Concerns, Issues, Challenges in Liquid Biomedical Waste Management

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ABSTRACT
Hospital effluents are increasingly a concern globally due to improper distinctions between sewage from hospitals and urban areas. Untreated wastewater stances a significant threat to health of human and also to the environment, and improper disposal can lead to hazardous reuse. Hospital waste water treatment procedures eradicate contaminants and yield a liquid effluent appropriate for disposal and sludge formation. Advanced treatment methods like Advanced Oxidation Technology, filtration, and adsorption are essential for public health and the environment. Activated sludge processes and Membrane bioreactor are effective, with hybrid systems incorporating tertiary treatments like ozonation, Ultraviolet light treatment, etc.

1. Introduction

Hospital waste water (HWW) is waste water generated from all hospital activities, both medical and non-medical, including procedures performed in operation theaters, laboratories, radiology department, kitchens, and laundry rooms. It is managed through mandatory sewage treatment plants (STP) and effluent treatment plants (ETP) [1]. Hospital effluents have gained global attention due to inadequate distinctions amid sewage from various sources such as the hospitals and the urban areas. Such potentially hazardous loads of hospital waste water are regularly released into general public sewage systems without previous identification of source of toxicity [2].

STP systems carries wastewater throughout facility to a central underground location for treatment or disposal, whereas ETP systems transport only medical liquid wastes. Liquid waste poses a major risk to health of both human and the environment when poorly handled and disposed of. It can pollute ground and drinking water, soil, air, and disrupting ecosystem balance by contaminating aquatic life. This unprocessed waste reuse can be enormously perilous, if not fatal [3], [4]. In many countries, hospital wastewaters are often combined with urban wastewaters and released into municipal sewage before being collected at a wastewater treatment facility and co-treated with urban or/and industrial effluents.

The quantity of wastewater generated in a hospital is influenced by many factors; hospital size, number of beds, type of wards, kitchen and laundry services, management policies of the institution etc. Literature search reveals that the average water consumption by hospitals is approximately 750L/d/b.

2. Types of Liquid Waste

Hazardous Liquid Waste:

Infectious Waste

- Blood (dialysis wastes, blood and it's by products) and body fluids (Spinal fluids, amniotic fluids etc.)
- Laboratory wastes (cultures, vaccines)
- Chemically hazardous wastes
- Formaldehyde and other Solvents (found in pathology labs, autopsies, embalming)
- Mercury (Broken thermometers, sphygmomanometer, dental amalgams)
- Radioactive liquid wastes
- X-Ray Film Processing chemicals (fixer and developer)

Non- Infectious Waste

- Pharmaceutical liquid waste (discarded/unused/expired medicines)

Non-hazardous Liquid Waste:

- Waste water from cleaning and washing

3. Process of Clinical Liquid Waste Management

Segregation of Liquid Waste- Liquid waste should be first disinfected then segregated and sealed, at the generation site. If transport is needed, collect in double containers and transport through public corridors, labelled with biohazard symbols and "biohazardous waste" [3].

When the powdered solidifying agent is introduced to the liquid waste container, it quickly begins to absorb the moisture present in the liquid. This absorption process occurs over a period of 5 to 10 minutes, during which the liquid waste undergoes a transformation into a gelatinous solid. The resulting solid mass effectively immobilizes the liquid, preventing it from sloshing around or leaking during transportation.

Once the liquid waste has solidified, the container can be sealed, and the risk of spills or leaks is significantly reduced. The solidified waste can then be transported more safely and conveniently to the appropriate disposal facility, where it can be treated or disposed of in accordance with the relevant regulations and guidelines.

Overall, the use of a powdered solidifying agent to convert liquid waste into a gelatinous solid offers practical benefit in managing biohazardous fluids. It improves safety, reduces the risk of contamination, and facilitates the transportation and disposal of these substances.

Solidifying agents are dry granular super absorbent polymers (sodium polyacrylate) capable of absorbing and retaining large amounts of liquid. This solidification process utilises microencapsulation technology to convert liquid waste to solid waste [3].

It is important to note that the management and disposal of pathological and chemical waste can vary depending on local regulations and guidelines. However, I can provide you with some general information on pre-treatment measures for liquid pathological and chemical waste.

