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WATERWHEEL DRAINAGE CLEANER (WDC): AN ECONOMIC TECHNOLOGY APPROACH INNOVATION FOR LAND-WATER RELATED MICROPLASTIC POLLUTION PREVENTION

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ABSTRACT

Microplastic pollution in water bodies is currently attracting attention worldwide due to its societal prevalence and long lifespan. It enters freshwater ecosystems through run-off, wastewater discharge, and atmospheric deposition in various colors, sizes (<5 mm), shapes, and polymer types. If microplastics are transported through the food chain, they can become harmful and negatively affect aquatic ecosystems and human health. Due to the high correlation with human activities, urban areas are a significant source of microplastic emissions into water bodies. All these sources are related to the collection and discharge of drainage systems, which are important pathways for moving pollutants between land and water. The common way to remove solid waste, especially plastic waste in drainage, is using the traditional way by humans. However, this method takes a long time and is dangerous for humans due to exposure to an unhealthy work environment. Innovation is needed to reduce plastic waste pollution in urban drainage. The Waterwheel Drainage Cleaner (WDC) uses an air wheel mechanism that rotates using the flow potential of water. The WDC is equipped with filter arms that end on the conveyor. The conveyors are beneficial for moving waste from drainage to WDC tubes. The WDC framework can be applied to other multi-locations, such as rivers, reservoirs, and lakes. The WDC innovation is expected to reduce microplastic pollution in the aquatic environment, reduce drainage sedimentation, and increase community sanitation at a more cost and time-efficient rate.

Keywords : Drainage, Microplastic, Sanitation, Waterwheel Drainage Cleaner (WDC)

ABSTRAK

Polusi mikroplastik di badan air saat ini menarik perhatian di seluruh dunia karena prevalensinya di masyarakat dan umurnya yang panjang. Ia memasuki ekosistem air tawar melalui limpasan, pembuangan air limbah, dan pengendapan atmosfer dalam berbagai warna, ukuran (<5 mm), bentuk, dan jenis polimer. Jika mikroplastik terbawa melalui rantai makanan, mikroplastik dapat berbahaya dan berdampak negatif terhadap ekosistem perairan dan kesehatan manusia. Karena tingginya korelasi dengan aktivitas manusia, daerah perkotaan merupakan sumber emisi mikroplastik yang signifikan ke badan air. Semua sumber ini berkaitan dengan pengumpulan dan pembuangan sistem drainase, yang merupakan jalur penting untuk memindahkan polutan antara tanah dan air. Cara pembuangan sampah khususnya sampah plastik pada saluran drainase yang umum dilakukan adalah dengan menggunakan cara tradisional yang dilakukan manusia. Namun cara tersebut membutuhkan waktu yang lama dan berbahaya bagi manusia karena terpapar lingkungan kerja yang tidak sehat. Diperlukan inovasi

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untuk mengurangi pencemaran sampah plastik di drainase perkotaan. Waterwheel Drainage Cleaner (WDC) menggunakan mekanisme roda udara yang berputar memanfaatkan potensi aliran air. WDC dilengkapi dengan lengan filter yang berakhir pada konveyor. Konveyor bermanfaat untuk memindahkan sampah dari drainase ke tabung WDC. Kerangka kerja WDC dapat diterapkan pada multilokasi lainnya, seperti sungai, waduk, dan danau. Inovasi WDC diharapkan dapat mengurangi polusi mikroplastik di lingkungan perairan, mengurangi sedimentasi drainase, dan meningkatkan sanitasi masyarakat dengan tingkat yang lebih hemat biaya dan waktu.

Keywords : : *Drainase, Mikroplastik, Sanitasi,* Waterwheel Drainage Cleaner (WDC)

Introduction

Waste management in residential environments is one aspect that is very influential in improving the quality of the urban environment. Sanitation is a measure of people's quality of life. An area with poor sanitation is proven to be accompanied by low levels of education, health quality, gender equality, and inclusivity (Kayser et al., 2019). Solid waste is one of the main sanitation problems faced almost worldwide. Pollution due to piles of rubbish on the ground, dumping rubbish into waterways or rivers, or burning rubbish can harm humans and nature.

Not least in urban drainage, reducing waste in drainage is an important threat to realizing good urban sanitation, one of which is because it can reduce the function of drainage in channeling runoff water. Some of the waste that is generally found in drainage is usually light types of waste, such as plastic. Plastic waste is a major environmental issue, especially because of its durability. Natural ecosystems cannot decompose plastic in nature but can be broken down into small particles measuring < 5 mm, now often called microplastics. Microplastics are also found in various shapes, colors, and polymer types (D'Hont et al., 2021). Microplastics have been found in various environmental media, such as water, air, soil, and living creatures.

