Peat Water Treatment as an Alternative for Raw water in Peatlands Area

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Abstract. Indonesia is the second country that has the largest percentage of peatlands in the world. Peatlands play an important role as a counterweight to environmental ecosystems. However, if not managed properly, then these benefits cannot be used optimally. Areas with peatlands are generally inland areas that do not yet have access to clean water. It is not uncommon to find clean water crisis conditions occurring in areas with peatlands, because peat water as a source of raw water has not yet been implemented. As for water resources in peatlands, most of them come from the peat water itself. The use of peat water as a source of raw water requires in-depth studies both in terms of quality, continuity, and quantity, so that it does not cause health, social, and economic issues, when used by the community as a source of clean water. Through this research, there will be a review of the application of peat water treatment that has been used in previous studies, so that it will be known the challenges to be faced and as an alternative solution to face these challenges, especially in Indonesia.

1. Introduction
Indonesia has the second largest distribution of peatlands in the world after Brazil, which is 22.5 million ha [1]. The peatlands are spread over three major islands, namely Sumatra, Kalimantan and Papua. Utilization of peatlands in Indonesia is done in terms of water management and plant management, which has been able to avoid peat damage until now. Excessive exploitation of peatlands can result in the loss of the function of the peat as a water reservoir so that the area around the peat is vulnerable to flooding and drought. Indonesian peat material generally consists of vegetation that contains a lot of lignin compared to peatlands in other regions in temperate climates. The nature of peatlands varies greatly physically, chemically, or biologically, which indicates that peatlands can be used for agricultural development and need to be maintained to preserve the environment [2]. To be used maximally, an in-depth analysis is needed in terms of thickness, level of maturity, and hydrological conditions so that peatland suitability can be obtained.

The current management of peatlands is not yet optimal. The use of peatlands in Indonesia is still focused on agricultural development, although not infrequently there are still conflicts in ecological terms because of the change in the function of peat and various reclamation actions that are at risk of increasing the release of carbon stocks and the risk of peat fires. Biodiversity is also experiencing significant impacts from the conversion of peat fungi. Local management is carried out to overcome
these problems include selecting the location of farming, land preparation, fertility management, land use planning, water management, and commodity selection.

Peatlands are an economic resource for the community, the government and the state, because they can be a source of economic activity for people living in peat areas. However, the current use of peatlands is not maximized in providing support to meet the needs of people living on peatlands. The basic needs that need to be met include the need for clean water. The clean water crisis on peatlands encourages people living in peat areas to be forced to use peat water directly to meet their daily needs, even though peat water is water that is not suitable for direct use because it has a high acidity level and can damage teeth and have an impact on digestion. High organic levels can trigger odors, while iron and manganese levels in peat water can cause organ damage if consumed continuously.

In 2019, Indonesia Institute of Science (LIPI) had created a Peat Water Treatment Plant designed for 60 liters per minute, known as IPAG60, to meet 400-500 people per day if operated for 10 hours [3]. From the results of the application in the field, IPAG60 can produce clean water from various types of peat water or non-peat water, and has met the standards based on Minister of Health Regulation No. 492/2010. Besides IPAG60, other treatment such as electrocoagulation [4] and plasma ozone [5] can be used for peat water. In this research, it is known that both use simple principles that easy to operate, no chemical coagulants, produces less sludge, and cost effective. By looking at the urgency of the above mentioned, and by considering several areas that have already implemented peat water treatment technology, this research will provide a review and recommendations for peat water management to be used as a source of raw for clean water.

2. Peatland Water Resource Management

In Indonesia, peatlands play an important role in providing optimal ecosystem functions, including water flow regulation and as a buffer for saltwater or freshwater movement. The hydrological process influences the conditions of peatlands. Its existence depends on holding water and its characteristics depend on the origin, volume, chemical quality and variability of water supply. In this case peatlands are classified as follows [6]:

1. Ombrogenous mires are the soil that is under the influence of the water from rainfall
2. Topogenous mires are controlled by horizontal flow of ‘mineral ground water’ limited by topography,
3. Soligenous mires, land developed in sloping locations where laterally moving mineral soil

