BIBLIOMETRIC ANALYSIS OF RESEARCH TRENDS ON FILTRATION AND QUALITY OF WASTE LIQUID IN HOSPITALS

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ABSTRACT

This study aims to conduct a bibliometric analysis of research trends regarding filtration and liquid waste quality in hospitals from 2018 to 2024. Using the Google Scholar database and bibliometric analysis applications such as VOSviewer, this study identified and analyzed relevant publications with the keywords filtration, effluent, hospital, COD, BOD, and Liquid Waste Quality. The data obtained was processed with occurrence 4 and term 20 parameters to identify the main patterns and trends in the literature. The analysis results show that the number of publications has increased significantly from year to year, with peaks in 2021 and 2022. The distribution of publication types shows the dominance of research articles with 42 out of 50 publications, followed by literature reviews (3) and conference articles (4). Analysis based on country of publication revealed the dominance of Indonesia with 23 publications, followed by India and several other countries with smaller contributions. Cluster analysis based on network visualization identified four main clusters: (1) effluent quality parameters such as BOD and COD; (2) hospital effluent management; (3) effluent treatment and management; and (4) effluent quality characterization and assessment.The results of density visualization showed a high concentration of quality parameters and treatment technologies, while overlay visualization revealed a close relationship between quality parameters and effluent management. The conclusions of this study highlight the major focus on technical parameters of effluent quality and treatment technology, as well as the importance of integration between effluent management and quality evaluation in research. The findings offer valuable insights for further research and development of innovative solutions in effluent management in hospitals.

Keywords: Bibliometrics, Filtration, Effluent Quality, Hospital, Network Analysis

INTRODUCTION

Nowadays, environmental problems are often the main topic of discussion in many countries, and have even become a political issue. Not far from the problem of environmental pollution is made as the main topic of environmental damage and pollution problems. Pollution means the addition of various materials as a result of human activities into the environment which will generally have an effect (Basri & Hamzah, 2016).

In recent decades, liquid waste management in hospitals has become an increasingly pressing issue. Hospitals generate various types of wastewater that contain harmful contaminants, such as pharmaceutical chemicals, pathogens, and other organic materials. These wastes, if not managed properly, can

cause environmental pollution and health risks to the public.

The interaction of hospitals with humans and the environment in hospitals can cause environmental health problems characterized by indicators of declining quality of environmental health media in hospitals, such as water, air, food, facilities and buildings as well as vectors and disease-carrying animals. As a result, the quality of the hospital environment does not meet the environmental health quality standards and health requirements that have been determined (Permenkes Number 7 of 2019).

Hospital waste is all waste generated by hospital activities and other supporting activities. Given the impact that may arise, it requires good management efforts including tools and facilities, finance, and organizational management that are determined with the aim of obtaining hospital conditions that meet environmental health requirements (Asmarhany, 2014).

Hospital waste is all waste generated from hospital activities in the form of solid, liquid, and gas containing pathogenic microorganisms, infectious, hazardous and toxic materials, radiocative, and domestic. Hospital solid waste can be divided into two, namely medical solid waste and non-medical solid waste (domestic). Medical solid waste includes infectious waste, pathological waste, sharps waste, pharmaceutical waste, cytotoxic waste, chemical waste, radioactive waste, pressurized container waste, and waste with high heavy metal content (Lulu, 2012: 1 in Rawis et al., 2022).

Some wastes that can pollute the environment and have a direct impact on health, one of which is hospital waste. Hospital activities in addition to providing health services also have a positive impact on society and the environment, including improving the degree of public health, while the negative impact includes waste generated by the hospital. Wastewater from hospital waste is a potential source of water pollution.

This is because hospital wastewater contains other chemical compounds and pathogenic microorganisms that can cause disease to the surrounding community. Hospital wastewater is all liquid waste that comes from the results of the process of all hospital activities which include clinical liquid waste, namely wastewater originating from hospital clinical activities such as used water from wound washing, blood washing and other liquid domestic waste, namely bathroom waste, kitchen, used water from washing clothes, and others (Susilawati, 2016).

Hospital liquid waste management is a very important part of hospital environmental health efforts that have the aim of protecting the public from the dangers of environmental pollution. Liquid waste that is not managed properly can cause pollution to water sources and become a breeding medium for pathogenic microorganisms, insects that can transmit diseases, especially cholera, dysentery, thypus abdominalis (Marlina, 2019).

One simple method that can be done in wastewater treatment is a filtration system. The filtration system is one of the tools in physical water treatment. This physical filter serves to separate suspended particles (>5 micrometers in size) from water by passing water through an appropriate substrate so that it can capture solids in the water before the water enters the storage container (Silaban, et al, 2012). Filtration is able to remove suspended particles, one of which is by filtering assisted by filter media as a particle absorber, besides that filtration is also able to remove odors in wastewater and eliminate bacteria effectively (Artiyani & Firmansyah, 2016).

