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Design of Prototype of Solar Power Based Waste Water Treatment Plant

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Abstract: This research aims to find out an overview of the prototype solar power-based Waste Water Treatment Plant (WWTP), the component requirements of the PLTS system as an energy source for the WWTP, and level of efficiency in using solar power plants in IPAL operations. The type of research used is experimental research. Based on the research results a prototype solar power-based IPAL system has been produced with a capacity of 800 liters per hour or 11,200 liters per day (14 operational hours) with a Biotech/biofilter type modified by adding a water filter after the chloronization process. Besides of that, a source of electrical energy for all electrical components of the WWTP with a solar panel and battery capacity of 200 wattpeak and 100 Ah respectively. The efficiency level of the solar panels used reached 88.36% at 12.00 (very sunny weather conditions) with input power above output power in the range 09.00-16.00. With this efficiency, electrical energy can be stored to operate the WWTP at night.

Keywords: Solar power plants; Waste water treatment plants (WWTP)

Introduction

Clean water and sanitation are the target of the seventh Millennium Development Goal (MDG) and based on the 2015 target, it is expected that up to half of the population without access to clean, potable water and basic sanitation can be reduced. Indonesia needs to achieve an increase in access to clean water of up to 68.9 percent and 62.4 percent for sanitation (Sudiajeng et al., 2018). Currently, Indonesia is not in the right direction to achieve the MDG targets regarding clean water issues. For example, calculations using Indonesia's national MDG criteria for clean water and data from the 2010 census show that Indonesia must reach an additional 56.8 million people with a clean water supply by 2015.

On the other hand, if the WHO-UNICEF Joint Monitoring Program (JMP) criteria for clean water were to be used, Indonesia would have to reach an additional 36.3 million people in 2015. Water is the most important natural resource on planet Earth because it is the essence of all life (Chitadze, 2023). One of these things can be seen from the water element on earth, which amounts to two-thirds of the earth's surface which is water. In fact, around 60-70% of the components of the human body consist of water (Sumardiyanto et al., 2021).

Water is a natural resource that is necessary for human life, even for all living creatures. Therefore, quality and quantity must be considered. Clean water is water that is used for daily needs and whose quality meets the health requirements for clean water in accordance with applicable laws and regulations (Edition, 2011; Sayato, 1989; WHO, 2008). Water as a component of the living environment will greatly influence and be influenced by various other

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components around It (Bahri & Fikriyahl, 2018). Attention to water quality in various community water sources is important in order to create a healthy society through the availability of adequate clean water (Exposto et al., 2021; Cosgrove & Loucks, 2015). In some places, one of the water sources that is widely used by people is rivers.

Rivers are one of the rich water resources used by the community to meet their daily needs (Loucks & Beek, 2017). However, apart from being used by the community to meet their daily needs, rivers are also used as a place to dispose of solid and liquid waste resulting from industrial waste, household activities, livestock, workshops and other businesses (Fahlupi et al., 2019; Sridhar & Hammed, 2014; Srinivas et al., 2020). The dumping of waste into rivers containing various types of pollutant materials, both biodegradable and non-degradable (Abdullahi et al., 2014), will cause the river to bear a heavier burden and have a significant negative impact on the health of living creatures in it and the communities around the river (Mohanaprasadh et al., 2022; Olabode et al., 2014).

The quality of several rivers in Indonesia is very worrying (Silalahi et al., 2022).We can prove this with the results of water quality tests carried out by Environmental Offices in various regions. The decline in water quality that occurs in several rivers in Indonesia is largely caused by surrounding industrial wastewater (Akhtar et al., 2021). Some entrepreneurs dispose of the waste directly into the environment without processing it first. This is caused by a lack of serious attention to the operation of integrated wastewater treatment plants. Integrated WWTP are usually built by the government to overcome the impact of water pollution by liquid waste and so on. In the city of Makassar, one of the rivers that has experienced a lot of pollution is the Pampang River.

The Pampang River and Pampang Canal are one of the most important water channels for the city of Makassar which is located in the city of Makassar with a length of around 8.4 km with a flow in the middle of Makassar city. However, due to its position, which is mostly in the middle of residential areas, this river has been used as a dumping ground for household and industrial waste which has not been managed properly. As a result, there is significant pollution, resulting in very poor water quality. Visually, the water has a dark black color and also has a very strong odor. However, so far, no research has been carried out to help reduce the level of water pollution in the Pampang river.

