

# Pathways and Legislation Towards Hospital Wastewater Discharged Around Globe

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Received: 4 May 2021 / Accepted: 7 June 2021

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**Abstract.** In every section of the environment pharmaceuticals are now can be observed and detected. Hospitals are one of the major sources of pollution via either through environment or wastewater treatment plants (WWTPs). The treatment plants are not prepared for effective treatment of emerging contaminants (ECs). This paper further illustrates the lack of understanding of the ecotoxicity of certain large concentrations of pharmaceutical compounds in HWW ( $\text{mg L}^{-1}$ ). In order to expand this analysis, the ecotoxic risks associated with numerous pollution scenarios, particularly water-dilution and metabolite processing, particularly during transit inside WWTPs, have now to be investigated. Furthermore, in hospitals, the average water demand is reported to be between  $200\text{--}1200 \text{ L bed}^{-1} \text{ day}^{-1}$ . Water is consumed in the hospital system with equivalent wastewater discharge. There is also domestic waste disposal in hospital fluids from kitchens, washrooms, and toilets. This paper reviews about characteristics of hospital wastewater, legislation around the globe and its paths ways in biotics system. This review also provides an overview of the pathways of ECs and focused few of its characteristics in biological treatment.

**Keywords:** hospital wastewater, emerging contaminants, risk, disposal, legislative governance.

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## 1. Introduction

Numerous emerging pollutants (ECs) are released into hospital wastewater, including antibiotics, drug active compounds, and different types of home and personal care products (PCPs). These pollutants have the potential to invade natural habitats, both marine and terrestrial, and thus pose a threat to human health. You are posing a danger to human and marine life (Wernery et al., 2017; Wang et al., 2019; Al-Turaiki et al., 2016). The traditional wastewater treatment plants are unable to handle both chemical and biological pollutants, allowing them to enter

water sources in the biotic system. As a result, appropriate controls towards such problems and advanced technology should be introduced to prevent such types of wastewater from entering aquatic environments. Taking steps to mitigate the environmental health risks associated with HWW is especially critical in light of the ongoing pandemic situation. The different types of regulations and guidelines for hospital wastewater (HWW) are absent in different counties; efficient removal of a pharmaceutical can only be done with advanced treatment technologies (Al-Jasser et al., 2019; Wang et al., 2016; Poissy et al., 2014). This article offers an in-depth examination of current healthcare systems, routes

to the environment, controlling and managing approaches. A critical assessment of existing research developments and prospective research directions is included during this study. This paper is a review about characteristics of hospital wastewater, legislation around the globe toward it, and its paths ways in the biotics system.

Chemicals are used in the provision of healthcare services. Substances were necessary to ensure a proper diagnosis, care, and disinfection recuperation of the patient. These substances are categorized according to their medicinal properties. Active pharmaceuticals compounds used (PACs) for healthcare procedures like different investigations, used in different surgery, types of medicine, and various types of imaging, as well as chemicals for the prevention of nosocomial infections (e.g., disinfectants). There are various chemical compounds present in the system, whether in their unprocessed state or as its metabolites, which are usually excreted from patients' bodies either inform of urine or feces that goes indirectly to the natural water bodies. Table 1 shows a few typical physical characteristics of hospital wastewater. It is worthy to note that emerging contaminants are nowadays present in a very low concentration which makes ways out from the conventional treatment plants and thus contaminates the environment. Healthcare institutions are accounted for about 20%–25% of human medicine use, for several hospitals consuming thousands of pounds of medication per year (Degnah et al., 2020; Lee et al., 2018; Subbaram et al., 2017).

As a result of their confirmed or potentially toxic effects on marine environments and human health, emerging contaminants such as antibiotics, pharmaceuticals, personal care goods, hormones and artificial sweeteners are known as additional groups of water contaminants. This review includes a detailed overview of emergent contaminants (ECs) occurs in influential, treated wastewater treatment plants, sludge and biosolids (WWTPs). The EC trends were comparable and assessed among the geographical regions in the raw influential and treated effluent of WWTPs. Most ECs in Asian raw influence appear to have more concentrations than in Europe and the Americas. In influences and effluents of WWTPs, several antibiotics were observed at concentrations near or above the projected no-effect (PNEC) concentration for the selection of the resistance. In view of the kinetics and the parameters such as sorption coefficients and biodegradation constants and the physical chemical properties, the effectiveness of EC removal through sorption and biodegradation is examined during wastewater treatment processes. There are analytical requirements for analysis and new study methods are suggested for prospective tracking studies. The objective of this review is to provision of a thorough overview of the destiny of ECs (i.e. sorption and biodegradation) focused on their sorption coefficients

and kinetic biodegradation constants. Also the goal of this study is to recognize information deficiencies and to propose guidance for potential analysis.

