COMBINATION METHOD OF ADVANCED OXIDATION PROCESS (AOPs) AND ELECTROMAGNETIC WATER TREATMENT (EWT) TO REDUCE HEAVY METALS IN PIT LAKE

KOMBINASI METODE ADVANCED OXIDATION PROCESSES DAN ELEKTROMAGNETIC WATER TREATMENT UNTUK MENYISIHKAN LOGAM BERAT DI DANAU BEKAS TAMBANG

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ABSTRACT

Mining areas in Indonesia still use water sources from the pit lake, called Kolong. Kolong is raw water material of the water local company (PDAM) in obtaining clean water. The lake water usually processed with chemical and physicsmethods before distributed to the community. Whereas in fact the former mine lake water has a heavy metal content that is still relatively high. In mining areas, river and lake water are still polluted by heavy metals that harm living things that can not be decomposed directly by microorganisms naturally and even require a relatively long time to process them. Processed by using Advanced Oxidation Processes (AOPs) and Electromagnetic Water Treatment (EWT) become one of the processing alternatives by removing the heavy metals. The advantage of using this method is high efficiency, ability to process will not cause another waste andincluding as clean technology. The aim of this research activity is to test integrated water treatment system using the physical and chemical method by utilizing surface water contaminated by heavy metals through a combination of advanced oxidation technology and electromagnetic water treatment for physics-chemical water quality improvement which can be utilized by PDAM as raw water to get clean water. This research comparing no processing water, processing water with AOPs and EWT, then combining AOPs-EWT. The result of heavy metal removal in water can be reduced up to ± 90%.

Keywords: Heavy Metals, Water, AOPs, EWT, Water Quality

ABSTRAK

Daerah pertambangan di Indonesia masih banyak menggunakan air sumbernya yang berasal dari danau bekas tambang yang biasa disebut dengan Kolong. Kolong merupakan sumber air baku utama dari Perusahaan Daerah Air Minum (PDAM) yang digunakan untuk memproduksi air bersih. Air dari kolong tersebut diproses menggunakan bahan kimia dan metode fisika sebelum didistribusikan ke masyarakat. Dimana kenyataannya adalah air yang berasal dari danau bekas tambanga tersebut masih memiliki kandungan logam berat yang relatif tinggi. Di daerah pertambangan, sungai dan danaunya masih terkontaminasi oleh logam-logam berat yang membahayakan makhluk hidup dimana tidak dapat dikomposisi secara langsung oleh mikroorganisme secara alami dan bahkan membutuhkan waktu yang sangat lamauntuk memprosesnya. Menggunakan proses Advanced Oxidation Processes (AOPs) dan Electromagnetic Water Treatment (EWT) menjadi salah satu alternatif untuk menghilangkan logam-logam berat. Keuntungan menggunakan metode ini adalah memiliki efisiensi yang tinggi, tidak menimbulkan limbah lainnya dan merupakan teknologi bersih. Tujuan dari kegiatan penelitian ini adalah untuk menguji sistem pengolahan air terintegrasi menggunakan metode fisik dan kimia dengan memanfaatkan air permukaan yang terkontaminasi oleh logam berat melalui kombinasi teknologi oksidasi lanjut dan pengolahan elektromagnetik untuk peningkatan kualitas air fisika-kimia yang dapat digunakan oleh PDAM sebagai air baku untuk mendapatkan air bersih. Penelitian ini membandingkan air tanpa pengolahan, air pengolahan dengan AOPs dan EWT, kemudian menggabungkan AOPs-EWT. Hasil pelepasan logam berat dalam air dapat dikurangi hingga ± 90%.

Kata kunci: Logam berat, Air, AOPs, EWT, Kualitas air

1. INTRODUCTION

The main problem of water resources includes the quantity of water that has been unable to meet the ever-increasing needs and decreasing water quality for domestic needs. Industrial, domestic and other activities have a negative impact on water resources. One of them causes a decrease in water quality. This condition can certainly cause interference, damage, and harm to all living things that depend on water resources.

