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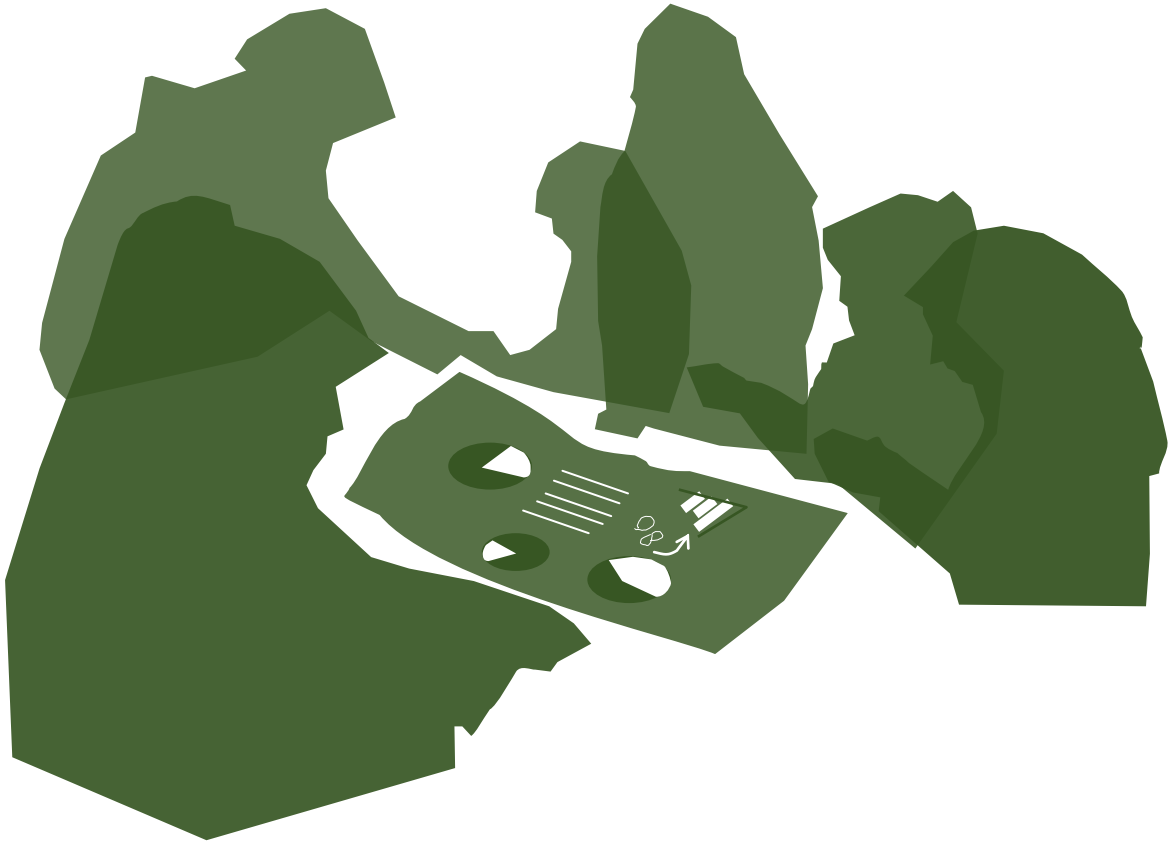

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REDUCTION OF CHEMICAL OXYGEN DEMAND (COD) AND TOTAL SUSPENDED SOLID (TSS) LEVELS IN RUBBER WASTEWATER USING BIOSAND FILTER REACTOR WITH ACTIVATED CARBON MEDIA BASED ON THE EFFECT OF RESIDENCE TIME

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Abstract

Wastewater from the rubber industry that is not treated optimally can be one of the causes of environmental damage. Initial concentration of COD waste rubber liquid 711 mg/l and TSS 407 mg / l. Biosand Filter with activated carbon can eliminate pathogenic bacteria by passing the sand in the filter and activated carbon will absorb organic substances. This study aims to determine the effectiveness of concentration reduction, COD and TSS, using a reactor with BioSand Filter reactor dimensions used measuring 12 cm x 12 cm x 120 cm and its effect on residence time. Filter Media used are sand, gravel, pumice and activated carbon. The research variable is the residence time in the reactor (10, 30, 50, 70, and 90 minutes). Removal efficiency after being processed using Biosand Filter technology with activated carbon media lowered the concentration of COD and TSS parameters to 93% for COD and 79% for TSS. Test the effect of residence time to reduce the levels of COD and TSS is done by regression test has a value of R^2=0.7014 for COD and R^2=0.681 for TSS, with $t_{count} > t_{table}$. the results show that the residence time of rubber wastewater in the reactor affect the decrease levels of COD and TSS, and quite effective in eliminating COD and TSS parameters.