Liquid Pathological Waste: Liquid pathological waste, which includes biohazardous materials such as bodily fluids or tissues, should be treated and neutralized before being released into the main sewage system. This pre-treatment process typically involves using chemical disinfectants to ensure that any potential pathogens present in the waste are effectively killed or inactivated.

The specific disinfectants used may vary depending on local regulations and facility protocols, but commonly used disinfectants for pathological waste include chlorine-based compounds, phenolics, or other suitable chemical agents. These disinfectants help to neutralize any harmful microorganisms, reducing the risk of contamination and ensuring the waste is safe for disposal in the sewage system.

Chemical Waste: Chemical waste, which includes various types of hazardous substances, must also undergo proper pre-treatment before being drained into the sewer. The pre-treatment process for chemical waste involves neutralization using appropriate reagents or chemical reactions to make the waste less hazardous.

The choice of neutralizing agents depends on the specific chemicals present in the waste. Different chemicals require different neutralizing agents to effectively neutralize their hazardous properties. Commonly used neutralizing agents include acids or bases that react with the chemical waste to produce non-hazardous by products. It is important to follow established procedures and guidelines to ensure effective neutralization and proper disposal of the chemical waste.

Compliance with Regulations: It is crucial to comply with local regulations, permits, and guidelines when treating and disposing of pathological and chemical waste. These regulations may specify the allowable methods of treatment, neutralization agents, and disposal practices to ensure environmental and public safety.

It is advisable to consult local authorities, environmental agencies, or waste management professionals to ensure that the appropriate protocols are followed for pre-treatment and disposal of pathological and chemical waste in specific location.

Pre-Treatment of Hazardous Liquids

Pre-treatment of liquid waste includes sediment filtering, acid-base neutralization, or autoclaving.

Infectious Waste

Chemical Disinfection: Certain liquid wastes, such as body fluids, may require chemical disinfection before being discharged into the sewer. Disinfection is performed to eliminate microorganisms or reduce the microbial load. Common disinfectants used include 1% sodium hypochlorite solution, 10-14 gm of bleaching powder, 70% ethanol, 4% formaldehyde, 70% isopropyl alcohol, 2-5% povidone iodine, or 6% hydrogen peroxide. The disinfection process usually involves diluting the disinfectant with water at the specified ratios and allowing sufficient contact time, such as at least 30 minutes [3].

Blood Disposal: Blood waste can be discharged into the sewer if a risk assessment determines that the organic loading does not require pre-treatment. However, if pre-treatment is necessary, a thermal method can be used. Thermal methods typically involve high-temperature treatment to ensure effective sterilization and inactivation of pathogens.

Laboratory Wastes: Laboratory wastes, including microbiological waste, blood samples, and blood bags, should undergo pre-treatment through on-site disinfection or sterilization before being sent to a common biomedical waste treatment facility for final disposal. Autoclaves are commonly used for pre-treatment. Gravity displacement autoclaves typically run at 121°C and 15 pounds per square inch of pressure for at least 60 minutes, while vacuum-type autoclaves operate at 132°C and 27 pounds per square inch of pressure for at least 10 minutes [5].

It is essential to follow local regulations, guidelines, and facility-specific protocols when pre-treating and disposing of pathological and chemical waste. Compliance with these regulations ensures safe and environmentally responsible waste management practices. Consulting with local authorities or waste management professionals is advisable to ensure adherence to the specific requirements of the area.

Chemically hazardous wastes

Mercury Spillage: In the case of mercury spillage from thermometers, sphygmomanometers, or dental amalgams, the spilled mercury can be collected and stored in water to prevent further spreading. Specialized mercury spill kits, which contain substances like sulfur or zinc powder, can be used to amalgamate the mercury and control mercury vapors. Once the mercury is contained, it should be appropriately handled and sent for proper disposal or recycling [6].

Radiotherapy Department: Pre-treatment in the radiotherapy department involves collecting and storing radioactive wastewaters in a die-away basin until background concentrations have decreased to safe levels. Once the radioactivity has sufficiently decreased, the wastewaters can be disposed of in the sewer system following relevant regulations and guidelines for radioactive waste management.

Dental Departments: Pre-treatment in dental departments often involves installing amalgam separators in sinks and patient treatment chairs. Amalgam separators are designed to capture and separate mercury waste from dental procedures. The separated mercury waste should be stored safely and disposed of appropriately in accordance with local regulations and guidelines for mercury waste management.