Community needs for clean water that is free of heavy metals and in accordance with the quality standards of clean water and drinking water are very large, considering that the source of their water comes mostly from former mining lakes, as well as in the world of industry the availability of clean water is also very necessary.

In recent years in several European countries, ozone technology for drinking water treatment has begun to be considered, the importance of using ozone has continued to increase over the past few years for the treatment of drinking water in all countries of the world. Since the early nineties, new regulations on the use of chlorine as a disinfectant and the formation of side products from chlorination reactions have been limited, so that there are expected to be technological alternatives that can improve the quality of the drinking water processing industry without the use of chemicals. However, a new problem was found from bromate as a by-product of the ozonation of drinking water treatment which certainly could reduce interest in the development of ozone in the field of drinking water treatment.

2. EXTENSION-RULE BASED THEOREM

So far the chemicals used in the ozonation process must be reduced, many of which have been published using chemicals in the ozonation process. It is now assumed that ozone reacts in aqueous solutions to various organic and inorganic compounds, either by direct reaction of molecular ozone or through a type of hydroxyl group radical reaction caused by the decomposition of ozone in water. Ozone decomposition is a chain reaction that includes chain initiation, propagation and breaking reactions.

The important role of hydroxyl ions in the process of ozone decomposition in water is well known. Based on the fact that many chemical compounds are capable of initiating (for example: hydrogen peroxide, humics, metal reducing compounds, formatting) and compounds to support processes (for example: primary and secondary alcohols, humics, ozone compounds themselves) or compounds to inhibit (for example: tertiary alcohols, carbonates) where they will form into a radical reaction. The general view of AOPs is the process of producing large amounts of radical compounds (especially OH ●) to oxidize organic matter.

Indeed OH ● radicals are less selective and are oxidants that are less strong than molecular ozone, there are some reaction rate constants based on a summary by Buxton et al. (Legube, 1999). The main mechanisms involved are: H abstraction, the addition of OH or substitution and displacement of electrons.

Ozone is naturally formed due to irradiation of ultra violet from the sun that works in fog, artificially can be formed from high-energy equipment, or made synthetically. Ozone radiation is expressed in ml of ozone per 1000 liters of air, or ppm. At the normal temperature of the room, ozone is a blue gas and has a distinctive odor. Ozone can be detected at a concentration of 2 x 10-5 to 1 x 10-4 g / m3 (0.01-0.05 ppm). The stability of ozone in the air is greater than in water. Ozone gas will explode at concentrations reaching 240 g / m3 or 20% by weight in the air.

The maximum ozone concentration in open space is 0.1 ppm while a concentration of 1.00 ppm can still be considered harmless as long as it is not inhaled into the respiratory tract for more than 10 minutes (Novarida, 2015). At 1 ppm, it can cause coughing and irritation after 8 minutes of irradiation, or after 1 minute at 4 ppm. Ozone radiation is fatal in less than 1 minute of radiation at 10,000 ppm.

The purpose of the present invention is to optimize the system in the prior invention and its specific purpose to produce a system for treating raw water into drinking water using a combination of physical and chemical processing, with an embodiment of equipment consisting of an oxidizing reactor unit equipped with a circulation tube, electromagnetic resonance unit equipped with circulation tubes, coagulator units and floculators, and reverse osmosis filtration units, and drinking water storage tanks, with a process through which they collect raw water from the source into the circulation tank; oxidize raw water from storage tanks using ozone from free air by separating nitrogen and oxygen in the ozone generator; remove nitrogen and take oxygen; breaking the double chain of oxygen into oxygen radicals by using a generator ozone between 5 to 15 minutes, so that ozone oxidizes heavy metals and harmful compounds in raw water; resonating raw water from the oxidation process using magnetic field resonance generated by a resonator tube containing direct current (DC) electric coils so that the molecules contained in the water will become groups (clusters) so that groups that are reactive (pure water) become larger and not obstructed by mixing material; accelerate the deposition of heavy metals and harmful compounds resulting from electromagnetic resonance by means of flocculation and coagulation; separating raw water and sediment from the results of the process with a screening process so as to produce drinking water that is suitable for consumption.

