Spring 5-4-2023

The Threat of Hospital Wastewater: An Evidence-Based Call to Action

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The author of this manuscript declares no conflicts of interest.

Acknowledgements: Dr. Nancy Selix, Dr. Jo Loomis, Dr. Barbara Sattler

Abstract

Introduction: Hospital wastewater carries a unique composition of pollutants, a burden that includes high chemical and biological residuals. These pollutants are discharged into sewage treatment plants and natural environments where they contaminate human water sources and larger ecosystems. Water treatment plants are not designed to treat the high loads of biomedical waste and persistent organic compounds found in hospital wastewater and therefore pollutants survive in conventionally treated water. Evidence of contaminated soil, municipal wastewater, surface water, ground water, and even drinking water have been demonstrated in studies conducted around the world highlighting the ubiquity of the problem. Hospital effluent as also been implicated in the increase of antimicrobial resistance. This manuscript serves as an integrated literature review investigating the effects of hospital wastewater and its implications on environmental health.

Methods: A literature search was conducted on the effects of hospital effluent through the Scopus, CINAHL, and PubMed databases using the keyword combinations: "hospital" AND "wastewater" OR "effluent". After set inclusion and exclusion criteria, Scopus yielded 2 results, CINAHL 0, and PubMed 4 (with one duplicate article yielded by both Scopus and PubMed). A synthesis of the articles are explored herein highlighting the effect of hospital effluent on human and ecological health and implications are discussed.

Results: The articles discussed in this manuscript focus on the pathogenic burden of hospital wastewater, the pharmaceutical components found in hospital wastewater and its effects on local and larger ecosystems, and the implication of hospital wastewater on antibiotic resistance.

Conclusion: The management of healthcare wastewater is a topic gaining international attention. Hospital wastewater is unique in that it carries a high burden of pathogens and active pharmaceutical compounds, and provides an ideal environment for promoting antibiotic resistance. Insufficient management and removal of chemical and biological pollutants found in hospital wastewater greatly impacts environmental and human health. These consequences demand that the issue be a high priority concern for public health organizations and to enact strict policies to surveillance and regulate pollutants released into waterways. There remains a strong need to bolster research efforts in order to measure the acute and longitudinal effects of hospital wastewater on human health.

Keywords: hospital wastewater, hospital effluent, pharmaceutical waste, public health, antibiotic resistance

The Threat of Hospital Wastewater: An Evidence-Based Call to Action

The treatment and management of healthcare effluent is an issue of growing international concern. Hospital wastewater has long been thought to contain the same pollutant nature as urban wastewater. However evidence from emerging studies show that hospital effluents carry a complex pollution load containing chemical and biological residuals such as active pharmaceutical compounds and drug-resistant microorganisms. This burden uniquely differentiates healthcare wastewater from urban wastewater. Effluents from hospitals have been shown to contain high levels of statin, analgesic, antibiotic (Verlicchi et al., 2012); antiviral (Prasse, Shlüsener, Schulz, & Ternes, 2010); and cytotoxic (Kovács et al., 2016) drugs. These pharmaceutically active effluents are discharged into sewage treatment plants and natural environments where they chemically and biologically contaminate water sources, and threaten aquatic life and the co-residing terrestrial ecosystems. Wastewater from healthcare facilities carry very high loads of micropollutants including bacteria and viruses that coexist in a mixture of pharmaceutical drugs which contributes to the development and dissemination of antimicrobial resistance. Many sewage treatment plants are not designed to treat biomedical waste and persistent organic compounds (Majumder et al., 2021). Therefore it is no surprise that these effluents make their way through treatment plants without significant changes in their structure and then enter surface water and household water sources (Mackullack et al, 2021). One study by Giri et al. (2021) details the detection of multi-drug resistant bacteria strains in municipal drinking water. Evidence of contaminated soil, municipal wastewater, surface water, and ground water have been demonstrated in all continents of the world highlighting the ubiquity of the problem. Additionally, antibiotic stewards recognize that antimicrobial resistance is a global challenge. From an economic perspective, the CDC estimates that United States alone expends $55 billion every year in in antimicrobial resistance-related costs, $20 billion for healthcare and $35 billion due to loss of productivity (Dadgostar, 2019).

