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Hospital Wastewater: Prediction of Contaminant Characteristics and the Possibility of Hybrid Membrane Process

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Abstract: Hospital as one of the possible causes of water pollutants containing infectious, pathogens, toxic, biodegradable, radioactive contaminants, pharmaceutical product that can be a hazard agent in the environment. Wastewater treatment plant owned hospitals generally have not been able to eliminate with either of these compounds. National estimates of production wastewater 48.985,70 tons/day, which the total of hospitals in Indonesia as 2.410 hospitals with beds 295.035. The focus of hospital wastewater treatment in Indonesia is basically accordance with government regulations for reducing the chemical, physical, biological and radioactive materials from the wastewater. Climate of Indonesia is located in tropical regions may be produce additional types and other characteristics of wastewater. The Objective of this study to give an overview study of the new pollutant types of contaminants that require special processing through a hybrid membrane technology. The method used in this research were study literature of any membrane process in other countries and investigation of secondary data from multiple hospitals in Indonesia to determine the wastewater characteristics with government regulation. The study of result showed the characteristics of hospital wastewater of tropical region to provide suggestions scientifically for improvements government regulations that are currently used in Indonesia. The other result of this study can provide a picture of hybrid membrane technology in reducing the special waste with optimum process.

Keywords: Water Pollutans, Hospital Wastewater, Tropical Region, Hybrid Membrane**.**

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1. INTRODUCTION

The frequency of water increased in a row with technological developments and population growth. [1] World Health Statistics reported in 2015 showed that about 85% of the population in Indonesia requires access to clean water for life. Accordingly, in recent decades the public is increasingly aware as the importance to solved environmental problems, especially the availability of clean water sources and sustainability of natural resources.

Environmental Technology Center through the Agency in 2010 [2] reported that the potential of water in Indonesia is currently estimated at 15,000 m^3/capita/year. In 2020 the total potential is estimated at 1200 m^3/capita/year, while the natural potential for a viable economy managed only 35%, so the real potential 400 m^3/capita/year, under of the UN minimum amounting to 1,000 m^3 /capita/ year.

Data in 2014 from the Ministry of Health reported [3] Indonesia has 2,410 hospital beds with 295.035. Sumatera Selatan has 55 hospitals in Palembang as many as 27 hospitals. [4] National estimates hospital solid waste product by 376.089 tons/day and wastewater excess 48.985,70 tons/day. [5] Organic, Inorganic chemicals and drugs used in hospital operations are potential sources of water pollution. [6,7,8,9,10,11,12] Hospital operations have the potential to produce waste caused environmental pollution. [13] Hospital including producers of hazardous wastes and toxic (B3) from specific sources waste code D.227. The wastewater effluent volume capacity of each hospital is different, it can be determined by the number of patients and the average water consumption.

Waste water management of the hospital is one way to ensure the sustainability of water resources and the environment. Wastewater treatment plant (WWTP) is one way that can be done to minimize contamination of hospital waste. WWTP is an instrument that is generally a combination of three wastewater treatment process of physical-mechanical, biological or chemical. Physical-mechanical processing and chemical essentially the same as wastewater treatment to get clean water. Biological wastewater treatment that many common is the activated sludge process.

[14] Hospitals have various substances and chemical reagents used for medical purposes such as diagnosis and research, once used for diagnostics, disinfection and pharmacy. It can't metabolized by the patient's body then gets mixed with hospital wastewater. Hospital as one of the causes emission of pollutants that generate waste of drugs. [15] Wastewater treatment plant owned hospitals generally have not been able to eliminate of these compounds.

[16] The problems that occurred that wastewater treatment technology the hospital has not degraded compounds are persistent in the environment effectively, especially wastewater containing drugs and micropollutans containing pathogenic bacteria. Pharmaceuticals and personal care products (PPCPs) are chemical pollutants with high solubility and bioactivity caused health complications in humans and living organisms. Pharmaceuticals and personal care products (PPCPs) were detected mainly through wastewater eventually reach the surface and ground water.

[17] Research in Saudi Arabia for wastewater hospitals to get the results of the 19 drugs investigated, four types of drugs - drugs (acetaminophen, metformin, norfluoxetine, atenolol) have been found in concentrations greater than the detection limit both in effluents and waste from WWTP. [18,19,20] Residual chemicals and pharmaceuticals from hospital wastewater that can't eliminate by the installation system in general will be a residue, viruses and bacteria transformed as agent multiresisten in the environment. [21,22, 23,24,25,26] Some of the studies that have been done concluded that the installation of effluent treatment owned by the hospital does not have the ability to reduce waste water containing medicines.