Keywords: *COD, TSS, Biosand filter-activated carbon, residence time, rubber wastewater*

Introduction

Indonesia has a very large rubber plantation land and circulates in various regions, and every year it will increase. Based on data from the Ministry of Agriculture, the national rubber plantation area at the end of 2021 it reached 3.69 million ha (Direktorat Jenderal Perkebunan, 2021). Rubber wastewater usually comes from cleaning, grinding, weakening, drying, and burn pressing activities to produce wastewater with high organic content (Sari Dewi et al, 2020). Based on testing in this study the characteristics of rubber wastewater containing COD and TSS at the inlet is 711 mg/l and 407 mg/l. Quality standards for industrial wastewater are regulation of the Minister of environment No. 5 of 2014 on wastewater quality standards. COD parameters have a maximum rate of 200 mg/l and TSS parameters maximum rate of 100 mg/l (Mayasari et al, 2020). Various rubber industries generally process liquid waste using biological treatment. But its effectiveness largely depends on the ability of its bacteria to be able to form flocks; this processing requires expensive costs and large area of land. Treatment using Biosand Filter with activated carbon can reduce organic and inorganic levels in rubber wastewater. In the

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upper layer of the media will occur biofilm growth, this layer will reduce the smell, taste and color, on waste rubber liquid. Adding this activated carbon to the BioSand filter treatment improves the efficiency of reducing organic content in wastewater and decomposing substances that have not been degraded from the BioSand Filter treatment. Research on the processing of industrial rubber wastewater with BioSand Filter Technology has been previously conducted Suligundi (2013), the results of processing with BioSand Filter and activated carbon COD efficiency of 98.33% (Suligundi, 2013), and also in Halim's research (2016) using Biosand Filter technology with activated carbon, it has the effectiveness of reducing COD levels up to 85.42% and TSS 82.65% (Halim, 2014). Based on this description, treatment for rubber liquid waste is chosen using Biosand Filter reactor with activated carbon, so that it can be known the efficiency of estimating COD and TSS levels in rubber liquid waste, and the influence of variations in residence time in reducing the concentration of COD and TSS in rubber liquid waste.

So that the removal efficiency of COD, TSS levels in rubber wastewater and the influence of variations in residence time in reducing the concentration of COD and TSS in rubber wastewater can be calculated.

Research Methodology

Scope and Design

This research's scope and design includes:

1. Rubber liquid waste samples were taken from the inlet of WWTP PTPN VII Lampung.
2. Preparations of sand, pumice, activated carbon, and gravel media by washing, drying and activation of media.
3. The height of the sand filter media is 50 cm, pumice stone 10 cm, activated carbon 20 cm and Gravel 10 cm and the total height of the media is 90 cm.
4. Biofilm formation was observed physically and isolated microorganisms to determine the formation of biofilms.
5. Variations of residence time used 10, 30, 50, 70, 90 minutes.

Material

a. Rubber Industry Wastewater

Rubber is currently widely produced synthetically, as a raw material for rubber, latex that can be made in a bowl container taken by grinding the bark of the rubber tree so that it will remove the thick liquid from the gutter and then be accommodated for later processing (Nuraini et al, 2019). Many rubber exports in Indonesia are provided in the form of crumb rubber which has been included in the Indonesian rubber standard (SIR). There are two products of crumb rubber, namely high grade, made from latex raw materials, and low grade produced from Felts (Sari Dewi et al, 2020).

The wastewater parameters of the rubber industry consist of physical and chemical parameters. Physical parameters include total suspended solids (TSS), temperature, turbidity, odor, and color. Chemical parameters consist of acid (pH), chemical oxygen demand (COD), biochemical oxygen demand (BOD), and ammonia (NH_3).

b. Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is the total oxygen required for a chemical compound in a reaction to be able to oxidize all organic matter contained in water (Rahmat and Mallongi, 2018). Rubber processing waste at the inlet has a COD concentration in liquid waste 120-15069 mg/l (Nasrullah et al, 2014). Determining COD concentration's value in water is done by reacting it with potassium dichromate as an oxidizer or reagent (Atima, 2015) (Nugroho et al, 2017).

c. Total Suspended Solid (TSS)

