IPAG60 as Alternative Solution to Provide Clean Water in Peatland Areas

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Abstract. Peatland areas generally have raw water with different characteristics compared to ordinary raw water. Peat water is acidic (pH 2 – 4), blackish brown in colour (250 – 600 TCU) and contains various other pollutants so it cannot be processed with conventional technology. The aim of this paper is to publish the capability of IPAG60 to treat raw peat water. This technology uses a simple and applicable process in producing processed water that is suitable for clean water and drinking water according to quality standards. The formulation of the purifying material applied was able to remove organic matter and other pollutants with high efficiency (more than 90%). The results of research conducted on several types of peat water coming from different locations such as Kalimantan and Sumatra show that IPAG60 is capable to treat peat water into clean water meeting the standards. The use of IPAG60 is not only limited to treating peat water, but also for various conditions of inland surface water. Keywords: clean water services, efficiency IPAG60, peat water, water quality

1. Introduction

Water is the main component for living things including humans to carry on their lives. The important roles of water are as a source of water, living or habitat, transportation, fisheries and recreation, etc. Although Indonesia is one of the countrdiscovered by almost more than six percent of water resources, Indonesia still has serious problem in term of clean water services level for the people. As noted by Sutapa [1], consumption of water increases significantly as population grows. Annual water demand is approximately 0.156 billion m³ in 2000, and will reach double in volume in 2015 0.356 billion m³ per year. The availability of clean water tends to be reduced because of environment pollution and degradation.

The Sustainable Development Goals (SDGs) are global development paradigms / platforms with 17 specific targets. Target number 6 from SDGs is “Ensure availability and sustainable management of water and sanitation for all”. Based on the Report of the Secretary-General, The Sustainable Development Goals Report 2018[2], there is still too many people in lack access to safely managed water supplies and sanitation facilities. 29 per cent of the global population lacked safely managed drinking water supplies, and 61 per cent were without safely managed sanitation services in 2015. In addition, water scarcity, flooding and lack of proper wastewater management also hinder social and economic development.
Like other developing countries, Indonesia has difficulty in improving clean water services for the community, especially those in rural areas. The level of clean water services in several countries in ASEAN are: Vietnam 10% in urban areas and 61% in rural areas; Cambodia 29% in urban areas and 69.5% in rural areas; Philippines 43%; Malaysia 98%. Based on the World Bank report [3], the level of clean water services in 2002 was 44.8% [4]. Meanwhile the target of access to clean water in 2009 (National RPJM) is 60% (urban), 30% (rural), and 40% (urban + rural), and according to the MDGs target for 2015, piped drinking water services in Indonesia are 80% (urban), 40% (rural), and 62% (urban + rural). Generally, for the reason of difficulties and limited access, large number of people in the remote area (villages) uses surface water directly for daily needs (bathing, washing, and drinking) [5].

An example of remote area having low availability of water services is peatland environment. Riau in Sumatra Island and Central Kalimantan in Kalimantan are two provinces with the largest peatland in Indonesia [6]. Peat water is used directly to cover their daily needs by most of the local people in this area. For the reason of very low quality, like brownish red color, containing high organic matter, pH 2–5, sour taste and low hardness [7][8], peat water is not suitable to be used for people daily needs. It must be treated in order to meet the standard as drinking water [9].

Several different methods to treat peat water, in laboratory or pilot scale, have been reported such as absorption [10], filtration [11], coagulation and flocculation [12][13][14], and combining [15][16], activated carbon for high concentrations of organic compounds [17][18]. It is important to note that the treatment process should be the most beneficial, economically feasible method as well as easy to operate for producing high quality of water in a particular location [19].

Despite of the progress in research for treating different raw water including peat water, there are still several constraints related to the provision of clean water in developing countries: political factors (water and sanitation sector are not in priority), financial (poverty), institutional (lack of proper institutions, non-functioning institutions), and technical (spread of settlements and climate factors like floods and droughts) [20]. The unsustainability of clean water services is often caused by a lack of community participation and a lack of public acceptance of new technologies [21][22]. The aim of this paper is to show the capability of IPAG60 to treat raw peat water in order to have alternative and compatible solution to provide clean water in peatland areas.

2. Material and Methods
The research activities were conducted in the period of 2014–2016 at the laboratory of drinking water for data sampling and analysis, Research Centre for Limnology, Cibinong Sciences Centre, completed by field studies for data sampling in Katingan, Central Kalimantan Province and Bengkalis District, Riau Province.