Although there is a large amount of water that can be retained by the peat blanket, only a little is acceptable because the rainfall is also absorbed [6]. As shown in figure 1, peat swamps are often described as "diplotelmic", which means they have two layers of soil with different characteristics: top active root layer and newly decomposed plants called "acrotelm", above the denser and more decomposed lower layer called "catotelm" [6]. In an ideal situation, the hydraulic conductivity of acrotelm is much higher than that of catotelm, along with its relative thinness resulting in limited storage capacity for the water in it. In contrast to acrotelm, catotelm remains permanently saturated because water movement in it is very low. Low hydraulic conductivity in the catotelm helps maintain water levels close to the ground surface, an important condition to protect the sustainability of surface vegetation functions. Water table on healthy peatlands is one factor that needs to be considered in determining the growth of vegetation on peatlands. In developing the function of peatlands, the water table is critical for peatland development because it controls species composition through anoxia (lack of oxygen) at depth, which retards decomposers and so enables peat accumulation. Rainfall flow received by peatlands depends on the flow route taken and the flow velocity achieved. On pristine peatlands, water tables tend to be close to the surface at almost all year round and rain will quickly make the peat saturated with water. Rainwater runoff is important because it affects the nature of peat, in this case the role of peat as a water provider and mitigate the risk of flooding downstream.
Based on the results of research [8], it is known that Indonesia’s peatlands in the form of forests (mangroves, swamp forests and plants) amounted to 52%, in the form of shrubs covering an area of 21.7%. The rest of the existing peatlands are already used for plantations, agriculture, rice fields and settlements. Peatlands that previously have ecological functions are now changing as supporting businesses in various agricultural systems. Besides, peatlands also play a role in producing palm oil for both the domestic and international markets. Based on spatial data in 2011[8], around 3.74 million hectares of peatlands have been degraded marked by closure of shrubs. This peatland not only becomes unproductive but also a source of greenhouse gas emissions. The increase in greenhouse gas emissions will not be significant, if agricultural expansion is carried out on degraded peatlands.

In some cases, this is a positive impact on carbon stocks if the initial carbon stock in the initial land is lower than the carbon stock in the plant developed [9]. In its development, peatlands as upland areas (non-rice food crops) did not experience rapid changes from 2000 and 2010, and rice fields due to high costs also low farming level [9]. However, based on statistical data sourced from the Ministry of Agriculture, change of peatlands to plantations experienced a fairly rapid change from 1970 to 2012. The plantation dominance of area came from oil palm plantations, then cacao, whereas for rubber and coffee plantations it almost did not experienced changes in the last two decades [3].

With carbon losses on peatlands causing habitat degradation, that give impact on water quality. Efforts to restore peatland damage are not easy because of the formation of peatlands that require millions of years and the natural condition of peat which cannot be returned due to fire or used as a dumping site. However, peat land can be replanted, so that the ecological function can be restored and peatland degradation can be minimized. Restoration must also benefit local communities, such as increasing income for the local community [10]. One important factor of restoration, namely water management. Water system planning with the help of computer modeling (Drainmod models) can predict daily groundwater levels and is effective in designing operational monitoring. The use of peatlands following its potential can maintain water levels close to the root zone, thus supporting the development of agriculture on the land.

If the peat water source used comes from a low-quality environment (colored due sediment and dissolved compounds), additional costs will be charged to the management company, consumers and water treatment. Some additional processing needs to be done to increase management costs including [11], energy needs, additives, add sludge to landfills, and additional processing infrastructure needed to remove color. Thus, the maintenance of water quality before entering the treatment system is very necessary to be more effective in terms of cost. The steps that can be taken to maintain water quality include returning peatland functions so as to reduce staining and improve raw water quality. Another thing that can be done is to restore hydrology and increase the coverage of peatland-forming vegetation. Some peat water users, such as Scottish Water [12], have begun to use earth observation data to study
peatland areas that state water catchments. This is certainly beneficial for the environment and has the potential to reduce the cost of clean water supply for the community. The protection of peatland water resources needs to be done in the long term, including understanding the benefits of peatland restoration for clean water company, and establishing cooperation between local organizations to manage land effectively to improve water quality on assist monitoring in the restoration of peatlands. In terms of peatland conservation, the Indonesian government has also imposed a moratorium to prevent new concessions. The revised moratorium in 2015 established a total ban on clearing peatlands, even in existing concessions, and banned the use of fire for land clearing. Also, the steps for planting in newly burnt areas are intended for future restoration [13]. As for the effectiveness of the moratorium in reducing peatlands, it still needs further study. Peatland management in Indonesia is not much different from other countries. In Indonesia, law enforcement related to peatland conservation is still not synergistic, due to unclear regulatory and policy accountability.