Table 1. Typical parameters of Hospital wastewater

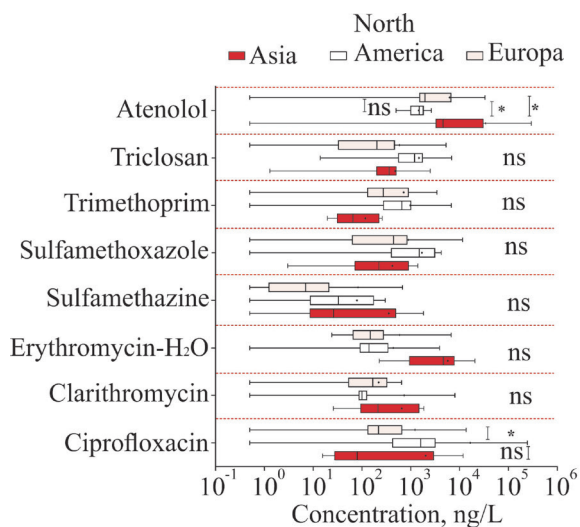
S.No.	Parameters	Max. detected (mg/L)	Ref.
1.	BOD <sub>5</sub>	1530	(Emmanuel et al., 2005; Sim et al., 2013)
2.	COD	2664	(Sanaa et al., 2019; Yuan et al., 2013)
3.	TOC	200	(Mubedi et al., 2013; Köhler et al., 2012)
4.	pH	8.6	(Sim et al., 2013; Verlicchi et al., 2012)
5.	Suspended Solids	900	(Jean et al., 2012; Lee et al., 2014)

## 2. Material and method

The negative impacts on marine environments, antibiotics have become recognized as a new form of water contaminants in the last couple of decades. The major issue about the release of antibiotics into the marine ecosystem is, however, potentially linked to the development of resistant genes and bacteria, which limits the therapeutic capacity for human and animal pathogens. Approximately 50% to 90% of human or animal-led antibiotics are excreted by urine and faeces as a combination of the compound's parents and their metabolite types. These compounds may then be transported to wastewater treatment plants (WWTPs), where some can be removed partially or the mechanism and remains unchanged. Although many countries have enacted legislation governing ECs, few countries have enacted legislation governing WWTPs. Are neither specially built nor equipped for the treatment of emissions Micropollutants treatment requirements and recommendations Take, for example, The European Parliament has controlled this by enacting Directive 2008/105/EC installed in the region for management and mitigation. There are different policies and regulations towards environmental quality and sustainability for a limited number of emerging technologies contaminants on a minuscule scale (Alagaili et al., 2019; Mahallawi et al., 2018; Kasem et al., 2018). Different drugs and their residue have been identified in a similar fashion by the government of Canada as hazardous substances. Unknown Micropollutants associated with HWW, such as PhACs, PCPs, and steroid hormones, remain unregulated compounds. Additional research is needed to conduct research into the toxicity of these pollutants and ecological health and to establish micropollutant

regulatory requirements (Albarrak et al., 2019; Al-Rabiaah et al., 2020; Bawazir et al., 2018). Micro-pollutants are present in the atmosphere on a microscopic scale. Matrixes present difficulties for public health and environmental protection. As a result, it is critical to optimize wastewater production. Facilities for the disposal of effluents discharged are critical in lowering the EC content of recycled water. Inadequate disposal during wastewater treatment processes contributes to its inclusion in treated wastewater, as well as after discharge into marine ecosystems (Jiaming et al., 2017; Amer et al., 2018; Lee et al., 2019). Numerous researches indicate that advanced treatment technologies be deployed in order to mitigate HWW as a carcinogen. The dangers to public health posed by these pollutants can be regulated in a variety of ways, including the following:

- Eradicating pathogenic bacteria and other environmental pollutants
- by separating wastewater from human waste and minimizing human exposure to waste. Pharmaceuticals can be eliminated from the supply chain through the implementation of
- All of these measures have the potential to significantly reduce the micropollutant load (Fig. 1).



