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Design and implementation of the electrochlorination filter model based on solar photovoltaic for daily watering systems at Eco-Garden-SD IT AI-Uswah Surabaya

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Abstract. AI-Uswah Elementary School holds an Eco-Garden program, but in the process, AI-Uswah has an issue with the lack of water to fulfil the daily watering needs. So we assumed the solution to this problem is filtering the wastewater in AI-Uswah into clean water, which is mainly available in AI-Uswah. Filtering of wastewater to supply clean water for the eco-garden and hydroponic system using electro-chlorination water filter integrated with Solar PV is one of the best ways to provide daily hydroponic water needs. This paper presents a method for modelling and sizing electro-chlorination water filter integrated with Solar PV for an eco-garden and hydroponic system. The model of electro-chlorination described how to convert wastewater into clean water, predict flow rate to meet the daily need, and provide an experimental result to calculate the accuracy of the model.

1. Introduction

The world's population is expected to grow from 7 billion to 9.3 billion in 2050, and the urban population from 3.6 billion to 6.3 billion, a 72% increase [1]. Its effect to availability of clean water requirements for daily watering such as agricultural need. Agriculture in semi-arid and arid regions is highly dependent on water for irrigation; however, water availability is already problematic in many regions with imbalances between renewable resources and total demands, which jeopardise irrigated agriculture and its resilience. The fulfilment of clean water at Surabaya city very depends on PDAM, because the water source of Surabaya city is very polluted, and beside it, the population density is also caused clean water scarcity. Individual water use in Surabaya is estimated at 150 litres per day, while the availability of clean water by PDAM is 10,000 litres per second, or the production capacity of PDAM is 21 million to 22 million cubic meters per month, which means that PDAM production can only serve 70% of Surabaya people [2]. Meanwhile, since 2010 the Surabaya city government promotes eco-garden and urban farming program to overcome environmental problem and food shortages, but in the implementation of this program, the water scarcity is the main problem of this program implementation. In order to overcome the problem of water scarcity and environmental problem in SD IT AI-Uswah Surabaya, Indonesia, we design electro-chlorination filter integrated with solar PV system to supply clean water for eco-garden and hydroponic system for daily watering. In this case wastewater can converted to clean water for daily watering eco-garden and hydroponic



system using electro-chlorination water filter integrated with Solar PV System as renewable energy source.

2. Literature review

Chemical disinfection is a common unit process used in water supply and wastewater treatment. Traditionally, chlorination is the most dominant method of disinfection. However, there are serious safety concerns and great ecological risks involved in the use of chlorine. Other methods, such as ozonation, UV radiation and ClO₂ application, are still more expensive or less convenient than chlorination. It has been reported that electro-chlorination can destroy a wide variety of microorganisms from viruses through bacteria and algae to larger species, such as *Euglena* [3].

An electro-chlorination system consists of electrodes, an electrolyte, and a circuit, and anodes are a significant factor for chlorine generation. According to the property of anodic materials, anodes are divided into active and nonactive electrodes; IrO₂ and RuO₂ are the former and boron-doped diamond (BDD) is the latter. Among various electrodes such as IrO₂, RuO₂, and BDD, the IrO₂ electrode has better efficiency than the others to produce chlorine in the presence of NaCl. Furthermore, the chlorine solution generated in an electrochemical system is slightly more efficient for inactivating microorganisms than free chlorine under certain pH conditions [4].

Wastewaters that contain heavy metals, organic complexing agents, and suspended matters from metal finishing industries are harmful to public health. Electro-chlorination filter was experimented by Khelifa, Aoudj Moulay, and De Petris-Wery to involve the indirect electrooxidation process of the active chlorine generation and promotes the oxidation of organic pollutants efficiently. Dimensionally stable anodes (DSA) are commonly used in wastewater treatment as the result of its numerous advantages. In addition, it has shown that the efficiency of high chlorine production may be achieved in an electro-chlorination cell by DSA ruthenium oxide coated titanium anode consider graphite anodes and platinized titanium. The previous research has resulted that Ni, Zn, Pb, Cu/CN can be efficiently removed from wastewater by using a two-compartment electrolytic cell before the filtration of brine. But the process is hindered by the use of platinum as its anode and the requirement of ion permeable. Khelifa has shown that electrochlorination is a promising way to replace the classical technologies and quite interesting as it is very suitable for wastewaters of the metal finishing industry [5].