In order to have comprehensive results, direct observation and water sampling were done in: the intake of installation, the coagulator, the six flocculation tanks and the reservoir tank of IPAG60. Based on APHA standard methods [23],[24] describes further process of water samples from the IPAG60 to was measure three main parameters (physical, chemical, and biological analysis). Figure 1 show IPAG60 installed in Central Kalimantan Province, with training activities for local peoples.
Figure 1. Introduction of IPAG60 system to local peoples in Central Kalimantan

**Biological Analysis.** Colony count method was used to have total quantity of *E. coli* and Coliform representing pollutant indicator bacteria in the water. Main components of this method were: 0.45 nm porous cellulose membrane, sterile filter device, tweezers, filtered water samples with a volume of 100 ml and 50 ml, M. endo and MFC as growth medium for the total coliform to fecal coliform.

**Chemical Analysis.** Measurement of nonmetallic parameters was done by titration method. These parameters include ammonia, hardness, nitrate, nitrite, pH, phosphate, sulphate, total organic matters (TOM), total N, and total P.

**Physical Analysis.** Water Quality Checker (WQC), turbidimeter, and TDS meter were used to measure respectively: temperature and salinity, turbidity and conductivity. While color level was detected using colorimeter at 455 nm wave length.

**IPAG60 Efficiency Test.** The efficiency test of IPAG60 was done by using three types of peat water coming from: (1) Air Raja River (Bengkalis District, Riau Province), (2) Sala River (Katingan District, Central Kalimantan Province), and (3) Hyang Bana River (Katingan Distric, Central Kalimantan Province) and under the operational conditions described by Sutapa [1] including the value of settleability of sludge floc below 100 ml/L after thirty minutes of decantation (settling). Removal efficiency (RE) will be calculated using formula 1 as below [7]:

\[
RE (\%) = \frac{1 - (Co - Ct)/Co}{1} x 100 \quad (1)
\]

*RE (%)*: Removal efficiency in %
*Co*: Concentration/condition for peat water
*Ct*: Concentration/condition for clean water

3. Results and Discussion

Three cluster of parameters: biological, chemical and physical respectively, were used to see the capability of IPAG60 in increasing water quality of different peat water. Calculating removal efficiency values will help to understand the ability of IPAG60 to produce clean waterform peat water.

3.1. Biological parameter

The total coliform and *E. Coli* tests are commonly considered as indicator, since the presence of bacteria in these groups indicate the possibility, that disease organisms may also be present in the water[25]. Table 1 shows the results of biological parameters analysis. Three types of peat water from three different locations contain Coliforms 640 col/100ml, 120 col/100ml, and 140 col/100ml respectively. It means that these three type of peat water did not meet the standard, as clean water, based on Minister of Health
Since total coliform organisms are prolific in the soil, their presence does not necessarily imply contamination from wastewater nor the presence of other sanitation-based health risks. It indicates the need for an analysis to determine how these organisms entered the water system [26]. Clear reduction of Coliform has been recorded after treatment by IPAG60. There was no coliform (0 col/100ml) in the clean water produced from three types of peat water. 100 % of removal efficiency for coliform content recorded in the Table 1 showed the ability of IPAG60 to eliminate this microbial contaminant.

In the same way, the result of analysis noted that three type of peat water contained *E. Coli* 85, 75 and 90 col/100ml respectively as shown in the Table 1. This quality of water did not comply with the standard based on Minister of Health Regulation No. 492/2010[8]. *E. Coli* is, generally, a species within the fecal coliform group. It originates from the animals or humans intestines. Their presence indicates a strong likelihood that human or animal wastes are entering the water system[26],[27]. Treatment by IPAG60 can eliminate the content of *E Coli* in the three types of peat water as shown in the Table 1, with 0 col/100 ml in the clean water and 100 % of removal efficiency.

