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An Assessment of Lime, Alum, and Activated Carbon in Purifying Peat Water for Clean Water

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ABSTRACT Central Kalimantan has a large area of peatland that contains a significant amount of peat water, which can be utilized as a source of clean drinking water. Meanwhile, the community still lacks clean water because peat water is acidic to highly acidic, corrosive, and reddish-black, making it unsuitable for human use. Therefore, efforts are needed to purify peat water to be suitable for human consumption. This study aimed to assess the effectiveness of using calcium carbonate lime, alum, and activated carbon to purify peat water. This research was divided into two stages: a preliminary study, which involved testing the combination of the three materials mentioned above at varying doses, specifically 0.3 g/L, 0.6 g, and 0.9 g/L, resulting in 33 treatments. Test parameters in preliminary research are pH, water colour, and water appearance. In the primary research, the observed variables were pH, water colour, TDS, and the appearance of water. In the main study, the best six treatments from the preliminary study were used, where the pH value was close to normal, ranging from 5.76 to 6.16, and the colour value ranged from 4 to 15 Pt-Co, with no foam. The best 3 main research results carried out complete testing of physical, chemical and microbiological water quality parameters for clean water, namely physical parameters (colour, odour, taste, turbidity, temperature, and TDS), chemistry (organic matter, pH, hardness, iron, manganese, sulphate, nitrite, chloride, nitrate, zinc, cyanide, fluoride, ammonia, aluminium and copper), and microbiology (total coliform and *E. coli*). Based on the results obtained, in the main study, the use of a combination of calcium carbonate, lime, alum, and activated carbon at doses of 0.3 g/L, 0.3 g, and 0.6 g/L respectively, was very effective in purifying peat water into water suitable for human consumption, so these doses are recommended for purifying peat water.

Keywords: Activated carbon, alum, lime, peat water

INTRODUCTION

Central Kalimantan is one of the provinces in Indonesia with extensive peatlands, covering approximately 2.66 million hectares, or around 55.7% of the total peatland area in Kalimantan (Osaki *et al.,* 2016). According to Yuliani (2014), peatlands are important because they can store around 850 litres of water in every cubic metre. Central Kalimantan has abundant water resources, such as peat water. This makes peat water a potential source of water that can be utilised for the community's needs. However, such great potential is somewhat limited in its use for the needs of the Central Kalimantan community for washing, bathing, and consumption because peat water has a low pH (3-5) which is acidic and corrosive, brownish red to blackish, and contains high levels of organic matter and humic acid (Sudoh *et al.*, 2015; Notodarmojo *et al.,* 2017), which can bind heavy metals such as iron (Fe) and manganese (Mn) (Zulfikar *et al.,* 2014), making it unfit for use and consumption (Amalina, 2018; Rusdianasari *et al.,* 2019) and if used and consumed can have negative impacts, such as skin irritation, tooth decay, dental caries, indigestion, and cancer (Rusdianasari *et al*., 2019; Sari & Shuri, 2020; Nawan *et al*., 2023). According to the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017, the quality of such peat water does not meet the requirements for sanitary hygiene and clean water. Therefore, special treatment is needed to use peat water for sustainable clean water (Ali *et al*., 2021). Furthermore, according to Government Regulation of the Republic of Indonesia No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, peat water, with its specific characteristics, is classified as class 4 water quality standards, which can only be used for irrigation purposes.

Meanwhile, water is a vital source of life for humans (Campbell *et al.*, 1999). Furthermore, water is a crucial and fundamental component for living things, as the bodies of living organisms contain more than 70% water (Campbell *et al.,* 1999; Syafalni *et al.,* 2013; Amalina, 2018). On the other hand, fresh water is one of the basic human needs that can be obtained from various sources. Meanwhile, clean water is used for daily needs, and its quality meets health requirements. It can be drunk after cooking, which fulfils the Regulation of the Minister of Health of the Republic of Indonesia No. 492 of 2010 (PERMENKES RI No. 492/MENKES/PER/IV/2010). The need for clean water increases yearly due to population growth and increased community activities. The growing need for clean water must be directly proportional to the community's availability of clean water resources.