The threat of hospital wastewater has dangerous implications to environmental and human health. Many pharmaceutically active compounds are highly toxic at very low concentrations, and many antibiotic resistant organisms survive even after passing through water treatment centers (Majumder et al., 2021). Of great concern is that very frequently there are no regulations mandating treatment of hospital effluent prior to discharge into the environment (Carraro, Bonetta, & Bonetta, 2017). Referencing the most recent United States Environmental Protection Agency (EPA) Municipal Wastewater Primer from 2004, no mention is made about the specific management of hospital wastewater and its unique challenges, and in regard to pharmaceuticals, states that “some are known to be highly poisonous at very low concentrations… and are not effectively removed by conventional wastewater treatment” (United States Environmental Protection Agency, 2004, p. 8). A more updated publication addressing the unique burdens of hospital effluent has not yet been made available to the public. Thus recognition of these threats should foster a resounding call for awareness of the need for environmental stewardship among healthcare leaders at the point source and to mobilize innovative ideas targeting the appropriate disposal of pharmaceuticals and effective hospital wastewater management. This manuscript attempts to highlight the effect of hospital wastewater in regards to its pathogenic threat, pharmaceutical burden, and its role in promoting antibiotic resistance.

Search Strategy

A literature search was conducted on this topic through the Scopus, CINAHL, and PubMed databases using the keyword combinations: “hospital” AND “wastewater” OR "effluent". The search was only inclusive of original peer-reviewed research articles published in the English language within the last 6 years. Preliminary searches of Scopus, CINAHL, and PubMed yielded 120, 43, and 49 results. The abstracts of the resulting articles were then screened for relevance. Environmental studies were limited to only those taking place in the United States to maintain geographic relevance. Although the international environmental and observational studies on this topic are fascinating, they are beyond the scope of this manuscript. As a final result, 7 articles were included in this review. The studies cited within the aforementioned articles were also considered based on the same inclusion criteria. A critical appraisal of the selected articles is included in Appendix A. A synthesis of the articles are explored herein highlighting the effect of hospital effluent on human and ecological health and implications are discussed.

Review of Evidence

Bacteria, viruses, and other pathogens in hospital effluent

Water is a necessity for life, and, as such, may be a vector that portends to its potential role in community illness and even widespread epidemics. Hospital wastewater is a host to a variety of highly resilient bacteria, viruses, and other microorganisms that are discharged into the environment oftentimes through effluent pipe systems that may have leakage. Parida et al. (2022) writes that the most common human transmitting infectious viruses are transmitted through water. These viruses include enveloped viruses such as Severe Acute Respiratory Syndrome (SARS), Middle East Respiratory Syndrome Coronavirus (MERS-CoV), Ebola, and avian influenza, and non-enveloped enteric viruses, such as hepatitis A, adenoviruses, enteroviruses, noroviruses, and rotaviruses, all of which can survive in and be transmitted through hospital wastewater (Parida et al., 2022).

A study by Beattie et al. (2020) sought to determine the extent to which hospital sewage contributes to the microbial community of disinfected wastewater which is released into the environment. The investigators sequenced hospital wastewater, wastewater treatment plant influent, treated effluents, and receiving sediments tracking changes in microbial community composition. Through the use of molecular source tracking, Beattie et al. (2020) found that "the hospital sewage microbiome contributes an average of 11.49% of the microbial community in Post-Chlorinated Effluents, suggesting microorganisms identified within hospital sewage can survive or are enriched by the chlorination disinfection process" (p. 1).

