation of wastewater with high temperatures [42, 43]. General hospital activities like cleaning, sterilisation and waste management generate wastewater [4••, 44••] and health institutions in Zimbabwe are not exempted since disinfectants and detergents are used for cleaning purposes. Sterilisation processes involve the use of chemicals or steam, which add chemicals like sodium hypochlorite, hydrogen peroxide, ethylene oxide, glutaraldehyde, paracetic acid and chlorine dioxide to wastewater. Hospital wastewater also has the potential to contain pharmaceuticals, since Shabani and Jerie [12] indicated that medical waste, including pharmaceutical waste, is usually mismanaged. In terms of specific constituents found in hospital wastewater, studies have identified various substances that are toxic while facilitating spread of various diseases, namely cholera, typhoid, diarrhoea, dysentery among others [30, 36].

Hospital Wastewater Management Practices and Challenges in Zimbabwe

Management of wastewater encompassing hospital wastewater is commonly based on utilisation of septic tanks, soak ways and anaerobic ponds [30]. Septic tanks are used for primary treatment, where solid waste settles at the bottom while partially treated effluent flows into soakaways or anaerobic ponds for further treatment [45••, 46]. Effectiveness of these systems is compromised by poor infrastructure maintenance, lack of resources and inadequate capacity. Most urban hospitals in Zimbabwe release wastewater into municipal sewer pipes [47], on the way to municipal sewer ponds. The scenario differs in rural hospitals, which construct their own

septic tanks, soakaways and anaerobic ponds to treat and dispose wastewater. Wastewater management legal frameworks, for instance the Environmental Management Act, stipulate that wastewater should be treated before disposal and hospital wastewater is not exempted. Adherence to this is limited at hospitals due to limited resources and technical expertise. Mismanagement of hospital wastewater in most developing countries, such as Angola [48], Botswana [49] and Mozambique [50], owes to a lack of awareness and failure to adhere to legislations and policies. Similarly, in Zimbabwe waste mismanagement is exacerbated by inadequate knowledge among individuals and responsible authorities [27, 45••]. There is need for more comprehensive training programs that address all aspects of wastewater and raise awareness of hospital authorities while urging co-operation among responsible stakeholders.

Management of waste is guided by Environmental Management Agency Act, Public Health Act, Water Act, Urban Council Act, Hazardous Substances and Articles Act, Zimbabwe's constitution and Environmental Impact Assessment Policy. However, while there are legislation and policies in place, there is a lack of legal framework directly related to hospital wastewater and inadequate enforcement of the existing ones. A robust regulatory framework which is clear in terms of roles and responsibilities of accountable stakeholders is essential to ensure effectiveness of legislations and policies while ensuring compliance of all hospitals. Socio-economic challenges also affect waste management negatively [51, 52] and hospital wastewater management is not spared. Hospitals struggle to find qualified staff who operate and maintain wastewater treatment systems effectively, therefore implementation of appropriate management practices is at infancy stage. The scenario is worse in rural areas where nearly incapacitated hospitals shoulder the burden of managing wastewater using their own limited resources. Financial constraints make it difficult to invest in advanced waste management approaches [53, 54] and wastewater management infrastructure receives little attention. As a result, enough resources must be channelled to rural hospitals in order to upgrade wastewater treatment methods and infrastructure.

Environmental Health Problems Associated with Hospital Wastewater Management in Zimbabwe

Inappropriately disposed hospital wastewater is among the culprits responsible for polluting water in rivers, streams and underground water sources [45••, 46], causing eutrophication and death of aquatic creatures, chiefly fish and frogs, among others. This concurs with Khan et al. [55••] and Ajala et al. [56••] that antibiotics, disinfectants and radioactive materials in wastewater from hospitals pose detrimental

impacts to aquatic ecosystem. In the Zimbabwean context, owing to water scarcity, both people and animals utilise water from open sources [57, 58], thus exposing themselves to ulcers, cancer and intestinal damage, since waste water from hospitals contain heavy metals. Hence, the outbreak of waterborne diseases such as cholera, typhoid, dysentery as well as diarrhoea is also exacerbated by mismanagement of wastewater [59••, 60] including wastewater from hospitals. Considering socio-economic problems experienced in Zimbabwe, the burden and prevalence of acute and chronic diseases associated with hospital wastewater will persistently grow unless immediate effective measures are taken.

