Hospital Wastewater Treatments Adopted in Asia, Africa, and Australia

Mustafa Al Aukidy, Saeb Al Chalabi, and Paola Verlicchi

Abstract This chapter provides an overview of the current management and treatment of hospital wastewater in Asia, Africa, and Australia. Twenty peer reviewed papers from different countries have been analyzed, highlighting the rationale behind each study and the efficacy of the investigated treatment in terms of macro- and micro-pollutants. Hospital wastewaters are subjected to different treatment scenarios in the studied countries (specific treatment, co-treatment, and direct disposal into the environment). Different technologies have been adopted acting as primary, secondary, and tertiary steps, the most widely applied technology being conventional activated sludge (CAS), followed by membrane bioreactor (MBR). Other types of technology were also investigated. Referring to the removal efficiency of macro- and micro-pollutants, the collected data demonstrates good removal efficiency of macro-pollutants using the current adopted technologies, while the removal of micro-pollutants (pharmaceutical substances) varies from low to high removal and release of some compounds was also observed. In general, there is no single practice which could be considered a solution to the problem of managing HWWs – in many cases a number of sequences are used in combination.

Keywords Antibiotic resistant bacteria, Hospital wastewater, Pharmaceuticals, Removal efficiency, Wastewater treatment

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M. Al Aukidy (✉) and S. Al Chalabi
Department of Civil Engineering, College of Engineering, University of Al Mustansiriya, Bab Al Mua'dam, Baghdad, Iraq
e-mail: mustafa.alaukidy@gmail.com; chalabi_sash@yahoo.com

P. Verlicchi
Department of Engineering, University of Ferrara, Via Saragat 1, 44122 Ferrara, Italy
Technopole Terra & Aqua Tech, Via Saragat 1, 44122 Ferrara, Italy
e-mail: paola.verlicchi@unife.it

P. Verlicchi (ed.), *Hospital Wastewaters - Characteristics, Management, Treatment and Environmental Risks*, Hdb Env Chem (2018) 60: 171–188, DOI 10.1007/698_2017_5,

Contents

1 Introduction

Hospital wastewater (HWW) is the wastewater discharged from all hospital activities, both medical and non-medical, including activities in surgery rooms, examination rooms, laboratories, nursery rooms, radiology rooms, kitchens, and laundry rooms. Hospitals consume consistent quantities of water per day. The consumption in hospitals in industrialized countries varies from 400 to 1,200 L per bed per day [1], whereas in developing countries this consumption seems to be between 200 and 400 L per bed per day [2].

HWWs are considered of similar quality to municipal wastewater [3, 4], but may also contain various potentially hazardous components which mainly include hazardous chemical compounds, heavy metals, disinfectants, and specific detergents resulting from diagnosis, laboratory, and research activities [5–9]. Higher concentrations of pharmaceutical compounds (PhCs) were found in hospital effluents than those found in municipal effluents [10, 11]. According to recent literature [8, 12–14], HWWs may be considered a hot spot in terms of the PhC load generated, prompting the scientific community to question the acceptability of the general practice of discharging HWWs into public sewers [8], where they are conveyed to municipal wastewater treatment plants (WWTPs) and co-treated with urban wastewaters (UWWs) [8, 13, 15, 16].

HWWs represent an important source of PhCs detected in all WWTP effluents, due to their inefficient removal in the conventional systems [17–20]. Indeed, HWWs may have an adverse impact on environmental and human health through the dissemination of antibiotics and antibiotic resistant bacteria in rivers [21–24]. The correct management, treatment, and disposal of HWWs are therefore of increasing international concern.

In European countries efforts are being made to improve the removal of PhCs by means of end-of-pipe treatments, and different full scale WWTPs have already been constructed for the specific treatment of hospital effluents [25].

In order to highlight this area of research in the rest of the world, this chapter provides an overview of the current management and treatment of HWWs in Asia, Africa, and Australia.