**Figure 1.** Box plots demonstrating differences in concentrations of ECs picked from various regional regions in WWTP influents (Tran et al., 2018)

Few chosen antifungal or antimicrobial agents in WWTPs from various geographical regions are present (i.e. miconazole, thiabendazole, triclocarban and triclosan). Depending on compound and sampling location, concentrations in influential antifungal and antimicrobial agents fluctuated significantly, from below M QL and multiple micrograms per litre. For starters, antimicrobial agents concentrations (such as triclocarban and triclosan) tend to be 1–3 magni-

tude higher than those of antifungal compounds (such as miconazole or thiabendazole). The quantities of most antimicrobials except for triclocarbons are considerably smaller than those of the influential agents in effluents, ranging mostly from under MQL to a few hundred nanograms per litre. The triclocarban maximum (5860 ng/L) concentration was observed at WWTP in India. Typically, triclocarban and triclosan concentrations of WWTP influents and effluents from the Asian zone (e.g., China) were higher than in European and North American countries. Figure 1 shows box plots demonstrating differences in concentrations of ECs picked from various regional regions in WWTP influents. Typically, the influents and effluents of WWTPs have been triclosane and triclocarban levels frequently above expected PNECs for marine species. As a result, a direct discharge into marine environments of raw influents or treatment effluents that include these medications could pose a significant danger.

### 3. Water demand and HWW pathways

Hospitals use large quantities of water for various uses and facilities every day, but the daily use of water in each hospital is different. There are also a number of factors in determining whether the wastewater created by hospitals is generated, such as the number of beds, water supplies, general service provision ward types, and management policies – the percentage of water intake in hospitals in different health systems (Fig. 2). Furthermore, in hospitals, the average water demand usually lay in the range of 200 L and 1200 L bed<sup>-1</sup> day<sup>-1</sup>. Water is consumed in the hospital system with equivalent wastewater discharge. There is also domestic waste disposal in hospital fluids from kitchens, washrooms, and toilets (Farrokhi et al., 2014; Rezaee et al., 2005; Hashisho & Hashisho, 1969).

A lot of wastewater is produced in Hospitals. Various pollutant varieties HWW include ECs and pathogenic agents, which are excreted by urine and feces from human bodies and often end in drains which continue to be the biggest route Contaminants that penetrate urban wastewater systems. Consumer goods include soaps, disinfectant materials, and shampoos; Other ECs sources, as shown in Figure 2. The ECs of these items are to be transported to WWTPs for the therapy. But not any of this in WWTPs will exclude all forms of ECs from hospitals; they therefore regularly assist ECs in entering the natural world. The environmental presence of these ECs will jeopardize public opinion, ecosystem, and health. Because of the unusual physicochemical properties of HWW, certain drugs, and their residue use to get accumulated. Human beings are particularly exposed to surface-water drinking water.