Water pollution by microplastics has been proven to have massive effects on humans and the environment (Pavani et al., 2022). Microplastics enter freshwater ecosystems through runoff, wastewater discharge, atmospheric deposition, etc. If microplastics are transported through the food chain, they can become harmful and negatively affect aquatic ecosystems and human health.

Due to the high correlation with human activities, urban areas are a significant source of microplastic emissions into water bodies. Urban drainage is the main track, which is an important pathway for moving pollutants between land and water. It transported plastic atau mikroplastik from urban activity ke ekosistem akuatik lainnya, seperti sungai dan laut. The annual emissions load of MPs via the urban drainage system was 5.83×10^{10} items/km^2. Generation MPs were 3461.5 items/capita/day (Adhiharto and Felvi, 2021).

Handling waste in rivers and drainage in waterways is usually carried out using traditional methods using human power (Karmiati and Rafiq, 2020). Both communities and government programs have carried out various river clean-up movements. However, it is necessary to have a tool that can work continuously

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without depending on certain events. So, there is a need for an innovative automatic drainage waste collector that is cheap and easy to reduce the amount of waste, especially plastic, that enters the wider aquatic ecosystem.

Methods

1. WDC Innovation Planning

In the planning phase, the problems identified included the large volume of plastic and microplastics originating from urban areas ending up in aquatic ecosystems through drainage and plastic waste pollution blocking the flow of water in drainage. In this innovation, the potential energy of water will be utilized to drive waterwheels. The water wheel that rotates due to the flow of water can convert potential energy into electrical energy to drive the waste collection conveyor. The conveyor will move the waste from the drainage to the waste bin automatically. Figure 1 shows the WDC innovation concept planning flow diagram.

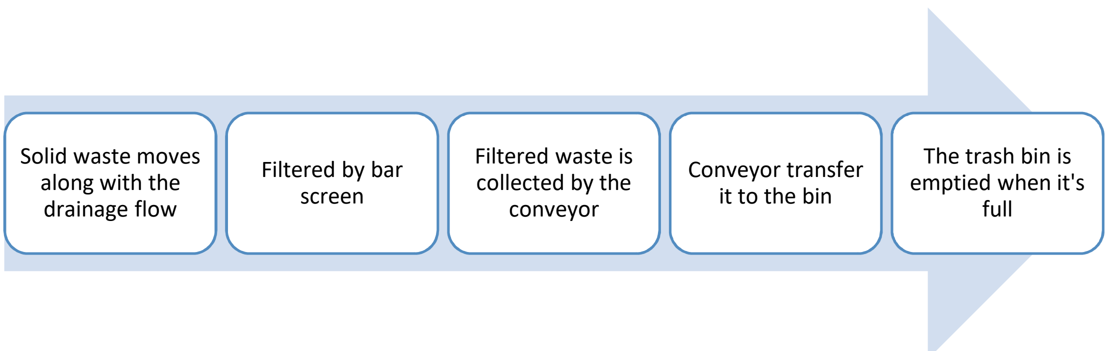

Figure 1. Innovation concept planning

Figure 2 shows how water flow can convert water potential energy into electrical energy, which is environmentally friendly, easy, and cheap. In this plan, the working method of a Microhydro Power Plant is adopted, where the electricity produced will be directly used for automatic waste collection equipment.

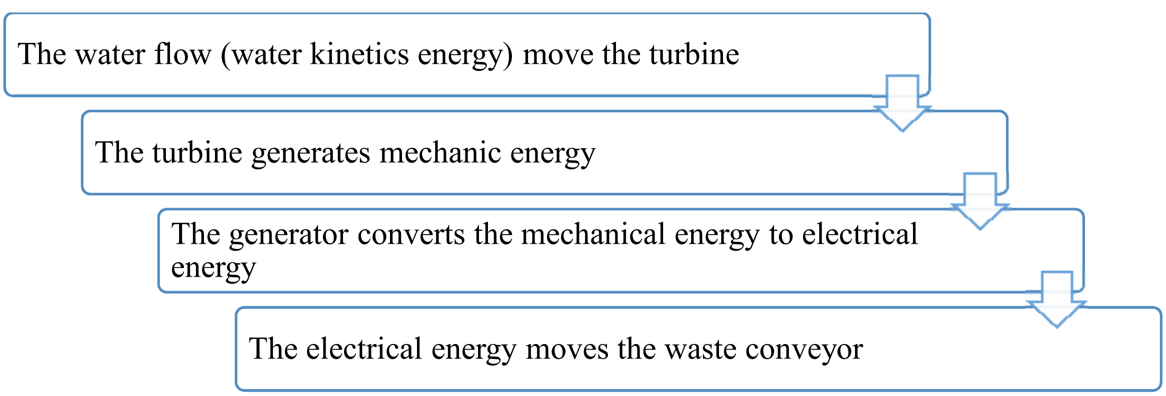

Figure 2. The turbine converts water potential energy for power the conveyor

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2. Water Discharge Measurement