Antibiotics, radioactive materials, pharmaceuticals and disinfectants cause detrimental impacts to the ecosystem and last longer in the environment [42, 61]. Persistent pollutants from hospital wastewater accumulate in the food chain, causing detrimental impacts to living organisms and people who earn a living from ecosystem services. Additionally, inadequate treatment and disposal of hospital wastewater into inappropriately lined discarding infrastructure leads to groundwater contamination as well as soil pollution. This signifies that improperly managed hospital wastewater is worsening scarcity of safe water in the country, yet availability of water is already threatened by climate change impacts [62••, 63]. Pharmaceutical residues persist in water bodies for long periods and have adverse effects on aquatic organisms [44••, 55••]. These detrimental effects include changes in behaviour, growth inhibition, reproductive disorders and even death of aquatic organisms. Furthermore, pollutants in wastewater from public and private hospitals have potential to affect soil quality as well as affecting lives of organisms that lives in the soil. Shabani and Jerie [12] and Shabani et al. [54] concur that pollutants from waste cause negative impacts to vegetation in the affected area. Similarly, pollutants from improperly managed hospital wastewater can suppress growth or cause extinction of native vegetation while supporting growth of invasive species. Table 1 summarise major environmental-health problems associated with improperly managed hospital wastewater.

Possible Directions to Attain Sustainable Hospital Wastewater Management in Zimbabwe

The increasing need for clean and affordable drinking water has led to a rise in demand for effective wastewater management practices and recycling [64, 65]. This highlights the importance of applying approaches that support circular economy in hospital wastewater management, hence the country needs to abandon the existing linear hospital wastewater treatment system that focuses on disposal. Application approaches like hospital wastewater treatment for reuse increase availability for various purposes, including agriculture and industry. If health institutions apply treat-reuse,

Table 1 Summary of major environmental-health problems that emanate from improperly managed wastewater from hospitals

Environmental-health problems	Description
Spread of antibiotic resistance	Hospital wastewater may contain antibiotics that contribute to the development of antibiotic-resistant bacteria, posing a significant public health threat.
Exposure to hazardous substances	Healthcare workers and individuals living near healthcare facilities may be exposed to hazardous substances present in hospital wastewater, leading to various health issues.
Respiratory issues	Improper management of hospital wastewater can result in the release of harmful gases like ammonia and hydrogen sulphide, which can cause respiratory problems among nearby populations.
Chemical pollution	Hospital wastewater can contain various chemicals such as pharmaceuticals, disinfectants, and heavy metals. These chemicals can contaminate water bodies, affecting aquatic life and potentially entering the food chain.
Microbial contamination	Hospital wastewater can carry pathogenic microorganisms like bacteria, viruses and parasites. If not properly treated, this contamination can lead to waterborne diseases in humans and animals.
Release of nutrients into the environment	Hospital wastewater often contains high levels of nutrients like nitrogen and phosphorus. When discharged into water bodies, these nutrients can cause eutrophication, leading to algal blooms and oxygen depletion in aquatic ecosystems.
Soil pollution	When liquid waste seeps into the soil, it can introduce harmful chemicals and pathogens. Soil pollution affects plant growth and can lead to long-term damage.

water scarcity could be minimised, since Khumalo et al. [66] and Musemwa [67] note that Zimbabwe is experiencing water scarcity. Appropriate policies and legislation are required to pin strategies that support circular economy in wastewater management [68, 69••], particularly policies that urge channelling of enough resources to activities and innovations aiming to recycle and recover fertilizer from hospital wastewater. Another step towards sustainable hospital wastewater management is implementation of appropriate treatment technologies and infrastructure. This is because wastewater treatment methods and infrastructure in developing countries are far from the acceptable standards from an environmental perspective [70]. Similarly, properly engineered treatment techniques and infrastructure is crucial so that disposed wastewater conforms to standards recommended by Environmental Management Agency. Consequently, comprehensive and clearly enforced hospital wastewater legislation and policies that cover wastewater quality standards, proper treatment and disposal must be implemented.