2 Treatment Scenarios of HWWs

Different treatment scenarios are applied in different countries for the treatment of HWWs. Table 1 lists all the treatment scenarios applied, with the corresponding references. Hospital effluents are usually discharged into the urban sewer system, where they mix with other effluents before finally being treated in the sewage treatment plant (co-treatment). This practice is common in Australia, Iran, Egypt, India, Japan, South Africa, and Thailand. However, in many other developing countries, such as Algeria, Bangladesh, Congo, Ethiopia, India, Nepal, Pakistan, Taiwan, and Vietnam, hospital effluents can represent a major source of toxic elements in the aquatic environment since the effluents are discharged into drainage systems, rivers, and lakes without prior treatment. According to Ashfaq et al. [41], no hospital, irrespective of its size, has installed proper wastewater treatment facilities in Pakistan. In Taiwan, some hospitals discharge their wastewaters

Table 1 Treatment scenarios of hospital effluents in different countries

Country	Treatment	Reference
Algeria	Direct disposal into the environment	[26]
Australia	Co-treatment	[14, 27]
Bangladesh	Direct disposal into the environment	[23]
China	Specific treatment	[10, 28–30]
Congo	Direct disposal into the environment	[31]
Egypt	Co-treatment	[4]
Ethiopia	Direct disposal into the environment	[32]
India	Direct disposal into the environment/co-treatment/specific treatment	[11, 31, 33]
Indonesia	Specific treatment/direct disposal into the environment	[34]
Iran	Specific treatment/co-treatment	[3, 35–37]
Iraq	Specific treatment	[38]
Japan	Co-treatment	[39]
Nepal	Direct disposal into the environment	[40]
Pakistan	Direct disposal into the environment	[21, 41]
Republic of Korea	Specific treatment	[42]
South Africa	Co-treatment	[43]
Taiwan	Direct disposal into the environment	[44]
Thailand	Co-treatment	[45]
Vietnam	Direct disposal into the environment	[6]

(legally or illegally) directly into nearby rivers with scarce treatment at all [44]. Of 70 governmental hospitals from different provinces of Iran, 48% were equipped with wastewater treatment systems, while 52% were not. Fifty-two percent of the hospitals without treatment plants disposed their raw wastewater into wells, 38% disposed it directly into the environment and the rest into the municipal wastewater network [35]. Comparison of the indicators between effluents of wastewater treatment systems and the standards of Environmental Departments shows the inefficiency of these systems and, despite recent improvements in hospital wastewater treatment systems, they should be upgraded.

In Indonesia, only 36% of hospitals have a WWTP and 64% of wastewater is discharged directly into receiving water bodies or using infiltration wells. Mostly, Hospital Wastewater Treatment Plants (HWWTP) use a combination of biological-chlorination processes with the discharge often exceeding the quality standard, such as Pb, phenol, ammonia free, ortho-phosphate, and free chlorine. The low quality of discharges into HWWTPs, especially of toxic pollutants (Pb and phenol), can be caused by not yet optimal biological-chlorination process [34].

An interesting investigation was carried out in 2004 in Kunming city, a large city in the southwest of China. Of 45 hospitals there were 36 with wastewater disinfection equipment. In the same year, the wastewater treatment facilities of 50 hospitals were investigated in Wuhan city, which is the biggest city in the central southern part of China. It showed that there were 46 hospitals with wastewater treatment facilities, and for only about 50% of them, the effluent quality from wastewater treatment facilities accorded with the national discharge standard [29, 46, 47].

In Iraq, most of the hospitals have their own treatment plant, but they are not capable of meeting Iraqi standards, especially in terms of nutrient and pathogen removal [38]. The scenario of hospital wastewater treatment is more stringent in countries like China, Indonesia, and the Republic of Korea, where HWW is treated onsite (specific treatment).

An effective, robust, and relatively low-cost treatment was used to disinfect HWWs during Haiti cholera outbreak occurred after the earthquake of January 2010. Two in-situ protocols were adopted: Protocol A included coagulation/flocculation and disinfection with hydrated (slaked) lime ($Ca(OH)_2$) by exposure to high pH and Protocol B using hydrochloric acid followed by pH neutralization and subsequent coagulation/flocculation, using aluminum sulfate. This approach is currently being adapted by non-governmental organizations (NGOs) to help managing human excreta in other emergency settings, including the outbreaks of Ebola and other infectious diseases in west Africa, Philippines, and Myanmar [48].