Total Suspended Solid (TSS) is the content in water consisting of solid substances (sand, clay,

mud, etc.) or suspended particles (phytoplankton, zooplankton, bacteria, fungi), and also the rest of dead microorganisms. Waste water rubber industry has a concentration of TSS 30 - 525 mg / l (Nasrullah et al, 2014). The brightness in water depends on the color and turbidity. High concentrations of TSS will inhibit the entry of sunlight for photosynthesis, so the content and dissolved oxygen needed by plants will decrease. The decreasing oxygen content causes the ecosystem in the water to be disrupted (Nuraini et al, 2019).

d. Biosand Filter

Biosand filter in principle is the development of a slow sand filter that is processing by flowing water on the media to remove pathogenic bacteria by flowing water by gravity through the filter media. Pollutants in the water are then retained and absorbed into the pores of the filter media this process can remove suspended particles and also dissolved in wastewater. Microorganisms and solid particles floating in the upper layer of the media when left at a certain time in the topmost sand layer will form a biofilm (Suligundi, 2013). Biosand filters in processing generally only use fine sand media, coarse sand and gravel. The addition of filter media is done to get maximum processing results with pumice media and the addition of activated carbon. The function of fine sand in the upper layer is for the initial filter that can hold solid particles in wastewater in large quantities, while for coarse sand, gravel, pumice media serves to buffer the media from the previous filter. Activated Carbon is used as an addition to the BioSand Filter to improve the efficiency of reducing dissolved organic matter content in liquid waste.

e. Residence Time

Residence time is the time required to carry out a treatment process in a reactor used under certain conditions (Ratnawati and Al Kholil, 2005), residence time is also a concept to express how fast a fluid that moves, through a system in equilibrium and consumes a substance in a certain space, such as a reservoir or reactor. The residence time is not only related to hydraulic but also the residence time of bacteria (Kencanawati, 2016). The longer the residence time of a fluid in the reactor will make the removal of substances greater, so as to set aside organic and inorganic compounds to the maximum

Methods

a. Research Variables

1. Independent Variable

Independent variables contained in this study are: variations in residence time (10, 30, 50, 70, 90 minutes).

2. Dependent Variable

The dependent variable contained in the test is the concentrations of the parameters studied are COD and TSS.

b. Procedure

1. Media Preparation

Media washed, then dried, for the activation of carbon using chemicals as activators that is by using a basic solution of NaOH. then the carbon is soaked for 24 hours. wash using aquadest until the pH of the activated carbon washing water is neutral.. Activated Carbon is filtered and dried in an oven at 105o C for 2 hours. Activated charcoal is then in the wind until it reaches room temperature (Primasari et al, 2020). Once all the substrate is ready, prepared by height.

2. Biofilm

Biofilm formation is done by immersing the reactor with waste water until at a certain time a slimy layer is formed with the water level in the reactor kept 5 cm above the topmost media by paying attention. speed between inlet and outlet faucets. This height is set so that the biofilm layer is not easily damaged and still maintain the life of microorganisms in the biofilm layer (Jin et al, 2021), (Harahap et al, 2020). Biofilm layer formed on the sand media can be observed

visually with a slippery layer such as mucus and the color of the sand surface layer will change from the initial light yellow color to brown color based on previous researchers this is a sign that there has been activity of microorganisms on the biofilm. The formation of biofilms can also be observed by isolating microorganisms to see what colonies of microorganisms contained in the biofilm layer after the biofilm layer grows (Srimurni, 2016), (BSN, 2004).

3. Data Analysis

Data analysis for the test results by descriptive analysis, and a linier regression test to know whether the variables affect each other.

Results and Discussion

Characteristics of Waste Rubber

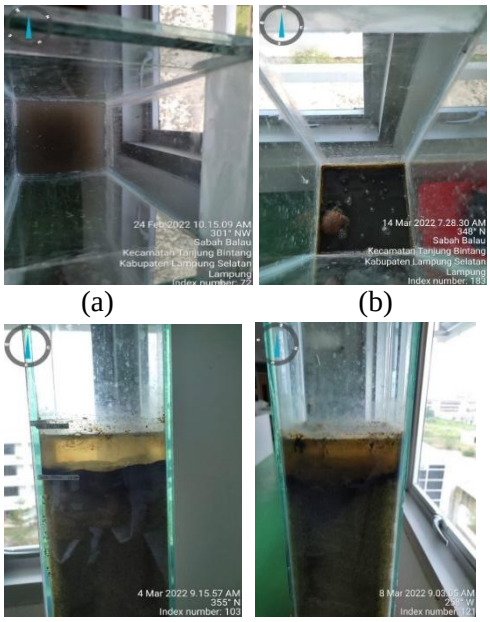
Preliminary test of COD concentration, and TSS with 3 repetitions obtained an average of 436 mg/l, and 711 mg/l, respectively.

