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Analysis of the application of polluted groundwater treatment technology using shell-based activated carbon media filters

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ABSTRACT

One source of clean water used by residents of Kp. Sendal Kopo, Panenjoan Village, Carenang District, Serang Regency comes from dug wells (groundwater). This clean water has problems with water conditions that are very cloudy, yellow, taste sour, and smelly due to the contamination of some wastes and the rest of the rice field irrigation system. One alternative in treating polluted groundwater is to design a water filter installation from PVC pipes using activated carbon media from coconut shells and additional media for filter foam, injuk, zeolite stone, activated carbon, and silica sand to produce good raw water quality. Simple water analysis by making a water filter. The results of the analysis showed that the water content of activated carbon as the main medium was made after adding the activating agent $ZnCl_2$, CaCl or KCl 25% for 12-18 hours, indicating that the results met the SNI 06-3730-1995 regarding the standard of quality requirements and testing of activated charcoal both for water content <15% and ash content <10% are 7.56% and 7.89% ash content, respectively. The tool was tested on water sampels ranging from color, pH, and Fe content from Panenjoan Village. The color of the water showed very good results, initially it was cloudy yellowish after passing through the filter to become clear white. The pH test shows the result of 6.9, in this case it is still within the threshold because according to the regulation of the minister of health, Number: 492/Menkes/Per/IV/2010 the pH is 6.5-8.5. The Fe content produced is 0.65 mg/l, while according to the Minister of Health Regulation No.492/Menkes/Per/IV/2010 it is 0.3 mg/l.

ABSTRAK

Salah satu sumber mata air bersih yang digunakan warga Kp. Sendal Kopo, Desa Panenjoan, Kecamatan Carenang, Kabupaten Serang berasal dari sumur galian (air tanah). Sumber mata air bersih ini memiliki masalah dengan kondisi air sangat keruh, kuning, berasa asam dan berbau akibat berasal dari pencemaran beberapa limbah dan sisa sistem pengairan sawah. Salah satu alternatif dalam pengolahan air tanah yang tercemar dengan mendesain instalasi filter air dari pipa PVC menggunakan media karbon aktif dari tempurung kelapa dan media tambahan busa filter, injuk, batu zeloit, karbon aktif dan pasir silika agar menghasilkan kualitas air baku yang baik. Analisis air sederhana dengan membuat filter air. Hasil analisis menujukan kadar air karbon aktif sebagai media utama yang dibuat setelah menambahkan agen aktivator $ZnCl_2$, CaCl atau KCl 25% selama 12-18 jam menujukan hasil memenuhi syarat standar SNI 06-3730-1995 tentang standar syarat mutu dan pengujian arang aktif baik untuk kadar air < 15% dan kadar abu <10%, yaitu 7.56% dan kadar abu 7.89%. Alat tersebut diuji terhadap sampel air mulai dari warna, pH, dan kadar Fe dari Desa Panenjoan. Warna air setelah diuji menujukan hasil yang sangat baik, dimana semula berwarna keruh kekuningan setelah melewati filter menjadi putih bening. Pengujian pH menunjukan hasil 6.9, dalam hal ini masih dalam ambang batas karena menurut peraturan menteri kesehatan, Nomor: 492/Menkes/Per/IV/2010 pH sebesar 6.5-8.5. Kadar Fe yang dihasilkan sebesar 0.65 mg/l, sedangkan menurut Permenkes No.492/Menkes/Per/IV/2010 yaitu 0.3 mg/l.

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1. Introduction

Mapping results from domestic wastewater zoning conducted by POKJA AMPL-BM Kab. Serang (2015) in Panenjoan Village, Carenang Sub-district, with on-site services with a communal approach through community-based sanitation programs, is considered less able to be combined with triggering household-based on-site services. This issue necessitates prompt treatment (red indication) in communities with high-risk locations. The water quality for residential use in Panenjoan Village is now murky, with a sour flavour and odour. The majority of inhabitants in Panenjoan Village depend on groundwater to satisfy their daily home needs for raw water (clean water). The use and utilization of water for domestic purposes will cause water pollution if it is not managed and handled in an integrated manner. The liquid environment that is polluted due to the increasing volume of domestic wastewater pollution, both from laundry wastewater, bathrooms (grey water) and waste from toilets (black water), is shown in Figure 1.

a b c

Figure 1. - (a) Laundry waste; (b) bathroom waste; (c) WC waste.