However, the availability of clean water remains inadequate, both in terms of quantity and quality. According to Fitriati *et al*. (2021), the current availability of clean water still falls short of meeting the needs of the people of Central Kalimantan, especially in rural areas. This is due to the lack of clean water supply companies and inadequate access to clean water in rural areas. Communities with areas that have not yet met their clean water needs generally rely on groundwater and rainwater to fulfill their daily needs. The communities in peat river areas still use peat water to fulfil household needs such as bathing, washing, and toileting (Sari & Shuri, 2020; Ulfa *et al.*, 2022; Nawan *et al.*, 2023). Therefore, processing peat water into water suitable for consumption and meeting quality standards is an effort to meet the community's water needs and utilise the potential sources of peat water.

Peat water treatment can be done using simple methods and affordable materials everywhere (Mirbagheri & Sesseini, 2005; Sururi *et al.*, 2020). One way to treat water is to use calcium carbonate ($CaCO_3$) lime, alum ($Al_2(SO_4)_3$), and activated carbon. Lime and alum function as coagulants that neutralize and bind dirt particles, allowing them to be easily deposited (Hamzani *et al.*, 2017; Kiswanto *et al.*, 2019; Sururi *et al.*, 2020; Muhammad, 2020). According to Sudoh *et al.* (2015), calcium carbonate is more effective in removing humic acid from peat water. Moreover, alum, polyaluminium chloride (PAC), and ferric chloride (FC) are commonly used in water treatment as coagulants to remove delicate particulate matter (USEPA, 1999; Sudoh *et al.*, 2015). Meanwhile, activated carbon filters reduce bacteria, odour, colour, and other organic substances. Activated carbon can also be used as an absorbent to reduce humic acid (Maghsoodloo *et al.*, 2011; Sari & Mashuri, 2020), especially ion pollutants with smaller molecular weights (Cai *et al.*, 2022). Therefore, this study aims to assess the effect of a combination of lime (CaCO3), alum ($Al_2(SO_4)$ 3 ·12H2O), and activated carbon on purifying peat water to meet the community's need for clean water.

MATERIALS AND METHODS

This research was conducted at the Peatland Laboratory of CIMTROP, University of Palangka Raya, from June 19 to September 19, 2022. This research was conducted in two stages. The first stage involved preliminary research to determine the optimal combination of calcium carbonate, lime, alum (aluminum sulfate), and activated carbon. This preliminary research design employed a factorial group-randomised design. The experiment was conducted on a 1.5 L plastic bottle filled with 1 L of peat water. The concentrations of the purifiers were 0.3, 0.6, and 0.9 g/L; therefore, the number of experimental units in this preliminary research was 33, with 27 units at each concentration. The treatments in this experiment are listed in Table 1. The peat water used in this study was taken from a canal in Cilik Riwut Street, Palangka Raya, Central Kalimantan.

Table 1. Combination of lime, alum, and activated carbon in preliminary research on peat water purification.

Treatment	Purification material/L		
	Lime $CaCO_3$ (g)	Alum (g)	Activated carbon (g)
A	0.3	0.3	0.3
B	0.3	0.3	0.6
C	0.3	0.3	0.9
D	0.3	0.6	0.3
E	0.3	0.6	0.6
F	0.3	0.6	0.9
G	0.3	0.9	0.3
H	0.3	0.9	0.6
I	0.3	0.9	0.9
J	0.6	0.3	0.3
K	0.6	0.3	0.6
L	0.6	0.3	0.9
M	0.6	0.6	0.3
N	0.6	0.6	0.6
O	0.6	0.6	0.9
P	0.6	0.9	0.3
Q	0.6	0.9	0.6
R	0.6	0.9	0.9
S	0.9	0.3	0.3
T	0.9	0.3	0.6
U	0.9	0.3	0.9
V	0.9	0.6	0.3
W	0.9	0.6	0.6
X	0.9	0.6	0.9
Y	0.9	0.9	0.3
Z	0.9	0.9	0.6
AA	0.9	0.9	0.9

The parameters observed and measured in the preliminary research were pH and colour. In the primary research, the parameters observed and measured were pH, colour, TDS, and the condition of the water. The YSI pH meter and Hanna instrument HI96727 measured the water pH and color, respectively. Meanwhile, TDS was measured using a TDS meter. The six best preliminary results used in the primary research were treatments B, C, N, O, P, and Q, which involved combinations of lime, alum, and activated carbon, as shown in Table 1.