[27] Membrane technology as one of the installation of effluent treatment plants, developments and progress has been promising in the process with the principle of the separation and purification of drinking water. [28] Membranes can be defined as the process of separation of components of fluid flow, the

membrane serves as a highly selective barrier between two phases and components. [29] Membranes based on particle size filtered consist of microfiltration, ultrafiltration, nanofiltration and reverse osmosis.

[30] The membrane process offers significant advantages due to the operational simplicity, flexibility, cost-effectiveness, reliability, low energy consumption, good stability, environmental compatibility, easy control, handling and scale with operating conditions such as temperature, pressure, and pH.

[31] The weaknesses of the processing use all kinds of membranes is the occurrence of fouling (clogging) caused by the interaction between the components, it can be anticipated with the optimization of the design and operating conditions (replacement membrane, backflushing, chemical cleaning).

[32] Membrane technology could be a solution in wastewater treatment hospital. The development of membrane can be combined (Hybrid Process) nanofiltration membrane and reverse osmosis. Hybrid Process nanofiltration and reverse osmosis membrane technology has not been used in hospital wastewater treatment. [33] Nanofiltration process combined with reverse osmosis can reduce impurity components have characteristics containing residues of drugs, the ability to eliminate the contaminants by 94% - 100%.

Further review of the system of WWTP in several hospitals in Indonesia, mostly using an activated sludge treatment system with a combination of aerobic and anaerobic pond. Most hospitals are not identifying drug compounds and other pathogenic bacteria from the WWTP effluent because the quality standards set by the government does not regulate in detail the components of other micropollutans.

2. HOSPITAL WASTEWATER

A. The Regulation of Indonesia

The Regulation of quality standards on of hospital wastewater effluent at Indonesia seen in Table 1 [34, 35, 36]. [37] The quality of the wastewater of hospital in the city of Malang and some reports a study of wastewater treatment quality hospitals in Indonesia (RS. Kelet Jepara, RS Dr. Muhammad Zein Painan West Sumatra, RS Permadi, RSU Prov. NTB, RS Dr. Wahidin Sudirohusodo South Sulawesi, RS PKT Bontang; RS Persahabatan) concluded the facts and data that are relatively the same aspects (physics, chemistry, biology and radioactivity) and does not focus on researching the content of medicines in the waste due to limitations of technology and the government regulations didn't set specifics.

B. Contaminant Characteristics of Hospital Wastewater

Review research on characteristics of hospital wastewater on aspects of physics, chemistry, biology and the radioactivity is visible on a summary table 2.

Specific research studies examining contaminants medicines, including studies conducted found some compound drugs such as Methamphetamines, Morpine, Codeine and Ketamine, which are present in wastewater effluents hospital after processing with the concentration of 1240, 378, 260 and 206 ng L – 1 [50]. [51] Antibiotic compounds such as Ciprofloxacin, Sulfamethoxazole, Ofloxacin, Clarithromycin, Azithromycin, Acetaminophen and Ibuprofen. [52] Antibiotic compounds classified in groups The Polar Organic Chemical Integrative Sampler (POCIS) compounds (Atenolol,Prednisolone, Methylprednisolone, Sulfamethoxazole, Ofloxacin, Ketoprofen). [53] Ciprofloxacin, Tamoxifen and Cyclophosphamide. Antibiotics Dexamethasone. [54] Carbamazepine. [55] Diclofenac, Amiodarone, Ritonavir, and [56] Amoxicillin, Ciprofloxacin, Fluoroquinolones, Arsenic, Mercury, Metracyclines, Sulfonamides and Penicillin G.

Table 1. Regulation of Hospital Wastewater in Indonesia

Parameter	Concentration
Physics	
Temperature	30^0 C
Chemical	
pH	6 - 9
BOD_5	30 mg/L
COD	80 mg/L
TSS	30 mg/L
NH_3	0,1 mg/L
PO_4	2 mg/L
Microbiology	
MPN **Coli**	10.000
Radioactivity	
^{32}P	7 x 10^2 Bg/L
S	2 x 10^3 Bg/L
^{45}Ca	3 x 10^2 Bg/L
^{51}Cr	7 x 10^4 Bg/L
^{67}Ga	1 x 10^3 Bg/L
^{85}Sr	4 x 10^3 Bg/L
^{99}Mo	7 x 10^3 Bg/L
^{113}Sn	3 x 10^3 Bg/L
^{125}I	1 x 10^1 Bg/L
^{131}I	7 x 10^1 Bg/L
^{192}Ir	1 x 10^4 Bg/L
^{201}Ti	1 x 10^6 Bg/L