POKJA AMPL-BM Kab. Serang 2015 in the District Sanitation Strategy (SSK) has determined priority areas for developing wastewater management systems in general. The system is either an on-site or off-site system [1]. The criteria used in determining development priorities include population density, area classification (urban, peri-urban, rural), land use characteristics (Central of Business Development (CBD)) and environmental health risks. The problem experienced by Panenjoan Village is that it has not enjoyed clean water like other villages. Although currently, Panenjoan Village has one unit of wastewater treatment technology, in reality, this has not been maximized to meet the needs of residents. The situation exists because the central government's community-based sanitation (Sanimas) program is confined to solely home wastewater. The results obtained are used to irrigate the fields, not to meet the domestic water needs of the residents of Panenjoan Village. In addition, the current condition of the water treatment technology unit is no longer functioning properly. It is proven that the water entering and leaving the processing unit is the same or not different.

Figure 2. Well water in Panenjoan Village.

Figure 2 shows that the residents of Panenjoan Village currently do not enjoy clean water for their residents' domestic needs because the condition of the water used is very cloudy, yellowish, has a sour taste and smells. This condition is strongly suspected of contamination from domestic water waste, bathroom washing wastewater, toilet waste, and the rice field irrigation system. The need for raw water (clean water) for all residents of Panenjoan Village is very important. The reason is based on the domestic wastewater zoning mapping conducted by POKJA AMPL-BM Kab. Serang 2015, which shows that this area is at high risk and requires immediate treatment (red indicator), is strengthened by the results of surveys and analysis. Analysis of water samples taken from Panenjoan Village showed cloudiness, sour taste and smell.

Water samples taken from Panenjoan Village were analyzed for colour, taste, and smell. The results of studies based on previous journals and articles with the same case as the research conducted in [2], activated carbon from coconut shell media can remove problematic chemicals in the most efficient and cost-effective water source. Potassium carbonate is used as an activating and destabilizing agent in charcoal to develop carbon pores with a high specific surface area (>1200mg−1) and efficient removal of water-soluble nitrates [3]. Filter media using activated carbon charcoal, sand, laterite can and efficiently reduce 100% iron, 53% sulfate reduction, 20% reduction in dissolved solids and 12% reduction in hardness [4]. Activated carbon is one of the most widely used adsorbents for water treatment and wastewater removal of organic and inorganic pollutants. Activated carbon in the adsorption process is strongly influenced by the surface area of the carbon and the pore structure of the carbon [5]. Filters with dual media made of coconut shell activated charcoal are proven to be more efficient, economical and durable. This dual media filter can also remove particulates and other suspensions in the form of impurities from the water that passes through the filter media to remove turbidity much better and is easy to apply [6].

Granular activated carbon is applied as a post-treatment technology in wastewater treatment plants (WWTP) to increase the elimination of organic micropollutants (OMP) [7]. The activated carbon filter treats residential effluent quickly and efficiently, reduces contaminants to 50% after 100 days of operation (<7200 BV), and has a more environmentally friendly footprint. The six researchers showed that the main water contaminants can still be removed by physical methods, namely simple water filtration. Two-stage co-pyrolysis synthesized a low-cost and well-developed type of activated carbon (AC) from coconut shells and municipal sludge [8]. Activated carbon with carbon nanotubes and graphene efficiently produces water purification performance [9].

After conducting a survey and analysis of colour, taste and odour tests and a research study conducted in [10-11], the results are in line with the conclusions made by POKJA AMPL-BM Kab. Serang, in 2015, shows that the pollution condition is strongly suspected of having come from contamination of residual domestic water discharge from laundry wastewater, bathrooms, toilet waste and the rest of the rice field irrigation system. The similarity of this research with previous research, namely the use of activated carbon from coconut shells as the main medium. The difference with this research is that the design is very economical to use for the needs of the residents of Panenjoan Village, who, on average, have low economic abilities. In addition, this tool is very flexible and can be installed easily from one place to another.

2. Research Methodology

Making a water filter from a PVC pipe is presented in Figure 3. The water filter from a PVC pipe is one assembly with a specific pipe size of 4 inches in diameter with a length of m as many as two pieces, 4 4 inch hubcaps, 5-inch valves, four tank clamps PVC inch, 6-inch outer shock thread, 2-inch inner shock thread, 7 inch L bow, 5-inch union, 3 inches T joint, 4-inch rubber seal, 21-inch water pipe 5 cm long, pipe 2 rods of an inch long water pipe, 17 cm long of 1 rod, 1 rod of 45 cm long, 1 rod, 2 rods of 7.5 cm long water pipe, pipe glue, then all the PVC pipe components are installed to form a single unit.

