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Challenges and Innovations in Hospital Wastewater Treatment for Enhanced Pathogen Removal – A Review

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Abstract : Hospital wastewaters are full of radioactive elements, hazardous chemicals, pathogenic microbes, laboratory and pharmaceutical residues, and partially metabolized pharmaceuticals. India's main cities produce an estimated 38354 MLD of sewage each day; however, there are only 11786 sewage treatment facilities in the country(Kaur et al., n.d.). According to the Central Pollution Control Board's 2015 report, India now has the ability to treat around 37% of its wastewater, or 22,963 million liters per day (MLD), versus a daily sewage generation of about 61,754 MLD. Since 1951, the average annual freshwater availability per person has decreased due to the country's growing population and overall growth, dropping from 5177m^3 in 1951 to 1869m^3 in 2001 and 1588m^3 in 2010. It is anticipated that it will continue to decline, reaching 1341m^3 in 2025 and 1140 m^3 in 2050. In rich nations, a hospital produces 400–1200 liters of wastewater per bed per day; however, in developing nations, the figure is 200–400 liters per capita per day, as opposed to 100–400 liters per population per day of household wastewater generation. Antibiotic-resistant bacteria, genes for antibiotic resistance, persistent viruses, and other microbes are also present in HWW. In comparison to domestic wastewater, HWW often contains higher concentrations of ammonia, nitrogen, and chemicals with high biological and chemical oxygen demands. Even after treatment, viruses, ARB, and ARG persist, posing a serious hazard to the ecosystem (Kumari et al., 2020). Numerous biological procedures, including membrane bioreactors, the activated sludge process, engineered wetlands, etc., were discovered to remove more than 80% of the contaminants. This article describes the different cutting-edge technologies that have been applied to the treatment of infections and pharmaceutically active substances. Finding a cutting-edge, ecologically safe method to remove the most pathogens from wastewater will take an hour. This study's objective is to determine the effluent quality and hospital wastewater treatment conditions in India. A systematic review was conducted to identify relevant publications, Google scholar, Pub Med and Scopus were searched for peer-reviewed articles published in English language. The data were identified according to the inclusion and exclusion criteria and by using the relevant keywords in the articles, with emphasis on the efficacy of hospital wastewater treatment. Qualitative data were collected using preferred reporting items for systematic reviews and Meta-analyzes (PRISMA) standard checklist. The Objective of this study was to determine the efficacy of current wastewater treatment systems in removing microbes and their contaminants.

Keywords: waste water; ‘wastewater treatment; effluent; sewage ‘Sewage treatment; ‘sewage disposal; ‘waste water disposal; ‘treat’ ‘remove;’ ‘microbe’ ‘pathogen’; bacteria;’ ‘virus;’ ‘parasite’ ‘FCs’ ‘Faecal coliforms’.

I. Introduction

Because of its great susceptibility to the outbreak of various diseases, hospital wastewater poses a serious threat to the safety of human health. Approximately 36.3 million people were admitted to US hospitals in 2018, making the healthcare industry one of the largest employers in the US(J. Elflein, 2020) . According to projections, the Indian healthcare industry's value will increase from 140 billion US dollars in 2016 to 372 billion dollars in 2022(S. Keelery, 2020). Hospital wastewater (HWW) is also characterized by the presence of a variety of developing pollutants, pharmaceutically active substances, and microorganisms such as antibiotic-resistant bacteria (ARB), antibiotic-resistant genes (ARG), persistent viruses, etc(Orias & Perrodin, 2013).

In contrast to COD, which is the quantity of oxygen equivalents used during the chemical oxidation of organic matter by a strong oxidant, BOD is the amount of oxygen consumed by microorganisms during the aerobic decomposition of organic matter under certain temperature and time conditions(Z. Hu, 2004). Since COD is a measure of both biodegradable and non-biodegradable organic components, BOD can be thought of as the portion of wastewater that can be broken down by biological processes(G. Tchobanoglous, 2004). The biodegradability index is the wastewater's ratio of BOD and COD(Y. Sun, 2016).

It is challenging to treat HWW using traditional biological systems because its biodegradability index is lower than that of municipal wastewater(Periasamy& Sundaram, 2013). Many of the refractory organic compounds found in HWW, such as PhACs, are extremely hazardous and have extremely low drinking water equivalent limits (DWEL), which pose a serious threat to the environment(Majumder et al., 2019).

Activated sludge processes, membrane bioreactors, moving bed bioreactors, built wetlands, advanced oxidation processes including photocatalysis, the Fenton process, etc. are examples of biological treatment technologies that have been used to treat HWW over time(Majumder et al., 2021).

The scope of the information provided is centered around hospital wastewater (HWW), its potential threats to human health and the environment, the challenges associated with its treatment, and various biological treatment technologies used to address these challenges. It also emphasizes the importance of addressing HWW due to its susceptibility to diseases and its potential impact on human health and the environment.

2. Study framework

This systematic review has been administrated through various studies and a statistical analysis using thejournals database to induce an outline of the research trends on HWW and BMW. Review was conducted to identify relevant publications, Google scholar, PubMed and Scopus were searched for peer-reviewed articles published in English language. The data were identified according to the inclusion and exclusion criteria and by using the relevant keywords like "hospital waste water", "hospital effluent", "hospital waste water treatment plant", "biomedical waste", "and effluent treatment". In this study, 1260 articles retrieved from environmental health journals were reviewed. After reviewing the quality of the articles in accordance with the research objectives, 12 articles were included in the study.