3. Research methods

3.1. Sampling and analysis

At the beginning, the wastewater is collected in the 1st-floor reservoir of SD IT Al-Uswah which include the wastewater from the 1st to the 3rd-floor and will be tested in the laboratories that are the physical and the chemical test. From physical test some results are obtained that are colour, smell, turbidity, solid particle, temperature, and electrical conductivity. While the chemical test includes pH, total hardness, the chemical components that are chloride, sulphate, nitrate, ammonia, nitrite, iron, manganese, lead, zinc, chromium, fluoride, arsenic, mercury, cadmium, selenium, cyanide, kmnO₄, and detergent.

3.2. Planning filter prototype

After the water test results are known, an electro-chlorination filter is used to filter the water because electro-chlorination is the most effective way to eliminate the organic content contained in wastewater. This electro-chlorination method uses 2 electrodes i.e. carbon plate on the cathode and stainless steel on the anode. The design of electro-chlorination filter prototype shown in figure 1.

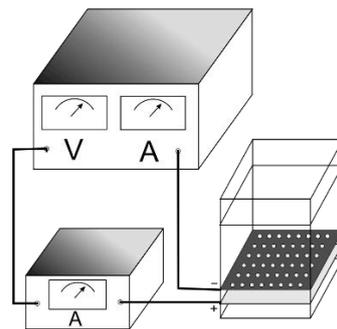


Figure 1. Electro-chlorination water filter prototype.

3.3. Lab-scale electro-chlorination test

The filter is injected with current and DC voltage until the value of the current and the voltage are obtained so that it can break the organic contents of wastewater ablation. In addition, also observing changes in water samples at some time variations to obtain the best results.

3.4. Making electro-chlorination filters

In this phase, the design and implementation of electro-chlorination filter are adapted to the laboratory test results considering the input-output of the wastewater and photovoltaic power supply, including that the DC converter dimension of the filter is adjusted to the planning of the filter placement and combined with a conventional filter as zeolite, sand, and gravel.

3.5. Running filter and integration with PV

At this stage experiments and implementation of electro-chlorination filter using the supply of photovoltaic in SD IT Al-Uswah and integrated with hydroponic system as shown in figure 2, in accordance with experimental results from the filter in the laboratories.

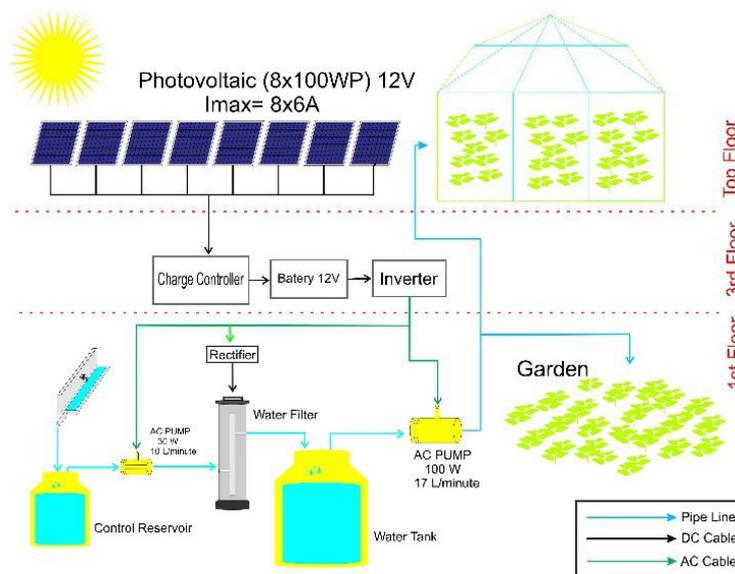


Figure 2. SD IT Al-Uswah Eco-Garden system integrated with Solar PV and Filter.