In the research of Sulianto, et al (2020) the design of a filtration unit was carried out for domestic waste treatment using a downflow system and tested for several parameters such as

Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), phosphate, Total Suspended Solid (TSS), and turbidity. It is known that the initial test result of BOD in domestic waste is 58.71 and then after filtration, the efficiency of reducing its level is 15.75% or quite effective in reducing high BOD levels in domestic waste. COD levels which initially amounted to 157.67 decreased by 15.44% after filtration treatment.

LITERATURE REVIEW

Definition and Basic Concepts

Hospital is a health care institution that organizes comprehensive individual health services that provide inpatient, outpatient, and emergency services (KMK No.1128 of 2022). Every hospital is required to provide liquid and solid waste management facilities so that all waste that will be discharged into public channels must meet the established liquid waste quality standards (Ferdiansyah, 2021).

Hospital waste is all waste generated by hospital activities and other supporting activities. Hospital waste can contain various microorganisms depending on the type of hospital and the level of treatment carried out before disposal (Noor, 2020). Hospital liquid waste can contain organic and inorganic materials which are generally measured and the parameters of temperature, PH, NH3, BOD, COD, TSS and MPN Coliform. Meanwhile, hospital solid waste consists of easily decomposed waste, infectious waste, and others. These wastes are likely to contain pathogenic microorganisms or hazardous toxic chemicals that cause infectious diseases and can be spread to the hospital environment caused by inadequate health service techniques, mishandling of contaminated materials and equipment, and poor provision and maintenance of sanitation facilities (Wijaya et al., 2021).

This waste disposal is done by sorting the waste into various categories. For each type of category, a different waste disposal method is applied. The general principle of hospital waste disposal is to avoid the risk of contamination and trauma (injury) as far as possible (Idayati, 2020).

Sources Of Wastewater In Hospitals

According to (RI No. 43 Permenkes, 2019) on Hospital Environmental Health, wastewater sources vary according to the type of hospital. The sources of hospital wastewater generally come from kitchens, linen washing, treatment rooms, polyclinic rooms, laboratories, toilets and bathrooms, morgues, and other units according to the type of hospital. Hospital wastewater sources come from various services ranging from inpatient, outpatient, food processing, nutrition installation, surgical room, ICU, emergency room, haemodialysis unit, loundry, laboratory installation and corpse care installation which are flowed through a piping network. Pre-treatment in the form of septic tanks and grease trap units which are then collected in a collection tub to be pumped to the centralized WWTP (Wastewater Treatment Plant) (Khafidz, 2022).

Laboratory wastewater contains antiseptic ingredients and antibiotics so that it is toxic to microorganisms, also contains heavy metals. If the wastewater is flowed into the biological treatment process, the heavy metals can interfere with the work process of biological treatment, therefore for wastewater originating from the laboratory is treated separately physically and chemically, then the processed results are flowed with other waste (Rodat et al., 2019).

Hospital Liquid Waste Parameters

Domestic wastewater consists of 5 parameters, which are as follows:

a. Potential Hydrogen (pH)

pH is the degree of acidity used with the aim of measuring

the acidity or basicity of the solution. The pH value is a measure to measure the concentration of hydrogen ions in aquatic solutions. The resulting value will determine the nature of the solution. A pH value of 1 then the solution is acidic, a pH with a value of 7 is neutral, and if the pH value is 14 the solution is very alkaline. (Mardiati et al, 2020).

b. Biological Oxygen Demand (BOD)

BOD or what is often called Biological Oxygen Demand (KOB) is the amount of dissolved oxygen needed by microorganisms in decomposing organic matter in wastewater (Sulianto, et al, 2020). The greater the BOD value, the greater the degree of dirty wastewater. The BOD test is carried out to determine the pollution power of wastewater, waste from industry and water that has been polluted (Izarna, 2022).

c. Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) or often referred to as Chemical Oxygen Demand (COD) is the amount of oxygen used in the chemical oxidation of organic compounds. The results of COD analysis show that the content of organic compounds contained in waste. COD is used as a source of pollution figure for organic substances naturally and can be oxidized by microbiological processes that cause dissolved oxygen to decrease in water (Ningrum, 2018).

d. Total Suspended Solid (TSS)

TSS is a solid substance that is suspended in wastewater and is floating in water. Efforts to make these substances settle, chemicals are needed as coagulants to bind substances suspended in water so that they can form a floc and within a certain time the substance will settle by itself (Hak et al, 2018).