Table 2. Research based on Hospital Wastewater Parameter

Parameter	Concentration
[38] Conductivity, µS/cm	300–000
[22] pH	6–9
[39] Redox potential, mV	850-950
[40] Fat and oil, mg/L	50–210
[6] Chlorides, mg/L	80–400
[41] NH_4, mgNH_4/L	10 - 68
[40] Nitrite, mg NO_2/L	0.1 - 0.58
[42,43] Nitrate, mg NO_3/L	1 – 2
[39,40] Phosphate, mg P-PO_4/L	6 – 19
[44] Suspended solids, mg/L	120 – 400
[45,46] Microorganisms, MPN/100 mL E. coli	10^3–10^6
[45] Enterococci	10^3–10^6
[39] Total surfactants, mg/L	4–8
[47,48] Total disinfectants, mg/L	2–200
[49] Specific disinfectants :	
BAC_C12–18, µg/L	49
BAC_C12, µg/L	34
DDAC-C10, µg/L	102
[48] Antibiotics, µg/L	30–200
[48] Antinflammatories, µg/L	5–1500
[48] Lipid regulators, µg/L	1–10
[48] Cytostatic agents, µg/L	5–50
[48] ICM, µg/L	0.2–2600
[48] Beta-blockers, µg/L	0.4–25

3. MEMBRANE PROCESS

A. The Characteristics of Membrane

[57] The membrane technology has a good ability as a filter barrier to contaminants or pollutant compounds that can be separated from the waste. Mechanism process model membranes have a good concept because only compounds that have a diameter smaller than the pores that can pass through a

membrane filter. The membranes are in a process of becoming a selective separator filter with some substances that can pass through the membrane, while other substances maintained.

Membrane filtration can be used as an alternative technology wastewater purification in addition to flocculation, sediment purification techniques, adsorption, sand filters and activated carbon filters, ion exchange, extraction, and distillation. The concept of the performance of the membrane can be seen in Fig. 1 that only contaminant particles are smaller than the membrane pores that can pass through the membrane breaks.

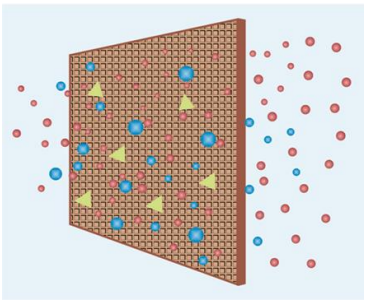

Fig. 1 Membrane Mechanism Process

Water treatment process is divided into several types, membrane microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO) and nanofiltration (NF) membrane. [58] MF membranes that have pore sizes of the largest and usually reduce large particles and various microorganisms. UF membranes have smaller pores of the membrane MF, therefore in addition to large particles and microorganisms, they can resist bacteria and soluble macromolecules such as proteins. RO membranes are effectively non-porous and includes many elements of particles low molar mass such as salt ions and organic. NF membranes are relatively new as porous membranes, because the pores in the order of 10 angstroms or less. A comparison between some membrane technology, in his latest Membrane Technology and Engineering for Water Purification provides a comparison of membrane technology based on membrane pore size diameter [59] as shown in Fig. 2.

B. Hybrid Membrane Process

[60] Development of a high-pressure membrane processing technology (RO and NF) to eliminate compounds Soluble organic compounds (DOC), Polycyclic Aromatic Hydrocarbon (PAH), Trihalomethanes (THM), volatile Haloacetic Acids (HAA), Pharmaceutical Active Compounds (PhACs) and Endocrine Disrupting Compounds (EDCs). ECDs include a variety of micropollutants, namely xenoestrogens, phthalates, polychlorinated biphenyls, alkilfenol, synthetic drugs, hormones and other chemicals produced by humans then enter into the environment. [61] Produces technology NF and RO which is capable of the reduction of Cyclophosphamide > 90%.

The comparison between the combination of processes that can be used in the reduction of contaminants in wastewater can be seen in table 3 [62]. The Hybrid Process using NF and RO membrane has a very good ability in the reduction of the typical hospital waste containing residues of medicines and other contaminants. The percentage reduction of contaminants that occur when processes demonstrates the ability of the average above 90%.

Table 4. Serves a wide range of research and previous studies ever done in the various countries regarding the reduction of hospital wastewater containing residues of medicines by using nanofiltrasi and the reverse osmosis system.