Measuring the potential water discharge can determine the amount of potential water energy as a source of electrical energy to drive the conveyor at the WDC. To calculate the flow, it is first necessary to measure the drainage speed using a simple float method. This method is done by sending an object floating on water over a certain distance. In this study, a distance of 10 meters was taken. Then calculate the time it takes for the object to get from the start point to the end point. To calculate the flow speed and water discharge, it can be calculated using the equation (1) and (2):

$$V = \frac{s}{t} \qquad \textbf{(1)}$$

$$Q = V\ x\ A \qquad \textbf{(2)}$$

Where, v = speed (m/s), s = distance (m), t = time (second), Q = flow (m^3/s), and A = cross-section area (m^2). In this paper, it is assumed that the WDC is built on a drainage measuring 120 cm wide and 40 cm deep.

3. Water Potential Power

Head and water discharge are two factors that greatly influence the amount of water energy that can be obtained and utilized. Head is the difference in height between the water level in the drainage and the water level in the water wheel/water turbine. The total energy available from water flow is the potential energy of water, which can be calculated using the equation *(3):*

$$P = \rho Q g H \qquad \textbf{(1)}$$

Where P = power (Watt), ρ = water density (kg/m^3), Q = flow (m^3/s), g = gravitational acceleration (m/s^2), and H = head (m). The designed head on the WDC is 15 cm.

Results and Discussion

Figure 3 depicts the relationship between land-water problems affected humans by the microplastic. Humans as producers of plastic and plastic waste will throw it into the environment. Both in the form of plastic and microplastics (results from combustion, recycling, etc.). Furthermore, these plastics and microplastics will enter the aquatic environment through urban and natural drainage. MPs that are in the aquatic environment will stay and can break down into smaller particles in the water. These MPs will stay in aquatic sediments, floating in the water until they can enter marine animals. MPs then entered the human food chain system.

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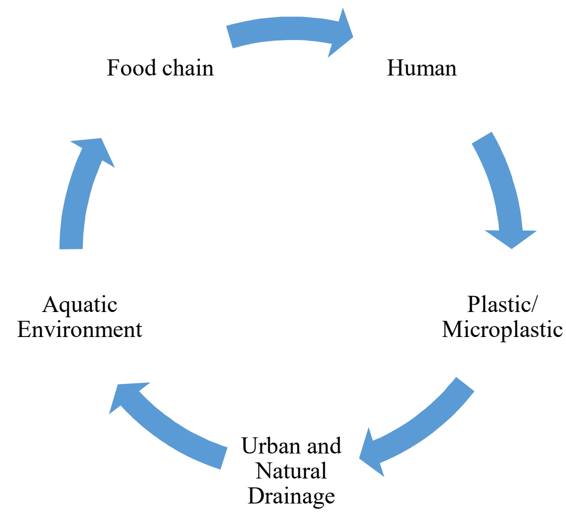
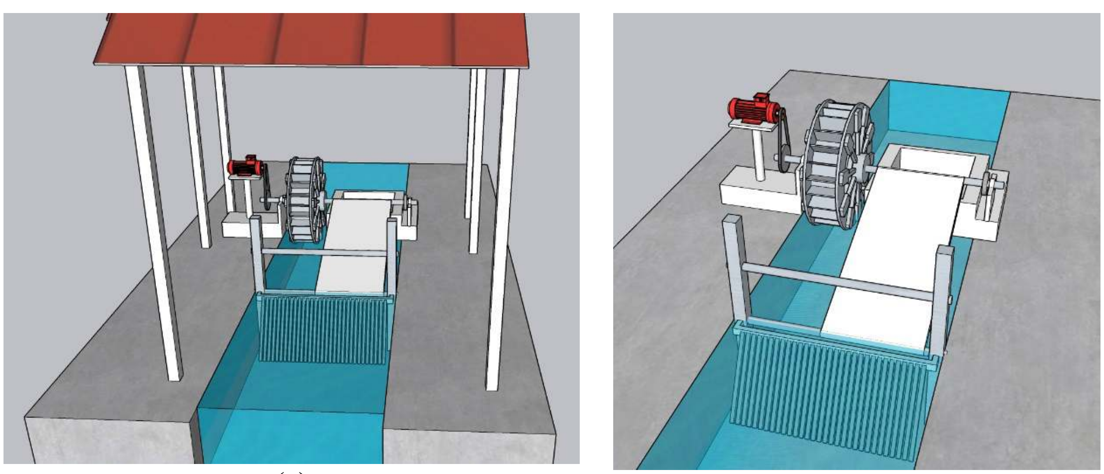


Figure 3. Land-water related microplastic contamination

1. WDC Innovation

The proposed WDC innovation is a development of several waste filter designs in rivers. Several innovations have been carried out, including a waste filter in the form of a 4-arm wheel, a waste filter made from perforated plates [3], and a waste filter with water potential power in the drainage using a wire mesh conveyor [4]. In this design, a waste collection device is created that uses water power from a turbine and is equipped with a bar screen filter to hold waste that passes through the drainage. So that the conveyor can be optimal in collecting filtered waste. Apart from that, a WDC house was also made to protect the equipment so that it is well maintained. Figure 4 shows the proposed WDC planning design.