Qualitative data were collected using preferred reporting items for systematic reviews and Meta-analyzes (PRISMA) standard checklist.

Search Strategy

A manual search was performed by checking all published articles. The data were collected by referring to the specialized site of each journal. In order to determine the content validity, search terms were re-reviewed by the members of the team. Then, in order to examine the maximum access to all papers related to the search terms, the initial search was conducted using selected keywords with high sensitivity in Embase, Web of Science, Science Direct, Scopus, and PubMed. Information was collected by searching for keywords on the site of health journals.

Key words include: hospital wastewater, hospital wastewater treatment, biomedical waste, multidrug resistance bacteria, bioremediation.

Publication databases

The databases will be searched for relevant articles include:

- MEDLINE using PubMed (www.ncbi.nlm.nih.gov).
- EMBASE (www.embas e.com).
- Web of Science Core Collection (webofknowledge.com)
- Scopus (www.scopus.com)
- Science direct (www.sciencedirect.com)

Inclusion criteria

Criteria include for study – year of publication, type of waste water samples (hospital waste water), number of samples (more than 5 wastewater samples) and treatment procedure (different type), type of purification (type of treatment, type of microbial agents, amount or percentage of microbial agents removed), Studies on the presence of microbiological and chemical substances in hospital wastewater, Study on eco-toxicological risk assessment of wastewater contaminants.

Exclusion criteria

Lack of access to full article, inappropriate subject matter, less than 5 wastewater samples, inadequacy of the method of treatment and purification, lack of expression of the type of microbial agents removed, review studies, No relevant intervention/exposure, No relevant comparator, No relevant outcome, Not quantitative, Topic specific reasons, Ambiguous data.

Quality assessment articles

The comprehensiveness of the search strategy was examined according to the method based on slandered checklist PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyzes). The US-based National Institute of Health Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies for qualitative studies were used.

Extract information from articles

All articles were examined independently by two reviewers based on inclusion and exclusion criteria. Duplicate cases were identified and removed. The articles were evaluated and summarized by two reviewers and approved by the third one. Then, the selected articles will be assessed very carefully extract for needed data.

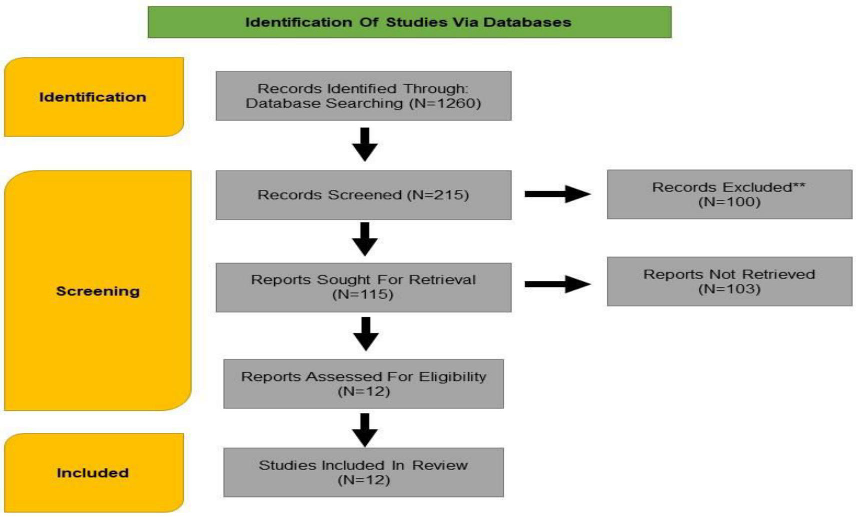

Fig.2: Flowchart: The Study Design

3. Characteristics of Hospital Wastewater

The effluent released from different hospitals is laden with microorganisms called PhACs and is distinguished by factors such as total nitrogen (TN), TKN, high COD, BOD, nitrate, ammonia, TSS, and TOC. Blackwater, greywater, stormwater, and specialized discharges are the four basic categories into which hospital discharges can be divided(Carraro et al., 2016).

The majority of the BOD in wastewater is found in the feces and urine that are released from hospital ward toilets, which is known as black water or sewage(Šunta et al., 2019). The water that is discharged from washing, bathing, doing laundry, and other operations, including disinfection and rinsing X-ray films, is known as greywater or sludge. Surfactants, detergents, and other cytotoxic or genotoxic substances, as well as radioactive materials, are refractory substances present in this water(Carraro et al., 2016).

Stormwater may be recycled for use in restrooms and hospital grounds, or it may be lost through groundwater percolation or drains. The wastewater produced by laboratory tasks, such as radiology department research and diagnostics, is categorized under distinct discharges(Kumari et al., 2020). Comparing HWW to domestic or municipal wastewater, the biodegradable component is significantly smaller. In some hospital effluents in India, the BOD concentration ranged from 92.8 mg/L to 270 mg/L, with the average concentration being 153mg/L(Verlicchi et al., 2010).