Reclamation of peatlands continues to this day. It seems from the large number of drainage canals built to provide access to pristine forests. Only about 7% of pure peatlands remain in Sumatra and Kalimantan [2], mostly in Papua. Residents, who play an important role in the development of the peat landscape, are still neglected. Many residents make ends meet by taking or sell existing natural products at low prices. This has an impact on the low economy of the local population and impacts the increasingly widespread exploitation of peatlands. By looking at the current conditions, it can be concluded that there is still a lack of education of residents regarding peatland conservation. Research shows that a moratorium on peat development, revocation of illegal company licenses, and rewetting of peatlands will face various stakeholders who have different perspectives, priorities, knowledge and interests [2]. Peatland management in the future needs to change behavior and develop the management of land use. Land and holding negotiations and dialogue to determine acceptable compromises for more effective policy development.

One of the functions of peatlands that needs to be developed, including to provide clean water. High levels of dissolved organic carbon indicate that water treatment from peatlands requires special treatment before it can be used for clean water. Water that flows from pure peatlands, generally still has a fairly good quality and can be developed into a supply of sustainable drinking water. Peatland degradation continues to increase, resulting in faster peatland decomposition, triggering the release of aquatic carbon and decreasing peatland water quality [8]. Rising temperatures and precipitation changes will increase the risk of forest fires which then have an impact on the provision of sustainable water resources. With a decrease in quality, it will increase water treatment cost because of the byproducts of carcinogenic water disinfectants. The potential of peatlands as water resources varies from region to region, for example in the western Siberian lowlands and the Hudson Bay lowlands, where the location is far from the population center so that the amount of investment is not proportional to the benefits to be gained [8].

The Peat Population Index (PPI) to identify the human population on peatland cover at the catchment scale [8]. Through the PPI, it will be known in detail the contribution of water from peat to potable water, and the dependence of the population on water resources from peatlands. The value of PPI in a small population, sometimes resulting in a small value even though it has large peatlands. Therefore, analysis of determination of peatlands as a supply of water resources needs to be developed to the next stage, the Peat Reservoir Index (PRI), which scales the contribution of peatland catches to the reservoir water that can be minimized. PRI is used to estimate the amount of drinking water that has been used from peatlands. PRI is calculated from the annual volume of clean water supply from a reservoir multiplied by flow through peatlands before flowing into the reservoir. For the sustainability of the function as a water provider, a study on the level of degradation of peatlands is also used as a water supply. Parameters that can be used as a reference include changes in land use and changes in economic activity. Figure 2 is a schematic used in determining peatlands as a source of clean water supply.
After collecting data, the PPI calculation illustrates the quantitative comparison between the population and peatland cover in the catchment area. To calculate the peatland area in the catchment area, ArcGIS is used. The calculation of population density can be done using the Statistical Zone in ArcGIS. PRI analysis is carried out to find out the proportion of flow that interacts with the water supply. Determination of peatlands that can be used as the water supply is done by combining data on water supply in reservoirs, peatland maps and river network systems. The next step is evaluating the changes in functions that have occurred or may occur in the future development of peatlands. For this analysis the EcosystemLand33 application can be used which can assess land degradation. Thus, it is expected that the optimization of peatlands as a supplier of clean water supply can be carried out sustainably and not harm the ecology of the peatlands themselves.