One preventive measure that can be taken is to utilize integrated wastewater treatment plants in the upstream section, and countermeasures in the water flow and downstream sections of the Pampang River which are currently not being implemented optimally. The results of observations in various positions around the Pampang river show that people on a household and industrial scale do not yet want to use WWTP because their understanding of WWTP is still very limited, the cost of building WWTP is quite expensive and the use of electrical energy is quite large. Therefore, it is very important to design a simple WWTP prototype and use renewable energy as a source of electrical energy, one of which is the use of solar energy. So far there has been no research that has succeeded in developing a WWTP using solar power as an energy source. The use of new, renewable energy as a source of electrical energy for all IPAL components is very important, this is because in certain situations, for example during the dry season, intense power outages occur very often in the city of Makassar.

Apart from that, the location and abundance of sunlight in Indonesia is one of the supporting factors for implementing solar power-based WWTP. Indonesia is very rich in renewable energy with a potential (Langer et al., 2021) of more than 400,000 Mega Watt (MW), 50% of which or around 200,000 MW is solar energy potential (Ramachandra & Shruthi, 2007). Meanwhile, the use of solar energy itself is currently only around 150 MW or 0.08% of its potential (Al-Kayiem & Mohammad, 2019; Benedek et al., 2018). In fact, Indonesia is an equatorial country which should be a leader in developing solar energy (Hasan et al., 2012; Santika et al., 2020). The world is moving quickly in reducing fossil energy and switching to clean, environmentally friendly energy. The demand for green products produced by green industry is increasing and has even become a necessity if you don't want the product to be subject to carbon border tax at the global level (Jayed et al., 2011). Apart from that, the role of various agencies is very much needed in order to reduce the level of fossil energy use by utilizing green and clean energy. Therefore, campuses as science and technology institutions are also required to optimize the use of new and renewable energy.

Based on the description above, research was carried out with the aim of developing a prototype for a solar power-based Waste Water Treatment Plant. The urgency of this research is that the resulting prototype can be an illustration and example for the government in developing IPAL so that its application can be maximized in order to reduce pollution in the Pampang River. The use of new, renewable energy in WWTPs is very important to campaign for the use of clean and friendly energy so that it can reduce environmental pollution from fossil fuel power plants. The formulations in this research are What is the description of the prototype of a solar power-based Waste Water Treatment Plant?; How to determine the component requirements of each PLTS system as a source of energy for the WWTP? What is the level of efficiency of using solar power plants in WWTP operations?

Method

The type of research used is experimental research. There are two types of data used, namely primary data obtained from observations of research locations, documentation and interviews with communities around the Pampang river, analysis of daily energy needs and analysis of the effectiveness of solar power-based WWTP. The initial survey was carried out directly at several points in the Pampang River Watershed. The following is the research flow.