Table 1. Characteristics of wastewate

Parameters (mg/l)	Results	Quality Standard
TSS	436	100 mg/l
COD	711	200 mg/l

Biofilm Formation

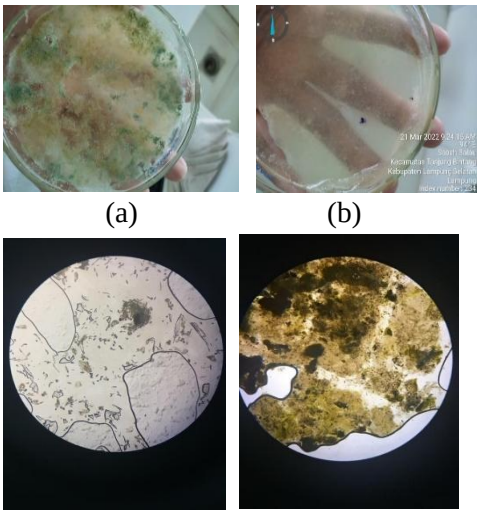
Biofilm growth process in this study formed up to 15 days. Biofilms were grown by immersing the media in a BioSand filter reactor with activated carbon media with a sample of rubber wastewater, with the water level maintained 5 cm above the sand media. Biofilm formation on the surface of the water until the 7th day there is still a small number of bubbles. On the 10th day, a film has formed. On 15th day already seen changes characterized by the formation of mucus at the top of the brown as the end of the formation of biofilm when the formation of factors that are considered are temperature, pH and nutrients.



(a) (b)

(b) (d)

Figure 1. Biofilm growth on water surface
(a). Day-1 (b). Day-15 with the addition of sugar, (c) front view
(d) side view



(a) (b)

(c) (d)

Figure 2 . Observation of microorganisms on biofilms
(a). PDA media observation, (b) NA Media observation,
(c,d) observation microscope magnification *40x dan 100×*

To determine the presence of microorganisms in the biofilm layer is to isolate bacteria and fungi

using NA and PDA media. Then observation with a microscope to see microorganisms on the biofilm layer.

Amount of fungal content in biofilms more than bacteria because the layer taken to be tested is the dominant top layer consisting of fungi. Fungi contain extracellular enzymes to be able to decompose complex compounds in water (Atima, 2015). Microscope observations were also carried out on the biofilm layer contained in the upper layer of sand and from the observations in the Figure (c-d) can be seen the presence of microorganisms such as bacteria and protozoa.

Analysis of cod and TSS levels reduction efficiency

Reduction COD levels

Processing with COD concentration 711 mg/l has an removal efficiency of COD levels reached 93% which is reinforced by research Bonifasia (2013) and Yuni lestari (2014) the efficiency of cod with BioSand Filter technology with activated carbon reaches 65% - 98,33% (Suligundi, 2013), (Yadav et al, 2018). rubber wastewater treatment has an optimum point at the 70 minute. Rubber wastewater treatment without biofilm has COD removal efficiency reached 68% in the 70 minute and COD levels and increased again in the 90 minute

Based on the results of processing carried out in the absence of biofilm, only applying adsorption with filter media in the reactor has not met the quality standards for COD parameters according to regulations and from these results it can be concluded that biofilm serves to degrade organic levels in water (Fadhillah and Wahyuni, 2016).The efficiency of reduce COD levels continues to reduce over time which indicates the filter media has reached the optimum point so that it is necessary to wash the media again this is in accordance with the Sulistyanti experiment (2018) controlled flow velocity at a point will occur decrease back after reaching the optimum point to decompose organic compounds in wastewater (Ramdja et al, 2008).