e. Temperature

Temperature is an important component in wastewater quality, the temperature should be cool or not hot to avoid dissolution of chemicals in the channels/pipes that can endanger health. Temperature changes can affect physical, chemical, and biological processes in a waste treatment process, temperature also plays a role in controlling cosystem conditions Conversely, high temperatures can result in increased viscosity, chemical reactions, evaporation, volatilization, and cause a decrease in gas solubility in water (O2, CO2, N2, CH4, and so on). Based on Kepmen LH No. 5 of 2014 concerning hospital liquid waste quality standards that the allowable temperature parameter value is 38 oC (Yanti, 2019).

f. Ammonia (NH3)

Ammonia (NH3) is a nitrogen compound that has a weak base with the formula NH3 and when it comes out it causes a rather sharp odor. When ammonia is dissolved in water it will become aqueous ammonia and when exposed to air it will become gas. Ammonia is an organic pollutant resulting from the oxidation of organic compounds, bacteria, and oxygen. (Utami, 2022).

Wastewater Treatment With Filtration

According to (Larasati, 2022), wastewater treatment is intended to remove materials that can interfere with the process or processing units. Preliminary treatment is very important as the basis for the success or failure of

the subsequent treatment process. In terms of hospital wastewater treatment technology, there are several types of waste treatment technologies such as wastewater treatment with contact aeration process, rotating biological contractor (RBC), activated sludge process, and wastewater treatment with anaerobic-aerobic biofilter system (Nair et al, 2015).

Several studies conducted in hospitals with waste treatment systems using anaerobic - aerobic biofilters such as those conducted by Mustafa (2018) at the Mamuju Regency Regional General Hospital with a sampling time of 3 (three) consecutive days stated that the quality of liquid waste in terms of BOD, COD, pH, temperature, has met the requirements when compared to the maximum levels according to the Decree of the Minister of Environment Number 5 of 2014. However, in terms of bacteriological parameters, the results obtained after treatment were (0 colonies / 100ml, 50 colonies / 100 ml, 24,000 colonies / 100 ml) when compared to the maximum levels according to the Decree of the Minister of Environment No.Kep-58 / MENLH / 12 1995, the quality of wastewater has not met the requirements (Astuti et al, 2016).

BOD (Biological Oxigent Demand) is the amount of oxygen required by microorganisms to stabilize organic substances that can be decomposed under aerobic conditions. The method of measuring BOD is by direct analysis method and dissolution analysis method. Measuring instruments using titration result documents and quality standard documents of the Indonesian Minister of Environment and Forestry Regulation No. P.68Menlhk/SetjenKum.1/8/2016 concerning Domestic Wastewater Quality Standards. Categories such as BOD meets quality standards if < 30 mg/L and BOD does not meet quality standards if > 30 mg/L.

COD (Chemical Oxigent Demand) is the amount of oxygen required by the reagent to chemically oxidize organics into CO2 and H2O. How to measure COD is by colorimetric or titrimetric method. Measuring tools with spectrometers and titration result documents and quality standard documents of the Indonesian Minister of Environment and Forestry Regulation No.P.68Menlhk/SetjenKum.1/8/2016 concerning Domestic Wastewater Quality Standards. The category if the good results in the form of COD meet the quality standard if < than 100 mg/L and COD does not meet the quality standard if > than 100 mg/L.

The filtration process is solid-liquid separation by passing liquid through porous media or with materials that can remove or set aside fine grains of suspended solids from liquid (Chaniago, 2019). In the filtration process, filter media is needed as a filter for suspended solids. In the filtration process, the filter media functions to filter out impurities suspended in water so that the water that comes out after the filtration process becomes clean and free from impurities (Shafira, 2020).

The characteristics of good filter media for the filtration process are media that have a large surface area per volume of the basin, are durable, and inexpensive (Handayani, 2023). The commonly used filter media is sand or a combination of sand, gravel, activated charcoal and palm fiber. The filter media used by each has the same function, namely to filter out polluting solids in the waste. The filter media is even able to remove organic and inorganic substances in the waste such as removing turbidity, color, fat and oil (Suriani, 2023).

With the right filter media, it will produce optimal processing quality as expected (Muharrami, 2021). In the process, filtration has a combination of different processes, namely the process of filtering suspended particles that are too large, the process of settling smaller suspended particles, the adsorption process through the force of attraction between different charges, chemical

processes, and biological processes due to the presence of microorganisms that live in the filtration media (Fauzan et al., 2021).