Glutaraldehyde: Glutaraldehyde, a commonly used disinfectant in healthcare settings, should be stored properly and neutralized with a suitable agent like glycine after use. Once neutralized, the waste can be gradually disposed of through a soakaway pit or other approved methods following regulations and guidelines for safe disposal.

Colourants and Formalin: Liquid forms of colourants and formalin should be collected separately. To immobilize or seal them, they can be combined with an absorbent material like sawdust. This combination helps to contain and minimize the risks associated with these substances. The immobilized or sealed waste should be handled and disposed of appropriately, following relevant regulations and guidelines for waste management [7].

Non-hazardous liquid waste

Non-hazardous chemicals, such as syrups, vitamins, or eye drops, can typically be discharged into the sewer without requiring pre-treatment. Since these substances are considered non-hazardous, they do not pose significant risks to human health or the environment when disposed of through the sewage system.

In general, substances that are safe for disposal in the sewer are those that do not pose a significant threat to water quality, public health, or the sewage treatment process. Non-hazardous chemicals, such as common pharmaceuticals, over-the-counter medications, or personal care products in small quantities, are often considered safe for disposal in this manner.

However, even for non-hazardous chemicals, it is important to avoid excessive or large-scale disposal. It is best to dispose of these substances in moderation and according to the recommended usage. Additionally, it is crucial to prevent the disposal of any substances that may harm the sewage treatment process or cause blockages in the sewer system.

4. On-Site Wastewater Treatment

Various treatment methods for HWW have been implemented and scaled up over the past two decades (Fig 1).

3 Stages are involved: –

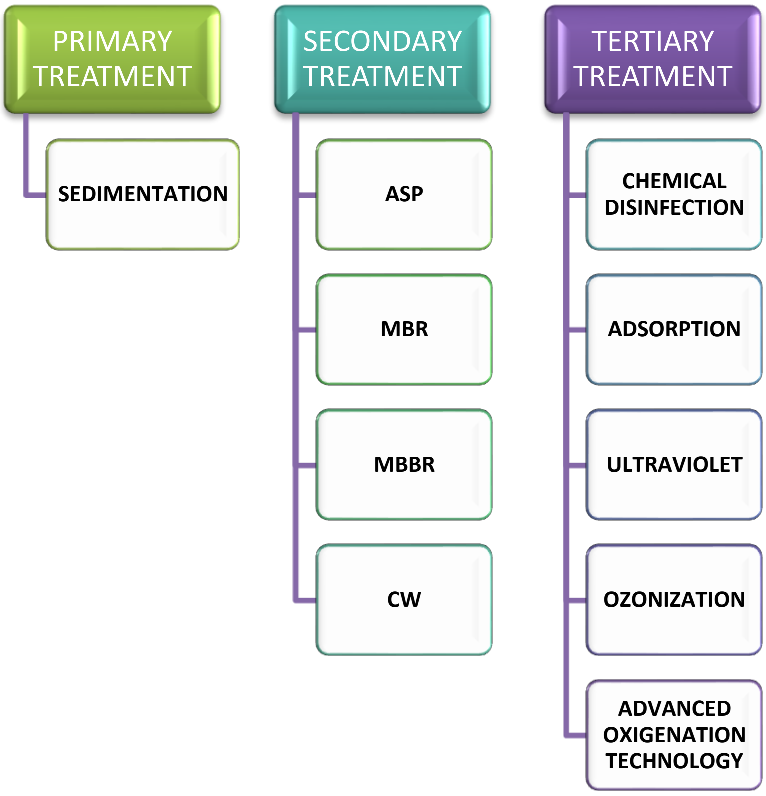

Fig 1. Stages of On-Site Wastewater Treatment

Primary Treatment:

Primary Clarifiers: Sewage passes through primary clarifiers or sedimentation tanks, where heavy solids settle, and floating materials like grease and oils rise to the surface. Sludge settles in these tanks and is later separated from the clear treated water.

Secondary Treatment:

Activated Sludge Processes (ASP): This conventional method involves treating wastewater in an open tank called an aeration tank, where air is injected. Microorganisms use the oxygen to convert organic matter into stable compounds. The resulting biological flocs are then settled in a tank, separating the biological sludge from the treated water. A portion of the sludge is recycled, while the rest undergoes further treatment and disposal [8].