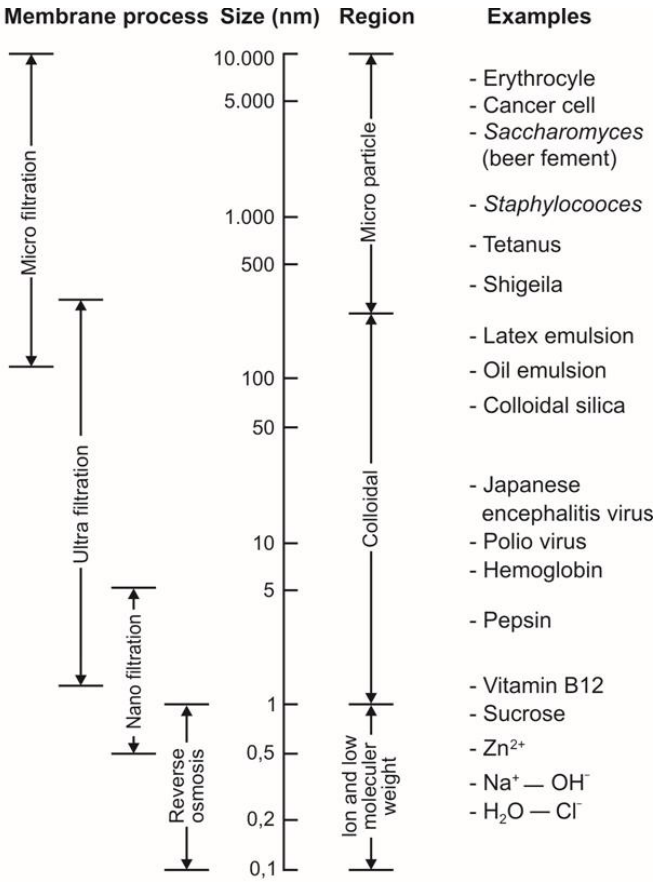

Fig. 2 Comparison of Membrane Process

Table 3. Comparison of Membrane Process

Type Process	MF/UF	NF/RO
Used	Particle and microorganism	Sea water, micropollutans, *Natural organic matter* (NOM)
Contaminant	Partikel	*Dissolved solutes*
Membrane module	*Hollow fiber*	*Spiral wound*
Flow Type	*Dead end*	*Cross-flow*
Material	Polymer, ceramic	Polymer

4. CONCLUSIONS AND RECOMMENDATIONS

Reality of circumstances, WWTP still leaves many problems and obstacles. The magnitude of the location where the instrument processing and cost required either for installation or maintenance can cause an economic burden on hospitals will increase. The resulting effluent from the WWTP still require further processing, so it will take the energy and the high cost.

The content of these contaminants is influenced by the type of hospitals, the amount of beds, amount of patients and the climate of a country. That fact can be proved by a study of the literature on several previous countries concluded that existing systems are not able to reduce to the maximum content of hospital wastewater. The Government should develop and revise regulations in order to improve the system of governance in hospital wastewater treatment.

The technology of wastewater treatment by hybrid process combines two processes nanofiltration membrane and reverse osmosis in Indonesia based on the literature search has not been done in the reduction of hospital wastewater containing residues of medicines. The climate of the region that have tropical characteristics, make a possibility additional types and characteristics of hospital wastewater.

Hospital wastewater has potential polluters that are very harmful to the environment, so that should the contaminants are reduced by a latest technology that is effective, efficient and able to reduce these contaminants to the maximum. The recommmendation is wastewater treatment system in hospitals by using nanofiltrasi membrane technology and reverse osmosis can reduce contaminants existing polluters in the wastewater of the hospital. An important use of the latest technology developed the installation of hospital wastewater treatment to replace the current technology because it still finds some compounds micropollutans after passing through the WWTP process.

Table 4. The Ability of Hybrid Membrane Process

Contaminant	% Reduction
Endocrine disrupting compounds (EDCs) and pharmaceutically active compounds (PhAC)	>90% [63]
Bezafibrate, bisoprolol, carbamazepine, klaritromisin, ciprofloxacin, diklofenak, ibuprofen, metronidazol, moksifloksasin, telmisartan dan tramadol	70% [45]
Pharmaceutical active compounds (PhACs), carbamazepine (CBZ) and diatrizoate (DTZ)	Variation of a % reduction, [64]
Pharmaceuticals Waste (sulfamethoxazole, trimethoprim, ciprofloxacin, dexamethasone, and febantel)	94 - 100%. [33]
Enrofloxacin	> 92%. [65]
Endocrine disrupting compound, bisphenol A (BPA)	> 98% [66]

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