Pharmaceuticals in hospital effluent

The major sources of environmental pollution by pharmaceuticals include agricultural, veterinary, pharmaceutical manufacturing, and healthcare industries. Up to the year 2014, a running total of 631 pharmaceutical substances have been detected in soil, surface water, and groundwater samples across the world (aus der Beek et al., 2016). Hospital wastewater carries a high burden of unused, leftover, and expired medications or excreted metabolites contributing to the pharmaceutical residues that exist in natural environment. In North America, ciprofloxacin, sulfamethoxazole, trimethoprim, norfloxacin, and ofloxacin were the most frequently reported antibiotics found in hospital effluent, as well as a variety of β-blocker medications such as atenolol, metoprolol, and propranolol. These detections were cited in an article by Majumder et al. (2021). Hospital effluents in the United States also contained the highest concentration of analgesics, specifically acetaminophen at 374 μg/L and ibuprofen at 2.8-36.5 μg/L, when compared to Asia and Europe (Majumder et al., 2021). Other pharmaceutical compounds commonly detected in hospital effluents of the United States included carbamazepine, theobromine, theophylline, metformin, and gabapentin (Majumder et al., 2021).

Many of the toxic contaminants found in hospital wastewater can cause various types of skin and kidney diseases; others can be carcinogenic and mutagenic (Parida et al., 2022). Contaminated soil and groundwater can increase the risk of exposure via ingestion (Parida et al., 2022). Furthermore, the decomposition of certain active pharmaceutical compounds are known to release toxic nitrogen oxides that may be harmful to humans. Similarly, fluoride-containing drugs release hydrogen fluoride gas during biodegradation, which irritates the eyes, nose, and respiratory tract (Parida et al., 2022).

Conventional wastewater treatment plants are often unable to completely degrade contaminants with complex structures such as active pharmaceutical compounds (Parida et al., 2022). The removal of pharmaceutical compounds using chlorination disinfection is mixed. In a study of antibiotic removal from wastewater Burch et al. (2019) found that erythromycin and trimethoprim were significantly removed. However sulfamethoxazole and ciprofloxacin were only partially removed, and tetracycline and norfloxacin were persistent and almost unchanged compared to pre-treatment levels. A study by Li et al. (2021) found detection frequencies of anticancer drugs in hospital wastewater at 58%, wastewater treatment plant influents and effluents at 78% and 52%, and surface water at 59% overall demonstrating the persistence of anticancer medications in various environmental samples. Presence of pharmaceutically active compounds can be highly toxic to the environment even at low concentrations; its direct effect on short- and long-term human health outcomes have yet to be formally measured.

Only a handful of the many pharmaceutical classes found in wastewater have been thoroughly studied with animal models or limited to lab-scale. Even fewer studies detail the direct observed effects on human populations, relying on theory based on pharmacological kinetics and dynamics. Jureczko and Kalka (2019) sought to study the role of cytostatic contaminants on human health, citing the presence of cytostatic drugs at genotoxic levels in hospital wastewater both prior to and after treatment at a wastewater facility. Cytostatic drugs are a type of anticancer therapy that pharmacologically inhibit the replication of DNA in rapidly growing tumor cells in cancer patients. For noncancer populations with exposure to cytostatic drugs (i.e. through contaminated water sources or ineffectively treated water sources), Jereczko and Kalka (2018) remark that this may cause DNA damage that is most sensitive among fetuses, babies, and children whose cells are dividing and under a period of rapid growth. This may trigger birth defects, fetal death, and a predisposition to cancer later in life. It is not yet clear what margin of exposure is considered negligible, however "generally it is well known that low-level exposures could cause cancer, developmental problems, allergic reactions, and other adverse effects, which can be irreversible" (Jereczko & Kalka, 2018, p. 5). In the environment, it has the effects of residual pharmaceuticals have had a profound impact on aquatic organisms. Even at low doses, such as those detected in hospital wastewater, cytostatic drugs have been shown to cause both acute and toxic effects such as DNA damage, histopathological transformations and malformations, impaired fertility, interference with endocrine function (Li et al., 2021).