The design in the primary research employed a completely randomised design with three replications. The experiment was conducted on a 6 L water gallon filled with 5 L of peat water. The results of the primary research of the three best treatments carried out complete testing for clean water with test parameters in the form of physical parameters (colour, odour, taste, turbidity, temperature, and TDS), chemistry (organic matter, pH, hardness, iron, manganese, sulphate, nitrite, chloride, nitrate, zinc, cyanide, fluoride, ammonia, aluminium and copper), and microbiology (total coliform and *E. coli*) were treatment B, C, and N. All the parameters were detected using the standard water quality analysis methods.

Data Analysis

Water quality in the preliminary study was analyzed descriptively, while water quality in the main study was analyzed using ANOVA in SPSS. Meanwhile, the quality of peat water samples before and after purification was analyzed descriptively by comparing the quality of the peat water samples with the drinking water quality requirements set by the Regulation of the Minister of Health of the Republic of Indonesia No. 492 of 2010.

RESULTS AND DISCUSSION

The preliminary research results on the quality of peat water samples, including pH and color, treated with calcium carbonate lime, alum, and activated carbon in various combinations, are presented in Table 2. An additional observation of the clarified peat water was the presence or absence of foam. Therefore, the six treatments selected were those with a pH close to normal, ranging from 5.76 to 6.16, and a colour that qualified as clean water according to the clean water quality standards, ranging from 4 to 15, and no foam. Hence, the treatments selected were B, C, N, O, P, and Q, which included a combination of calcium carbonate, lime, alum, and activated carbon, as shown in Table 2. This preliminary

Table 2. The pH and colour values, as well as the condition of the sample water in each treatment.

Treatment	pH	Colour	Description
A	5.03	3	No foam
B	6.16	5	No foam
C	6.03	15	No foam
D	4.71	4	No foam
E	4.25	5	No foam
F	4.36	16	No foam
G	4.29	4	No foam
H	4.23	8	No foam
I	4.06	17	No foam
J	5.42	4	No foam
K	5.51	8	No foam
L	5.57	16	No foam
M	4.66	5	No foam
N	6.08	10	No foam
O	5.76	15	No foam
P	5.99	4	No foam
Q	5.98	5	No foam
R	4.36	16	Slightly foam
S	6.13	4	Foam
T	6.21	8	Foam
U	6.10	17	Foam
V	6.05	5	Foam
W	5.88	9	Foam
X	5.96	17	Foam
Y	5.76	4	Foam
Z	6.55	7	Foam
AA	5.80	15	Foam

research shows that lime, alum, and activated carbon can purify peat water. This is supported by the research of Prasad *et al.* (2019) and Sudoh *et al*. (2015), which indicates that lime and alum are commonly used to treat water because they are relatively inexpensive and effective in removing dissolved chemicals, suspended solids, and water colour. Lime is specifically helpful in increasing the pH of water and precipitating suspended solids over time. Furthermore, activated carbon is an effective absorbent for purifying water high in organic compounds (Eltekova *et al*., 2000; Syafalni *et al*., 2012). Furthermore, the results of this preliminary test also indicate that the optimal combination of lime, alum, and activated carbon yields relatively good results in purifying peat water.