It is essential to employ treatment methods that effectively remove or reduce pollutants to acceptable levels [71, 72], so that hospital wastewater becomes recyclable and reusable. The country must invest in processes such as desalination, evaporation and crystallisation, oxidation, disinfection, filtration and reverse osmosis, which removes undesired components and pathogens. Regular monitoring and maintenance of wastewater treatment plants is still inefficient [45••, 73••]. Hence, conduction of routine inspections, sampling and analysis of wastewater quality to assess the performance of hospital wastewater treatment systems is significant. Wastewater treatment plants that accommodate hospital wastewater need monitoring to unearth biochemical oxygen demand, chemical oxygen demand, total suspended solids and pathogen levels. Monitoring of wastewater

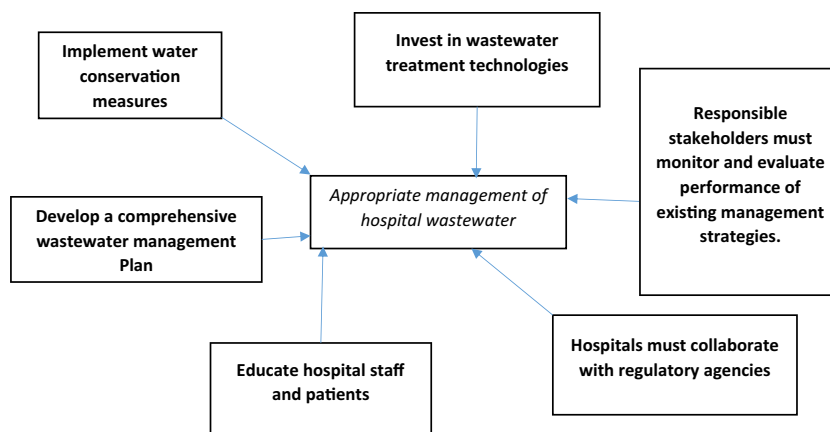
treatment plants facilitates detection of the treatment plant inefficiency and deviations of wastewater quality parameters from desired standards [74••, 75••].

A number of healthcare workers lack adequate knowledge on proper waste management [11, 12, 76], including hospital wastewater. Providing comprehensive training programs on wastewater segregation, disposal and treatment techniques ensure that hospital staff are equipped with necessary skills to manage wastewater effectively. Workshops as well as seminars aiming to train and raise awareness of healthcare staff involved in wastewater management are required to reduce burden in managing wastewater from rural and urban hospitals. Implementation requires collaboration between healthcare institutions, government agencies and educational institutions to develop training modules and workshops tailored to the specific needs of healthcare workers. Promoting research and innovation by offering enough resources to researchers is crucial to move towards efficient, cost-effective, sustainable hospital wastewater management. Figure 4 illustrates some of the major aspects that can be integrated to achieve appropriate management of hospital wastewater. Further research is needed to identify additional challenges faced by hospitals in managing their waste [11, 12], including hospital wastewater.

Conclusion and Recommendations

Hospital wastewater mismanagement is among several contemporary problems impacting Zimbabwe due to inadequate infrastructure, missing resources, limited technical expertise, financial constraints, lack of awareness, legal framework gaps and lack of coordination among accountable stakeholders. Hospital wastewater mismanagement

Fig. 4 Summary to minimise obstacles faced during moving towards sustainable hospital wastewater management



causes water, soil and air pollution while disturbing native flora and fauna. Improperly managed hospital wastewater facilitates outbreak of diseases like cholera, typhoid, dysentery, diarrhoea while exposing people to bad odours translating to respiratory disease and nose irritation. Mismanaged hospital wastewater widens the gap to achieve SDGs, Zimbabwe Vision 2030 and National Development Strategy 1 targets. Therefore, sustainable hospital wastewater management require collaboration of all stakeholders, application of recycling and reuse, clearly defined and enforced legislation, adequate resources and raising awareness of involved stakeholders. Continuous monitoring and inspection of wastewater treatment plants is essential while reviewing of legal frameworks related to hospital wastewater management can lessen wastewater management challenges. Generally, there is no singular approach that can be deemed as a definitive resolution for effectively handling the issue of hospital wastewater management, hence integrated approaches have potential to harvest low-hanging fruits to attain sustainable hospital wastewater management.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

All authors have read, understood, and have complied as applicable with the statement on 'Ethical responsibilities of Authors' as found in the Instructions for Authors and are aware that with minor exceptions, no changes can be made to authorship once the paper is submitted.

Consent to Publish All authors agreed to publish the review.

Conflict of Interest The authors declare no competing interests.

Informed Consent to Participate All authors participated and agreed to participate up to final revision of the manuscript.

Ethical Approval N/A.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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