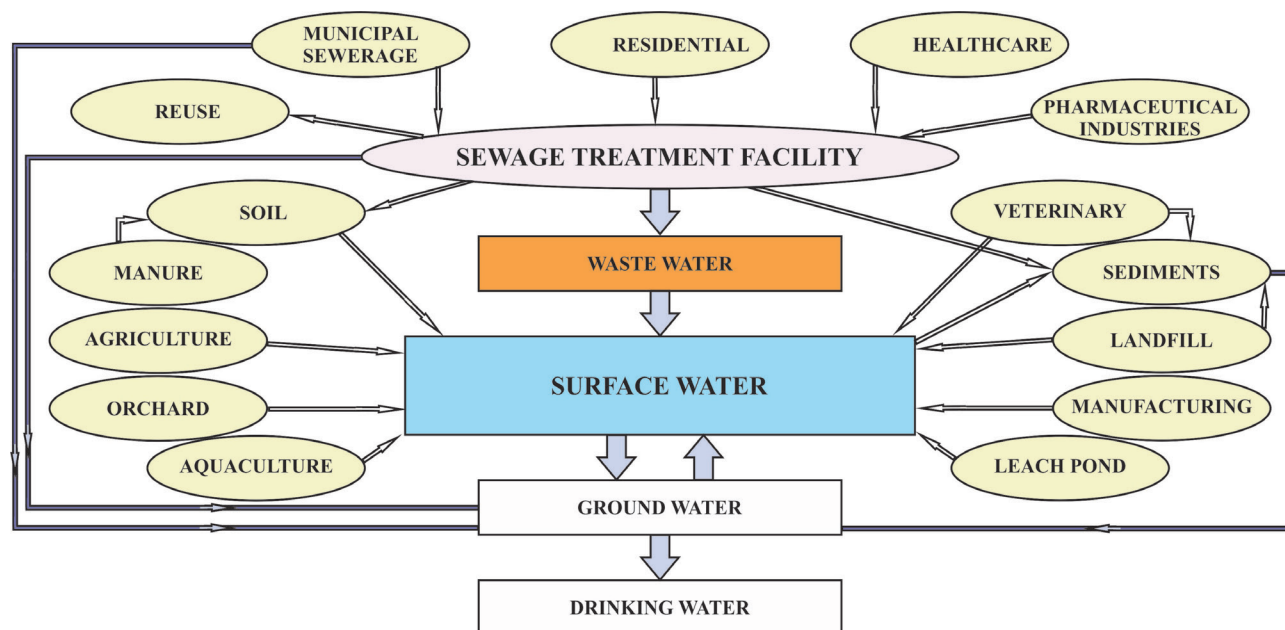


Figure 2 Pathways of Hospital wastewater in the Environment

The testing for the presence of pharmaceutical residues was conducted using expected concentrations or assessed concentrations in hospital effluents. The estimated concentrations are calculated based on factors such as intake of active ingredients, per bed water demand as well as excretion percentage. It is seen from different researches that measured concentrations from the laboratory are usually defined by taking samples and subsequent analytical device analysis. Different findings can be seen in predicted and tested prescription quantities in hospital effluents. The time scales perceived can partly be due to these variations. Although, in the majority of cases, estimated concentrations are extrapolated using annual drug intake statistics, at a certain stage, only over a limited period of time measured concentrations are measured. According to the compound, measured concentrations can be more variable than expected. Some scholars view expected concentrations as a safer way to assess pharmaceutical discharge over longer periods. Each methodology has merits and shortcomings, as described in another chapter of this novel, and should be weighed when creating a source characterization attempt. Ultimately, one of the other distinguishing variables will focus on the expense, usage information access and sewage systems access, and study objectives. The predicted concentration and the actually calculated concentrations are usually taken into account. The researchers are concerned about the effluent characteristics as well as planning to develop and upgrade existing treatment plans, and they also plan to evaluate their effect on WWTP. Because thousands of drugs are present on the market and many can be found in their parent form and as conjugates in the environment, priority strategies

have been developed. The priority strategies consider various parameters (e.g., ecotoxicity, danger, degradability/perpetuity, and resistance to treatment), consumption/sales, physicochemical properties). Recently, more than 310 pharmaceuticals and their residues are tested and detected in hospital effluent. More and more analytical instruments have been incorporated into recent studies, which have resulted in a growing number of evaluation-based compounds. The growing evidence of possible consequences on marine species like genetic modifications, organ, and reproductive problems, and most common behavioral changes have been observed. The main concern nowadays is antibiotic-resistant gene development in the biotic system. Figure 3 shows the different treatment schemes for hospital wastewater and its discharge into the Environment

Most WWTPs in WWTPs are planned mostly for the removal of organic nutrients such as carbonate, nitrogen and phosphorous organics. They may not actually remove ECs, particularly toxic ECs such as antibiotics. Many ECs were also often included in WWTP effluent. The municipal WWTPs usually include main, secondary and even tertiary treatment. The primary treatment is intended as an effort to minimize suspended solids (i.e. oils, fats, grasses, sand, granules and solids) but the overwhelming majority of ECs, especially for hydrophilic contaminants, have been typically not removed by such treatment ( $\log \text{Dow}=1.0$ ). This was stated. However, several hydrophobic ECs ( $\log \text{ of DOW } >3.0$ ) appear to be heavily absorbed into primary loam and partly eliminated after primary treatment from the dissolved level. For example, the removal treatment for UV filters category of benzophenones was stated by Tran et al., 2018 to vary