### Table 1. The Results of the Biological Parameters Analysis

| Parameter  | Std*) | Peat Water | Clean Water | Efficiency (%) |
|------------|-------|------------|-------------|----------------|
|            |       | 1  2  3   | 1  2  3     | 1  2  3        |
| *Coliform* (col/100ml) | 0  640 120 140 | 0  0  0 | 100 100 100 |
| *E. Coli*  (col/100ml) | 0  85  75  90 | 0  0  0 | 100 100 100 |

*) Standard based on Minister of Health Regulation No. 197/2002

### 3.2. Chemical Parameter

The problems associated with chemical constituents of drinking water arise primarily from their ability to cause adverse health effects after prolonged periods of exposure, of particular concern are contaminants that have cumulative toxic properties, such as heavy metals and substances that are carcinogenic[28]. The most common problems in household water supplies may be attributed to hardness, iron, sulfides, sodium chloride, alkalinity, acidity, and disease-producing pathogens, such as bacteria and viruses[28]. In this study, twelve parameters were used to see the quality of water before and after treatment by IPAG60. These parameters include two parameters for metallic content (Fe and Mn) and ten parameters for nonmetallic metallic content (pH, ammonia (NH₃-N), nitrate (NO₃-N), nitrite (NO₂-N), total N, phosphate (PO₄-P), total P, sulphate (SO₄-S), Total Organic Matter (TOM), and hardness. Table 2 summarized the results of chemical parameters analysis. Based on this data, seven parameters (Fe, Mn, pH, phosphate (PO₄-P), total P, TOM, and hardness) indicated pollution in the peat water with chemical contents above the standard [9]. While five other parameters (ammonia, nitrate, nitrite, total N, and sulphate) met the standard with the values were under the limits.
The concentrations of Fe and Mn in peat water were 0.3, 0.5, 0.4 mg/l and 0.12, 0.11, 0.14 mg/l respectively. These indicated that the content of metallic compound exceeded the standard (0.3 mg/l for Fe and 0.10 mg/l for Mn) [9]. However, the removal of Fe and Mn concentrations can be observed after treatment with 93 – 95 % of efficiency for Fe and 70 – 85 % efficiency for Mn, and met the standard based on Minister of Health Regulation No. 492/2010.

The hydrogen ion concentration in water is usually measured by pH. The pH between 6.5 to 8.5 is generally considered satisfactory for drinking water [29][30]. The pH values of peat water were recorded very low compared to the standard, 3.40, 2.70 and 3.10 respectively as shown in the Table 2. The treatment process by IPAG60 can increase the pH values until 51 – 60.9 % from the initial to reach pH 6.9 – 7.0 and complying with the standard.

The nitrogen, as component of protein, is essential for all living and exists in the environment in many forms such as NH₃, Nitrate NO₃⁻, or Nitrite NO₂⁻. However, excessive concentrations of nitrate-nitrogen or nitrite-nitrogen in drinking water can be hazardous to human health. Beside fertilizer, nitrogen can occurs naturally in the soil in organic forms from decaying plant and animal residues[31]. Concentration of nitrogen compounds (NH₃, Nitrate NO₃⁻,Nitrite NO₂⁻) in peat water were found all under the standard (1.5 mg/l, 50 mg/l and 3 mg/l) and it still comply with regulation. However, IPAG60 can reduce the concentration of these compounds up to 70.5 – 97.9% for NH₃, 85.7 – 97.7 % for Nitrate NO₃⁻, and 97.9 – 99.2 % Nitrite NO₂⁻.

The orthophosphate, polyphosphate, and organic phosphate in water are the main components of phosphate (PO₄³⁻) in nature[32]. Although this phosphorus compound is one of the major nutrients required by living organisms in the environment, it can be considered as a pollutant if the concentrations are high under specific environmental conditions[33]. Fertilizer and soap industries are the possible entry of phosphorous ion into aquatic environment coming from the household sewage water and