Membrane Bioreactors (MBR): MBR technology combines an activated sludge reactor with a membrane filtration unit. It involves biological treatment with membrane-based solid-liquid separation using microfiltration or ultrafiltration [9]. MBRs have a high capacity for breaking down organic compounds and removing microorganisms, resulting in pathogen-free effluent. Regular commercial MBR plant capacities for hospital wastewater treatment range from 20 to 200 m3/d. However, over 50 MBR plants, mostly using submerged technology, have been successfully applied in hospital wastewater treatment with capacities ranging from 20 to 2000 m3/d in China [10].

Moving Bed Bioreactor (MBBR): MBBR combines biological treatment processes with membrane-based solid-liquid separation. It includes an aeration tank and special plastic carriers that provide a surface for the growth of a biofilm. The carriers ensure good contact between the influent wastewater and the sludge, which is collected on recycled plastic carriers.

Constructed Wetlands: Constructed wetlands are organic wastewater treatment systems that mimic and enhance the purification processes of natural wetlands. Water flows through aquatic plants, filter beds (composed of sand, soil, and/or gravel), and naturally occurring microorganisms. The plants and bacteria naturally break down pollutants and nutrients, removing them from the water [11].

These treatment methods aim to remove suspended solids, organic matter, and microorganisms from the wastewater to produce treated effluent that meets regulatory standards before it is discharged or reused.

It's important to note that the selection of the appropriate treatment method depends on various factors such as the characteristics of the wastewater, the required effluent quality, local regulations, and available infrastructure.

Tertiary Treatment:

This is the also known as the sterilization/disinfection step. It removes all remaining suspended particles and other contaminants that were not removed in the preceding processes. The effectiveness is determined by the quality of the water to be treated. The primary goal of disinfection is to lower the quantity of microorganisms in wastewater discharged into the natural environment, also removes nitrogen, phosphorus and other harmful contaminants. Disinfection or sterilisation technology removes harmful chemicals from wastewater by using ozone, chlorine, and ultraviolet (UV) light.

Disinfection of hospital wastewater

Disinfection is critical in hospital wastewater treatment to ensure the removal of pathogens and protect public health. It is defined as the removal of all pathogens, including viruses, bacteria, and other microorganisms. There are different methods of disinfection commonly used, are given below. The choice of a disinfection strategy is influenced by a variety of factors, including volume of discharge stream, safety and hazard factors, availability of supply, economics, , funding, and process feasibility [12].

Chlorination: Chlorination is a widely used and cost-effective method for disinfection. Bleaching powder, which contains accessible chlorine, is commonly used for disinfection purposes. It is typically applied multiple times before further disinfection, especially at the end of peak lavatory use. The powder can be flushed into the septic tank with flowing water, and residual chlorine levels should be measured at the outlet to ensure water quality standards are met.

Chlorine-Containing Disinfectants:

Liquid Chlorine: Liquid chlorine is commonly used in hospital wastewater treatment as a strong oxidizer and broad-spectrum bactericide [13]. It is important to use a vacuum chlorinator and pipe immersion for proper aeration and removal of contaminants during disinfection. Directly adding chlorine to wastewater without a chlorinator is prohibited. Copper and hard PVC pipes should be utilized to deliver chlorine gas and disinfection solutions containing chlorine. Storage of liquid chlorine carries certain risks and may not be suitable for densely populated areas. Chlorine is added to wastewater during primary and secondary treatments at specific rates depending on the treatment stage [14]. Chlorine is added to wastewater during primary and secondary treatments usually at rates of 30-50 mg/L and 15-25 mg/L, respectively.

Chlorine Dioxide: Chlorine dioxide is an effective disinfectant with high oxidation capability, even in acidic conditions. It inhibits the protein anabolic pathways of microorganisms and is effective against bacteria, viruses, fungi, spores, and Clostridium botulinum. Chlorine dioxide also has decolorization, deodorization, and oxidation properties. It is more soluble than chlorine and has a higher oxidation potential. The dosage of chlorine dioxide varies based on water quality and contamination levels, with typical concentrations ranging from 0.5% and residual chlorine dioxide concentrations of up to 5 ppm.

Sodium Hypochlorite: Sodium hypochlorite, commonly used for disinfection, is typically applied using a double syphon automatic fixed-ratio dosing chlorine system. The available chlorine content of sodium hypochlorite ranges between 5% and 20%.