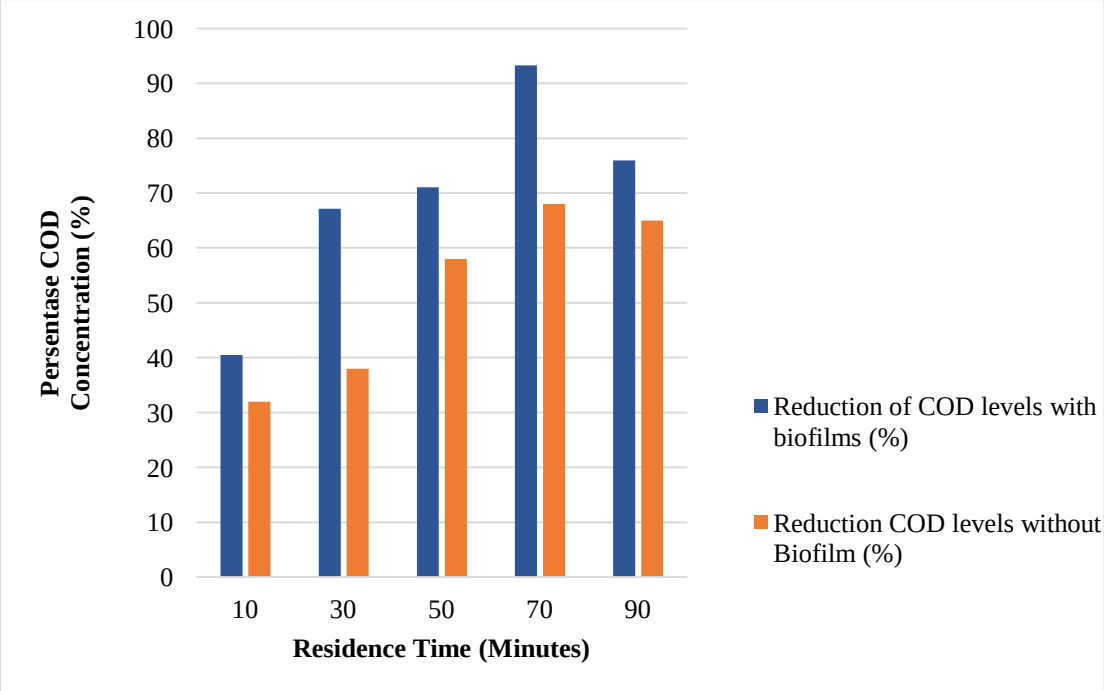


Figure 3. COD reduction percentage

Reduction TSS levels

TSS concentration of 407 mg/l, has efficiency removal of TSS levels reached 79% in the 70 minute so that the treatment of rubber wastewater has an optimum point in the 70 minute. Rubber wastewater treatment without biofilm has an efficiency of removal of TSS levels reached 70% in the 70 minute and TSS levels increased again in the 90 minute. The efficiency of reducing TSS levels by processing using biofilm is higher than processing without biofilm, due to the presence of microorganisms that can reduce the levels of organic and suspended solids in rubber wastewater. Processing without using biofilm TSS levels have not met the quality standards for TSS parameters so that additional processing is required. The Re-increase in TSS concentration in the 90 minute of processing is caused by TSS that occurs in rubber wastewater containing suspended particles.