3 Overview of the Included Studies

The main characteristics of the studies included in this chapter referring to the specific treatment of hospital effluents are reported in Table 2. The main reason for research in European countries is generally an awareness of the potential risks

Table 2 List of the studies included in the overview together with a brief description of the corresponding investigations and rationale

Reference	Main characteristics of experimental investigations and treatment plants	Rationale	Investigated parameters
[6]	Investigation into the occurrence and behavior of fluoroquinolone antibacterial agents (FQs) in HWWs in Hanoi, Vietnam. A specific hospital CAS treatment plant was also investigated for the removal of FQs	The potential environmental risks and spread of antibacterial resistance among microorganisms	Ciprofloxacin and norfloxacin
[10]	Investigation carried out in Beijing (China) for the quantification of 22 common psychiatric pharmaceuticals and their removal in two psychiatric hospital WWTPs (CAS)	Potential impact of PhCs on ecosystems and human health	22 psychiatric pharmaceuticals
[11]	Investigation undertaken to identify the presence and removal of selected PCs in four STPs located in South India. The treatment process that treats HWWs is an extended aeration activated sludge process	The risk associated with the presence of pharmaceuticals in the environment	7 PhCs
[17]	Investigation carried out at the hospital located in Vellore, Tamil Nadu (India), by means of a lab-scale plant consisting of coagulation (by adding $FeCl_3$ up to 300 mg/L), rapid filtration, and disinfection (by adding a bleaching powder solution) steps	Options for hospital effluent pretreatment before discharge into public sewage	Conventional parameters: COD, BOD_5, SS, and P
[35]	Investigation carried out in Iran to analyze the hospital wastewater treatment system of 70 governmental hospitals from different provinces	Control of the discharge of chemical pollutants and active bacteria contained in hospital wastewater	Conventional parameters: TSS, BOD_5, COD
[34]	Investigation on a pilot-scale plant consisting of an aerated fixed film biofilter (AF2B reactor) coupled with an ozonation reactor fed by the effluent from Malang City hospital in Indonesia	Pollution and health problems for humans being caused by the discharge of HWWs	Conventional pollutants: BOD, phenols, fecal coliform, and Pb
[28]	Investigation carried out at Haidian community hospital (China), where a full scale submerged hollow fiber MBR was installed	Efficiency and operation stability of MBR equipped with microfiltration membranes in treating HWWs	Monitored pollutants were COD, BOD_5, NH_4, turbidity, and *Escherichia coli*

(continued)

Table 2 (continued)

Reference	Main characteristics of experimental investigations and treatment plants	Rationale	Investigated parameters
[29]	Investigation carried out in China on the operating conditions and MBR efficiency in treating hospital effluents	Attempts to avoid the spread of pathogenic microorganisms and viruses, especially following the outbreak of SARS in 2003	Conventional parameters: COD, BOD_5, NH_3, TSS, bacteria, and fecal coliform
[30]	A combination process of biological contact oxidation, MBR, and sodium hypochlorite disinfectants was applied to treat HWWs in Tianjin (China)	To meet the requirements of the Chinese discharge standards of water pollution for medical organizations	Conventional parameters: SS, BOD_5, COD, NH_3, total coliforms, fecal coliform
[40]	Analysis of the removal performance in a full scale two stage constructed wetland (CW) designed and constructed in Nepal to treat hospital effluent (20 m^3/d). The system consists of a three chambered septic tank, a horizontal flow bed (140 m^2), with 0.65–0.75 m depth, and a vertical flow bed (120 m^2) with 1 m depth. The beds were planted with local reeds (*Phragmites karka*)	Transferring CW technology to developing countries to reduce pollution in aquatic environments	Conventional parameters: TSS, BOD_5, COD, NH_4, PO_4^{2-}, total coliforms, *E. coli*, streptococci
[42]	Investigation carried out at two hospital WWTPs located in Korea to assess the occurrence and removal of selected pharmaceutical and personal care products. The wastewater treatment plants consist of (1) flocculation (FL) + activated carbon filtration (AC); (2) flocculation + CAS	Potential risks of anthelmintics on non-target organisms in the environment and their resistance to biodegradation	33 pharmaceutical and personal care products
[45]	Investigation carried out in Bangkok, Thailand, on the pretreatment of hospital effluents by using a lab-scale photo-Fenton process	Improvement in the biodegradability of hospital effluents by using the photo-Fenton process as a pretreatment	Conventional parameters: COD, BOD_5, TOC, turbidity, TSS, conductivity, and toxicity
[49]	Investigation carried out in Taiwan on the disinfection by continuous ozonation of the hospital effluent and in particular of the effluent from the kidney dialysis unit and on the increment of hospital effluent biodegradability	Disinfection effect and improvement in biodegradability of hospital effluent by ozonation	Conventional parameters: COD, BOD, total coliforms