To find out the effectiveness and efficiency of the equipment, it is necessary to look for the system configuration that has been made. The step taken to implement this configuration is to test the performance of each existing system. After knowing the usefulness of each tool, the merger of the two systems is carried out, which is initiated by AOPs which functions to degrade organic material and solve compounds that are in the water. Then proceed with the EWT system to eliminate hardness and reduce the composition of metals in the water under.

Ozone can be produced in various ways, most of which require the breakdown of stable molecular oxygen bonds into two short-lived oxygen atoms. This reactive oxygen atom reacts almost directly (k = 1,9.10-11) with oxygen molecules that make up the ozone. There are many methods for producing ozone, including thermolysis of ozone in plasma above the temperature of 2760^{o}C followed by cooling using liquid oxygen, slow oxidation, beta radiation on oxygen in nuclear reactors, high current electrolysis in phosphate solutions at room temperature, electron beam radiation, oxidation of yellow phosphorus in air, ultraviolet (UV) radiation in air or oxygen and corona discharge.

In general there are two categories of ozonation reactions in liquids, namely:

i. Reactions that take place so quickly that the reaction rate is affected by the mass transfer of ozone into the liquid,

ii. A very slow reaction refers to the reaction rate. Because of the solubility of ozone in small water at low partial pressure, equipment is needed to contact ozone with water so that ozone mass transfer from the gas to water is optimum (Munter, 2001).

Electromagnetic Water Treatment (EWT) is processing hard water using static magnetic fields generated from permanent magnets. The magnetizing effect will cause the water to lose its ability to form a hard scale (calcite) and lead to the formation of a softer scale (aragonite). From the basis of the magneto hydrodynamic theory it can be seen that the dynamic fluid of a fluid that is condensed like a liquid electrolyte, can be changed by a trajectory through transconducting through a magnetic field (Martiningtyas, 2009). When conduction flows through a magnetic field, an electric field is produced based on Farady's law (Munter, 2001).

The method of water treatment with electromagnetic fields has a principle that is almost the method of treating water with a permanent magnetic field.

However, this electromagnetic field water treatment uses coils which are electrified with adjustable frequency so that there is a change in the magnetic field which will produce precipitation that is more effective and faster than the static magnetic field of the permanent magnet. This is because permanent magnets only produce static and continuous frequencies so that collisions of ions will be uniform throughout the hard water flow (Eckenfelder, 2000).

Iron/Fe (II) and manganese/Mn (II) which are usually contained in natural water can be rapidly oxidized by ozone to an insoluble oxide compound which can then be easily removed using a filtration process. The oxidation of Fe (II) by ozone is based on the theory of Hart where the reaction shows the occurrence of electron transfer from reduced metal to ozone, forming Fe (III) and radical ions O3 ● and then forming OH ●. The remaining Fe (II) from the reaction can be further oxidized by OH radicals which ultimately leads to a stoichiometric ratio of 0.5 moles of ozone per mole of iron per mole.

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3. METHODOLOGY

The research methodology is to use Advanced Oxidation Processes (AOPs) and Electromagnetic Water Treatment (EWT). AOPs functions to reduce heavy metals and organic compounds in water, as well as sterilization. AOPs is an equipment system that can produce O and OH radicals which function to degrade heavy metals in water.

EWT uses a magnetization method to treat water. EWT consists of a pipe which is given primary and secondary coils with a low-voltage electric current that causes an electromagnetic pulse.

The pulse electromagnetic functions is to eliminate hardness, to reduce the composition of metals in the water and to increase pH. The chemicals used in this research came from pit lake in Bangka Barat and without any condition.

The system built is specifically designed for local water company West Bangka which has been adapted to the characteristics of the originating material. To find out the effectiveness and efficiency of the equipment, it is necessary to look for the system configuration that has been made. The step taken to implement this configuration is to test the performance of each existing system. After knowing the usefulness of each tool, the merger of the two systems is carried out, which is initiated by AOPs which functions to degrade organic material and solve compounds that are in the water under.