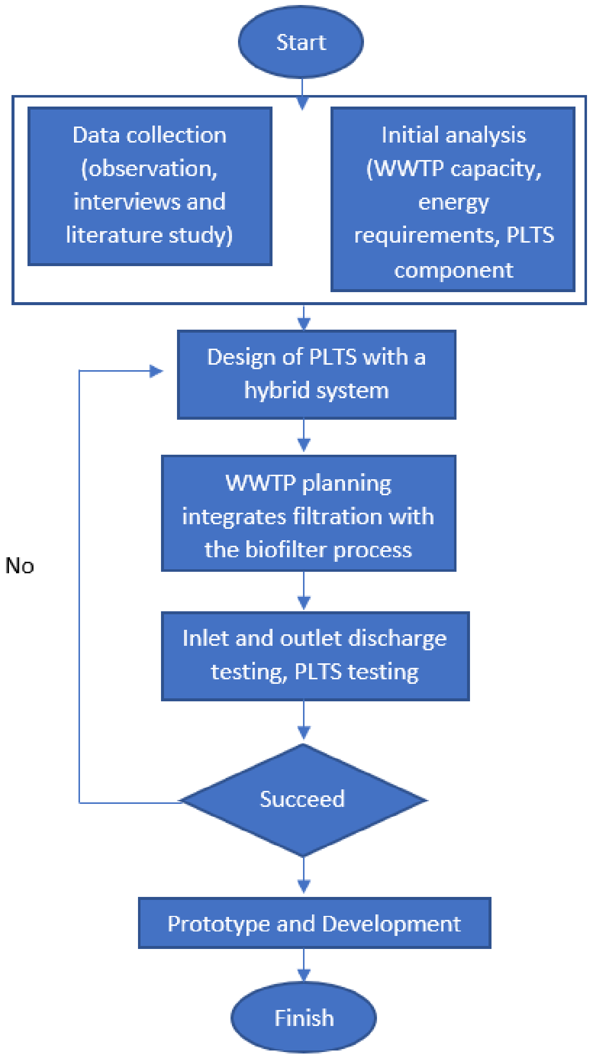

Figure 1. Research flow

The research began by collecting data through direct observation around the Pampang river, conducting interviews with several local communities and conducting a literature review. Furthermore, an initial analysis was also carried out in the form of IPAL capacity, electrical energy requirements and required PLTS components. Next, an IPAL is made that is integrated with filtration through a biofilter process. Next, the installation of a solar power plant with a hybrid model was carried out. Meanwhile, the installation of a solar-based IPAL is located next to building I, Bosowa University. The next step is testing the discharge/capacity of the IPAL and also testing the ability of the PLTS to supply electrical energy for pumps and aerators. The test was carried out several times to obtain accurate data. Due to the very fluctuating weather conditions during testing, data collection was quite difficult because data collection had to be carried out in sunny conditions.

The time of the research was carried out from September-December 2023, the research object was the Pampang River Watershed which is located next to building I, Bosowa University, Makassar. As stated on the map with longitude coordinates 119°34'22.95"E and latitude 4°59'28.37"S which can be seen in the following image.

Figure 2. Location of IPAL construction and testing

Result and Discussion

Solar Power Based WWTP Design

The type of IPAL used is the Biotech/biofilter IPAL type with an air processing scheme as in Figure 3. Water is first flowed into the initial reservoir to settle mud particles, sand and suspended organic dirt. Apart from being a settling tank, it also functions as a tank for decomposing organic compounds in solid form, sludge digestion (sludge decomposer) and sludge reservoir. The runoff water from the initial settling tank is then channeled to the anaerobic contactor tank (Anaerobic biofilter) in a flow direction from top to bottom. In the anaerobic contactor tank, it is filled with special media made from honeycomb type plastic material (Wang et al., 2011; Xu et al., 2018). The number of anaerobic contactor tanks consists of two rooms. The decomposition of organic substances in waste water is carried out by anaerobic or facultative aerobic bacteria

(Prisanto et al., 2015). After several days of operation, a film layer of micro-organisms will grow on the surface of the filter media. These microorganisms will decompose organic substances that have not had time to decompose in the settling tank (Bella & Rao, 2023; Tauseef et al., 2013).

Waste water from the anaerobic contactor (biofilter) tank flows into the aerobic contactor tank. In this aerobic contactor tank, it is filled with a special media made of honeycomb type plastic material, while being aerated or blown with air so that the existing microorganisms will decompose the organic substances in the waste water and grow and stick to the surface of the media (Akpor et al., 2014; Zheng et al., 2013). In this way, waste water will come into contact with microorganisms suspended in water or attached to the surface of the media, which can increase the efficiency of decomposing organic substances, as well as speed up the nitrification process, so that the efficiency of ammonia removal is greater. This process is often called Contact Aeration.