4. Analysis and result

The wastewater test is divided into 2 sections, the first section was tested without electro-chlorination water filter, and the second section was tested with the filter. On the first section the wastewater tested to find out the wastewater content. The result of the first section shown in table 1.

Table 1. wastewater result analysis.

Parameter	unit	Clean Water Requirement (PERMENKES RI No.416 MENKES/PER/IX/90)	Analysis Result	Analysis Method
1. PHYSICS TEST				
Colour	PtCO	50	80	Spectrophotometry
Taste	-	No taste	No taste	-
Aroma	-	No aroma	No aroma	-
2. CHEMICAL TEST				
<i>a. inorganic Chemistry</i>				
pH	-	6.5 – 9.0	7.70	pH meter
Hardness Total	mg/L CaCO ₃	500	185.71	Complexometry
Chloride	mg/L Cl-	600	56	Argentometry
Sulphate	mg/L SO ₄	400	640.36	Spectrophotometry
Nitrate	mg/L NO ₃ -N	10	2.05	Spectrophotometry
Nitrite	mg/L NO ₂ -N	1	0.03	Spectrophotometry
Ammonia	mg/L NH ₃ -N	-	1.41	Spectrophotometry
Fluoride	mg/L F	1.5	3.56	Spectrophotometry
<i>b. organic Chemistry</i>				
KMnO₄	mg/LKMnO ₄	10	17.95	Oxidase
Detergent	mg/L	0.5	0.28	Spectrophotometry

From the test result, in chemical test from wastewater exceeds of organic and inorganic content that doesn't needed by crop such as sulphate, fluoride and KMnO₄. Furthermore, in physical test the wastewater colour exceeds of determined limit at 50 PtCO.

The second section is filtering wastewater by using electro-chlorination test. The purpose of this test is to remove organic, and inorganic content of the wastewater, and also to purify the wastewater. After this process the output of the water is sufficient to use by hydroponic.

From the result given in figure 3, the optimal injection of DC voltage and DC current are 30VDC and 0.24A, which takes 25 minutes to obtain 100% efficiency. By optimizing the voltage and current value to supply electro-chlorination filter, it will decrease the filtering time. Power consumption for filtering process will decrease along with the filtering time process reduction.

So, two step of filtering process the wastewater become sufficient for eco-garden used. After finishing the prototype, the actual design filter depends on the field requirements. Next the actual design of the electro-chlorination filter is integrated with hydroponic system and solar PV.

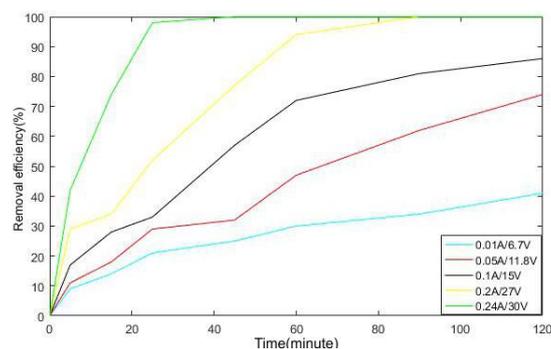


Figure 3. removal efficiency (%) as time function.

5. Discussion and conclusion

Installation of the electro-chlorination filter is integrated with solar PV as power supply and hydroponic system. The electro-chlorination filter used to supply clean water requirements for the eco-garden at SD IT Al-Uswah Surabaya. It obtains optimal removal efficiency of organic and inorganic contents by injecting DC voltage 30V and 0.24A of DC current, it takes 25 minutes time delay to filter wastewater into clean water.

Acknowledgement

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