Hospital effluent as a hotbed for antibiotic resistance

Wastewater from all sources have repeatedly been implicated in the spread of antibiotic resistance and pathogenic bacteria. The environment of hospital wastewater is a intermixing of bacteria, viruses, and a variety of pharmaceutical compounds including antibiotics and antiviral drugs. Such an environment offers ample opportunity for selective pressures that foster mutations, horizontal gene transfers, and antimicrobial resistance (Beattie et al., 2020). As the prevalence of antibiotic resistant organisms continues to rise worldwide, the challenge of not only managing treatment-resistant infections is one of greatest threats to human health because it reduces the curative potential of antibiotics to fight against pathogens causing disease in humans and animals (Parida et al., 2022). The rapid increase of antibiotic-resistant organisms places pressure on pharmaceutical engineers to keep up with antibiotic development. It is estimated that 50-70% of all bacterial infections demonstrate some degree of antibiotic resistance (Parida et al., 2022). This presses on the importance and urgency of developing effective strategies to remove antibiotics from wastewater.

Beattie et al. (2020) revealed that seven of 28 identified potential pathogens remained detectable in post-chlorinated effluent and environmental sediments in the Lake Michigan region. These pathogens were cultured on media containing β-lactam, ceftazidime, and meropenem antibiotics. A resistant survivor community of pathogens was identified. These results indicate not only the persistence of microbes through the water treatment process, but also demonstrates the selective environment that microbes proliferate within that foster their ability to evade certain antibiotics (Beattie et al., 2020)

Discussion

The management and treatment of hospital wastewater is an emerging topic of interest. This is evidenced by the growing body of literature surrounding the issue in recent years. This manuscript serves as a small stepping stone in the vastness of further research opportunities on this topic including the effects of specific drug concentrations at various wastewater concentrations on human and/or ecological health, strategies to dispose of unused pharmaceuticals, technologies to effectively treat wastewater. Ethical considerations certainly contribute to the difficulty in studying this topic.

Perhaps it is because there is not enough data on their toxicity assessment that few countries have established standards or regulations in the management of hospital wastewater. Beattie et al. (2020) brings this lack of awareness to the forefront, stating: “federal and state monitoring programs for these pollutants remains minimal or nonexistent” (p. 2). In the United States, the Environmental Protection Agency is the governing body that issues wastewater limitation guidelines and regulatory standards which are outlined in the Federal Water Pollution Control Act of 1948 and the Clean Water Act of 1972. Therein, the EPA recommends the point sources of water pollution like hospitals to follow specific regulations and discharge permits, however the specifics of those regulations were vague if not nonexistent. It appears that neither the Federal Water Pollution Control Act 1948, the Clean Water Act of 1972, nor any of its subsequent revisions and amendments ((United States Environmental Protection Agency, 2002; United States Environmental Protection Agency, 2018) have yet to address the complexities of hospital effluent. One impactful and most direct management option is to employ point-source supervision having agencies either appointed by the hospital or independent of the hospital system to monitor wastewater discharge. Further oversight of waste processes within the hospital (for example, disposal of pharmaceuticals into the appropriate waste stream) can also be implemented internally.

Despite the apparent lack of modern government regulation on the topic, many thoughtful and proactive researchers remain committed to finding solutions. Parida et al. (2022) summarizes the water treatment strategies being employed by other countries like Korea, Spain, and Greece. Studies like Majumder et al. (2021) and Parida et al. (2022) highlight the hopeful emerging technologies to remove active pharmaceutical particulates, remove bacteria, and inactivate viruses from wastewater. These innovations include constructed wetlands, membrane bioreactors, biofilm reactors, adsorption-based processes, and membrane filtration-based processes.

Limitations

Although some literature exists on the topic of hospital wastewater and environmental health, no studies were found regarding the direct influence of healthcare effluent directly on human health. The relative lack of exploration in this field has stimulated investigation around the world to provide insight on the effect of pharmaceuticals, pathogens, antibiotic resistant organisms, and other contaminants on both the natural environment and human health (Verlicci, 2021). In the absence of ethical randomized control trials, retrospective observational studies and animal studies have demonstrated how ecologic toxicity is intricately linked with human health outcomes. The use of zebrafish as a model as allowed for a highly predictive method for estimating drug absorption, metabolism, and toxicity in humans (Poon et al., 2016) and various studies beyond the scope of this manuscript have demonstrated deleterious effects on animal models related to exposure to endocrine disruptors and other contaminants at low, but toxic concentrations. Further investigations in this emerging area of study should elucidate short- and long-term effects on human health as well as technologies to reduce the pollutant burden of hospital wastewater.