The choice of disinfection strategy depends on various factors such as the volume of the discharge stream, safety considerations, availability, economics, funding, and process feasibility. It is essential to adhere to local regulations and guidelines for wastewater disinfection and to monitor disinfection efficacy through residual chlorine measurements or other appropriate methods.

Ozone: Ozone is a strong oxidizing agent with high bactericidal properties. It also has decoloring and deodorizing effects. Ozone is generated by applying a high voltage alternating current across a dielectric discharge gap filled with an oxygen-bearing gas. This process dissociates oxygen molecules into oxygen atoms, which then recombine to form ozone. Ozone molecules attach to pollutants or microorganisms and oxidize them, effectively destroying them. In wastewater treatment, ozone can oxidize organic material in bacteria, viruses, and parasite membranes, leading to cell death. It can also oxidize iron, manganese, and copper into solid particles, which can be removed using mechanical or activated carbon filters [15].

Ultraviolet Light (UV): Ultraviolet light is an electromagnetic wave with wavelengths ranging from 200 nm to 400 nm. Wavelengths between 200 nm and 315 nm have the best bactericidal effect [16]. UV disinfection is typically achieved by using light sources, such as mercury-based sources or pulsed-xenon bulb sources, to generate ultraviolet radiation. UV radiation is effective for inactivating viruses, antibiotic-resistant bacteria (ARB), and antibiotic-resistant genes (ARG).

Both ozone and UV disinfection are effective methods for removing microorganisms and pathogens from wastewater. The choice between ozone and UV disinfection depends on various factors, including the specific requirements of the wastewater treatment plant, the target pathogens, the treatment capacity, and the availability of equipment and resources. Proper design, operation, and maintenance are essential for ensuring the effectiveness of ozone and UV disinfection processes in wastewater treatment.

Adsorption Methods

Adsorption technology is indeed a simple and cost-effective method for decontaminating wastewater. It involves the interaction between adsorbate (contaminants or pollutants) and adsorbent materials, where the adsorbent material, such as activated carbon (AC), adsorbs the contaminants from the aqueous matrix.

Activated carbon is widely used as an adsorbent material due to its high surface area and pore structure, which provide ample sites for adsorption. It has the ability to remove a wide range of contaminants, including organic compounds, heavy metals, and certain inorganic substances, from wastewater.

There are two primary methods of adsorption: static and dynamic. In the static adsorption process, finely divided adsorbents are mixed with water and allowed to come into contact for a certain period. Afterward, the adsorbents are separated from the water through decantation or filtration, and the purified water is collected. This method is suitable for batch treatment or small-scale applications.

On the other hand, dynamic adsorption involves the continuous flow of wastewater through a fixed, mobile, or fluidized bed of adsorbent material. The adsorbent bed retains the contaminants as the wastewater passes through, and the purified effluent is collected downstream. Dynamic adsorption is commonly used in larger-scale wastewater treatment systems and allows for continuous operation.

The selection of adsorption method depends on factors such as the nature and concentration of contaminants, treatment capacity requirements, and available resources. Both static and dynamic adsorption processes have their advantages and limitations, and the choice between them will depend on the specific wastewater treatment needs [17], [18].

Advanced Oxidation Technology

Advanced oxidation processes (AOPs) have gained attention in wastewater treatment technologies for removing and converting toxic pollutants into biodegradable compounds.

Photocatalytic Treatment

Photocatalytic treatment is a method that utilizes photocatalysts, which are low bandgap materials, to degrade organic contaminants in wastewater. This process takes advantage of the interaction between the photocatalysts and photons from a light source.

When photons with energy higher than the bandgap of the photocatalysts strike the material's surface, electron-hole pairs are generated. These electron-hole pairs are highly reactive and can participate in various chemical reactions. In the context of wastewater treatment, the holes formed in the photocatalyst react with water molecules to produce hydroxyl radicals (•OH).

Hydroxyl radicals are powerful oxidizing agents and can react with organic contaminants present in the wastewater, leading to their degradation and mineralization. This process breaks down the organic compounds into simpler, less harmful substances. Photocatalytic treatment can effectively reduce the concentrations of pharmaceuticals and personal care products (PhACs) in wastewater by up to 90-100%.

One advantage of photocatalysis is its relatively short reaction time compared to many biological processes. The photocatalytic degradation of contaminants occurs rapidly upon activation by the light source, allowing for efficient treatment within a shorter timeframe. However, the effectiveness of photocatalysis can be influenced by factors such as the properties of the photocatalyst, light intensity, reaction conditions, and the presence of other substances in the wastewater [19].