Figure 3. The process of making water filters from PVC pipes.

Figure 4 is the manufacture of activated charcoal through the coconut shell burning process carried out in an iron tank (drum capacity 200 L), which had previously been drilled with a small 4-point drill machine at the bottom with a size of an inch, and 3 inches at the top connected to an iron pipe. Three inches touch the bottom of the 920 mm long inner drum. At each end of the welded iron pipe bottom and top, the top end can be closed. The coconut shell is then inserted and burned little by little until it ignites to produce a bluish flame, then it is tightly covered with clay and left overnight until the coconut shell completely turns into charcoal.

Figure 4. Drum design for making charcoal from coconut shells.

The cooled burning charcoal is removed from the combustion drum, then the charcoal that has undergone perfect charcoal formation is selected by looking at the dark black charcoal results, which, when slammed, will break like pottery from clay. Furthermore, the charcoal is activated by soaking for 12-18 hours with a $ZnCl_2$, CaCl or KCl 25% solution and then filtered and dried in the sun [12-13]. The immersion then activates the carbon element, which has an amorphous form with an irregular structure contained in the charcoal. After making a simple water filter tube is complete and the manufacture of activated charcoal has been completed, it is continued by placing all the ingredients into a water filter pipe made of filter foam, injuk, silica sand, activated carbon and zeolite stone properly.

Wastewater treatment technology is a water technology that can change cloudy water, sour taste and smell into clean water through a filtering process using activated carbon as the main media, which has an irregular amorphous shape, wide surface pores with carbon properties as an adsorbent capable of adsorption of ions. Which is present in cloudy water, sour taste and odour, for example, NO^{3-}, NH_4, and H_2S maximally [14-15]. In addition to the main filter media, supporting media has a perfect function in the water purification process, such as silica sand, which is used to filter mud, soil, and large/small particles in the water. It is commonly used for early-stage filtration, and zeolite stone is a natural ion exchanger, binding E. Coli bacteria in the water that produces good quality water and is suitable for use in meeting the domestic needs of all Panenjoan residents [16-17]. Figure 5 is an implementation prototype carried out directly by trying to drain the cloudy and smelly water sample through the Kp in filter pipe. Sandal Kopo RT/RW: 004/001. The experimental design was carried out by draining each sample of wastewater as many as six samples of wastewater from different points with the discharge of the waste stream passing through a water filter set at an average of 6 litres/minute. Then from each sample point, the results were tested starting from colour, taste, pH and Fe content (mg/L).

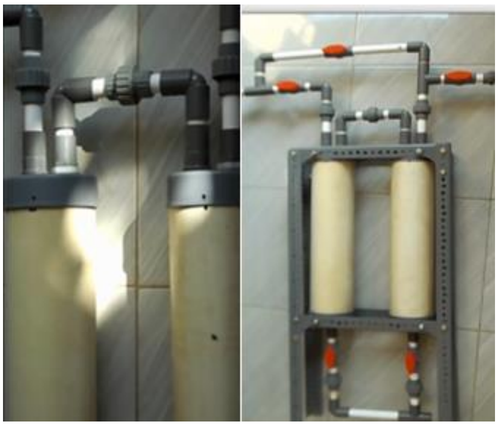

Figure 5. Water filter design.

3. Results and Discussion

3.1. Analysis of Moisture Content of Activated Carbon from Coconut Shell

Figure 6 is the result of coconut shell media processed into charcoal. This media is the result of combustion, then activated with a solution of $ZnCl_2$, CaCl or KCl 25% for 12-18 hours, then 1 gram is taken from every 12 hours, 16 hours and 18 hours and dried in an oven at a temperature of 110ºC for 2 hours and then cooled and weighed [18-19]. The average moisture content is calculated using Equation (1). The results of determining the water content of activated charcoal from coconut shells in this study obtained the results presented in Table 1.

Figure 6. Carbon soaking process with $ZnCl_2$, NaCl or 25% KCl for 12-18 hours.

$$\text{rate} = \frac{\text{initial active weight} - \text{active weight after heating}}{\text{initial active weight}} \tag{1}$$

Table 1. Results of determining the moisture content of activated charcoal from coconut shells.