Conclusion

Wastewater treatment is vital to the health of animals and humans alike. The treatment and management of healthcare effluent specifically is a topic rapidly gaining attention among the international community. Hospital wastewater is unique in that it carries a high burden of pathogens and active pharmaceutical compounds, and provides an ideal environment for promoting antibiotic resistance. Insufficient management and removal of chemical and biological pollutants found in hospital wastewater carries damaging effects on environmental and human health. This phenomenon has been evidenced in areas where effluent is directly discharged into the natural environment; however, pharmaceuticals and microbial populations surviving the process of wastewater treatment and disinfection has also been demonstrated (Beattie et al., 2020). All the articles included in this review of literature agree that the pollutants found in hospital wastewater are ecotoxic, contributory to formation of antimicrobial-resistant organisms, and are a threat to human health. Furthermore, even post-treatment water may retain detectable levels of active pharmaceutical compounds and antibiotic resistant genes that make their way to public water delivery systems. These consequences demand that the issue be a high priority concern for public health organizations and healthcare centers, and serve as a call to action to enact strict policies to surveillance and regulate pollutants released into waterways. As the research in this review has highlighted, wide utilization of pharmaceutical products and improper handling and disposal contributes to large effluent burden (Zhang et al., 2020). Hospitals serve as one major source point for pharmaceutical pollution therefore healthcare centers need to play a more active role in overseeing the proper handling and disposal of pharmaceutical waste. Finally, as demonstrated through the scarcity of high-quality primary research on the topic, further research needs to be conducted to determine the acute and longitudinal effects of hospital wastewater on human health.

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Appendix A: Johns Hopkins Evidence Based Practice Evaluation Tool

Purpose of Article or Review	Design/ Method	Sample/ Setting	Major Variables Studied (and their Definitions)	Measurement of Major Variables	Data Analysis	Study Findings	Level of Evidence (Critical Appraisal Score) / Strengths and Weaknesses / Conclusion(s)
aus der Beek, T., Weber, F. A., Bergmann, A., Hickmann, S., Ebert, I., Hein, A., & Küster, A. (2016). Pharmaceuticals in the environment—Global occurrences and perspectives. *Environmental toxicology and chemistry*, *35*(4), 823-835.							
To elucidate the measured environmental concentrations (MEC) of pharmeceuticals in industrialized and developing countries	Literature review	1016 original publications and 150 review articles	Human and veterinary pharmaceutical substances in surface water, groundwater, tap/drinking water, manure, soil, and other environmental matrices	Measured environmental concentration (MEC)	Thematic analysis, quantitative analysis via a simplified data quality assessment aggregated environmental matrices into one database	Distribution of pharmaceuticals and their substrates have been detected in all continents. 631 different pharmaceutical substances were found at MECs above the detection limit, and many exceeding the predicted no-effect concentrations.	**Level of Evidence** Level III, high quality **Strengths** Many sampling sites throughout the world **Limitations** Limited data based on grab samples at individual sampling sites with scare long-term monitoring data **Conclusions** Urban wastewater was the dominant emission pathway globally, however industrial production, hospitals, agriculture, and aquaculture was had a significant local impact.