3. Peat Water Treatment Technology

Peatlands originating from piles of organic material that have been or bare undergoing decay, have characteristics such as brownish black color, high acidity, high organic matter, moderate turbidity, moderate hardness, containing E-Coli and coliform quite high and moderate to high Fe concentrations [13]. Thus, if analyzed using the STORET method, it will be seen that peat water is in the quality of group C, which can only be used for agriculture and fisheries. To be used as clean water, peat water needs to go through further processing. Environmentalists focus on the species composition of biota on peatlands, where proportion of biota depends on the chemical composition of the water phase and vice versa. Existing biota can affect the chemical nature of water [14]. From the review of peat water quality characteristics that have been carried out, it can be seen that some parameters require special attention in determining their eligibility as a source of raw water. Parameters that need to be considered are divided into major and minor elements. Major elements include, acidity (pH), major cations, major anions. The minor elements, nutrients, metals, dissolved organic material (acidity and characteristics).

The acidity level of peatland waters is the most stable chemical parameter that can be measured. The location of water sampling will influence the acidity level, sampling method, sample treatment and holding time as for the major cations that play a role in peat water include Ca\(^2+\), Mg\(^2+\), Na\(^+\), and K\(^+\). These four elements are commonly found in swamp and fen waters in the northern hemisphere [14]. Major anions, consisting of HCO\(_3\), Cl\(^-\), dan SO\(_4\)\(^{2-}\), where the concentration can be determined through alkalinity titration. The form of NO\(_3\), \(\text{NH}_4\)\(^+\) and PO\(_4\)\(^3-\), which are usually present in the acrotelm pores [15]. Increased levels of NO\(_3\) dan PO\(_4\)\(^3-\) indicate that peatland water lacks nutrients, which means nutrients are correlated.
with the type of peatland to be used. NO₃ levels tend to be higher during winter when biological activity is low. As for metal content, concentrations of Mn and Fe originating from ground water are swapped at the bottom of the peat profile under poor swamp conditions [16], whereas Al and Fe are commonly found in conserved swamps. Swamp vegetation is often used to monitor changes in metal deposits. Dissolved organic material (DOM) is produced in peat and soil by microbial degradation of plant material and dissolution in pore waters [17]. DOM will double with a temperature increase of 10°C [18]. Increased primary production can also result in increased DOM concentrations [19]. DOM concentrations are generally expressed as dissolved organic carbon (DOC) content from the water. DOM plays a role in low pH in low-quality swamps and waters due to photochemical reactions.

Figure 3. Peat Water Treatment Technology: IPAG60

Figure 4. Peat Water Treatment Technology: Electrocoagulation batch system (a), continuous system (b) and Plasma Ozone (c)

Peat water treatment methods have been extensively developed both on a laboratory or pilot plant scale, such as absorption, filtration, coagulation and flocculation and combining activated carbon for high concentrations of organic compounds. The most commonly used methods are the flocculation coagulation method and the membrane filtration method [20]. From the research results [21], it can be seen that the reverse osmosis method is considered the best compared to the flocculation coagulation method and the absorption method even though there are fouling problems. Thus, it can be said that the combination of various methods can be an effective and efficient way to process peat water into clean water. There is a technological innovation in Indonesia, namely IPAG60 (Figure 3) which has been successfully implemented to solve the shortage of access to clean water/drinking water in peat areas.
This processing technology integrates the flocculator, coagulator, and sedimentation jackets to facilitate mobilization. In addition, there is also a combination of peat water treatment materials that are more efficient and effective.

Peat water treatment can also be done using an electrocoagulation system (Figure 4(a)) that requires simple equipment so that it can be easily operated, does not use chemical coagulants, produces less sludge and is cost-effective, [4], performs kinetic and statistical modeling for electrocoagulation processes gradually and continuously on peat water treatment in Sarawak using aluminum and copper electrodes. Electrocoagulation systems are designed to match the characteristics of materials and systems available locally so that they are easy to make and maintain low costs for the construction and operation phases. The research also used Minitab and Microsoft Excel software for kinetic studies, statistical modeling, and optimization processes. The optimization process is carried out to minimize energy consumption, turbidity and total suspended solids.