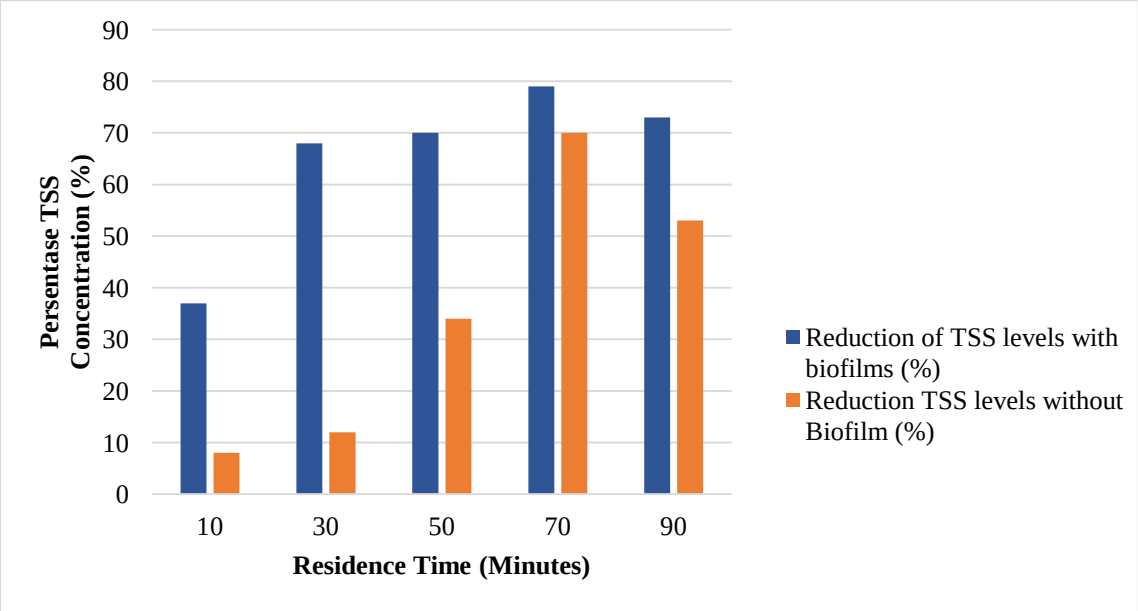


Figure 4. TSS reduction percentage

Analysis the effect of variation residence time on the reduction of COD and TSS levels

Analysis the effect of variation residence time to reduce COD levels

Regression analysis of the variation residence time to reduce COD levels resulted in the value of R2 or coefficient of determination of 0.7014 means that the variation of residence time to reduce COD levels of liquid rubber waste 70.14% and the remaining 29.86% are influenced by variables that are not discussed. P value<0.05 that is 0.037 indicates that the regression line equation is significant. Based on statistical results using Jamovi can be seen that the value of t count is 3.07 is greater than the T table with the level of significance allowed %. The value of T table is 2.772 hence the decision is to reject the null hypothesis. The value of t with a negative sign that explains the existence of a counter-directional relationship between residence time and COD levels. So it can be concluded that the true residence time affect COD levels.

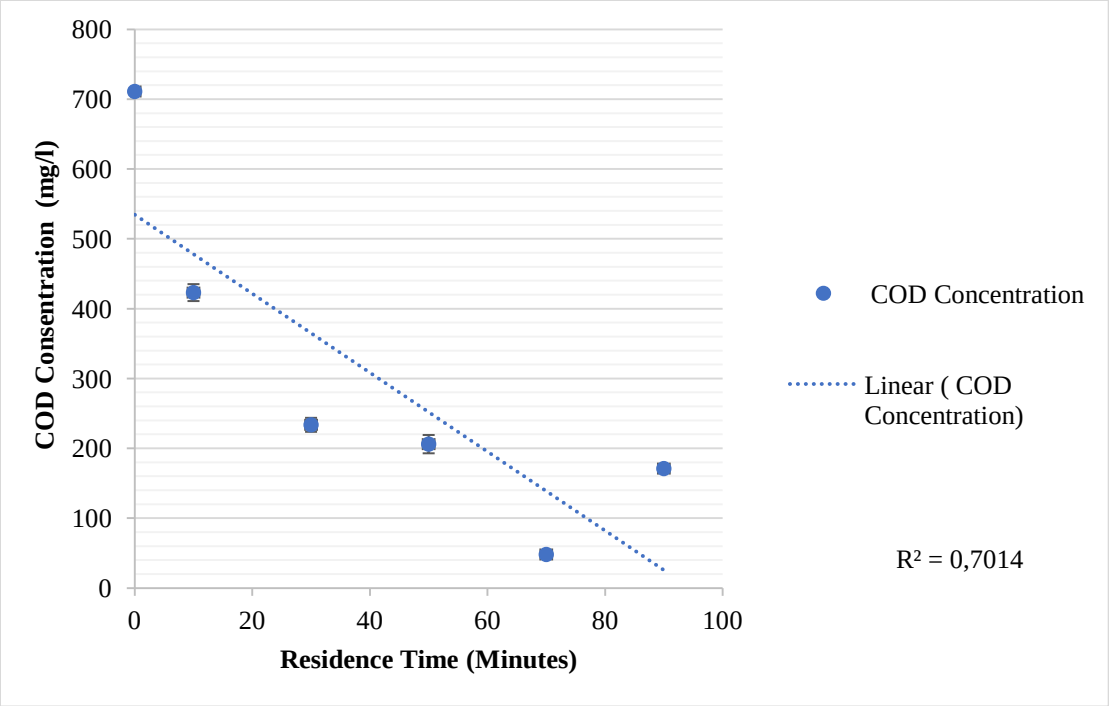


Figure 5 Regression analysis effect of variation residence time to reduction COD levels

Analysis the effect variation of residence time to reduce TSS levels

Regression analysis of variations in residence time to reduce TSS levels resulted in the value of R2= 0.681 means that variations in residence time affect the reduce TSS levels to 68.1% and 31.2% are influenced by other variables that are not discussed. P value<0.05 that is 0.043 indicates that the regression line equation is significant. Based on statistical results using Jamovi t value results calculate the test results are 2.92 greater than T table with a significance level of 5%. The value of T table is 2.772 so the decision is to reject the null hypothesis. The negative sign for the calculated t value illustrates the opposite relationship, and it can be concluded that the residence time has an effect on the reduction of TSS levels. The dwell time has the most optimum reduce at the 70 minute. From the results of testing the treatment of rubber wastewater using a BioSand filter reactor with Activated Carbon, the results showed that the residence time of rubber wastewater in the reactor has an effect to reduce the levels of COD and TSS with a negative X-marked value which explains the relationship in the opposite direction.