In some studies in Brazil, Spain, and India, high COD concentrations of 2480 mg/L, 2464mg/L, and 1142 mg/L, respectively, were noted. The typical pH of hospital effluent was discovered to be around 7.5, with the highest value being 8.7 in Spain and the lowest value being 6.42 in some studies(Suarez et al., 2009).

Table 1: Physico-Chemical Parameter of Hospital Wastewater

Sr. No.	Test Parameter	Result	References
1.	pH	8.7	(Periasamy& Sundaram, 2013)
2.	TSS	340mg/L	(Nasr &Yazdanbakhsh, 2008)
3.	TDS	1970mg/L	(Oliveira, 2018)
4.	COD	2464 mg/L	(Periasamy& Sundaram, 2013)
5.	BOD	92.8 mg/L to 270 mg/L	(Verlicchi et al., 2012)
6.	Fluoride	<0.1mg/L	(Chavhan, 2012)
7.	Conductivity	2850μS/cm	(Mubedi et al., 2013)

8.	Chloride	240mg/L	(Mazzitelli et al., 2018)
9.	DO	6.2mg/L	(Lin et al., 2010)
10	Alkalinity	1194mg/L	(Oliveira, 2018)
11	Hardness (Total)	495mg/L	(Mazzitelli et al., 2018)

4. Pilot/full-scale treatment systems for HWW management

1) Activated sludge processes

To treat wastewater containing PhACs, HDPE biofilms and ultrafiltration were coupled with ASP. The method removed about 100%, 93%, and 91% of TSS, COD, and TN, respectively. The average PhAC elimination rate was discovered to be 78%. Diclofenac, trimethoprim, and hydrochlorothiazide, on the other hand, had low elimination rates of 30%, 21%, and 11%, respectively(Mousaab et al., 2015).

The removal of the PhACs from the HWW of Vietnam, the study considered two full-scale treatment facilities. The first unit used physical and chemical treatment, followed by a standard ASP, and it removed PhAC at a rate of 66.3% on average. The second unit, which had an extra sand filtering unit after the ASP, provided an average PhAC removal percentage of 55.2% (Lien et al., 2016). In Brazil, the performance of a full-scale ASP with extended aeration and chlorination to cure HWW combined system's COD, BOD, and ammonia removal percentages were 75.3%, 85.7%, and 84%, respectively (Prado et al., 2011).

2) Membrane Bioreactor (MBR)

Ibuprofen, carbamazepine, and frusemide were completely eliminated by the MBR. Only 18% to 32% of pharmaceutical residues are successfully removed on average in MBR. For tertiary treatment methods using MBR, removal efficiencies rose by 30% to 65%. An ideal method for the pre-treatment of hospital wastewater seems to be the combination of MBR and ozonation. It is clear that the primary treatment methods used for hospital wastewater around the world are MBR, packed activated carbon, ozonation, and UV irradiation(A. H. Khan et al., 2020).

When compared to current wastewater treatment methods, membrane bioreactor (MBR) technology offers a more effective technique for eradicating pathogenic microorganisms.When compared to current wastewater treatment methods, membrane bioreactor (MBR) technology offers a more effective technique for eradicating pathogenic microorganisms. Over 50 MBR plants for hospital wastewater treatment have been successfully constructed in the last eight years, with capacities ranging from 20 to 2000 m3/d. MBR significantly reduces the need for disinfectants (chlorine addition can be reduced to 1.0

mg/L), speeds up the response time (about 1.5 min, 2.5–5% of the traditional wastewater treatment process), and successfully achieves a good effect of microorganism inactivation. In MBR effluents, higher disinfection efficiency is achieved at a lower disinfectant dose with fewer disinfection by-products (DBPs). Additionally, the operating cost of MBR plants drops significantly as their capacity rises from 20 to 1000 m3/d(Liu et al., 2010).

In a Swiss hospital, a pilot-scale membrane bioreactor (MBR) was constructed and run for a year. It received its influent from the hospital's sanitary collection system. An automated online SPE-HPLC-MS/MS analytical method was developed to investigate the effectiveness of micropollutant removal in raw hospital wastewater, which contains a complex matrix with micropollutant concentrations ranging from low ng/L to low mg/L. Continuous flow-proportional sampling of the MBR influent and continuous time-proportional sampling of the MBR effluent were used to determine the micropollutant elimination efficiency. The overall load elimination of all drugs and metabolites in the MBR was 22%, with persistent iodinated contrast media accounting for more than 80% of the load(Kovalova et al., 2012).

Pilot-scale tests revealed that a membrane bioreactor (MBR) followed by ozone, ozone + hydrogen peroxide, or powdered activated carbon (PAC) could efficiently remove the vast majority of APIs. MBR + ozone (156 mg O3/L administered over 20 minutes) proved to be the most cost-effective method. MBR was found to be effective at removing E. coli and enterococci, and no antibiotic-resistant bacteria were found in the effluent. API concentrations (e.g., ciprofloxacin, sulfamethoxazole, and sulfamethizole) were detected in the effluent of MBR + ozone and MBR + PAC (Nielsen et al., 2013).