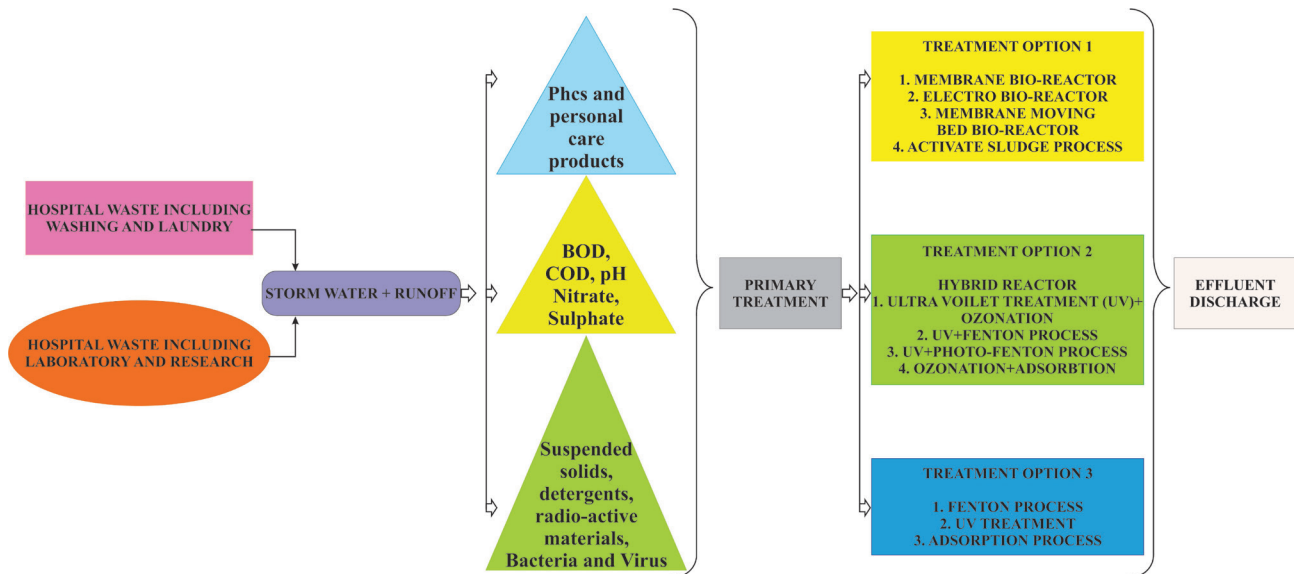


Figure 3. Different treatment schemes for hospital wastewater and its discharge into the Environment

from 10 to 27 percent after primary processing. Likewise, Lozano et al. (2013) observed that more than 75 percent in the dissolved process of influences of triclocarbons and Triclosans are eliminated after primary therapy. The secondary stage of treatment in WWTPs is usually planned for the removal of chemical and/or biologic nutrients (i.e. aerobic and anaerobic systems). ECs are often biologically biodegraded to different degrees at this point which contribute to mineralization or incomplete degradation (i.e. transformation products). Biodegradation of ECs in secondary treatments can occur by two major mechanisms such as metabolism and co-metabolism.

In order to preserve their biomass for metabolism, microorganisms in the active framework use ECs as sole source of energy and/or carbon to generate enzymes and cofactor coefficients for oxidation and reduction. To be metabolised with microbes, ECs should not be poisonous or less detrimental to microbial growth but should also be present at high levels to support biomass thus inducing the development of relevant ingredients / cofactors in the degradation phase (Tran et al., 2018). For co-metabolism, ECs (i.e. non-development substrates) in the presence of an obligatory growth substratum can be degraded. Several experiments have to date shown that biodegradation of ECs seems to be carried out in wastewater treatment systems through co-metabolism rather than metabolism, since a large number of ECs are microbial-resistant and mostly exist at trace amounts in wastewater. Both features mean that most ECs don't enter the catabolism of microbial cells. In other words, the energy produced by biological degradation of ECs is not enough to sustain microbiological growth and

induce the relevant biodegradation enzymes/cofactors. The existence of primary substrates (e.g. ammonium, carbonate salts or organic carbon fuels) as well as the presence of co-metabolic microorganisms is thus primarily determining the biodegradation of ECs in wastewater treatment systems.

This analysis gives an exhaustive overview of several groups of ECs in WWTPs from various geographical regions (North America, Europe, and Asia). Furthermore, the distribution and removal in WWTP of ECs in sewage sludge and/or biosolids was summarised. Most studies into the incident and destiny of ECs in WWTPs have centred mostly on the dissolved process, though, although scant evidence (i.e. sewage sludge and biosolids) for the particulate phase have been reported. Further experiments in WWTPs on the occurrence and destiny of ECs should also provide, in addition to the dissolved form, analyses of particle phases. Influential samples obtained in separate WWTPs within a single research area or between various geographical regions have varied significantly in EC concentrations. The variations in consumption habits, climatic conditions, population size/density, analytical approaches, and particularly sampling techniques, may be ascribed to this. The most serious drawback of the recorded occurrence data may be the usage of unsuitable samples. The majority of research in WWTPs about the occurrence and destiny of ECs is focused in particular on the collecting of samples. This technique is limited since at a single point in time it just offers a snap shot of the EC concentration. Future ECs and fate studies should be focused on a hybrid sampling approach to address this disadvantage. In assessment of the occurrence of ECs in WWTPs, inter-day, intra-day and

seasonal variations should also be addressed. Taking into account analytical techniques, responsive and accurate analysis methods for measuring ECs must be enhanced in a number of environmental samples. In order to compensate losses of ECs in spectrum preparation and to correct MS/MS analyses, the usage of isotopically-labeled compounds as internal/substitute criteria is important.