Purpose of Article or Review	Design/ Method	Sample/ Setting	Major Variables Studied (and their Definitions)	Measurement of Major Variables	Data Analysis	Study Findings	Level of Evidence (Critical Appraisal Score) / Strengths and Weaknesses / Conclusion(s)
Beattie, R. E., Skwor, T., & Hristova, K. R. (2020). Survivor microbial populations in post-chlorinated wastewater are strongly associated with untreated hospital sewage and include ceftazidime and meropenem resistant populations. *Science of the Total Environment, 740*, 140186.							
To determine the extent to which hospital sewage contributes to the microbial community of disinfected wastewater which is released into the environment	Environmental grab sampling and RNA sequencing of hospital sewage	Hospital sewage, wastewater treatment plant influent, primary effluent, post-chlorinated effluent, and receiving sediments of Jones Island Water Reclamation Facility in the Milwaukee, WI metropolitan area	The total microbial community (including potential pathogens) and the microbial burden present after treatment and disinfection	Molecular source tracking	Comparison of microbial burden at different sampling points	Hospital sewage microbiome contributes to an average of 11.49% of the microbial community in post-chlorinated effluents	**Level of Evidence** Level III, high quality **Strengths** Samples multiple time-points at both the pre-and post-treatment process **Limitations** Single metropolitan area **Conclusions** Although wastewater treatment does significantly reduce pathogenic loads, their presence does persist in disinfected wastewater and receiving sediments. This suggests that additional treatment and microbial tracking systems are needed.

Purpose of Article or Review	**Design/ Method**	**Sample/ Setting**	**Major Variables Studied (and their Definitions)**	**Measurement of Major Variables**	**Data Analysis**	**Study Findings**	**Level of Evidence (Critical Appraisal Score) / Strengths and Weaknesses / Conclusion(s)**
Burch, K. D., Han, B., Pichtel, J., & Zubkov, T. Removal efficiency of commonly prescribed antibiotics via tertiary wastewater treatment. *Environmental Science and Pollution Research 26,* no. 7 (2019): 6301-6310.							
To summarize the current literature regarding antibiotics removal from common tertiary processes at full-scale municipal wastewater treatment plants	Literature review	Not discussed	Antibiotic residuals after treatment through a variety of modalities: chlorination, ultraviolet radiation, and sand filtration	N/A	Thematic analysis	Chlorination significantly reduces antibiotic burden in wastewater effluents. By comparison, sand filtration and UV irradiation were less effective treatment modalities. However, a large discrepancy of removal efficiencies is apparent across different studies of these treatment processes.	**Level of Evidence** Level V, low quality **Strengths** Wide scope of wastewater treatment modalities examined. **Limitations** Study design was unclear; selection of articles from selected databases was not discussed. **Conclusions** The outcomes of tertiary treatment on antibiotic removal efficiency are still unclear. Caution should be taken when sampling wastewater in full-scale wastewater treatment plants for comparison of removal efficiencies of antibiotics.

Purpose of Article or Review	Design/ Method	Sample/ Setting	Major Variables Studied (and their Definitions)	Measurement of Major Variables	Data Analysis	Study Findings	Level of Evidence (Critical Appraisal Score) / Strengths and Weaknesses / Conclusion(s)
Jureczko, M., & Kalka, J. (2020). Cytostatic pharmaceuticals as water contaminants. *European Journal of Pharmacology, 866*, 172816.							
To sums up the current knowledge about the sources, pathways, detection and degradation methods of cytostatic drugs in aquatic matrices. It also presents their physicochemical properties that have an influence on their occurrence in the surface water	Literature review	Articles selected from ChemSpider Database, Drug Bank Database, PubChem Database, Human Metabolome Database, and Toxnet: Hazardous Substances Data Bank	Cytostatic drugs	N/A	Thematic analysis	Cytostatic drugs in the detected concentrations can cause chronic toxicity and damages genetic material, though acute toxicity is less likely. Detection of cytostatic levels exceed the HC_5 level, suggesting that anticancer drugs are real hazardous contaminants for the environment.	**Level of Evidence** Level V, low quality **Strengths** Well-summarized technical content from selected material discussing detection methods of water pollution, occurrence of cytostatic pharmaceuticals in surface water, and discussion about environmental risk assessment. **Limitations** Study design was unclear; selection of articles from selected databases was not discussed. **Conclusions** Cytostatic drugs are genotoxic, carcinogenic, mutagenic, embryotoxic, and teratogenic. The level of active compounds detected in different environmental matrices demonstrates a real environmental hazard.