Recent Research Trends

In recent years, research trends in hospital effluent management have shown a significant shift towards more advanced and sustainable technologies. One of the key trends is an increased focus on the use of membrane technologies, such as ultrafiltration (UF) and nanofiltration (NF), to improve effluent treatment efficiency. Membrane technologies offer the ability to remove very small particles and specific contaminants with high effectiveness, thus making them a popular choice in hospital wastewater management.

In addition to membrane technology, research is also increasingly focusing on the application of biofilter and bioreactor systems, which combine biological processes with filtration technology to efficiently reduce COD and BOD. These systems use microorganisms to break down organic matter, reducing reliance on chemical processes that often require hazardous and expensive chemicals. Innovations in biofilter design and optimization, such as more effective use of biomass and improved environmental control, are active research areas that promise better results in sewage treatment.

In addition, recent trends show greater attention to resource recovery from wastewater effluents, such as energy recovery and valuable materials. Technologies such as anaerobic treatment systems not only reduce the volume of effluent but also produce biogas that can be used as a renewable energy source. Research into the recovery of valuable materials, such as heavy metals and nutrients, from wastewaters is also growing, offering the potential to reduce waste and improve economic efficiency.

These trends reflect a greater shift in research focus towards more holistic and sustainable solutions for hospital wastewater management. Innovations in treatment technologies, resource recovery, and biologically-based approaches underscore the importance of adapting and developing methods that can meet increasingly stringent regulatory demands and environmental needs.

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RESEARCH METHODS

The research design used a bibliometric approach, which focuses on quantitative analysis and visualization of data from scientific literature to identify research trends and patterns. This study was designed to explore developments and trends in the field of filtration and effluent quality in hospitals by analyzing articles published between 2018 and 2024. The design involved collecting literature data from Google Scholar, followed by analysis using bibliometric software. The main objective of this design was to identify the main keywords, the relationship between research topics, as well as the evolution of trends in the literature. The analysis was conducted using parameters such as a minimum keyword occurrence frequency of 4 and a minimum term count of 20 to ensure that the data analyzed was relevant and reflected significant research trends.

The population in this study consisted of all relevant scientific publications with the specified keywords: “filtration,” ‘effluent,’

'hospital,' 'COD,' 'BOD,' and "liquid waste quality." This included articles published in international journals and indexed on Google Scholar. The research sample was drawn from this population with the following criteria:

a. Year Criteria: Publications published from 2018 to 2024 to ensure current relevance.
b. Keyword Criteria: Articles that include one or more major keywords in the title, abstract, or keywords.
c. Frequency of Occurrence Criteria: Articles that have a keyword occurrence frequency of at least 4 times to ensure that the article is sufficiently relevant to the topic.
d. Term Criteria: Using a minimum of 20 terms to ensure adequate coverage of the research topic.

With these criteria, the data collected includes publications that provide a comprehensive overview of research trends in this area. The venue for this research was Google Scholar, which was used as the main platform to identify and collect related scientific literature. Google Scholar provides access to a wide range of scientific articles from international journals, conferences and research reports. The search process was conducted using the advanced search features in Google Scholar to find relevant articles with predefined keywords. After article identification, the data is exported in a suitable format, such as CSV or BibTeX, for further analysis. Google Scholar was chosen due to its wide coverage of academic publications and its ease of access to find relevant literature in the research field.

The research procedure consisted of several key steps as follows:

a. Data Search: A search was conducted on Google Scholar using predefined keywords. Search filters were used to limit the results to publications published from 2018 to 2024.
b. Data collection, relevant articles were downloaded in an exportable format, such as CSV or BibTeX. Only articles that met the frequency of occurrence and term criteria were retrieved for further analysis. The collected data were imported into bibliometric analysis software, namely VOSviewer and Publis/Peris. Data analysis used VOSviewer and was used to create keyword network maps and visualization of inter-topic relationships. Publis/Peris was used for additional statistical analysis and data processing.
c. Interpretation The results of the analysis, including network maps and statistics, were interpreted to identify key trends, relationships between topics, and the evolution of research in this area.

As this was a bibliometric study using secondary data from published scientific literature, no ethical review result number was required. This study adhered to ethical guidelines applicable to the use of public data, ensuring that the data used did not violate copyright or privacy. The researcher also followed the principles of academic ethics in data processing and presentation to maintain the integrity and accuracy of the study. The main instrument used in this research is bibliometric software:

a. Publis/Peris: Used for statistical analysis and additional data processing. Publish/Peris helps in more detailed data processing and statistical analysis to evaluate trends and patterns in the literature. It also allows data clustering and co-citation analysis.
b. VOSviewer: Used for bibliometric visualization and analysis. VOSviewer allows the creation of network maps that show the frequency of keyword occurrence and the relationship between topics. This tool allows in-depth visualization of research patterns

and interrelationships between topics.