It's important to note that photocatalytic treatment is just one method among various wastewater treatment technologies. Its application and feasibility depend on the specific wastewater composition, treatment goals, available resources, and regulatory considerations.

Fenton Oxidation

The Fenton process is an effective treatment method for the removal of hazardous organic pollutants from refractory wastewater. It is based on the generation of hydroxyl radicals, which are highly reactive oxidizing species.

In the Fenton process, the reaction between hydrogen peroxide (H2O2) and ferrous ions (Fe2+ or Fe3+) generates hydroxyl radicals (•OH). These hydroxyl radicals then react with the organic contaminants present in the wastewater, leading to their oxidation and degradation.

The Fenton process has been found to be highly efficient in the oxidation of refractory organic pollutants and can effectively remove a wide range of hazardous substances. It offers high performance in terms of organic oxidation.

However, there are some drawbacks associated with the Fenton process. The process operates under acidic conditions, typically pH 2-4, which requires the addition of acid to maintain the optimal pH range. This can lead to corrosion issues and may require additional measures for pH adjustment during treatment.

Another drawback is the cost associated with the use of hydrogen peroxide and ferrous ions, which can be relatively expensive. Moreover, the Fenton process generates a significant amount of fermented sludge, which needs to be properly managed and disposed of.

Due to these limitations, the application of the Fenton process in wastewater treatment may be restricted in certain cases. However, advancements and modifications in Fenton-based processes are continuously being explored to address these challenges and improve its efficiency and sustainability [20].

It's important to consider the specific characteristics of the wastewater, treatment goals, and cost-benefit analysis when determining the suitability of the Fenton process or any other treatment method for a particular application.

Anodic Oxidation

Anodic oxidation is a commonly used technology for the degradation of organic pollutants in wastewater treatment. It involves the oxidation of water at the anode, leading to the generation of hydroxyl radicals (•OH), which are highly reactive and capable of degrading organic contaminants.

In anodic oxidation, high O2 evolution overvoltage anodes such as platinum (Pt), lead dioxide (PbO2), tin dioxide (SnO2), and boron-doped diamond (BDD) are used. These anodes facilitate the electrochemical reaction at the anode surface, resulting in the oxidation of water and the production of hydroxyl radicals.

Boron-doped diamond (BDD) anodes have gained significant attention in anodic oxidation due to their unique properties. BDD anodes have a high electrical conductivity and a wide electrochemical potential window, allowing for efficient oxidation reactions. They also have low energy consumption compared to other technologies such as photocatalysis, making them a viable option for the degradation of pharmaceuticals and personal care products (PhACs) and the inactivation of microorganisms present in hospital wastewater [21].

Anodic oxidation with BDD anodes can effectively remove a wide range of organic pollutants, including refractory and persistent compounds. It has shown promise in addressing specific contaminants found in hospital wastewater, making it suitable for treating wastewater with unique composition and challenges.

However, it's important to note that the implementation of anodic oxidation requires careful consideration of factors such as electrode materials, reactor design, operating conditions, and the specific characteristics of the wastewater. Optimization and proper design are necessary to achieve efficient and effective treatment.

Overall, anodic oxidation, particularly with boron-doped diamond anodes, is a promising technology for the degradation of organic pollutants in wastewater, including hospital wastewater. Ongoing research and development efforts continue to improve the efficiency and applicability of this technology in wastewater treatment.

Treatment Using Nanoparticles

Nanotechnology involves the study and application of materials with dimensions at the nanoscale, typically less than 100 nano meters. Nanomaterials exhibit unique properties and behaviours due to their small size and large surface area, which make them highly suitable for various applications, including water and wastewater treatment.

In the field of water and wastewater treatment, nanomaterials have shown great potential in removing a wide range of contaminants. Their high surface area-to-volume ratio allows for increased contact with pollutants, enhancing adsorption and catalytic processes. Some commonly studied nanomaterials for water treatment include zero-valent metal nanoparticles (such as iron or silver nanoparticles), metal oxide nanoparticles (such as titanium dioxide or zinc oxide), carbon nanotubes, and nanocomposites.