For the treatment of hospital wastewater, a pilot-scale membrane bioreactor (MBR) was operated at a short hydraulic retention time (HRT) of 3 hours. The removals of eleven pharmaceutical chemicals in MBR at various mixed liquor suspended solids (MLSS) levels were examined, and the degree of nitrification was varied. The findings of the tests demonstrated the significance of immediate adsorption onto colloidal particles in MBR sludge supernatant and subsequent removal by membrane filtration of the recalcitrant pharmaceutical chemicals. Nonetheless, removals via biodegradation during brief HRT were shown to be considerable for several chemicals (Prasertkulsak et al., 2016).

The performance of a submerged hollow fiber membrane bioreactor (MBR) for hospital wastewater treatment was examined. The removal efficiency for COD, NH4 +-N, and turbidity was 80, 93, and 83%, respectively, with an average effluent quality of 25 mg/l for COD, 1.5 mg/l for NH4 +-N, and 3 NTU for turbidity. The elimination of E. coli was 98%. The effluent was colourless and odourless (Wen et al., 2004).

3) Supercritical Water Oxidation

The Supercritical Water Oxidation (SCWO) technique was used to remove medicines as well as traditional contaminants from real hospital effluent. Following a series of early tests, the best parameters for the treatment of hospital wastewater at 251 MPa were determined to be 450°C, 60s, and 1:1 for temperature, reaction time, and oxidant ratio (H_2O_2/COD), respectively. COD, BOD, TOC, TN, and SS removal rates from hospital wastewater were determined to be greater than 90%. In hospital wastewater, phosphorus removal was greater than 90%, while phenol, AOX, and surfactant removal rates were approximately 80%. In the real hospital wastewater samples, nine medicines were found. After SCWO treatment of hospital wastewater, the maximum removal rate for paracetamol was 99.9%, while the lowest removal rate for warfarin was 72%. As a result, it is possible to infer that the SCWO method is sufficient for the treatment of hospital wastewater, with high removal rates in a short reaction time, without the need for additional treatment steps(Top et al., 2020).

4) Moving Bed Biofilm Reactor (MBBR)

Pilot-scale MBBR has been found to be successful in the treatment of hospital wastewater. Pharmaceutical degradation often occurs concurrently with COD and nitrogen elimination, indicating that co-metabolic processes are primarily involved. The reduced COD effluents obtained made a subsequent ozonation treatment more viable. Intermittent feeding of biofilm increases the concentration of biomass effective against medicines and, consequently, pharmaceutical clearance. Although MBBR technology appears promising, transformation products, which may be persistent, may be produced throughout the therapy procedure (Ooi et al., 2018) .

MBBRs are a small, resilient, and simple-to-use technology that has been shown to be effective in removing COD, nitrogen, and some refractory micropollutants. As a result, MBBR is a potential approach for hospital wastewater treatment. Pharmaceutical elimination was investigated in two experiments: 1) a batch experiment in which pharmaceuticals were introduced into each reactor, and 2) a continuous flow experiment at native quantities. The first reactor was primarily responsible for DOC removal, nitrification, and pharmaceutical removal (including x-ray contrast medium, ß27 blockers, analgesics, and antibiotics). Most chemicals in the batch experiment followed a single first-order kinetic degradation function, with degradation rate constants ranging from 5.77×10^{-3} to 4.07 h^{-1}, -5.53×10^{-3} to 9.24×10^{-1} h^{-1}, and 1.83×10^{-3} to 2.42×10^{-1} h^{-1} for the first, second, and third reactors, respectively(Casas et al., 2015).

5) Constructed Wetlands

The constructed wetlands treatment indicated 100% removal of ofloxacin (A. H. Khan et al., 2020).Pilot scale for horizontal subsurface flow Artificial wetlands were built to test their efficacy in removing antibiotic-resistant germs from hospital wastewater.The current investigation found that the majority of the bacterial isolates in the intake hospital wastewater were extremely resistant to routinely prescribed antibiotics, with a significant percentage of bacterial isolates being multidrug resistant. Total coliforms, fecal coliforms, and Staphylococcus sp. had been efficiently eradicated from both the vegetated and non-vegetated wetlands. Antibiotic-resistant bacteria were eliminated in greater numbers in vegetated broken brick and gravel bed wetlands than in non-vegetated gravel bed wetlands. This demonstrates the beneficial use of plants in the eradication of antibiotic-resistant bacteria from wastewater. In general, horizontal subsurface flow wetlands, which are comparable to activated sludge treatment systems for lowering indicator, pathogenic, and antibiotic-resistant bacteria, should help tackle the problem of cost-effective hospital wastewater disposal. In order to prevent water pollution in low-income nations like Ethiopia, it is advised that CW be promoted for hospital wastewater treatment(Dires et al., 2018).

Horizontal surface flow at pilot scale From February to May 2019, a Constructed Wetland (HSFCW) with Tubesettler was installed in New Delhi, India. The purpose of this study is to compare the removal of contaminants from hospital wastewater using constructed wetlands and related tubesettler dosed with hospital wastewater. For treating 10m3/day of hospital wastewater, a pilot size CW system was used. The system was evaluated for three months to determine its efficacy in removing contaminants from wastewater. The HSFCW in conjunction with the tubesettler, achieves an overall removal efficiency of 94% (COD, MLSS, TSS, BOD5, and phosphate). In terms of eliminating contaminants from hospital wastewater, the Constructed Wetland outperformed the tubesettler(N. A. Khan et al., 2020).