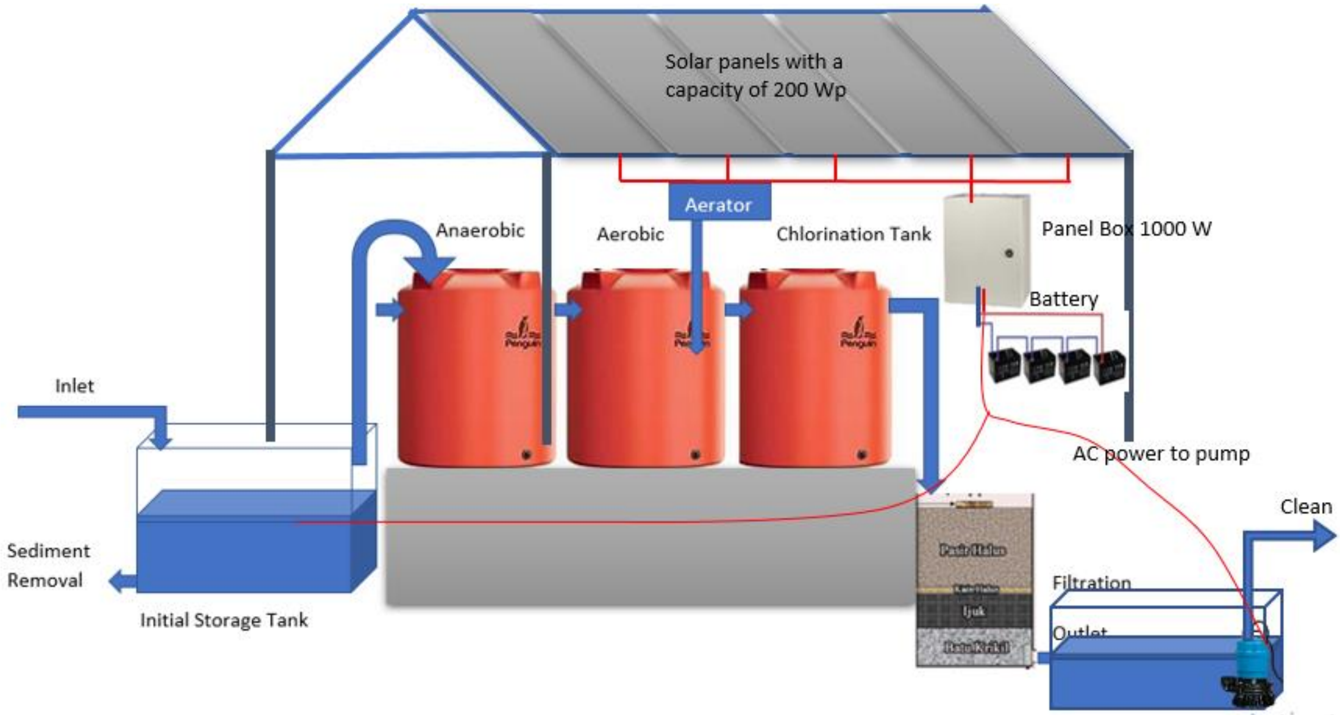

Figure 3. Wastewater treatment process diagram with a solar powered anaerobic-aerobic biofilter process

From the aeration tank, water flows to the final settling tank. In this tank the activated sludge containing microorganisms is deposited, in this final settling tank the waste water is contacted with chlorine compounds to kill pathogenic microorganisms (Al-Sa'ady et al., 2020; Ghernaout, 2017). Chlorine addition can be done using chlorine tablets or with a chlorine solution supplied via a dosing pump. Processed water, namely the water that comes out after the chlorination process, flows into a filtration tank which aims to purify the water, reduce the metal content, lime and the smell of the water (Ahmad & Azam, 2019; Bolisetty et al., 2019).

One of the innovations in this research is the use of solar power as a source of electrical energy in IPAL as a source of electrical energy. There are 3 pumps used in this WWTP, namely a submersible pump which functions to drain water from the Pampang River to a reservoir and also a pump which functions to drain water from a reservoir to an anaerobic basin. Apart from that, there is also an air pump (aerator) which functions to channel oxygen from outside to the aerobic tank. Apart from using electricity from new, renewable energy, this WWTP is also equipped with a filtration system so that the water coming from the chloronization tank does not go straight out through the outlet pipe but goes into a filter tube equipped with various filter media such as activated carbon silica sand and zeolite stone (Sariman & Nurdin, 2022).

Effectiveness of Solar Power Plants as a Source of Electrical Energy in WWTPs

After designing and making a prototype IPAL, then proceed with determining, installing and testing the effectiveness of a solar-based IPAL. The energy consumption requirement according to the targeted outlet water discharge is 800 liters per hour assuming the system is able to work for 14 hours. So, an initial calculation analysis is carried out to determine the need for electrical energy that must be produced by the Solar Power Plant system. The following is the flow of initial analysis of electrical energy needs (Auliq et al., 2020). Based on the results of observations, several initial data were obtained as follows: the size that can be used as a PLTS-based IPAL is 6 x 6 meters and the total energy required from 8.00-24.00 (for 14 hours) is as follows.