Interpretation and Presentation of Results: Results from VOSviewer and Publish/Peris were integrated to get an overall picture of research trends. Network map visualizations and statistics were analyzed to identify key patterns, relationships between topics, and the evolution of research in the field of filtration and effluent quality in hospitals.

RESULTS AND DISCUSSION

The results of this bibliometric analysis include several key aspects that provide a comprehensive overview of related research. From the results of the search and collection of literature conducted on July 22, 2024. Literature searches and collections are based on literature titles using keywords in the last 7 years, namely 2018 to 2024. The search database uses Google Schollar by limiting a maximum of 50 most relevant and related searches from each database. The following are the main findings of this analysis:

Temporal analysis of publications related to preoperative fasting showed significant fluctuations in the number of articles published each year. The data showed that the number of publications increased significantly from 2021 to 2023, but decreased from a decline in 2024.

Table 1. Number Of Documents Published By Year Of Publication

No.	Year	Total
1	2018	5
2	2019	3
3	2020	6
4	2021	12
5	2022	11
6	2023	12
7	2024	1
	Total	**50**

The data shows a significant spike in the number of publications from 2020 to 2022, with the number of publications increasing from 6 in 2020 to a peak of 12 in 2021 and 2023. This increase reflects the growing attention to filtration technology and effluent management in hospitals. The main possible causes are the response to increased awareness of environmental issues and technological advances in effluent treatment. Notably, the COVID-19 pandemic may influence the push for more efficient waste management solutions, driving research in this area. The number of publications remains high in 2023, indicating continuity of interest in research. However, the sharp drop in 2024 may be due to delays in publications or a change in research focus. This decline could signal a transition to a stabilization phase or a shift in interest to new topics in wastewater management. It is possible that the 2024 research is not yet fully indexed or that the topic is entering a period of consolidation.

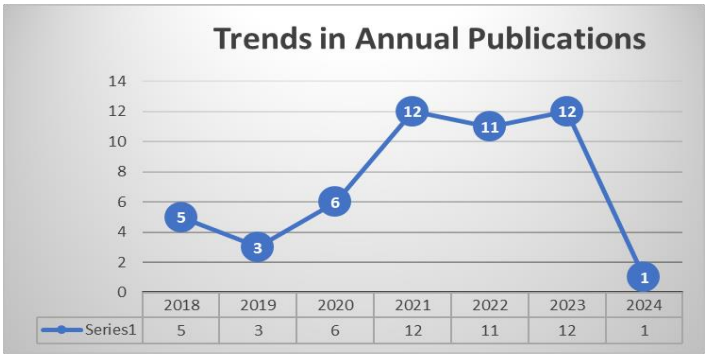

Figure 1. Related Publication Trends From Google Schollar Databases Using Pop Application

The increase in publications demonstrates the need for continued research on sewage treatment technologies, including evaluation of effectiveness and long-term impacts. Researchers need to focus on studies that integrate different approaches and address existing gaps. Policies and guidelines that support the adoption of innovative technologies and further research can improve wastewater management in hospitals. Continuous monitoring of research trends will be important to ensure that the solutions implemented remain relevant and effective.

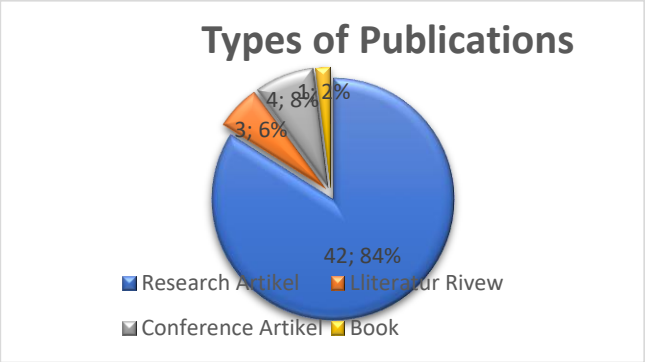

Figure 2. Types of Publications

The distribution of publication types in this study shows the dominance of research articles, with a total of 42 articles out of 50 publications analyzed. This reflects that most studies in the field of filtration and effluent quality in hospitals are empirical research that provides in-depth data and analysis. The dominance of research articles signifies a major focus on experimentation and technology development. On the other hand, there are only 3 literature reviews, indicating that systematic reviews and literature reviews have a relatively small contribution. This may indicate that thorough reviews have not been a top priority for publications in this field. Conference articles numbered 4, illustrating the role of conference articles in introducing new ideas and early research results. Although not as numerous as research articles, conference articles are important for disseminating emerging research results. In addition, there is only 1 book, indicating that books are a small part of the overall publication. Books usually provide comprehensive guidance or in-depth perspectives, but in this case, publications more often appear in the form of journal and conference articles. Overall, this distribution suggests that

empirical research is the main source of knowledge in this field, with a need for more systematic review and integration of different types of publications for continued development.