Microbial degradation, phytodegradation, phytoextraction, filtration, sedimentation, and adsorption are the most common methods for pollutant removal in CWs. Vertical flow subsurface CWs and hybrid CWs performed well in terms of TN, BOD, and COD removal, while horizontal flow subsurface CWs performed well in terms of TP removal. The performance of the CWs is affected by a variety of factors, including hydraulic loading rate, pH, dissolved oxygen, temperature, and so on. In cold regions, CW performance in terms of TN, TP, and COD elimination was much lower than in tropical and subtropical climates. Greenhouse building increased TN and COD removal by 20%, whereas plant collocation increased COD removal by up to 18%. Artificial aeration, insulation, and bio-augmentation all improved CW performance in cold temperatures (Varma et al., 2021).

In Belgium, a transportable pilot-scale subsurface flow CW (1 m^3) was used to treat HWW. This system removed 83% of COD and 95% of ammonia, respectively. However, negative nitrate removal was reported, which was caused by the conversion of ammonia to nitrate (Auvinen et al., 2017).

Similar negative nitrate removal was discovered in India utilizing constructed horizontal subsurface flow CWs (5 m long, 0.65 m wide, and 0.5 m deep). TSS, COD, and BOD removal rates are better than 90%. The average proportion of PhACs removed was 54%(N. A. Khan et al., 2020).

6) Advanced oxidation processes

The efficiency of AOP in removing pharmaceuticals and the fact that it is unaffected by other technologies, along with its quick reaction rate and low chemical sluggishness, make it a viable technology. However, it also has several drawbacks, including an unselective •OH radical, an increase in hydrophilic molecules, and challenges with by-product treatment. The BOD, COD, and TSS levels have also been found to be greatly reduced by the Electro Bio-Reactor and Sequencing Batch Reactor technologies(A. H. Khan et al., 2020).

7) Heavy metal treatment

In recent years, the use of marine algae for heavy metal removal from aqueous solutions has been examined. Raw algae, modified algae, and their derivatives were examined and compared in terms of biosorption performance. The mechanism was closely tied to the biochemical compositions of the algae, particularly their cell walls, as well as water chemistry.The theoretical equilibrium model for biosorption behaviour describes and predicts the metal uptake process accurately. The biosorption kinetics can be effectively described by the intraparticle 400 diffusion model. A number of functional groups are important in metal uptake bybiosorbent(He & Chen, 2014).

8) Coagulation–flocculation and flotation processes

Coagulation-flocculation and flotation methods were studied for hospital wastewater pre-treatment, including the removal of 13 pharmaceutical and personal care products (PPCPs). Coagulation-flocculation tests were carried out in a Jar-Test device and a continuous pilot-scale facility. A flotation cell was used to handle raw hospital wastewater as well as effluent from the continuous coagulation unit. The combined coagulation-flotation method was particularly effective in removing total suspended solids (TSS), with an average removal rate of 92%. Musk fragrances were eliminated to a high extent during batch coagulation-flocculation (tonalide: 83.4 14.3%; galaxolide: 79.2 9.9%; celestolide: 77.7 16.8%), presumably due to their strong lipophilic nature, which promotes interaction with the lipid fraction of solids. Maximum removals of 46%, 42%, and

23% were reported for diclofenac (DCF), naproxen (NPX), and ibuprofen (IBP), respectively, whereas the remaining PPCPs were unaffected by the physicochemical treatment. Flotation of raw wastewater had somewhat worse outcomes than coagulation-flocculation, but the combined action of both enhanced total process efficiency(Suarez et al., 2009).

9) **Fenton reaction**

Although the waste water microbiological and organic matter content was significantly reduced after the aerobic septic tank treatment stage, the remaining microbiota (including multi-resistant bacteria) are sufficient to pose environmental and public health concerns. As a result, a low-cost chemical oxidation procedure was used to assure complete waste water disinfection and further minimize the organic content. The Fenton reaction for 120 minutes reduced BOD5 by 90.6% and COD by 91.0%, resulting in an increase in waste water biodegradability (final BOD5/COD ratio of 0.48). There was no bacterial growth in the treated hospital waste water samples, and biotests with S. subspicatus and D. magna revealed a considerable reduction in the hospital's ecotoxicity(Berto et al., 2009).

Several organic compounds in hospital wastewater are resistant to biological breakdown and have poor biodegradability ratios (BOD_5/COD = 0.3). These complex matrices exhibit resistance to the standard activated sludge biological treatment method. Prior to the biological treatment procedure, the photo-Fenton process was launched as a pre-treatment method to promote biodegradability and minimize the toxicity of wastewater. The following ideal circumstances were discovered to significantly improve biodegradability: a dose ratio of COD:H_2O_2:Fe(II) of 1:4:0.1 and a reaction pH of 3. The BOD_5:COD ratio grew from 0.30 in raw wastewater to 0.52 in treated wastewater under these conditions, while the oxidation degree of the organic material, measured as AOS, increased from 1.14 to +1.58. This method significantly lowered the toxicity of the effluent. The combined photochemical-biological systems in this work constitute an appropriate option for the treatment of hospital wastewater samples with an efficient remediation of the principal wastewater characteristics (BOD_5, COD, and TOC) (Kajitvichyanukul&Suntronvipart, 2006) .