Table 1. Estimated Total Energy Required

Electrical Tools	Power (Watt)	Duration of Use (hours)	Energy (Wh)
2 submersible pump 22 watt	44	14	616
1 aerator 6.50 watt	6.50	24	156
Total			772

The electrical energy produced by PLTS is not 100% used, 20% of the energy is lost. So, it is necessary to add energy equal to the total real energy = Total Energy + Total Energy x (20%) = 772 + (772 x 20%) = 924.60 Wh. From the estimated electrical energy requirements in the table, the following calculations are made for the need for tools and materials: Solar panels = total real energy: optimal time = 924.6 : 6 = 154.1. So if you use solar panels with a capacity of 100 Wp, then the number of panels needed is 154.1 : 100 = 1.5 ≈ 2 solar panels. Because PLTS needs to only be used during the day, using batteries is optional. However, to provide energy storage when the weather is cloudy, batteries are needed. Reserves = Energy + (energy x 5%) = 772 + (772 x 5%) = 810 Wh. Then the number of batteries = reserves : (voltage x current) = 810 : (12 x100) = 0.675 ≈ 1 battery.

After determining the components according to needs, we then proceed with installing the PLTS components and then testing is carried out to see how the solar power-based IPAL performs. The following table shows how effective the PLTS components were during the tests carried out.

Table 2. Effective the PLTS Components were During the Tests Carried Out

Time	Input Current (A)	Input Current (V)	Input Power (W)	Solar panel Efficiency (%)	Battery Capacity (%)
8.00	2.32	14.10	32.72	16.36	100
8.30	3.40	14.14	48.08	24.04	100
9.00	5.72	14.40	82.37	41.18	100
9.30	6.40	14.60	93.44	46.72	100
10.00	6.87	17.20	118.16	59.08	100
10.30	7.20	19.20	138.24	69.12	100
11.00	7.29	19.89	144.99	72.49	100
11.30	7.97	19.90	158.60	79.30	100
12.00	8.88	19.90	176.71	88.36	100
12.30	8.22	19.40	159.47	79.73	100
13.00	5.80	19.20	111.36	55.68	100
13.30	7.40	19.20	142.08	71.04	100
14.00	7.50	19.20	144.00	72.00	100
14.30	6.40	18.80	120.32	60.16	100
15.00	5.72	17.40	99.53	49.76	100
15.30	5.20	17.67	91.88	45.94	100
16.00	4.28	16.60	71.05	35.52	100
16.30	3.40	14.28	48.28	24.14	100

Based on the table 2, it can be seen that all the electrical energy used by the IPAL electrical equipment components during the day can be covered by PLTS from 9.00-16.00, where the required power (input power) is 50.5 watts while in that time range it is in the input power range of 82.37 watts - 71.0 watts. This also shows that some of the energy produced by PLTS can be stored in batteries for IPAL use at night. This allows the IPAL not only to be used during the day but also to be able to operate at night even though there is no flow of electrical energy from the solar panels. Table 2 also shows the efficiency of the solar panels used, where during the test, the greatest efficiency was at 12.00 with a percentage of 88.36 percent or 176.71 watts from a maximum power of 200 watts.

The results of this research which developed an innovative solar power-based WWTP prototype is one of the novelties in this research, so far there has not been one. Several studies that use solar panel as a source of electrical energy only focus on certain components, for example Prastyo's research which uses PLTS as a source of electrical energy for monitoring WWTP water quality (Prastyo, 2023). Therefore, this research can be a reference for further research or development of solar power-based IPAL on a larger scale.

Conclusion

Based on the research that has been carried out, the author can draw the following conclusions. Firstly, a prototype solar power-based WWTP system has been produced with a capacity of 800 liters per hour or 11,200 liters per day (14 operational hours) with a Biotech/biofilter type modified by adding a water filter after the chloronization process. Secondly, to produce a water capacity of 11,200 liters, a PLTS system is used as a source of electrical energy for all electrical components of the WWTP with a solar panel and battery capacity of 200 wattpeak and 100 Ah respectively. Thirdly, the efficiency level of the solar panels used reached 88.36% at 12.00 (very sunny weather conditions) with input power above output power in the range from 09.00-16.00. With this efficiency, electrical energy can be stored to operate the WWTP at night. Although the results of this research can be a reference for developing a solar power-based IPAL with a larger capacity, there are weaknesses in this research which of course can be used for further research. This research only focuses on the design of a solar power-based IPAL by explaining in detail the development process, especially the application of PLTS, while IPAL testing based on comparing tests of physical, chemical and biological parameters of water flowing in the inlet and outlet pipes has not been carried out. So, the effectiveness of the innovation in the form of adding a filtration system after the chloronization tank cannot yet be measured.

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Author Contributions
Conceptualizing, D. A, M. F. B.; developing products, A. I, S. S.; analyzing data, and writing articles, A. S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare that there is no conflict of interest regarding the publication of this paper.

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