The main research results for sample water quality, in terms of pH and average colour, are presented in Table 3. Based on these results, the pH value ranges from 4.29 to 6.97, while the colour ranges from 4 to 15. At the same time, the condition of the sample water is no foam, little foam, and foam. Based on the results of this primary research, the optimal combinations of lime, alum, and activated carbon were found to be 0.3-0.6 g/L, 0.3-0.6 g/L, and 0.6-0.9 g/L, respectively. Treatments with a pH close to neutral were used as candidate samples for testing physical, chemical, and microbiological parameters, namely treatments B, C, and N. While based on the colour of the water samples, all treatments in this study met the clean water quality standards; therefore, the limiting factor was the condition of the samples, specifically whether they were foaming or not. Therefore, the three water samples selected for water quality analysis were treatments B, C, and N, which had the highest pH value and lowest colour, with no foam and little foam, respectively.

Table 3. Average pH and colour values, and appearance of sample water in the primary research.

Treatment	pH	Colour (Pt-Co)	TDS (mg/L)	Description
B	6.97 ± 0.05[a]	5 ± 0.2[a]	156 ± 5.89[a]	No foam
C	6.98 ± 0.19[a]	15 ± 1.4[c]	158 ± 1.18[a]	No foam
N	6.89 ± 0.02[ab]	10 ± 0.2[b]	267 ±17.91[b]	Slight foam
O	6.55 ± 0.15[b]	15 ± 0.9[c]	264 ± 8.49[b]	Slight foam
P	4.41 ± 0.07[c]	4 ± 0.2[a]	324 ± 4.48[c]	Foam
Q	4.29 ± 0.01[c]	5 ± 0.2[a]	333 ± 1.41[c]	Foam

*Superscript with the same letter in the same column means not different.

Based on ANOVA analysis, the different combinations of lime, alum, and activated carbon in peat water purification significantly affected the water's pH, colour, and TDS values (Table 4), with a p-value of <0.01. However, based on the results of further tests for the pH value of the purified water with the Duncan test, treatment B was not significantly different from treatment C, and N, but significantly different from treatment O, P and Q. Meanwhile, treatment P was not significantly different from treatment Q, just as treatment N was not significantly different from treatment O (Table 3).

Whereas, based on the results of further tests for the colour of purified water with Duncan's test, treatment B was not significantly different from treatment P and Q, but significantly different from treatment C, N and O. Otherwise, treatment P was not significantly different from treatment Q, just as treatment C was not significantly different from treatment O (Table 2). Meanwhile, based on the results of further tests for TDS of purified water with Duncan's test, treatment B was not significantly different from treatment C, but significantly different from treatments N, O, P, and Q. Instead, treatment N was not sig-

Table 4. ANOVA results of the effect of the combination of lime, alum, and activated carbon on peat water purification on water pH, colour, and TDS.

		Sum of squares	Df	Mean square	F	Sig.
pH	Between groups	25.327	5	5.065	133.653**	.000
	Within groups	.455	12	.038		
	Total	25.782	17			
Colour	Between groups	363.111	5	72.622	32.680**	.000
	Within groups	26.667	12	2.222		
	Total	389.778	17			
TDS	Between groups	90339.333	5	18067.867	134.112**	.000
	Within groups	1616.667	12	134.722		
	Total	91956.000	17			

nificantly different from treatment O, just as treatment P was not significantly different from treatment Q (Table 3). Therefore, the most effective treatment from this main study was treatment B, which consisted of doses of lime, alum, and activated carbon at 0.3 g/L, 0.3 g/L, and 0.6 g/L, respectively.

The water quality of the three selected treatments in the main study is presented in Table 5. After water purification using calcium carbonate lime, alum and activated carbon, the colour of the water decreased significantly from 868 to 6 in the best treatment, namely treatment B with a combination of calcium carbonated lime, alum and activated carbon of 0.3/0.3/0.6 g/L each, but dissolved solids TDS increased significantly from 28 mg/L to 250 mg/L in treatment B. This occurred due to the use of purifying agents. This occurred due to the use of clarifying materials. The same finding was also reported by Saputra et al. (2014), who stated that lime and alum can be used to purify peat water. Although there was an increase in dissolved solids in treatment B in this study, it still met the quality standards for clean water. Similarly, the pH value increased significantly from 3.8 to 7.3 in treatment B, representing a 92.1% increase in pH. At the same time, the colour experienced a significant decrease from 868 Pt-Co to 6 Pt-Co in treatment B, representing a 99.3% decrease. This colour reduction value is higher using a combination of lime, alum, and activated carbon compared to using NaClO as an oxidation catalyst and a physical filter, namely manganese sand, where the colour reduction is around 78.77% at low iron content (Arifianingsih *et al.*, 2020).