10) Nanoparticles

Adsorption of organic contaminants, toxic metal ions, and the elimination of dangerous microorganisms from wastewater resources can provide us with clean and pure drinkable water. Respective magnetite nanoparticles (MNPs) were produced in an open-air setting utilizing the crude latex of Jatropha curcas (JC) and the leaf extract of Cinnamomum tamala (CT). The effect of magnetic nanoparticles generated in wastewater treatment (bacterial portion), dye adsorption, toxic metal removal, and antibacterial, antioxidant, and cytotoxic activities was investigated. This treatment will boost the availability of pure drinking water in the future(Das et al., 2020).

The antimicrobial properties of several nanoparticles, including silver nanoparticles, copper oxide nanoparticles, zinc oxide nanoparticles, iron oxide nanoparticles, and others, have been shown to be effective in inactivating ARB and ARG(Ali et al., 2016). Biosynthesized hematite nanoparticles removed 90% of carbamazepine. Ibuprofen was removed 92% of the time using composite iron nanoparticles. Metal-organic frameworks have been proven effective in the elimination of PhACs(Rajendran & Sen, 2018).

Sr. No.	Treatment	Country	Plant Type	References
1.	Activated sludge processes	Vietnam	Pilot scale	(Lien et al., 2016)
		Brazil	Full-scale	(Prado et al., 2011)
2.	Membrane Bioreactor (MBR)			(A. H. Khan et al., 2020)
				(Liu et al., 2010)
				(Kovalova et al., 2012)
				(Nielsen et al., 2013)
				(Prasertkulsak et al., 2016)
				(Wen et al., 2004)
3.	Supercritical Water Oxidation			(Top et al., 2020)
4.	Moving Bed Biofilm Reactor (MBBR)			(Casas et al., 2015)
				(Ooi et al., 2018)
5.	Constructed Wetlands			(Dires et al., 2018)
				(N. A. Khan et al., 2020)

				(Varma et al., 2021)
				(Auvinen et al., 2017)
6.	Advanced oxidation processes			(A. H. Khan et al., 2020)
7.	Heavy metal treatment			(He & Chen, 2014)
8.	Coagulation–flocculation and flotation processes			(Suarez et al., 2009)
9.	Fenton reaction			(Berto et al., 2009)
				(Kajitvichyanukul&Suntronvipart, 2006)
10	Nanoparticles			(Das et al., 2020)
				(Rajendran & Sen, 2018)

Future Perspectives: -

The field of hospital wastewater treatment is poised for significant advancements as the challenges associated with pathogen removal become increasingly complex and critical. The exploration of cutting-edge technologies such as advanced oxidation processes, membrane bioreactors, and nanotechnology holds great promise. Developing integrated systems that combine multiple treatment processes could significantly improve pathogen removal efficiency. Future research should focus on optimizing these technologies for cost-effectiveness and scalability, ensuring they can be widely adopted across diverse healthcare settings.

Focusing on these prospective areas, the field of hospital wastewater treatment can make significant strides towards enhancing pathogen removal, protecting public health, and promoting environmental sustainability. Continued innovation and collaboration will be key to overcoming the challenges and harnessing the full potential of advanced treatment technologies.

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References:

1. Ali, I., Al-Othman, Z. A., &Alwarthan, A. (2016). Synthesis of composite iron nano adsorbent and removal of ibuprofen drug residue from water. Journal of Molecular Liquids, 219, 858–864.
2. Auvinen, H., Havran, I., Hubau, L., Vanseveren, L., Gebhardt, W., Linnemann, V., Van Oirschot, D., Du Laing, G., & Rousseau, D. P. L. (2017). Removal of pharmaceuticals by a pilot aerated sub-surface flow constructed wetland treating municipal and hospital wastewater. Ecological Engineering, 100, 157–164.
3. Berto, J., Rochenbach, G. C., Barreiros, M. A. B., Corrêa, A. X. R., Peluso-Silva, S., &Radetski, C. M. (2009). Physico-chemical, microbiological and ecotoxicological evaluation of a septic tank/Fenton reaction combination for the treatment of hospital wastewaters. Ecotoxicology and Environmental Safety, 72(4), 1076–1081.
4. Carraro, E., Bonetta, S., Bertino, C., Lorenzi, E., Bonetta, S., & Gilli, G. (2016). Hospital effluents management: Chemical, physical, microbiological risks and legislation in different countries. In Journal of Environmental Management (Vol. 168, pp. 185–199). Academic Press.
5. Casas, M. E., Chhetri, R. K., Ooi, G., Hansen, K. M. S., Litty, K., Christensson, M., Kragelund, C., Andersen, H. R., & Bester, K. (2015). Biodegradation of pharmaceuticals in hospital wastewater by staged Moving Bed Biofilm Reactors (MBBR). Water Research, 83, 293–302.
6. Chavhan, A. (2012). Review on Waste Water Treatment Technologies. www.researchgate.net
7. Das, C., Sen, S., Singh, T., Ghosh, T., Paul, S. S., Kim, T. W., Jeon, S., Maiti, D. K., Im, J., & Biswas, G. (2020). Green synthesis, characterization and application of natural product coated magnetite nanoparticles for wastewater treatment. Nanomaterials, 10(8), 1–19.
8. Dires, S., Birhanu, T., Ambelu, A., &Sahilu, G. (2018). Antibiotic resistant bacteria removal of subsurface flow constructed wetlands from hospital wastewater. Journal of Environmental Chemical Engineering, 6(4), 4265–4272.