(continued)

Table 2 (continued)

Reference	Main characteristics of experimental investigations and treatment plants	Rationale	Investigated parameters
[50]	Investigation carried out in India on a pilot plant consisting of preliminary and primary treatments, a conventional activated sludge system, sand filtration, and chlorination	Investigation into the microbiological community and evaluation of the risk of multidrug resistant bacteria spread	Different microbiological parameters: total coliforms, fecal enterococci, staphylococci, *Pseudomonas*, multidrug resistant bacteria
[51]	Analysis of the performance of seven WWTPs (CAS + chlorination) in the Kerman Province (Iran) receiving hospital effluents in terms of removal of main conventional parameters and malfunctions	Malfunctions in WWTPs receiving hospital effluents	Conventional parameters: COD, BOD_5, DO, TSS, pH, NO_2^-, NO_3^-, Cl^-, and SO_4^{2-}
[52]	Investigation carried out in Iran on a pilot-scale system consisting of an integrated anaerobic – aerobic fixed film reactor fed with hospital effluent before co-treatment with urban wastewater	Potential reduction of the organic load in hospital effluents by biological pretreatment before co-treatment	Conventional parameters: COD, BOD_5, NH_4, turbidity, bacteria, and *Escherichia coli*

posed by the occurrence of PhC residues in secondary effluents and the need to reduce the PhC load discharged into the environment via WWTP effluents [25]. However, the rationale behind the studies presented in this chapter was to evaluate different options for hospital effluent treatments before discharge into public sewage or into the environment, to improve the biodegradability of hospital effluents, to avoid the spread of pathogenic microorganisms, viruses, antibiotic resistant bacteria, pharmaceuticals, and chemical pollutants, to reduce the organic load and finally, to meet the requirements of discharge standards in different countries. Of all the studies, only four deal with the occurrence of PhCs in hospital effluents, while the remaining studies take into consideration pathogenic bacteria and conventional pollutants like COD, BOD, and SS.

4 Antibiotic Resistant Bacteria in HWWs

Although antibiotics have been used in large quantities for some decades, the existence of these substances in the environment has received little attention until recently. In the last few years a more complex investigation of antibiotics has been undertaken in different countries in order to assess their environmental risks. It has been found that the concentrations of antibiotics are higher in hospital effluents than in municipal wastewater, which has higher concentration levels than different surface waters, ground water, and sea water [53]. HWWs could be a source of antimicrobial-resistant bacteria which are excreted by patients. The HWWs either flow into a hospital sewage system or directly into a municipal wastewater sewer, before being subsequently treated in a WWTP. After treatment in a WWTP, the effluent is discharged into surface waters or is used for irrigation. Studies have shown that the release of wastewater from hospitals was associated with an increase in the prevalence of antibiotic resistance. A study conducted in Australia by Thompson et al. 2012 [27] revealed evidence of the survival of antibiotic resistant strains in untreated HWWs and their transit to the STP and then through to the final treated effluent. The strong influence of HWWs on the prevalence of antimicrobial-resistant *E. coli* in Indian WWTPs has been revealed by Alam et al. [24] and Akiba et al. [33]. Untreated hospital and municipal wastewaters were found to be responsible for the dissemination of antibiotics and antibiotic resistant bacteria in the rivers of Pakistan [22].

In Bangladesh, a study was conducted by Akter et al. [23] concerning the effects of hospital effluents on the emergence and development of drug-resistant bacteria. They concluded that hospital and agricultural wastewater is mostly responsible for causing environmental pollution by spreading un-metabolized antibiotics and resistant bacteria. Analyses of the results obtained from South Africa indicated that HWWs may be one of the sources of antibiotic resistant bacteria in the receiving WWTP. The findings also revealed that the final effluent discharged into the environment was contaminated with multi-resistant *enterococci* species, thus posing a health hazard to the receiving aquatic environment as these could eventually be transmitted to the humans and animals exposed to it [43, 54].