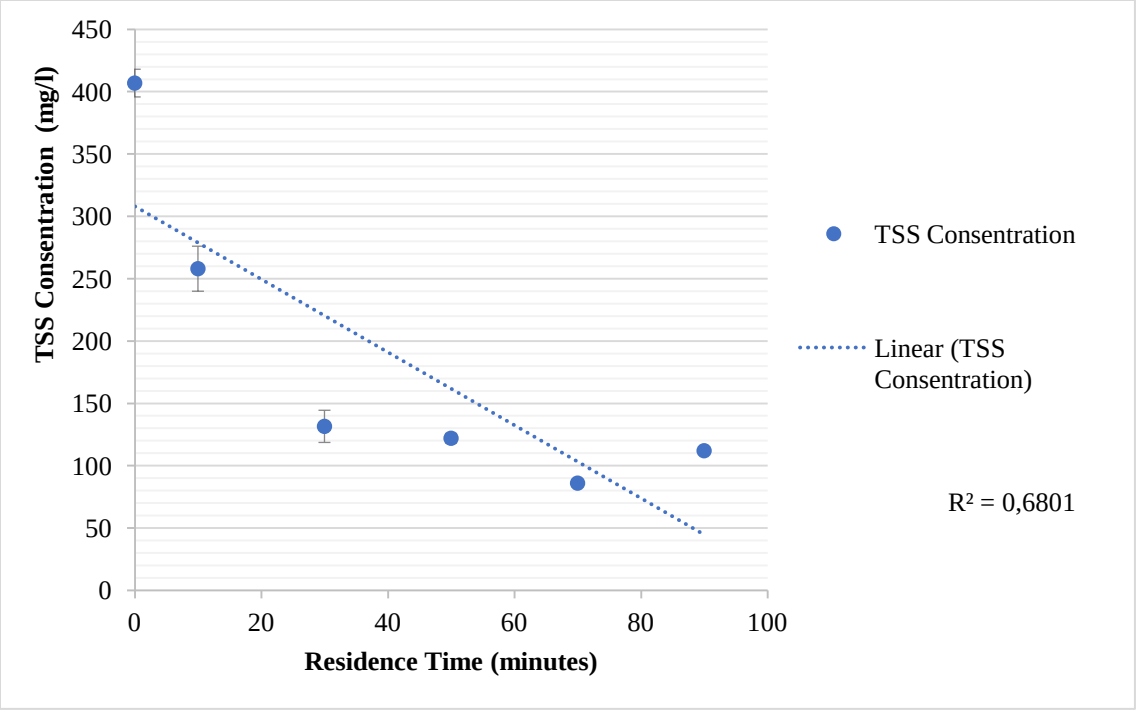


Figure 6. Regression analysis effect of variation residence time to reduction TSS levels

Conclusions

Based on the research of COD and TSS reduction in rubber wastewater with BioSand Filter with activated carbon media, concludes that:

1. Reduction of COD and TSS levels of rubber wastewater using BioSand filter reactor with activated carbon media based on the variation of residence time has the highest efficiency in the 70th minute of 93% and 79% respectively.

2. Residence time effect on reduce COD and TSS levels, based on a simple regression test of reduce COD and TSS levels in rubber wastewater with variations in residence time has a value of R2= 0.7014 for COD and R2= 0.681 for TSS, the value of t count obtained is greater than t the table shows the influence reduce COD and TSS

References

Atima, W.. (2015). BOD dan COD Sebagai Parameter Pencemaran Air Dan Baku Mutu Air Limbah. *Biosel Biol. Sci. Educ.*, *4*(1), 83 Doi: 10.33477/Bs.V4i1.532.

BSN. (2004). SNI 06-6989.3-2004: *Air dan air limbah- Bagian 3: Cara uji padatan tersuspensi total (Total Suspended Solid, TSS) secara gravimetric*.