In addition to the preceding, peat water treatment can also be carried out using plasma ozone technology (Figure 4(c)), which has been proven to be used to treat peat water very effectively compared to other conventional technologies [19]. The contact mechanism that occurs in plasma ozone takes place chemically-physically which cause the formation of OH. In this process the form of reactive oxygen and hydrogen peroxide in the form of ozone, will be used to break the covalent electron gas to generate plasma. The interaction between plasma ozone and liquid will provide additional oxidation which will affect oxidation levels better than conventional methods. Ozone and hydroxide radicals that have been used will split into H2O and O2 which will impact the high dissolved oxygen in treated water. In this study, research on four parameters of peat water, namely turbidity, color, coliform, and permanganate with the final results of processing can reach the quality standards set by the Minister of Health, manganese parameters still have not reached the quality standard. However, manganese is estimated to be in accordance with quality standards if the contact time is extended to more than 15 minutes. The table 1 compares the quality of processed peat water using processing technology as mentioned above. From this table, it can be seen that peat water can be used as an alternative source of raw water. This can be seen from the high efficiency of water quality parameter removal from each technology.

Furthermore, things that need to be considered in the selection of technology are related to investment costs, ease of operation and maintenance, and side effects on the environment that may result from the processing of raw water.

Table 1. Comparisson of Treated Peat Water Quality

| No | Water Quality Parameter | Unit | IPAG60[3] | Electrocoagulation[4] | Plasma Ozone[5] |
|----|------------------------|------|-----------|-----------------------|-----------------|
|    |                        |      | Influent Quality | Effluent Quality | Influent Quality | Effluent Quality | Influent Quality | Effluent Quality |
| 1  | Color                  | TCU  | 462-503   | 2                     | 7.8 Pt-Co       | 1.1-3.5 Pt-Co    |
| 2  | Odour                  |      | Odour     | Odourless             |                 |
| 3  | Taste                  |      | Sour      | Tasteless             |                 |
| 4  | Turbidity              | NTU  | 7.5       | 1                     | 16              | 1.99-15.57       | 50.15          | 5.84-34.6       |
| 5  | pH                     |      | 7.5       | 7.5                   | 6.7             |
| 6  | Iron (Fe)              | mg/l | 0.174     | <0.009                |                 |
| 7  | Manganese              | mg/l | 0.071     | 0.039                 |                 |
| 8  | Total Suspended Solid | mg/l | 8         | 2.91-6.99             |                 |
|    | (TSS)                  |      |           |                       |                 |
| 9  | Permanganate           | mg/l |           | 122.3                 | 11.8-26.3       |
| 10 | Coliform               | MPN/100ml |           | 13                   | 2                |

Notes: a the effluent quality depends on current density and contact time (20 min, 40 min, 60 min) b the effluent quality depends on contact time (10 min, 12 min, 15 min)
Apart from the quality aspects of the water produced, each peat water treatment technology also has a different production cost, adjusting to the needs of the processing unit to be used. IPAG60 has a production cost of 1–2 USD per cubic meter [21], while electrocoagulation and plasma ozone has a production cost of 0.03 [20]–0.05 per cubic meter [15]. Chemical can cause significant cost differences by using coagulant and the processing unit as precipitation. However, with the simplicity of the system and ease of operation of IPAG60, this technology will be easier to use in developing countries, especially Indonesia.

4. Conclusion
In managing peatlands, the main thing to note is the hydrology of the peatland, which is influenced by many factors, including rainfall and underground water levels, Peatland development, often has a negative impact on the sustainability of the peatlands themselves. Many peatlands have become damaged due to development that is not accompanied by restoration. As a result, the deterioration in the quality of the environment and the surrounding communities have experienced difficulties in meeting their daily needs, including the need for clean water, and the high possibility of land fires and floods. This study has explained the steps needed to determine the need for peat water supply as one of the clean water supplies. Thus, it is expected that the use of peat water can run in a sustainable and effectively. Peat water treatment has also been carried out in many other countries, as previously described, which shows that peat water is an alternative source of clean water. The simplicity of technology principles and easy operation accompanied by relatively inexpensive production and maintenance costs must be considered in selecting of peat water treatment technologies. By comparing the parameters and operational cost of the treatment process, it can be seen that IPAG60 can be recommended in the application of the technology of peatlands in Indonesia. This is considering the completeness of the parameters that have been tested and currently IPAG60 is also starting to be widely used in peat areas in Indonesia due to the minimum initial cost [12]. For other methods, further studies can be done regarding the costs and ease of technology operations, to add alternative technological options for peat water treatment. Both methods will be very promising considering the absence of chemicals used in the treatment.

5. References

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