As a result, hospitals are important point sources which contribute to the release of both antimicrobials and antibiotic resistant genes into surface waters, especially if hospital wastewaters are discharged into the receiving ambient waters without being treated.

5 Treatment Sequences for HWWs Under Review

The sequences adopted for the specific treatment of hospital effluent in different countries are reported in Table 3, along with the corresponding bibliographic reference. As can be seen, treatments differ with a trend towards MBR, followed by CAS. Most of the investigations refer to full scale plants and include the following treatment trains: CAS in China, India, Iran, and Vietnam; MBR, MBR + disinfection in China; Flocculation + Activated carbon, Flocculation + CAS in South Korea; Septic Tank + H-SSF bed + V-SSF bed in Nepal, and Ponds in Ethiopia. Seventy-eight percent of the equipped hospitals in Iran used activated sludge systems and 22% used septic tanks [35].

Several pilot plants were also tested in different countries: CAS + Sand Filtration + Chlorination in India; Aerated Fixed Film Biofilter + O_3 in Indonesia; CAS and Fixed film bioreactor in Iran, and finally preozonation in Taiwan. Lab scales of

Table 3 Treatment sequences for hospital effluents included in the chapter

Country	LAB	PILOT	FULL scale	Reference
China			MBR MBR + chlorination	[29]
China			MBR	[28]
China			CAS	[10]
China			Biological contact oxydization + MBR + sodium hypochlorite disinfection	[30]
Egypt	CAS			[4]
Ethiopia			Ponds	[32]
India		CAS + SF + chlorination		[50]
India	Coagulation + filtration + chlorination			[17]
India			CAS	[11]
Indonesia		Aerated fixed film biofilter + O_3		[34]
Iran		CAS		[36]
Iran			CAS + chlorination	[51]
Iran		Fixed film bioreactor + co-treatment		[52]
Iran			CAS, septic tank	[35]
Iran	Electrocoagulation			[55]
Iraq	MBR			[38]
Nepal			Septic tank + H-SSF bed + V-SSF bed	[40]
Republic of Korea			Floc + activated carbon, Floc + CAS	[42]
Taiwan		Preozonation		[49]
Thailand	Photo-Fenton Photo-Fenton + CAS			[45]
Vietnam			CAS	[6]

Floc flocculation, *SF* sand filtration, *H-SSF* horizontal subsurface flow, *V-SSF* vertical subsurface flow

CAS were tested in Egypt, coagulation + Filtration + Chlorination in India, MBR in Iraq, and Photo-Fenton, Photo-Fenton + CAS in Thailand. Recently, HWWs were also treated by electrocoagulation using aluminum and iron electrodes in Iran [55]. In this study the removal of COD from HWWs was investigated in a lab scale achieving a good removal at pH 3, 30 V, and 60 min reaction time using iron electrodes.

6 Efficiency of the Adopted HWW Treatment Plants

The removal efficiencies of conventional parameters as well as PhCs from HWWs using different systems are discussed below. As previously reported, different technologies were tested for the treatment of HWWs acting as primary, secondary, and tertiary steps.

6.1 Removal Efficiency of Conventional Pollutants

Figure 1 shows the removal efficiency of conventional pollutants obtained from different studies using a primary treatment (Coagulation + filtration + disinfection; Photo Fenton) and secondary treatment (CW; Ponds; CAS; MBR; Biological contact oxidation + MBR + NaClO disinfection; Anaerobic aerobic fixed film reactor, and Aerated fixed film bioreactor + O_3).

Very good removal efficiencies were observed for TSS and BOD_5 (97–99%), COD (94–97%), N–NH_4 (80–99%), total coliform (99.87–99.999%), *E. coli* (99.98–99.999%), and *Streptococcus* (99.3–99.99%) using a septic tank followed by a H-SSF and a V-SSF bed purposely designed for the treatment of HWWs in Nepal [40].