Table 3. List Of Journal Publishers By Country

No.	Country	Total
1	Indonesia	23
2	India	10
3	Iran	2
4	Turkey	2
5	Morocco	2
6	Malaysia	1
7	Benin	1
8	Hong Kong	1
9	China	1
10	Sri Lanka	1
11	Algeria	1
12	Tanzania	1
13	Bangladesh	1
14	Norway	1
15	Ghana	1
16	Nigeria	1
		50

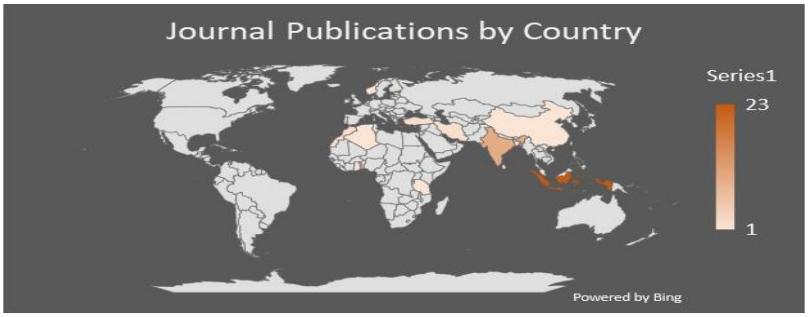

Figure 3. Distribution Of Countries That Publish Related Research

Analysis of journal distribution by country of publication showed that Indonesia dominated the publications with a total of 23 journals out of 50 publications analyzed. This reflects the high level of research activity in Indonesia on filtration and effluent quality in hospitals. This could be related to the urgent need to address waste management issues in the healthcare sector that are increasingly relevant in the country. India also contributed a significant number of publications with 10 journals, indicating that the country is an important hub for research in this area, which may be driven by the large scale and complexity of waste management challenges in the healthcare sector.

Some countries such as Iran, Turkey, and Morocco had 2 publications each, indicating the presence of research efforts in the Middle East and North Africa. The publications from these countries may reflect similar challenges in wastewater management in hospitals that drive local and regional research. Countries with one publication

include Malaysia, Benin, Hong Kong, China, Sri Lanka, Algeria, Tanzania, Bangladesh, Norway, Ghana and Nigeria. Although the number of publications from these countries is relatively small, their presence shows that the issue of effluent filtration and quality attracts attention globally and covers a wide range of regions with diverse challenges and needs.

The distribution of journals by country of publication revealed that Indonesia and India are the main leaders in publications on filtration and quality of hospital effluent, reflecting the significant research activity in both countries. Other countries, despite having smaller publication contributions, show that this topic is a global issue with interest and research efforts spread across different parts of the world. Research in countries with a smaller number of publications can provide insights into local challenges and innovative solutions that may not be covered in the literature from countries with more publications. In conclusion, this study confirms the importance of international collaboration and knowledge exchange to address global issues in hospital wastewater management.

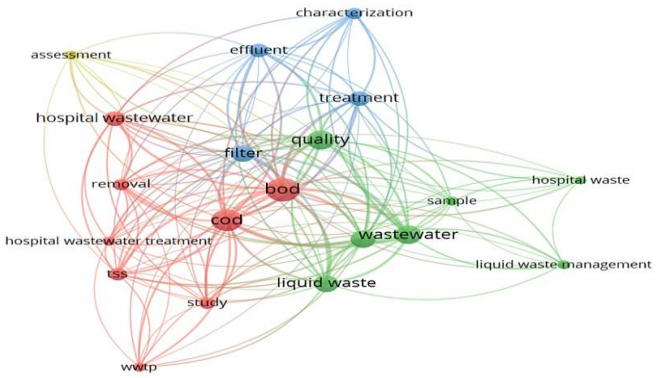

Figure 4. Network Visualization Overview Publications

The cluster analysis results from the network visualization identified four main clusters in the research on filtration and effluent quality in hospitals. A discussion of each cluster follows:

1. **Cluster 1: Focus on Effluent Quality Parameters**

   Cluster 1 contains keywords such as BOD, COD, Removal, and TSS. This cluster focuses on effluent quality parameters, especially biological and chemical parameters that are often used to evaluate effluent quality. BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) are key indicators in assessing the level of organic and chemical pollution in effluent. Removal and TSS (Total Suspended Solids) show interest in the methods and effectiveness of contaminant removal in effluent treatment processes. Research in this cluster may be oriented towards measurement and assessment of effluent quality as well as development of technologies to improve contaminant removal.