Nanoparticles, due to their small size and unique properties, can adsorb heavy metals, organic pollutants, inorganic anions, and bacteria from water. They can also exhibit catalytic activity, which can facilitate the degradation or transformation of contaminants. Additionally, nanomaterials can be functionalized or modified to enhance their specific adsorption or catalytic capabilities.

One effective approach is to incorporate nanomaterials into membranes or composite materials. This allows for the creation of filtration membranes with enhanced adsorption or separation properties. Nanoparticles can be embedded or coated onto the membrane surface to improve its efficiency in removing contaminants from water. Similarly, nanocomposites, which combine nanomaterials with other matrices or supports, can be designed to have improved adsorption or catalytic capabilities [22].

However, it's important to consider the potential risks and challenges associated with nanomaterials, such as their release into the environment and potential toxicity. Proper handling, characterization, and risk assessment are crucial to ensure the safe and sustainable use of nanomaterials in water and wastewater treatment applications.

Nanotechnology continues to be an active area of research and development in the field of water treatment, with ongoing efforts to optimize the synthesis, characterization, and application of nanomaterials for efficient and cost-effective water and wastewater treatment processes.

Before discharge into the sewer, the treated effluent must adhere to the following standards by Central Pollution Control Board (CPCB), India:

Table. 1: Standards of liquid waste

Parameters	**Permissible limits**
pH	6.5-9.0
Total suspended solids	100 mg/
BOD	30 mg/l
COD	250 mg/l
Oil and grease	10 mg/l

5. Risks and Challenges of Liquid Bio-Medical Waste

Individuals exposed to hazardous liquid biomedical waste, including those in healthcare institutions and those outside, are at risk due to irresponsible handling or handling of the material. Untreated waste contains pollutants that harm the population's health, posing a significant threat to their well-being.

Untreated biomedical waste may contain high concentrations of microorganisms, including bacteria and viruses, which can lead to the spread of infections and diseases if they come into contact with individuals. This is especially concerning when antibiotic-resistant genes and bacteria are present in the wastewater, as they can contribute to the development of antibiotic resistance and make infections more difficult to treat.

Pharmaceutically active compounds (PhACs) are another concern in hospital wastewater. These compounds, which include various medications and drugs, can enter the environment through wastewater discharge. They may have adverse effects on aquatic organisms and can potentially interact with biological targets in unintended ways.

Heavy metals, such as mercury, present in hospital effluents are persistent and can accumulate in the environment. They are toxic to both ecosystems and human health, as they can enter the food chain and cause harmful effects when ingested.

The presence of high levels of biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia, and nitrogen in hospital effluents indicates organic and nutrient pollution. These pollutants can lead to water quality degradation, oxygen depletion in water bodies, and eutrophication, which can negatively impact aquatic ecosystems [23], [24].

To address these risks, it is essential to implement proper treatment methods for hospital liquid waste. Effective treatment processes, as discussed earlier, can help remove or reduce the concentration of harmful pollutants, disinfect the wastewater, and minimize its impact on human health and the environment. It is important for healthcare institutions to adhere to appropriate waste management protocols and regulations to ensure the safe handling and treatment of biomedical waste.

6. Conclusion

Hospital effluent treatment plants are vital for ensuring the proper management and treatment of the contaminated water generated by hospitals. The large amount of water used by hospitals on a daily basis, along with the various contaminants it carries, highlights the need for effective treatment before discharge.

Hospital wastewater contains a wide range of pollutants, including medications, chemicals, sediments, and potentially harmful microorganisms. If this wastewater is not properly treated, it can have a negative impact on water quality and pose a risk to public health. Therefore, it is crucial to have a well-designed and properly functioning effluent treatment system in place.

The primary goal of a hospital effluent treatment plant is to remove or reduce the concentration of contaminants to meet both municipal and hospital standards before the water is discharged into the municipal sewage system or the environment. This ensures that the discharged water does not adversely affect the receiving water bodies or the health of the population.

However, constructing and maintaining these treatment facilities can require a significant financial investment. The costs involve various factors such as infrastructure development, installation of treatment technologies, regular operation and maintenance, and compliance with regulatory standards. Hospitals and healthcare institutions need to allocate sufficient resources to build and sustain efficient treatment systems to protect public health and the environment.

Investing in effective hospital effluent treatment is a responsible approach to managing the potential risks associated with contaminated wastewater. It helps mitigate the environmental impact, reduce the spread of pollutants, and contribute to the overall well-being of both the hospital staff and the surrounding community.

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