Purpose of Article or Review	Design/ Method	Sample/ Setting	Major Variables Studied (and their Definitions)	Measurement of Major Variables	Data Analysis	Study Findings	Level of Evidence (Critical Appraisal Score) / Strengths and Weaknesses / Conclusion(s)
Li, D., Chen, H., Liu, H., Schlenk, D., Mu, J., Lacorte, S., Ying, G., & Xie, L. (2021). Anticancer drugs in the aquatic ecosystem: Environmental occurrence, ecotoxicological effect and risk assessment. *Environment International, 153*, 106543. https://doi.org/10.1016/j.envint.2021.106543							
To elucidate the global occurrence of major classes of anticancer drugs in water and sediments of freshwater ecosystems and their ecotoxicological effects at different biological levels	Literature review	N/A	Anticancer drugs	N/A	Thematic analysis, quantitative analysis	Effluent concentrations of most anticancer drugs ranged from < 2 ng/L to 762 µg/L. Sediments levels ranged from 0.25 to 42.5 µg/kg. Their detection frequencies were 58%, 52% (78%) and 59% in hospital wastewater, wastewater treatment plant effluents (influents) and surface water, respectively.	**Level of Evidence** Level V, low quality **Strengths** Identifies accumulation of different types of anticancer drugs and their effects on the aquatic ecosystem **Limitations** Study design was unclear; selection of articles from selected databases was not discussed. Findings focus on effects on the aquatic environment rather than human health. **Conclusions** Anticancer drugs found in receiving effluent and sediments demonstrate a high potential for persistence and bioaccumulation.

Purpose of Article or Review	Design/ Method	Sample/ Setting	Major Variables Studied (and their Definitions)	Measurement of Major Variables	Data Analysis	Study Findings	Level of Evidence (Critical Appraisal Score) / Strengths and Weaknesses / Conclusion(s)
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), 104812.							
To characterize the composition of hospital wastewater	Literature review	Not discussed	Pharmaceutically active compounds, viruses, and microorganisms present in hospital wastewater	N/A	Thematic analysis	Hospitals are significant contributors to complex wastewater, particularly in developed countries, and comprise of many contaminants including recalcitrant pharmaceutically active compounds, viruses, antibiotic resistant organisms, and high nutrient content at higher than the drinking water equivalent limit. A comparison of treatment modalities was performed each modality having limitations to effective removal.	**Level of Evidence** Level V, low quality **Strengths** Examines the full scope of hospital wastewater generation to treatment (pilots and full-scale) modalities **Limitations** Study design was unclear; selection of articles from selected databases was not discussed. **Conclusions** Antibiotic resistant microorganisms and viruses were found to be persistent even after the treatment of hospital wastewater.

Purpose of Article or Review	Design/ Method	Sample/ Setting	Major Variables Studied (and their Definitions)	Measurement of Major Variables	Data Analysis	Study Findings	Level of Evidence (Critical Appraisal Score) / Strengths and Weaknesses / Conclusion(s)
Parida, V. K., Sikarwar, D., Majumder, A., & Gupta, A. K. (2022). An assessment of hospital wastewater and biomedical waste generation, existing legislations, risk assessment, treatment processes, and scenario during COVID-19. *Journal of environmental management,* 114609.							
To present an overview of worldwide hospital wastewater generation, regulations, and guidelines on wastewater management and various treatment techniques	Systematic review	Scopus database	Wastewater generation, composition, pathways into the environment, regulations, and guidelines on wastewater management and various treatment techniques	N/A	Thematic analysis	Conventional wastewater treatment methods remove approximately 50-70% of contaminants. Biological or physical treatment processes in conjunction with advanced oxidation processes could remove approximately 90% of emerging contaminants.	**Level of Evidence** Level III **Strengths** Thorough examination of hospital wastewater timeline and charts/graphs comparing treatment processes of different countries **Limitations** Does not provide appraisal of sources included in the review. **Conclusions** Analgesics were found to be more easily removed than antibiotics, β-blockers, and X-ray contrast media. Mishandling of BMW can spread infections, deadly diseases, and hazardous waste into the environment, however, utilizing a combination of treatment methods can greatly reduce contaminant burden in hospital wastewater.