There is considerable difference between countries and also among WWTP's within the same country in removal efficiencies of ECs in WWTPs. This may be attributed to restrictions of the sampling techniques used historically. As such, full scale WWTPs must be reassessed utilising suitable techniques for sampling (e.g. composite sampling strategy) or for the replacement of computational methods (e.g. time-shifted mass balancing or fractionated approaches).

Furthermore, the removal efficiency of ECs should be assessed using laboratory or pilot-scale WWTPs in biological wastewater operation. Conventional WWTPs focused on sludge activation processes also show limited removal of many ECs, notably in the context of persistent compounds (for instance antibiotics, anticonvulsants, beta-blockers and X-ray contrast). While there is little to no knowledge about the effectiveness and efficiency of these treatment systems with pilot-sized or full scale WWTPs, alternate process technologies, such as moving-bed biofilm reactor with membrane bioreactor or white-red fungale culture/enzyme membrane reactor, have been noted. Thus it is essential to further assess the utility of the membrane systems or fungal crop / enzyme-based reactors in the full-scale removal of ECs. In addition, more research on the presence and toxicity of processed EC products during the WWTPs are strongly suggested in both dissolved and particulate phases.

#### 4. Legislation towards HWW

It has been observed that many countries and different international organizations have been working and installed their own guidelines for wastewater treatment. The WHO's pretreatment rules for healthcare facility effluents continue to be dominant. It is to consider the different types of treatment methods employed in the healthcare facility that usually contains the active pharmaceutical, different lab chemicals, and different types of pathogens generated from such facilities, including radioactive residues. The WHO guidelines serve as a basic framework in order to define the toxicity of hospital wastewaters and proposing a safety management process. Although medical laboratories and dental departments typically pre-treat their wastewater (Amouei et al., 2012; Tiwari et al., 2021). The below said are a few requirements for safe effluent discharge of hospital wastewater in a conventional treatment scheme:

1. A sewage treatment system that is both an effective and efficient, conventional type of treatment system.
2. The community wastewater treatment system must be in connection with the locally/central treatment plant and are able to remove at least 95% of bacteria from wastewater.
3. After treatment, it was supposed that the sludge residue subjected to anaerobic digestion for proper digestion and dewatering contains the fewest possible microscopic helminth eggs per liter.

The International Commission on Radiological Protection (ICRP) released few guidelines towards the safe effluent discharge of hazardous waste from a treated patient with radioactive materials. Table 2 summarizes the legislation governing HWW in various countries. The risk that patients undergoing during the treatment with radioactive material, which is later excreted by him either through urine or feces, poses a great risk to the sewage system. This was supposed to be one of the causes of antibiotics resistant gene development in the environment and may cause radiation exposure to sewage workers and others (Yuan et al., 2013; Jean et al., 2012). In the United States, the Environmental Protection Agency (EPA) adopted the 1972 Clean Water Act, which regulates effluent discharge into water and establishes effluent parameters for WWTPs (Yuan et al., 2013; Verlicchi et al., 2012; Jean et al., 2012; Dolar et al., 2012). As such, there are no strict guidelines or regulations for pharmaceuticals wastewater discharge in developing as well as developed countries. European unions frame few regulations in 1999 (91/271/CEE as amended by Directive 27 of February 1998 n. 98/15/CE), which allows pre-treatment as well as authorization of discharge either in the sewer or in treatment plants (Mubedi et al., 2014; Köhler et al., 2012). Additionally, the European Directive n. 98 of November 19, 2008 (EU, 2008/98/EC) states that such hospital effluents (i.e., pharmaceuticals and personal care items, or PPCPs) must be handled as waste and collected prior to disposal. There are different types of treatment process available in the market and is summarized in Figure 3.