Soaking solution	Soaking time 1 gram charcoal (hours)	Activated charcoal weight (grams)		Water content (%)
		Initial state	After heating	
$CaCl_2$, $ZnCl_2$, KCl 25%	12	1.0956	1.0127	7.567
$CaCl_2$, $ZnCl_2$, KCl 25%	16	1.1095	1.0286	7.292
$CaCl_2$, $ZnCl_2$, KCl 25%	18	1.1183	1.0308	7.824

Table 1 shows that the activated carbon produced has good adsorption capacity compared to without the activation process with a 7-8% water content. This condition is because charcoal that has undergone an activation process produces a larger surface area of charcoal, as indicated by the volume and diameter of the charcoal pores that are getting wider. The pores of the charcoal are getting cleaner, which previously was still covered with impurities, especially the mineral components of silica, hydrocarbons, tar and organic compounds. After the condition of the carbon is activated, the adsorption capacity increases well when used.

3.2. Analysis of Activated Carbon Ash Content from Coconut Shell

The activated carbon, tested for moisture content, is then burned for 2 hours at a temperature of 110ºC in a nickel cup with a known constant weight. The activated carbon was then ashed in a furnace at 700ºC for 2 hours, cooled, and weighed. [20-[21]. Furthermore, calculations are carried out using Equation (2) to calculate the levels. Table 2 shows the results of the carbon condition after the activation process will give the characteristics of different carbon, especially water content and ash content which will give the charcoal quality to be good in absorbing impurity minerals in the water. The water content contained in the carbon after activation becomes 7.56%. This condition meets the requirements according to SNI 06-3730-1995 regarding quality, and testing for activated charcoal is a maximum of 15%. While the ash content contained in the carbon after activation is 7.89%, where the condition meets the maximum requirements of 10% by using the same SNI. The moisture content and ash content of activated carbon will give the maximum ability to activate carbon in absorbing hygroscopic properties.

$$\text{rate} = \frac{\text{initial active weight} - \text{active weight after ashing}}{\text{initial active weight}} \tag{2}$$

Table 2. The results of determining the ash content of activated charcoal from coconut shells.

Soaking solution	Soaking time 1 gram charcoal (hours)	Activated charcoal weight after heating (grams)	Ash content (%)	average ash content (%)
$CaCl_2$, $ZnCl_2$, KCl 25%	12	1.0127	9.647	
$CaCl_2$, $ZnCl_2$, KCl 25%	16	1.0286	7.253	7.890
$CaCl_2$, $ZnCl_2$, KCl 25%	18	1.0308	6.771	

3.3. How Water Filters Work

Water samples taken from Panenjoan Village are passed through a water filter with several stages of work. The first water stage is to pass through the injuk/foam filter. This stage is the stage of filtering water from materials with larger particle sizes, such as mud. After that, the water passes through the second stage, namely passing through the silica sand. At this stage, the silica sand (SiO_2) can remove the content of mud or soil and sediment in the water that is not lost after passing the first stage. At this stage, the water condition has shown to be clear but still contains Fe metal minerals and the like.

The third stage is water passing through activated carbon. This stage is where the water is absorbed through the pores of the activated carbon. Activated carbon functional groups such as carboxyl, hydroxyl and carboxylate, which give amphoteric properties to carbon, cause the activated carbon surface to be chemically reactive and affect its adsorption properties. Activated carbon with these functional groups can be acidic or basic. Water samples that pass through activated carbon contain many negative ions, and few positive ions can be seen from the pH value, indicating acid. The sour taste itself in the water sample, both negative and positive ions, will be bound by the functional group of activated carbon. The result of the process at this stage is that water containing some unwanted minerals such as colour, taste, odour and metal content will be absorbed by carbon substances [22]. The fourth stage is water passing through the zeolite stone. This stage is a perfecting stage after passing the previous stage. Zeolite pores filled with Na, K, Ca, Mg, and H_2O ions allow ion exchange and water release back and forth. The pH level after passing through the zeolite stone will increase. The condition results from the zeolite stone as an exchange and cation absorber.