### Table 2. Result of Chemical Parameters Analysis

| Parameter   | Std *) | Peat Water | Clean Water | Efficiency (%) |
|-------------|--------|------------|-------------|----------------|
|             |        | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| Fe (mg/l)   | 0.3    | 0.30 | 0.50 | 0.40 | 0.02 | 0.01 | 0.01 | 93.3 | 98 | 97.5 |
| Mn (mg/l)   | 0.1    | 0.12 | 0.11 | 0.14 | 0.03 | 0.03 | 0.02 | 75 | 70 | 85.7 |
| pH          | 6.5-8.5| **3.40** | **2.70** | **3.10** | **7.0** | **6.9** | **6.9** | **51.4** | **60.9** | **55.1** |
| NH₃-N (mg/l)| 1.5    | 0.95 | 1.05 | 1.10 | 0.02 | 0.31 | 0.30 | 97.9 | 70.5 | 72.7 |
| NO₂-N (mg/l)| 50     | 2.10 | 1.16 | 2.20 | 0.30 | 0.06 | 0.05 | 85.7 | 94.8 | 97.7 |
| NO₃-N (mg/l)| 3      | 1.15 | 1.25 | 0.95 | 0.01 | 0.01 | 0.02 | 99.1 | 99.2 | 97.9 |
| Total N (mg/l)| -   | 1.50 | 1.75 | 1.80 | 0.2 | 0.1 | 0.2 | 86.7 | 94.3 | 88.9 |
| PO₄-P (mg/l)| 0.2    | 0.25 | 0.45 | 0.27 | 0.01 | 0.05 | 0.04 | 96 | 99.2 | 85.2 |
| Total P (mg/l)| 0.2  | 0.27 | 0.98 | 0.40 | 0.04 | 0.07 | 0.03 | 85.2 | 92.8 | 92.5 |
| SO₄-S (mg/l)| 400    | 65  | 75  | 90  | 3.9 | 2.5 | 2.4 | 94 | 96.7 | 97.3 |
| TOM (mg/l)  | 50     | 490 | 385 | 320 | 12 | 10 | 7 | 97.6 | 97.4 | 97.8 |
| Hardness (mg/l) | 500 | 750 | 220 | 370 | 70 | 40 | 50 | 90.7 | 81.8 | 86.5 |

*) Standard based on the Minister of Health Regulation No. 492/2010
industrial effluents [34]. Table 2 showed that the concentrations of \( \text{PO}_4^{3-} \) ion and total P in peat water were above the standard [8], 0.25, 0.45, 0.27 mg/l and 0.27, 0.98, 0.40 mg/l respectively. Water quality improvement can be noted after treatment by reduction of phosphorus compound concentration with removal efficiency 85.5 – 99.2 % for \( \text{PO}_4^{3-} \) ion and 85.2 – 92.8 % for Total P, and meeting the standard (under 0.2 mg/l).

The term natural organic matter refers to a wide spectrum of chemical compounds resulted from natural processes in the environment, including the decomposition of organic matter and algalmetabolic reactions [35]. Humic compounds usually dominate organic content in the peat water providing a variety of effects, such as color, organic load, and biochemical decomposition [36]. Total Organic Matter (TOM) may sometimes be responsible for the formation of disinfection by products, causing microbiological regrowth in water distribution systems [37]. Very high concentration of TOMs were observed in three types of peat water 495 mg/l, 385 mg/l and 320 mg/l, meaning that it did not meet the standard (Table 2). Significant reduction of TOMs content up to 7 – 12 mg/l, occurred after treatment with IPAG60 with removal efficiency 97.4 – 97.8 %. As reported by Mahmud et al. [38] in Sutapa [1], peat water with a high content of TOM had more hydrophobic and aromatic characters and most contributed to the color of peat water.

The bicarbonates, carbonates, sulphates, and chlorides of calcium and magnesium are generally the main chemical compounds determining the hardness level in water [39]. The acceptable limit of total hardness in drinking water is 500 mg/l refering to Minister of Health Regulation No. 492/2010 [9]. Based on this regulation, peat water from location 1 has total hardness 750 mg/l above the standard (500 mg/l). While peat water from locations 2 and 3, contained total hardness under the standard 220 mg/l and 370 mg/l. Reduction of total hardness was observed in clean water produced by IPAG60 up to 40 – 70 mg/l with removal efficiency 81.8 – 90.7 %. This level of total hardness is classified as soft to moderate based on Durfor et al classification [39].

3.3. Physical Parameter

The content of organic matter most probably influences the natural colour of peat water, usually brown to dark brown to [38],[40]. The colour intensity is closely related to the concentration of organic matter, mostly composed by humic acids. Table 3 showed that the colour of peat water from three locations were very high 610 TCU, 400 TCU and 250 TCU compared to the standard (15 TCU) for clean water. It means that these types of water are not suitable to be used directly by the local people. Treatment process by IPAG60 produced clean water meeting the standard by reducing the colour intensity up to 2 – 3 TCU with removal efficiency 99.2 – 99.5 %.