Table 2. Regulation installed in different countries towards HWW

S.No.	Country	Year	Ref.
1.	WHO	1999–2014	Prasertkulsak et al., 2016
2.	India	1986	Prasertkulsak et al., 2016
3.	Germany	2004	Prasertkulsak et al., 2016
4.	Spain	2005	Prasertkulsak et al., 2016

#### 4.1. WHO recommendation towards hazardous effect discharge

The World Health Organization's (WHO) only current recommendations on hospital effluents were issued in the 90s' as "Safe Management of Wastes from Health-Care Activities" and were revised in the 20s'. This section is based on legislation towards the treatment of hospital wastewater. According to the recommendations, hospital effluent is classified into the below said categories:

- Blackwater is highly contaminated wastewater with a high percentage of feces and urine.
- Greywater includes residues from different hospital activities like bathing, laboratory procedures, and research processes, and other related works.

These waters can be lost to drains and watercourses or used to irrigate hospital floors, toilet flushing, and other general cleaning uses. Naturally, wastewater can include a variety of environmental, physical, and biological pollutants depending on the service level and activities performed by the hospitals. The management of effluents could pose a danger, especially in countries where proper knowledge is less towards it and where the majority of hospital wastewaters are discharged indirectly or directly to natural water bodies without any dedicated treatment or with only partial treatment. So, they pose a great risk of leaching into underlying groundwater aquifers if they get in contact with it. Following that, the recommendations discuss the dangers of liquid chemicals, pharmaceuticals, and toxic compounds. Additionally, the major diseases associated with wastewater are discussed. The typical example, if the concentration of nitrate is high or getting mixed with natural stream used to cause methemoglobinemia, which is especially dangerous in infants. Through dumping untreated wastewater into the atmosphere, the nutrient will stimulate algal growth and blooms, thus favoring potentially harmful bacteria (e.g., Cyanobacteria). Uncontrolled wastewater discharge into the atmosphere can result in many waters related diseases that pose a great threat to the biotic system in developing countries. Although isolation, minimization, and proper handling of hazardous materials are critical for both liquid and solid wastes, a portion is devoted to the treatment of liquid pharmaceutical waste. Figure 4 demonstrates variations in the elimination efficiencies of chosen ECs in the biological water treatment.

#### 4.2. EPA recommendation towards hazardous effect discharge

The Clean Water Act is the primary environmental statute regulating surface water discharges in the United States of America (CWA). The EPA, governments, and municipal

city pretreatment services enforce the CWA by issuing detailed rules and laws for such types of sources having a high quantity of pharmaceutical discharge. The discharge of such type of waste either in natural water bodies or conventional treatment plants need to follow strict rules like pre-treatment and dedicated treatment facilities and are referred to as publicly operated treatment works shall conform with the stricter technology-based requirements ("effluent guidelines") and site-specific effluent restrictions ("local limits"). Effluent restriction requirements and standards (ERR) are a critical component of the nation's clean water policy, which was developed in 1972 through CWA amendments. ERR is technology-based rules for municipal wastewater discharge management. The EPA issues ERR for current and existing sources that discharge directly into surface waters as well as to publicly operated treatment works. ERR is used in discharge permits to establish the maximum number of contaminants that facilities can discharge. The EPA has developed ERR in order to manage such types of discharges from around 58 different types of point sources. This regulatory policy significantly decreases municipal wastewater runoff and remains a vital component of the nation's initiative to clean up its waters. Along with creating a new ERR, the CWA allows the EPA to revise existing ERR as required. The EPA has updated ERR over the years in response to technological advancements and improvements in business processes. The EPA performs an annual evaluation and preparation process for effluent recommendations in order to continue its attempts to mitigate industrial wastewater emissions and to comply with CWA specifications. The annual evaluation and preparation process have three primary objectives:

- (1) to review current ERR in order to determine applicants for reform,
- (2) to define the different categories of direct dischargers for potential ERR growth, and
- (3) to define the different categories of indirect dischargers for possible pretreatment norm development.