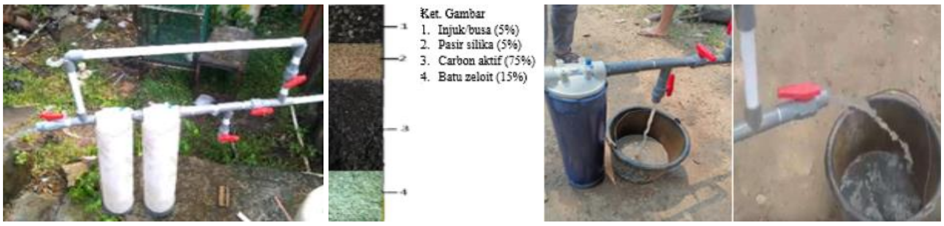

Figure 7. How the left water filter, right backwash, and clean water work.

Water samples taken from Panenjoan Village had originally cloudy yellowish, sour tasted and smelled conditions. The water sample was then tested using a water filter starting from the colour test, pH and Fe metal test. After being investigated and analyzed with the help of a spectrophotometer with a wavelength of 510 nm, these results showed the presence of Fe metal and other minerals at 6 sample points taken with the mean value was 3.02 mg/l. This value is not much different from the research conducted in [23], where the high suspended solids due to the impact of waste from domestic activities contained high Fe in several resident wells due to the influence of surface water entering the groundwater.

Table 3. The results of sample testing before and after filtration.

Well water quality	Condition		Chemical content	
	Taste	Colour	Average pH	Average iron (Fe) content (mg/l)
Before filtration	Sour	Yellow cloudy	4	3.02
After filtration	Normal	Clear white	6.8	0.65

Table 3 results after filtration using activated carbon media and other supporting media. The results showed a change in colour, taste, pH and metal content of Fe changed much better. The water's colour transformation from yellowish murky to clear as a result of the foam/injuk medium and silica sand absorbing the minerals in the sample. The foam/injuk filters coarse impurities such as mud, while silica sand acts as a pre-filter to remove mud, soil, small particles, and sediment from the water. The sour taste is caused by the pH of the water sample itself caused by bacteria and the negative ion content. The pH was originally four after passing through the filtering, rose to 6.8. This condition is due to the operation of zeolite stone as a mineral ion exchanger with a positive charge bound by a negatively charged zeolite to balance the ions in the water sample.

Figure 8. Result of pH test and Fe metal test.

The results of the iron content test shown in Figure 8 decreased from 3.02 mg/l to 0.65 mg/l because activated carbon has a major role in absorbing pollutants in samples with amorphous properties and a surface area ranging from 300-3500 m^2/g. In addition, as a good metal ion binder, the Fe content in water should not exceed 1 mg/l following Minister of Health Regulation No. 32 of 2017 [24]. The results obtained from the water condition before and after the research are shown in Figure 9. The figure shows the difference in polluted water from Panenjoan Village after being filtered using a very different filter, meaning that the filter works optimally starting from a colour change from cloudy yellow to clear and has a bland taste.

The results obtained as a whole from a series of tests of wastewater passing through a water filter show results that are in line with research that has been carried out in [2], namely the main medium of activated carbon is capable of removing chemical elements such as Fe, eliminating odours and purifying water. The same thing was also done in [4-5], that activated carbon reduced 100% of Fe and removed organic and non-organic pollutants. In this study, the maximum use of activated carbon could only reduce Fe levels by 0.65 mg/lt because the contact time between wastewater and the media in the filter is less long. The condition is influenced by the capacity and dimensions of the less extensive filter, so the contact time is very short. Suppose the contact time between the water and the media in the filter is longer. In that case, the absorption and bonding capacity between the wastewater and the media it passes will be perfect, especially with activated carbon with amorphous properties that maximize its absorption.

Figure 9. Water yield before (left) and after (right) filtration.

4. Conclusion

The well water condition is cloudy yellowish, has a sour taste and smells. After the analysis, the results show that the main cause is domestic waste, laundry waste, bathrooms, toilet waste, and the rice field irrigation system. The results of the water after passing through the water filter turned cloudy yellow to clear white, the sour taste became normal, the originally acidic pH increased to neutral pH, and the content of iron metal (Fe) dropped significantly into the good threshold and met the requirements to become water suitable for use, based on Permenkes No. 32 of 2017. The results of the overall test analysis show how important the role of the coconut shell activated carbon media filter is in producing clean water quality following the regulations set by the government. If the water used is not following water quality standards, it will impact the water users themselves, both physically and in the user's environment.

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