Furthermore, the copper (Cu) content decreased slightly in the treated water sample, which was 31.1%. The odour, taste, and metal content of iron, manganese, and zinc in the treated water samples did not differ from those of the untreated peat water samples. There were no coliform or *E. coli* bacteria in the peat water, as indicated by a result of 0 (zero) for both total coliform and *E. coli* bacteria. This indicates that the quality of the peat water used as a sample remains good, except for its colour and pH, so the peat water can still be used as clean water. This is consistent with Rasidah *et al*. (2017), who reported that peat water can become clean. Based on all parameters tested, treatment B fulfills all drinking water quality requirements, while treatments C and N have parameters that do not meet these requirements. Nevertheless, all selected samples contained fluoride ions, ranging from 0.13 to 0.22 mg/L, which is not harmful to human teeth and bone health. According to Saini et al. (2021), concentrations of fluoride ions greater than 1.5 mg/L are detrimental to dental and bone health.

Table 5. Water quality of selected samples in the primary research on peat water purification.

Parameter	Treatment			
	Peat water	B	C	N
Physics				
Colour	868	6	16	11
Odour	No odour	No odour	No odour	No odour
Taste	No taste	No taste	No taste	No taste
Turbidity, NTU scale		0.38	0.29	0.26
Temperature □C		27.3	27.2	27.3
Dissolved solids (TDS), mg/L	28	250	230	357
Chemistry				
Organic substances (as $KMnO_4$), mg/L		9.4421	10.605	9.954
Acidity degree (pH)	4.5	7.3	7.7	7.8
Hardness, mg/L		172.656	167.31	289.278
Iron (Fe), mg/L	<0.027	<0.027	<0.027	<0.027
Manganese (Mn), mg/L	<0.014	<0.014	<0.014	<0.014
Sulphate (SO_4^{2-}), mg/L		203.5	173.5	321
Nitrite (as NO_2), mg/L		<0.010	<0.010	<0.010
Chloride (Cl^-), mg/L		0.4829	0.1084	0.0493
Nitrate (as NO_3), mg/L		3.071	3.551	3.157
Zinc (Zn), mg/L	<0.007	<0.007	<0.007	<0.007
Cyanide (CN), mg/L		<0.008	<0.008	<0.008
Fluoride (F), mg/L		0.15	0.13	0.22
Ammonia (NH_3), mg/L		<0.07	0.15	0.1
Aluminium (Al), mg/L		<0.062	<0.062	<0.062
Copper (Cu), mg/L	0.045	0.031	0.034	0.034
Microbiology				
Total coliform, amount/100 mL	0	0	25	15
Escherichia coli (*E. coli*), amount/100 mL	0	0	0	0

CONCLUSION AND RECOMMENDATION

Conclusion

Based on the results obtained, the use of calcium carbonate, alum, and activated carbon, with concentrations of 0.3 g/L, 0.3 g/L, and 0.6 g/L, respectively, is highly effective in purifying peat water to produce clean water that meets health standards.

Recommendation

Calcium carbonate, lime, alum, and activated carbon with compositions of 0.3 g/L, 0.3 g/L, and 0.6 g/L, respectively, can be used in peat water purification as an effort to utilise peat water for the clean water needs of communities surrounding peatlands. Since the method used is still on a small scale, upscaling is required by conducting demonstration plots in the community, followed by an economic analysis.

AUTHORS' CONTRIBUTIONS

The outhors contributions in the manuscript as follows, YY: preparation, research, data analysis, article writing and publication; EH: proposal writing and research method design; PP: preparation, literature study, research; MAW: literature study, research, article writing; IT: data analysis, research; KB: data analysis; DN: article writing and publication; RE: article writing and publication.

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