Turbidity is defined as an expression of the optical properties of a sample that causes light rays to be scattered and absorbed through the sample. Turbidity is caused by the presence of suspended and dissolved matter such as clay, silt, finely divided organic matter, plankton, other microscopic organisms, organic acids, and dyes in the water [41]. The turbidity of peat water coming from three different locations was 20 NTU, 25 NTU and 18 NTU respectively. It was slightly higher than the standard 5 NTU. Clean water produced by IPAG60 showed water quality improvement in term of turbidity by decreasing its values up to 1 – 2 NTU with removal efficiency 92 – 95 % as shown in Table 3. Sutapa [1] explained that the reduction of turbidity during the treatment was closely due to the process of coagulation-floculation followed by species formation occurring through a series of reactions as coagulant hydrolysis when coagulant was added. The ability of the positive charge of the coagulant floc in absorbing humic and fulvic acid before floc settlement will cause the reduction of color and turbidity levels in the water [42].
Table 3. The Results of Physical Parameters Analysis

| Parameter       | Unit | Average Value | Result after 48 hr | Standard Limit*) |
|-----------------|------|---------------|--------------------|------------------|
| Colour (TCU)    |      | 610 400 250   | 3 2 2             | 99.5 99.5 99.2   |
| Turbidity (NTU) |      | 20 25 18     | 1 2 1             | 95 92 94.4       |

*) Standard based on the Minister of Health Regulation No. 492/2010

The results of this research showed the performance of IPAG60 was comparable to the work done by Syafalni et al [14]. These authors used a batch plastic column with dimensions: 5.4 cm diameter and 48 cm length to treat peat water originating from Beriah Peat Swamp Forest, Malaysia. Their system can increase peat water quality initially: pH = 4.67 – 4.98, colour = 224.7 TCU, turbidity = 20.8, Fe = 1.24 mg/L to pH = 7.78, colour = 12 TCU, turbidity = 0.23 NTU, and Fe = 0.11 mg/L on the 48 hours treatment (Table 4).

Table 4. Results of peat water treatment using combination of cationic surfactant, modified zeolite, granular activated carbon, and limestone in laboratory scale [14].

| Parameter       | Unit | Average Value | Result after 48 hr | Standard Limit*) |
|-----------------|------|---------------|--------------------|------------------|
| pH              |      | 4.67 – 4.98   | 7.78               | 6.5-9.0          |
| Temperature     | °C   | 27.8          | 29                 | -                |
| TDS             | mg/L | 20.6          | 74                 | 1000             |
| DO              | mg/L | 3.4           | 4.03               | 7                |
| Conductivity    | uS/cm| 34.5          | 137                | 0.5              |
| Salinity        | ppt  | 0.002         | 0.05               | 0.5              |
| Colour          | TCU  | 224.7         | 12                 | 15               |
| Turbidity       | NTU  | 20.8          | 0.23               | 5                |
| COD             | mg/L | 33.3          | 0                  | 10               |
| Iron (Fe)       | mg/L | 1.24          | 0.11               | 0.3              |
| NH₃-N           | mg/L | 0.51          | NA                 | 15               |

Note: 1. *) Malaysian standard for drinking water quality  
2. NA = Note analysed

4. Prospect of IPAG60

The main aim of clean/drinking water treatment is, in general, to improve water quality, by removing: a) suspended particles carried along with the surface water; b) dissolved organic and inorganic matter; c) disease causing micro-organisms in the water to ensure its safety for different uses [43][44]. Based on this study, IPAG60 showed the ability to produce clean water meeting the standard, from different types of peat water with high removal efficiency for almost all of relevant parameters. Sutapa [1] reported that IPAG60 had a good ability and reliability in improving peat water quality, by using STORET score method. IPAG60 produced clean water with good status and comply with the standard based on Minister of Health Regulation No. 492/2010. These results confirm the capability of IPAG60 as alternative solution to provide clean/drinking water in peatland areas. IPAG60 can probably be used to treat different types of raw water coming from various conditions of inland surface water that generally have better quality than peat water.
Despite of IPAG60 performance, it is important to take into account the compatibility of this technology to the readiness of local people to adopt it (Figure 2). Field experiences of IPAG60 implementation in two locations (Bengkalis, Riau Province and Katingan, Central Kalimantan Province), showed that local peoples in peatland areas had quite high awareness and readiness to receive new technology. However, it necessary to involve them from the beginning of IPAG60 introduction including: problem identification related to water services, planning, construction, operation training, monitoring, maintenance and evaluation activities.

5. Conclusion
This paper showed that IPAG60 had ability to improve peat water quality for three clusters of parameters (biological, chemical and physical) with high removal efficiency. Clean water produced by IPAG60 form different types of peat water, had a very good quality and complied with the standard of Minister of Health Regulation No. 492/2010. With certain conditions, IPAG60 had a good compatibility as alternative technology to provide clean/drinking water in peatland areas.

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