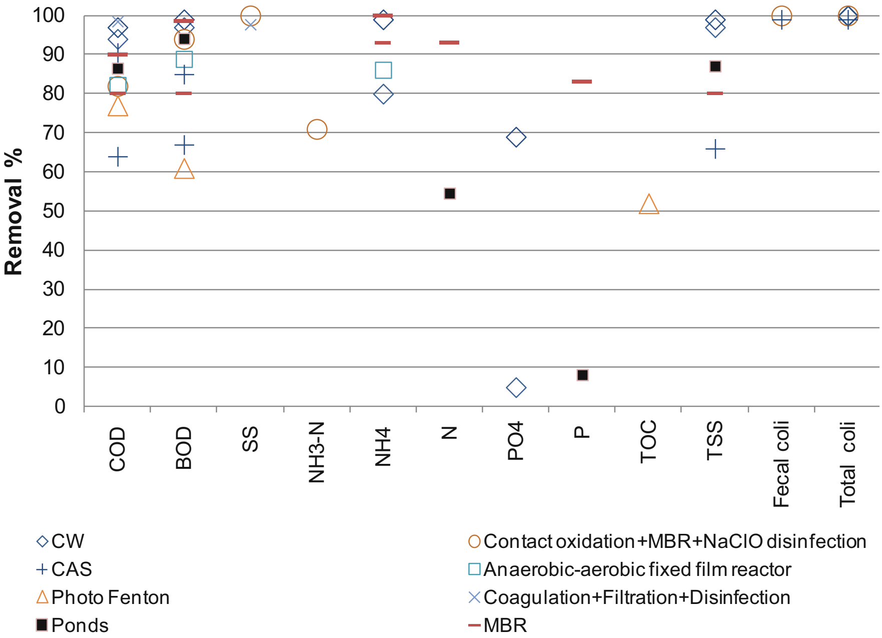

Fig. 1 Removal efficiencies from HWW for conventional pollutants in different primary and secondary treatments. Data from [4, 17, 28–30, 32, 35, 38, 45, 52]

The suitability of a series of facultative and maturation ponds for the treatment of HWWs has been examined in Ethiopia [32]. The percentage treatment efficiency of the pond was 94, 87, 87, 69, 55, 55, and 32 for BOD_5, TSS, COD, Nitrate, Nitrite, Total Nitrogen, and Total Dissolved Solids, respectively, while the treatment efficiency for total and fecal coliform bacteria was 99.74% and 99.36%, respectively. However, the effluent still contains large numbers of these bacteria, which are unsuitable for irrigation and aquaculture.

A pilot-scale system integrated anaerobic–aerobic fixed film reactor for HWW treatment was constructed and its performance was evaluated in Iran [52]. The results show that the system efficiently removed 95, 89, and 86% of the COD, BOD, and NH_4, respectively. COD removal was greater than 70% when 200 mg/L of ferric chloride was added to an Indian raw hospital effluent and removal increased to over 98% if the coagulant was added to settle HWW. A subsequent disinfection step using calcium hydrochloride reduces not only microorganisms, but also COD [17].

Attempts have been made to reduce toxicity and improve the biodegradability and oxidation degree of pollutants in HWWs prior to discharge into the existing biological treatment plant [45, 56]. Using the photo-Fenton process as a pretreatment method, a significant enhancement of biodegradability was found at the following optimum conditions: a dosage ratio of COD:H_2O_2:Fe (II) of 1:4:0.1 and a reaction pH of 3. At these conditions, the value of the BOD_5:COD ratio increased from 0.30 in raw wastewater to 0.52 for treated wastewater. The toxicity of the wastewater drastically reduced with this process [56].

Nasr and Yazdanbakhsh [35] investigated the treatment efficiency of 70 governmental hospitals from different provinces of Iran, where 78% of them use the CAS system and 22% use septic tanks. The mean removal rates of BOD, COD, and TSS were found to be 67%, 64%, and 66%, respectively. A high removal rate (99–100%) of fecal and total coliforms was obtained using CAS and MBR, followed by disinfection treatment [4, 30].

Figure 1 clearly demonstrates how MBR technology is capable of achieving good removal efficiency (80%) of all the macro-pollutants, with the sole exception of NH_3–N, whose removal was found to be 71%.