After going through the AOPs and EWT processes the water produced enters the coagulation and flocculation tanks to precipitate impurities and colloid in treated water. After the formation of the floc, it must be filtered to separate the solids formed to obtain clean water and drinking water. The water produced is analyzed according to drinking water standards.

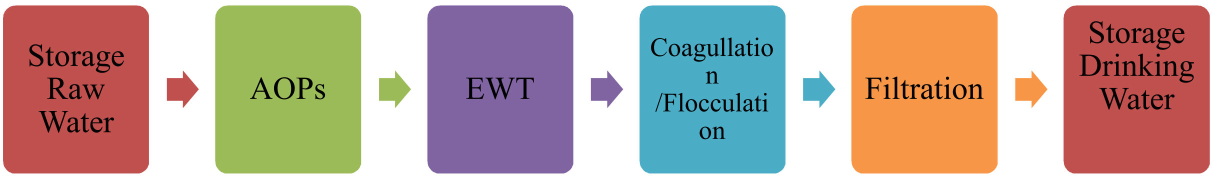

Figure 1. Scheme Process

Figure 2. Drawing Tools

4. EXPERIMENTAL RESULT

The physical condition of ex-mine lakes or commonly known as kolong in Bangka Belitung which has no inflow and outflow, the geochemical structure of rocks and soil, climate change and underwater utilization activities determine the limnologic characteristics of ex-mine lakes. Changes in the characteristics of extreme ex-mine lakes can occur due to climate change and exploitation of the use of ex-mine lakes which add to the burden of input such as organic compounds and other minerals such as tin under. Utilization of ex-mine lakes can directly worsen water quality and change the limnologic characteristics of the underwater.

Improving the quality of kolong water by using advanced oxidation technology that can reduce and eliminate heavy metals in the underwater source is expected to be one of the technological solutions that can be applied in Bangka Belitung. From the technological studies that have been done, it shows that ozone can react with metals in underwater so it will form metal oxides and become deposits. Ozone in the water besides functions as a reducing agent as well as a sterilizer in water.

The oxidation process will then be followed by an electromagnetic water treatment (EWT) process, where the bonds of water molecules that were originally mixed with other molecules, such as Iron (Fe) and Calcium (Ca), will separate from other molecules. This assumption is obtained based on the results of testing of water that has been processed using the EWT method. The test results show that water that has been processed with EWT elements of Fe and Ca separate from water molecules, then form larger particles so that they are easy to settle and easily filtered. This is evidenced by the measured levels of Fe and Ca lower than water that is processed by EWT.

The results of this system configuration using artificial compounds made according to the results of the initial analysis of water under. Analysis of configuration results is obtained according to the following table 1.

The configuration results show that AOPs processing is optimal in 30 minutes of processing and after the filtration process, where the results are 41% to 98%. This processing process determines the performance of the tool to be more optimal in processing. Iron increases in the 30th minute because the reverse of the ionization process is the recombination process.

Tabel 1. Analysis Result of Fe and Mn on theAOPs and EWT System Configurations.

NO.	CODE/TIME	ANALYSIS RESULT			UNIT	QUALITY STANDARDS		
		Fe	Mn	Pb		Fe	Mn	Pb
1	Initial Sample	8,447	1,656	2,845	mg/L			
2	AOP 15’	0,193	1,280	2,541	mg/L			
3	AOP 30’	0,102	0,977	2,447	mg/L			
4	AOP 60’	6,328	0,726	2,314	mg/L			
5	AOP 90’	7,987	1,487	3,237	mg/L	1	0,5	0,05
6	AOP 120’	9,558	1,283	3,363	mg/L			
7	AOP KF	9,600	0,898	3,603	mg/L			
8	EWT 120’	6,423	1,328	0,317	mg/L			
9	EWT KF	0,592	1,286	1,527	mg/L			

Recombination occurs by binding of electrons by ions and binding between atoms into molecules so that they become neutral species or negative ions accompanied by emission of photons. Iron in kolong can be Fe^{2+} or Fe^{3+} radicals. The optimum condition for ozone to work in water is at 14 minutes. From the experiments that have been conducted, the results of heavy metal degradation are in accordance with the Minister of Health Regulation 492 of 2010. Table 2 is the result of the analysis after filtration, so that are very small value for each element is obtained. This happens because most metals undergo precipitation and can be separated through a filtration process.