## 5. Conclusion

Hospital and pharmaceutical industries routinely discharge emerging contaminants and their residues into aquatic environments without dedicated treatment. It is worth noting that waste treatment units are dealing with high toxicity and pollutant load with no dedicated treatment methods and facilities. Pharmaceutical industry inputs may also be considered, and financial institutions may be rewarded for their sponsorship of wastewater treatment facilities and infrastructure. Dedicated management of such effluent will aid and help in overall management during pandemic and

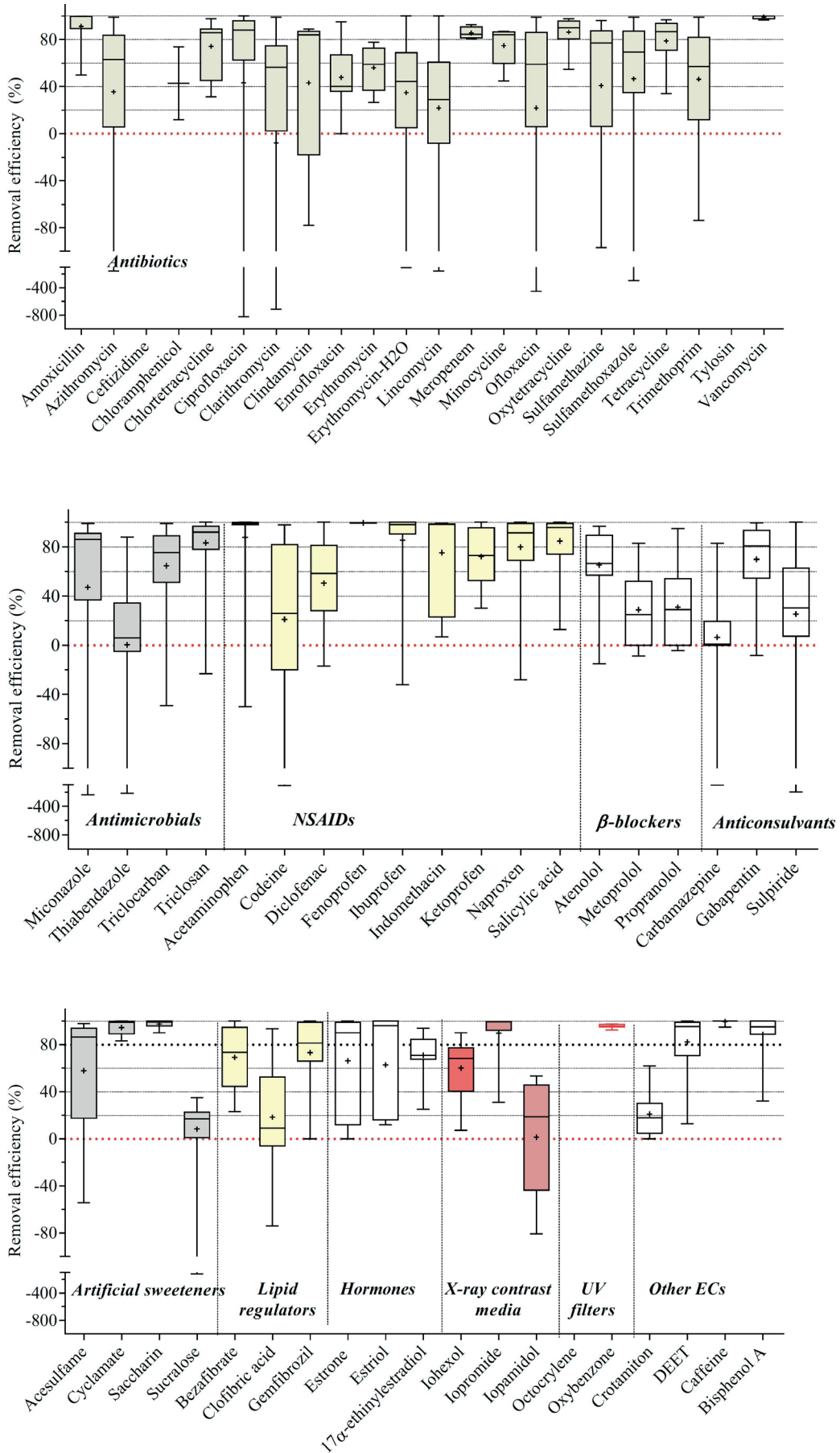


Figure 4. Box plots demonstrating variations in the elimination efficiencies of chosen ECs in the treatment of biological water (Tran et al., 2018)



advance preparation for the possibility of another outbreak of infection.

The COVID-19 pandemic has generated additional environmental problems due to the wastewater released by hospitals and quarantine centers. The basic view towards the inconsistency and non-homogenous nature made it difficult to frame any specific legislation around the globe. In many countries, there are no such rules towards the management of sewage, so we can think about differentiating hospital waste from domestic effluent. This leads us to think and draw a guideline and framework for the detection and treatment of such type of waste.

### Acknowledgment

The authors are thankful to Jamia Millia Islamia, New Delhi, for providing help and support during this work.

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