In Iraq, local wastewater treatment units in various hospitals are not capable of meeting Iraqi standards, especially in terms of nutrient and pathogen removal. For this reason, a lab scale sequencing anoxic/anaerobic membrane bioreactor system is studied to treat hospital wastewater with the aim of removing organic matter, as well as nitrogen and phosphorus under a different internal recycling time mode [38]. The system produces high quality effluents which can meet Iraqi limits for irrigation purposes for all measured parameters.

Membrane separation plays an important role in ensuring excellent and stable effluent quality. The advantages of MBR systems, such as complete solid removal from effluents, effluent disinfection, high loading rate capability, low/zero sludge production, rapid start-up, compact size, and lower energy consumption, have driven authorities to use them in treating HWWs.

An interesting approach to managing hospital effluents has been established in China, where over 50 MBR plants have been successfully built for HWW treatments, with a capacity ranging from 20 to 2,000 m^3/d (see Table 4). MBR can effectively save disinfectant consumption (chlorine addition can decrease to 1.0 mg/L), shorten the reaction time (approximately 1.5 min, 2.5–5% of the conventional wastewater treatment process), and deactivate microorganisms. Higher disinfection efficacy is achieved in MBR effluents at lower doses of disinfectant with fewer disinfection by-products (DBPs). Moreover, when the capacity of MBR plants increases from 20 to 1,000 m^3/d, their operating costs decrease sharply [29].

The performance of a submerged hollow fiber membrane bioreactor (MBR) for the treatment of HWW was investigated by [28]. The removal efficiencies for COD, NH^{4+}–N, and turbidity were 80%, 93%, and 83%, respectively, with the average effluent quality of COD <25 mg/L, NH^{4+}–N <1.5 mg/L, and turbidity <3 NTU. *Escherichia coli* removal was over 98%. The effluent was colorless and odourless.

A combination process of biological contact oxidation, MBR, and sodium hypochlorite disinfectants has been applied to treat HWWs in Tianjin (China). The obtained results showed that the main parameters meet the requirements of the Chinese discharge standards of water pollution for medical organizations [30].

6.2 Removal Efficiency of PhCs

Figure 2 reports all collected data regarding the removal of PhCs in hospital effluents using a full scale CAS system operating in different countries (Vietnam,

Table 4 Application of MBR in hospital wastewater treatments in China (Adopted from [29])

Treatment train	Membrane area (m^2)	Membrane material	Membrane pore (μm)	Capacity (m^3/d)	HRT (h)	Commissioned
MBR	96	Hollow fiber membrane (PE)	0.4	20		2000
MBR + $NaClO_3$			0.2	100		2004
MBR				140	6	2004
MBR		Organic membrane	1.3	200	5	2002
MBR				200		2004
MBR + NaClO	900	PVDF	0.22	400	7.5	2005
MBR + ClO_2	2,000	PVDF	0.22	500	7	2003
MBR + NaClO	4,000	Hollow fiber membrane (PVDF)	0.22	1,000	5	2005
MBR + ClO_2	8,000	Hollow fiber membrane (PVDF)	0.4	2,000	5.4	2008