9. G. Tchobanoglous, F. L. B. H. D. S. (2004). Wastewater Engineering: Treatment and Reuse. McGraw-Hill Education,, Boston.
10. He, J., & Chen, J. P. (2014). A comprehensive review on biosorption of heavy metals by algal biomass: Materials, performances, chemistry, and modeling simulation tools. Bioresource Technology, 160, 67–78.
11. Kajitvichyanukul, P., &Suntronvipart, N. (2006). Evaluation of biodegradability and oxidation degree of hospital wastewater using photo-Fenton process as the pretreatment method. Journal of Hazardous Materials, 138(2), 384–391.
12. Kaur, R., Wani, S. P., Singh, A. K., & Lal, K. (n.d.). Wastewater production, treatment and use in India.
13. Khan, A. H., Khan, N. A., Ahmed, S., Dhingra, A., Singh, C. P., Khan, S. U., Mohammadi, A. A., Changani, F., Yousefi, M., Alam, S., Vambol, S., Vambol, V., Khursheed, A., & Ali, I. (2020). Application of advanced oxidation processes followed by different treatment technologies for hospital wastewater treatment. Journal of Cleaner Production, 269.
14. Khan, N. A., El Morabet, R., Khan, R. A., Ahmed, S., Dhingra, A., Alsubih, M., & Khan, A. R. (2020). Horizontal sub surface flow Constructed Wetlands coupled with tubesettler for hospital wastewater treatment. Journal of Environmental Management, 267.
15. Kovalova, L., Siegrist, H., Singer, H., Wittmer, A., & McArdell, C. S. (2012). Hospital wastewater treatment by membrane bioreactor: Performance and efficiency for organic micropollutant elimination. Environmental Science and Technology, 46(3), 1536–1545.
16. Kumari, A., Maurya, N. S., & Tiwari, B. (2020). Hospital wastewater treatment scenario around the globe. In Current Developments in Biotechnology and Bioengineering: Environmental and Health Impact of Hospital Wastewater (pp. 549–570). Elsevier.
17. Lien, L. T. Q., Hoa, N. Q., Chuc, N. T. K., Thoa, N. T. M., Phuc, H. D., Diwan, V., Dat, N. T., Tamhankar, A. J., & Lundborg, C. S. (2016). Antibiotics in wastewater of a rural and an urban hospital before and after wastewater treatment, and the relationship with antibiotic use-a one year study from Vietnam. International Journal of Environmental Research and Public Health, 13(6).
18. Lin, A. Y. C., Wang, X. H., & Lin, C. F. (2010). Impact of wastewaters and hospital effluents on the occurrence of controlled substances in surface waters. Chemosphere, 81(5), 562–570.
19. Liu, Q., Zhou, Y., Chen, L., & Zheng, X. (2010). Application of MBR for hospital wastewater treatment in China. Desalination, 250(2), 605–608.
20. Majumder, A., Gupta, A. K., Ghosal, P. S., & Varma, M. (2021). A review on hospital wastewater treatment: A special emphasis on occurrence and removal of pharmaceutically active compounds, resistant microorganisms, and SARS-CoV-2. Journal of Environmental Chemical Engineering, 9(2).

21. Majumder, A., Gupta, B., & Gupta, A. K. (2019). Pharmaceutically active compounds in aqueous environment: A status, toxicity and insights of remediation. In Environmental Research (Vol. 176). Academic Press Inc.
22. Mazzitelli, J. Y., Budzinski, H., Cachot, J., Geffard, O., Marty, P., Chiffre, A., François, A., Bonnafe, E., & Geret, F. (2018). Evaluation of psychiatric hospital wastewater toxicity: what is its impact on aquatic organisms? Environmental Science and Pollution Research, 25(26), 26090–26102.
23. Mousaab, A., Claire, C., Magali, C., & Christophe, D. (2015). Upgrading the performances of ultrafiltration membrane system coupled with activated sludge reactor by addition of biofilm supports for the treatment of hospital effluents. Chemical Engineering Journal, 262, 456–463.
24. Mubedi, J. I., Devarajan, N., Faucheur, S. Le, Mputu, J. K., Atibu, E. K., Sivalingam, P., Prabakar, K., Mpiana, P. T., Wildi, W., &Poté, J. (2013). Effects of untreated hospital effluents on the accumulation of toxic metals in sediments of receiving system under tropical conditions: Case of south india and democratic republic of congo. Chemosphere, 93(6), 1070–1076.
25. Nasr, M. M., &Yazdanbakhsh, A. R. (2008). STUDY ON WASTEWATER TREATMENT SYSTEMS IN HOSPITALS OF IRAN. In J. Environ. Health. Sci. Eng (Vol. 5, Issue 3).
26. Nielsen, U., Hastrup, C., Klausen, M. M., Pedersen, B. M., Kristensen, G. H., Jansen, J. L. C., Bak, S. N., & Tuerk, J. (2013). Removal of APIs and bacteria from hospital wastewater by MBR plus O 3, O3 + H2O2, PAC or ClO2. Water Science and Technology, 67(4), 854–862.
27. Oliveira, T. S. (2018). Environmental Contamination From Health-Care Facilities. In Health Care and Environmental Contamination (pp. 7–19). Elsevier.
28. Ooi, G. T. H., Tang, K., Chhetri, R. K., Kaarsholm, K. M. S., Sundmark, K., Kragelund, C., Litty, K., Christensen, A., Lindholst, S., Sund, C., Christensson, M., Bester, K., & Andersen, H. R. (2018). Biological removal of pharmaceuticals from hospital wastewater in a pilot-scale staged moving bed biofilm reactor (MBBR) utilising nitrifying and denitrifying processes. Bioresource Technology, 267, 677–687.
29. Orias, F., & Perrodin, Y. (2013). Characterisation of the ecotoxicity of hospital effluents: A review. In Science of the Total Environment (Vols. 454–455, pp. 250–276).
30. Periasamy, D., & Sundaram, A. (2013). A novel approach for pathogen reduction in wastewater treatment. Journal of Environmental Health Science and Engineering, 11(1).
31. Prado, T., Silva, D. M., Guilayn, W. C., Rose, T. L., Gaspar, A. M. C., &Miagostovich, M. P. (2011). Quantification and molecular characterization of enteric viruses detected in effluents from two hospital wastewater treatment plants. Water Research, 45(3), 1287–1297.