2. **Cluster 2: Focus on Hospital Waste Management and Treatment**

   Cluster 2 includes keywords such as Hospital, Hospital Waste, Hospital Wastewater, and Hospital Wastewater Treatment. The focus of this cluster is on the management of wastewater generated by hospitals. Keywords such as Hospital Wastewater and Hospital Wastewater Treatment indicate that the research emphasizes on how to manage and treat wastewater specific to

healthcare facilities. Research in this cluster is likely to focus on the challenges and solutions in hospital effluent management as well as the technologies used for effluent treatment.

3. **Cluster 3: Focus on Liquid Waste Treatment and Management**

   Cluster 3 consists of keywords such as Effluent, Liquid Waste, Liquid Waste Management, and Treatment. This cluster shows interest in liquid waste treatment and management in general, with attention to Effluent (liquid waste generated from industrial processes) and Liquid Waste Management. Research in this cluster tends to explore various methods of liquid waste treatment and management, as well as innovations in filtration and treatment technologies to improve efficiency and effectiveness.

4. **Cluster 4: Focus on Characterization and Assessment**

   Cluster 4 includes keywords such as Characterization, Assessment, and Quality. This cluster focuses on wastewater effluent characterization and assessment, as well as overall quality evaluation. The keywords Characterization and Assessment indicate that research in this cluster is oriented towards a thorough understanding and evaluation of effluent properties and quality, often involving in-depth analysis of how the effluent affects the environment and health.

The division into four clusters reflects the different aspects of research on filtration and effluent quality in hospitals. Cluster 1 emphasizes effluent quality parameters, Cluster 2 on hospital waste management, Cluster 3 on effluent treatment, and Cluster 4 on characterization and quality assessment. This analysis shows that research in this area covers a wide range of themes, from specific treatment techniques to overall effluent quality evaluation, reflecting the complexity and depth of issues faced in effluent management in healthcare facilities.

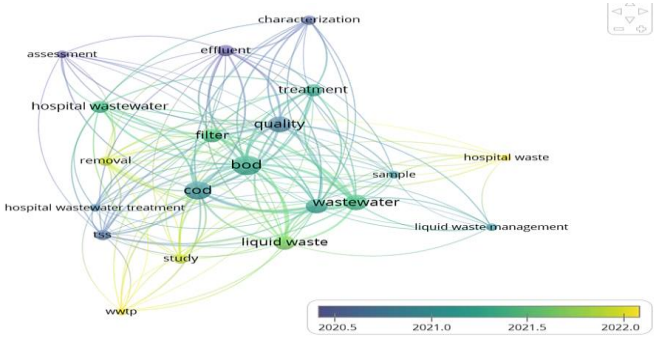

Figure 5. Network Visualization Overview Publications

Cluster analysis based on overlay visualization identified four main clusters that group keywords based on thematic proximity and co-occurrence in publications on filtration and effluent quality in hospitals. A discussion of each cluster follows:

1. **Cluster 1: Focus on Effluent Quality Parameters**

   Cluster 1 includes keywords such as BOD, COD, Removal, and TSS. This cluster focuses on technical and analytical parameters to evaluate effluent quality. BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) are key indicators in assessing organic and chemical pollutant loads, while Removal and

TSS (Total Suspended Solids) show interest in the effectiveness of the process of removing contaminants and particles from wastewaters. Research in this cluster is most likely to examine quality analysis methods and treatment technologies to improve effluent management outcomes.

2. **Cluster 2: Hospital Waste Management and Treatment**

   Cluster 2 consists of keywords such as Hospital, Hospital Waste, Hospital Wastewater, and Hospital Wastewater Treatment. The main focus of this cluster is on the management and treatment of waste generated by hospitals. These keywords indicate that the research in this cluster is concerned with the specific challenges of dealing with wastewater from healthcare facilities and the technologies and methods used for the treatment of such wastes. This reflects the attention to overall hospital waste management.

3. **Cluster 3: Liquid Waste Treatment and Management**

   Cluster 3 covers Effluent, Liquid Waste, Liquid Waste Management, and Filters. This cluster highlights aspects of liquid waste treatment and management in general, including effluent handling (liquid waste from industrial processes) and filtration systems. Keywords such as Liquid Waste Management and Filters indicate that research in this cluster focuses on various methods to manage and treat liquid waste, as well as filtration technologies used to improve effluent quality.