PVDF poly vinyldene fluoride, *PE* polyethylene

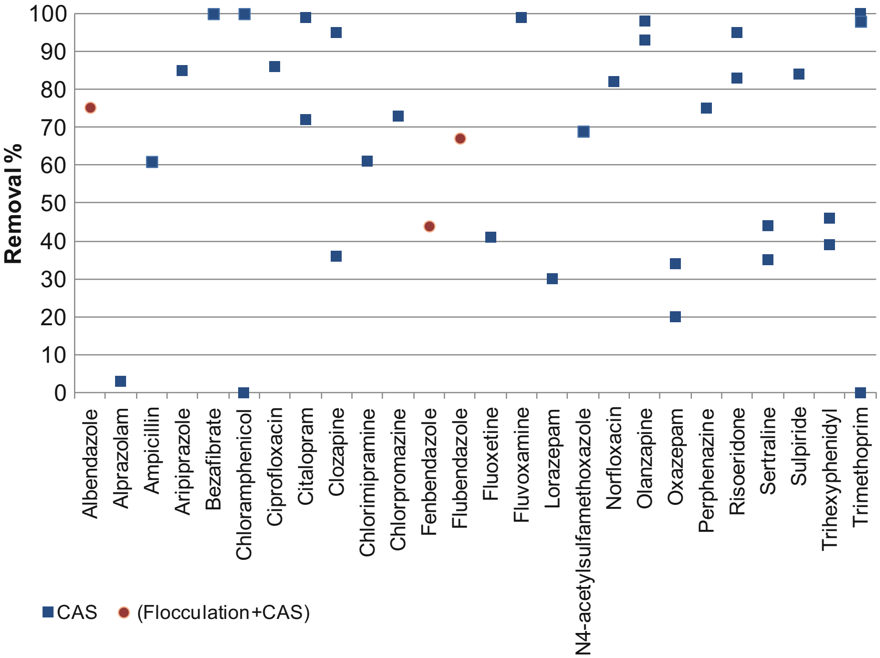

Fig. 2 Removal efficiencies from HWW for selected PhCs in CAS system. Data from [6, 10, 11, 42]

India, South Korea, and China). High removal efficiencies (>80%) were observed for bezafibrate, chloramphenicol, trimethoprim, aripiprazole, clozapine, fluvoxamine, olanzapine, risperidone, sulpiride, and citalopram. Albendazole, ampicillin, N4-acetylsulfamethoxazole, chlorpromazine, chlorimipramine, flubendazole, and perphenazine were moderately removed (60–80%), whereas low removal (less than 50%) was observed for alprazolam, oxazepam, sertraline, trihexyphenidyl, clozapine, fluoxetine, lorazepam, and fenbendazole.

Negative removals of sulfamethoxazole, chloramphenicol, erythromycin, naproxen, bezafibrate, and ampicillin in sewage treatment plants treating hospital effluents in South India were also observed [11].

The results achieved by Yuan et al. [10] showed that a secondary treatment of a psychiatric hospital was more effective in removing the majority of target compounds [e.g., olanzapine (93–98%), risperidone (72–95%), quetiapine (>73%), and aripiprazole (64–70%)] than treated municipal wastewater.

The overall removal values of ciprofloxacin and norfloxacin in a small HWWTP consisting of a CAS+ anaerobic biological treatment system situated in Vietnam were found to be 86% and 82%, respectively [6].

7 Regulation

As previously reported, HWWs are often considered similar to urban wastewater. As a result, they are usually co-treated with urban wastewater in the WWTP. Moreover, in many developing countries, they are directly discharged into the environment along with urban wastewater.

There is no regulation in most of the studied countries that imposes authorities to treat HWWs as special waste, with the exception of China where, in July 2005, the Chinese authorities published the "Discharge standard of water pollution for medical organization," a document outlining comprehensive control requirements for HWWs [30]. Recently, a new law regarding environmental protection has been presented in Vietnam (No. 55/2014/QH13, article 72) [57]. This law obliges hospitals and medical facilities to collect and treat medical wastewater in accordance with environmental standards.

On a global scale, the only existing guidelines concerning hospital effluents management and treatment were published by the World Health Organization (WHO) in 1999: "Safe Management of Wastes from Health-Care Activities" [58] and updated in 2013 [59]. This publication describes basic methods for the treatment and disposal of health-care wastes and in particular recommends a pretreatment of effluents originated from specific departments as discussed in [60] of this book. These guidelines could be a reference in the management and treatment of HWWs mainly for developing countries in order to preserve the environment.

8 Conclusions

Hospitals are important point sources contributing to the release of both PhCs and antibiotic resistant bacteria into surface waters, especially if hospital wastewaters are discharged without treatment into the receiving ambient waters. This problem is more severe in developing countries because no wastewater treatment facility is available in most of the cases. Hospital wastewaters are subjected to different treatment scenarios in the studied countries (specific treatment, co-treatment, and direct disposal into the environment). Due to the lack of municipal wastewater treatment plants, the onsite treatment of hospital wastewater before discharge into municipal sewers should be considered a viable option and consequently implemented. Where applicable, the discharge of HWWs into municipal wastewater collection systems is an alternative for wastewater management in hospitals. Upgrading existing WWTPs and improving operation and maintenance practices through the use of experienced operators are recommended measures.

In general, there is no single practice which could be considered a solution to the problem of managing HWWs. Indeed, in many cases, a number of sequences are used in combination. Each practice has its own strengths and weaknesses. More effective disinfection processes coupled with membrane filtration should be adopted for better removal of harmful bacteria and PhCs.

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