32. Prasertkulsak, S., Chiemchaisri, C., Chiemchaisri, W., Itonaga, T., & Yamamoto, K. (2016). Removals of pharmaceutical compounds from hospital wastewater in membrane bioreactor operated under short hydraulic retention time. Chemosphere, 150, 624–631.
33. Rajendran, K., & Sen, S. (2018). Adsorptive removal of carbamazepine using biosynthesized hematite nanoparticles. Environmental Nanotechnology, Monitoring and Management, 9, 122–127.
34. Suarez, S., Lema, J. M., &Omil, F. (2009). Pre-treatment of hospital wastewater by coagulation-flocculation and flotation. Bioresource Technology, 100(7), 2138–2146.
35. Šunta, U., Žitnik, M., Finocchiaro, N. C., Bulc, T. G., & Torkar, K. G. (2019). Faecal indicator bacteria and antibiotic-resistant β-lactamase producing Escherichia coli in blackwater: A pilot study. Arhiv Za Higijenu Rada iToksikologiju, 70(2), 140–148.
36. Top, S., Akgün, M., Kıpçak, E., & Bilgili, M. S. (2020). Treatment of hospital wastewater by supercritical water oxidation process. Water Research, 185.
37. Varma, M., Gupta, A. K., Ghosal, P. S., & Majumder, A. (2021). A review on performance of constructed wetlands in tropical and cold climate: Insights of mechanism, role of influencing factors, and system modification in low temperature. In Science of the Total Environment (Vol. 755). Elsevier B.V.
38. Wen, X., Ding, H., Huang, X., & Liu, R. (2004). Treatment of hospital wastewater using a submerged membrane bioreactor. Process Biochemistry, 39(11), 1427–1431.
39. Z. Hu, D. G. (2004). Water analysis- chemical oxygen demand, in: Encyclopedia of Analytical Science. In: Encyclopedia of Analytical Science, Second Ed.

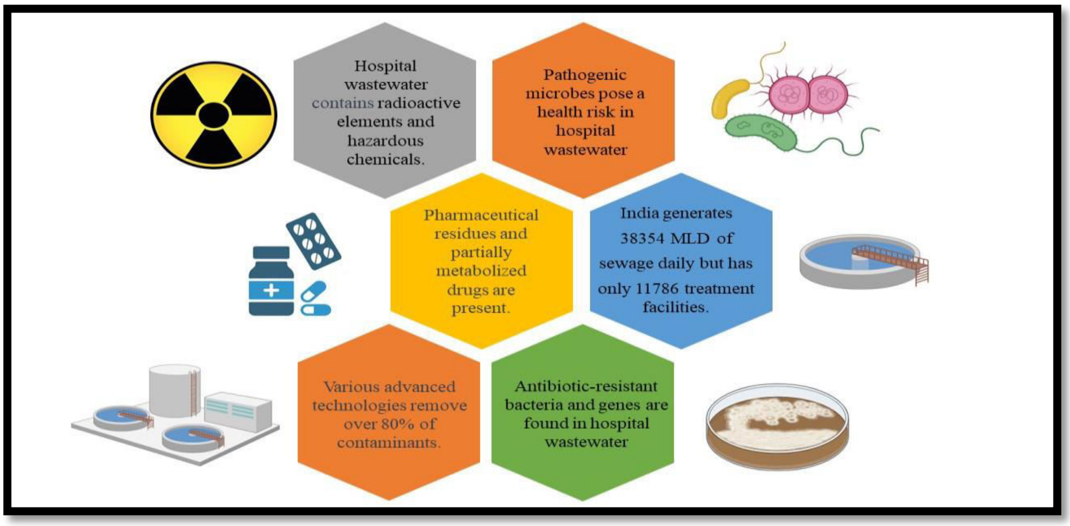

Fig1: Graphical Abstract