4. **Cluster 4: Characterization and Assessment**

   Cluster 4 contains keywords such as Characterization, Assessment, Quality, Study, Waste Water, and WWTP (Waste Water Treatment Plant). This cluster focuses on characterization and assessment of wastewater effluents as well as comprehensive studies on quality and effluent treatment technologies. Characterization and Assessment indicate that research in this cluster evaluates the nature of effluents and their impacts, while WWTP indicates an interest in wastewater treatment facilities and systems. Research in this cluster aims to provide an in-depth understanding of effluent quality and treatment effectiveness.

The distribution of keywords in these four clusters reveals various important aspects of filtration and effluent quality research. Cluster 1 focuses on technical parameters of effluent quality, Cluster 2 on hospital effluent management, Cluster 3 on effluent treatment, and Cluster 4 on characterization and quality assessment. This analysis shows that research in this field covers a wide range of interrelated themes, from effluent quality measurement to effluent treatment technology and management, reflecting the complexity and depth of issues faced in hospital effluent management.

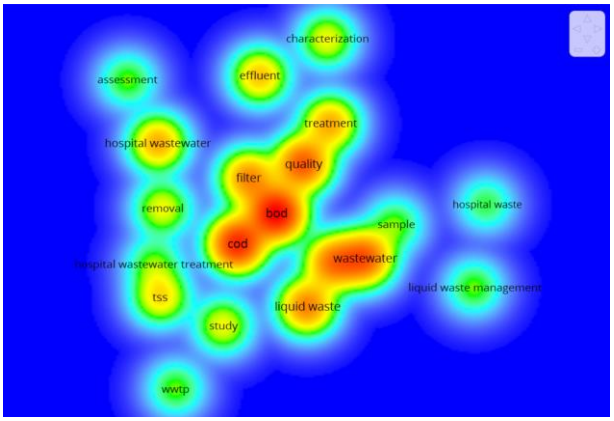

Figure 6. Publication Density Visualization Overview Publications

5. **High Concentration: Quality and Treatment Parameters**

In the density visualization, the keywords BOD, COD, Filter, Quality, and Treatment show areas of high concentration. This density indicates that existing research often focuses on: BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) are key parameters in evaluating effluent quality, indicating significant attention to organic and chemical pollution measurement. Filter and Treatment shows a concentration on technologies and methods to treat effluent. This reflects a strong focus on technical solutions to improve effluent treatment efficiency and contaminant removal. Quality highlights attention to the overall assessment of effluent quality, linking to technical parameters and treatment technologies used. These keywords are interconnected and form an integrated picture of how effluent quality parameters and treatment methods are assessed and applied in research.

6. **Relationship with Other Densities: Liquid Waste Management**

The keywords Liquid Waste and Waste Water also appear in the density visualization with densities associated with these high concentration areas. This relationship shows:

Liquid Waste and Waste Water are often related to the study of BOD, COD, Filter, Quality, and Treatment. Research that focuses on Liquid Waste and Waste Water often integrates quality parameters and treatment technologies to evaluate and manage liquid waste from various sources. The concentration on Liquid Waste and Waste Water reflects that research often links technical and treatment aspects to liquid waste management more broadly, integrating various methods and parameters in a comprehensive study.

7. **Implications of the Density Distribution**

This density distribution highlights that there is a significant focus on quality parameters and effluent treatment technologies. The high density of the keywords BOD, COD, Filter, Quality, and Treatment indicates that the main research in this area is oriented towards quality measurement and technology development for effluent treatment. The association with the keywords Liquid Waste and Waste Water shows the integration of research covering various aspects of liquid waste management, reflecting a holistic approach in addressing this issue.

Overall, the density visualization reveals that research in the field of filtration and quality of wastewater effluent in hospitals focuses on key quality parameters and treatment methods, with particular attention to the overall management of wastewater effluent. This provides insight into areas of major concern and potential for further exploration in the field of wastewater management.

CONCLUSION

This study successfully identified and analyzed research trends related to filtration and effluent quality in hospitals through a bibliometric approach. Analysis of data from Google Scholar and applications such as VOSviewer showed that the number of publications experienced a significant increase from 2018 to 2023, with peaks in 2021 and 2022. This reflects the growing academic interest in this issue. The dominant publication type is research articles, emphasizing a focus on development and empirical reports, while literature reviews and conference articles play a role in complementing knowledge in this area. Geographical distribution shows Indonesia's dominance in publications, indicating high research activity at the local level, while contributions from other countries add a global perspective to the issue.

Cluster analysis and density visualization revealed four main clusters: effluent quality parameters (BOD, COD), hospital effluent management, wastewater treatment, and characterization and quality assessment. The high concentration of keywords such as BOD, COD, filter, quality, and treatment indicates a major focus on the technical and technological aspects of effluent treatment, while the relationship between liquid waste and waste water indicates integration in effluent management and evaluation.

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