(a) (b)

Figure 4. WDC design

WDC is an innovation that combines a conveyor concept with the help of a vortex on a waterwheel to clean waste from water channels. This tool is designed to

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be an effective, efficient, and environmentally friendly solution to overcome the problem of accumulation of plastic waste in urban drainage systems. WDC works on a simple but effective principle. First, the waste carried by the water flow will be retained by the bar screen, which functions as an initial filter to separate the waste from the water. Then, the trapped waste will be lifted to the surface of the water by the rotating waterwheel. This waterwheel uses kinetic energy from flowing water to rotate, so it does not require an external energy source.

One of the superior features of the WDC is the use of a generator installed on the waterwheel. This generator is capable of converting the kinetic energy produced by the waterwheel rotation into electrical energy. The electrical energy produced can be used for various purposes, such as lighting or operating other equipment needed in the drainage system. With a combination of a conveyor concept, vortex assistance on a waterwheel, and the use of a generator to produce electrical energy, the WDC is a comprehensive solution for cleaning waste from urban waterways. This tool is not only effective in cleaning up waste, but is also environmentally friendly because it reduces dependence on external energy sources and produces electrical energy independently.

2. Expected Result

Water velocity measurements were taken at a drainage in Lhokseumawe City, Aceh, Indonesia using the float method. Obtained water speed data of 2 m/s and cross-sectional area is 0.72 m2. So, it is known that the drainage water discharge is 1.44 m3/s. The potential water power in the study location drainage is 2,118 Watts or 2.1 kW. However, this water potential value can decrease or increase depending on the drainage water level.

If it is assumed that the turbine efficiency is 75%, then the output power of the drainage water wheel is 1.6 kW. When selecting a generator, it is assumed that the generator efficiency is 80%, so the output power that can be generated by the generator in the system is 1.28 kW. To determine the generator's apparent capacity of 1.6 kVA.The estimated water surface height of the conveyor belt is 0.15 m, and the turbine weight is 30 kg, so the power requirement is 151.62 Watts [6]. In this research, the load from the turbine will be smaller because the planned diameter can be smaller, so the power requirement can also be smaller. So, it is predicted that with this water flow, the turbine can produce electricity to drive the conveyor.

Conclusion

It can be concluded that the WDC innovation is an economic, technological approach to prevent microplastic pollution related to land-water problems. WDC is designed to clean waste from urban waterways effectively, efficiently, and environmentally friendly. By using a conveyor concept and the help of a vortex on the waterwheel, WDC can filter plastic waste from the water well. Using a generator on a waterwheel also provides the additional advantage of producing electrical energy independently. Thus, it is hoped that this prototype design can design a detailed turbine that can be applied directly to overcome the problem of microplastic pollution

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in urban environments, making a significant contribution to environmental sustainability and community welfare.

References

Adhiharto, R. and R. Y. Felvi. (2021) "Perancangan Sistem Konveyor Pembersih Sampah pada Saluran Air dengan Menggunakan Tenaga Air". *Jurnal TEDC.* pp. 55-63.

D'Hont, A., A. Gittenberger, R. S. Leuven and A. J. Hendriks. (2021). "Dropping the microbead: Source and sink related microplastic distribution in the Black Sea and Caspian Sea basins". *Marine Pollution Bulletin.* pp. 1-15.

Karmiati, B. T. and R. N. Rafiq. (2020). "Perancangan Bentuk Penyaring Sampah Pada Alat Penyaring Sampah Sungai". *Jurnal Terapan Teknik Mesin,* pp. 1-11.

Kayser, G. L., N. Rao, R. Jose and A. Rajb. (2019). "Water, sanitation and hygiene: measuring gender equality and empowerment". *Bull World Health Organ,* p. 438–440.

Pavani, Dulanja Dissanayake., S. K. S., a b, P. Oleszczuk, M. K. Sang, M. N. Haque, J. H. Ahn, M. S. Bank, and Y. S. Ok. (2022). "Effects of microplastics on the terrestrial environment: A critical review". *Environmental Research.* vol. 209, no. 112.734.

Zhou, Y., Y. Li, Z. Yan, H. Wang, H. Chen, S. Zhao, N. Zhong, Y. Cheng, and K. Acharya. (2023). "Microplastics discharged from urban drainage system: Prominent contribution of sewer over flow pollution". *Water Res Journal.*