Tabel 2. AOP and EWT Process Result

NO.	PARAMETERS	UNITS	STANDARDS	PROCESS		METHODS
				1	2	
A	PHYSICS					
1	Odor	-	Odorless	Odorless	Odorless	APHA 2150B-2005
2	Total Dissolved Solid (TDS)	mg/L	1500	32	36	SNI 06-6989.27-2005
3	Turbidity	NTU	25	0,28	0,31	SNI 06-6989.25-2005
4	Taste	-	Tasteless	Tasteless	Tasteless	-
5	Temperature	°C	Air Temperature $\pm$ 3	25,7	25,9	SNI 06-6989.23-2005
6	Colour	PtCo	50	1,0	1,1	SNI 06-6989.24-2005

B	**CHEMICALS** **ANORGANIC CHEMICAL**					
1	Mercury(Hg)	mg/L	0,001	< 0,00005	< 0,00005	APHA 3112B-2005
2	Arsenic (As)	mg/L	0,05	<0,005	<0,005	SNI 06-2463-1991
3	Ferro (Fe)	mg/L	1	<0,007	<0,007	SNI 6989.4:2009
4	Fluoride (F^-)	mg/L	1,5	<0,008	<0,008	SNI 06-6989.29-2005
5	Cadmium (Cd)	mg/L	0,005	<0,001	<0,001	APHA 3111B-2005
6	Total Hardness ($CaCO_3$)	mg/L	500	8,12	8,40	SNI 06-6989.12-2004
7	Chloride (Cl^-)	mg/L	600	5,13	5,39	SNI 6989.19:2009
8	Hexavalent Chrome(Cr^{+6})	mg/L	0,05	<0,01	<0,01	SM 3500 - Cr B **
9	Manganese (Mn)	mg/L	0,5	<0,006	<0,006	SNI 06-6855-2002
10	Nitrate (NO_3^--N)	mg/L	10	0,041	0,050	SNI 6989.79:2011
11	Nitrite (NO_2^--N)	mg/L	1	<0,01	<0,01	SNI 06-6989.9-2004
12	Acidity (pH)	-	6,5 - 9,0	6,78	6,83	SNI 06-6989.11-2004
13	Selenium (Se)	mg/L	0,01	<0,004	<0,004	SNI 06.2475-1991
14	Zinc (Zn)	mg/L	15	<0,008	<0,008	APHA 3111B-2005
15	Cyanide (CN)	mg/L	0,1	<0,003	<0,003	SNI 6989.77-2011
16	Sulfate (SO_4^{-2})	mg/L	400	3,52	4,04	SNI 06-6989.20-2004
17	Plumbum (Pb)	mg/L	0,05	<0,03	<0,03	APHA 3111B-2005
C	**ORGANIC CHEMICAL**					
1	Detergent (MBAS)	mg/L	0,5	<0,02	<0,02	SNI 06,6989,51-2005
2	Organic Substances ($KMnO_4$)	mg/L	10	1,56	1,60	SNI 06-6989.22-2004
D	**MICROBIOLOGY**					
1	Total Koliform	Jumlah per 100 mL	50	8	7	SNI 01- 2897-1992

5. CONCLUSION

Improving the quality of kolong water by using advanced oxidation technology that can reduce and eliminate heavy metals in the underwater source is expected to be one of the technological solutions that can be applied in Bangka Belitung. From the technological studies that have been done, it shows that ozone can react with metals in underwater so it will form metal oxides and become deposits.

This assumption is obtained based on the results of testing of water that has been processed using the EMR method. The test results show that water that has been processed with the EMR of Fe and Ca elements are separated from the water molecule, then forms a larger particle making it easy to settle and easily filtered. This is evidenced by the measured levels of Fe and Ca higher than those not processed by EWT.

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