Direktorat Jenderal Perkebunan. (2021). *Luas Areal Kelapa Menurut Provinsi di Indonesia , 2016-2019 Coconut Area by Province in Indonesia, 2016-2019.*

Fadhillah, M. and Wahyuni, D.. (2016). Efektivitas Penambahan Karbon Aktif Cangkang Kelapa Sawit (Elaeis Guineensis) dalam Proses Filtrasi Air Sumur. J. *Kesehat. Komunitas*, *3*(2), 93–98, 2016, doi: 10.25311/keskom.vol3.iss2.110.

Halim, P.A.. (2014). *Biosand Filter dengan*

Reaktor Karbon Aktif Dalam Pengolahan Limbah Cair Laundry (Studi Kasus Bung Laundry Makassar). Skripsi: Universitas Hasanuddin.

Harahap, M. R., Amanda, L. D., and Matondang, A. H.. (2020). Analisis Kadar COD (Chemical Oxygen Demand) dan TSS (Total Suspended Solid) pada Limbah Cair dengan Menggunakan Spektrofotometer Uv-Vis. *Amina*, *2*(2), 79–83.

Jin, S., Park, J. H., Yang, W. S., Lee, J. Y., and Hwang, C. W.. (2021). Anti-biofilm ability of garlic extract on Pantoea agglomerans and application to biosand filter. *Desalin. Water Treat.*, *228*, 84–91, 2021, doi: 10.5004/dwt.2021.27317.

Kencanawati, C. I. P. K.. (2016). *Sistem Pengelolaan AiIr Limbah*. Diktat: Universitas Udayana.

Mayasari, R., Purba, E., and Djana, M.. (2020). Penyisihan Kadar Amoniak (NH3) Dalam Limbah Cair Karet Dengan Kombinasi Adsorben Bentonit Dan Zeolit Secara Kontinyu. *Seminar Nasional Ilmu Teknik Dan Aplikasi Industri (Sinta)*.

Nasrullah, S., Hayati, R., and Kadaria, U.. (2014). *Pengolahan Limbah Karet Dengan Fitoremidiasi Menggunakan Tanaman Typha Angustifolia.* (https://media.neliti.com/media/publications/191120-ID-none.pdf accessed September 2022)

Nugroho, F.L., Rusmaya, D., Yustiani, Y.M., Hafiz, F. I., Putri, R. B. T. (2017). Effect of Temperature on Removal of COD and TSS from Artificial River Water by Mudball Made from EM4, Rice Bran and Clay. *Int. J. of Geomate*, *12*(33), 91-95.

Nuraini, E., Fauziah, T., and Lestari, F.. (2019). Penentuan Nilai BOD dan COD Limbah Cair Inlet Laboratorium Pengujian Fisis Politeknik Atk Yogyakarta. *Integr. Lab J.*, *7*(2), 10–15.

Rahmat, B. and Mallongi, A.. (2018). Studi Karakteristik Dan Kualitas Bod Dan Cod Limbah Cair Rumah Sakit Umum Daerah Lanto Dg. Pasewang Kabupaten Jeneponto. *J. Nas. Ilmu Kesehat.*, *1*(69), 1–16.

Ramdja, A. F., Halim, M., and Handi, J. (2008). Pembuatan Karbon Aktif Dari Pelepah Kelapa (Cocus nucifera) A. *J. Tek. Kim.*, *15*(2), 1–8.

Ratnawati, R. and Al Kholif, M.. (2018). Aplikasi Media Batu Apung Pada Biofilter Anaerobik Untuk Pengolahan Limbah Cair Rumah Potong Ayam. *Jurnal Sains & Teknologi Lingkungan*, 10(1), 1–14.

Primasari, B., Indah, S., Afrianita, R., and F. Rahmatesa. (2020). Biosand Filter for Removal of Organic Pollutant from Laboratory Wastewater. *J. Phys. Conf. Ser.*, 1625.

Sari Dewi, D., Eko Prasetyo, H. & Karnadeli, E.. (2020). Pengolahan Air Limbah Industri Karet Remah (Crumb Rubber) Dengan Menggunakan Reagen Fenton. *Jurnal Redoks*, *5*(1), 47–57. https://doi.org/10.31851/redoks.v5i1.4120

Suligundi, B. T.. (2013). Penurunan Kadar COD (Chemical Oxygen Demand) Pada Limbah Cair Karet Dengan Menggunakan Reaktor Biosand Filter Yang Dilanjutkan Dengan Reaktor

Activated Carbon. *J. Tek. Sipil Untan*, *13*(1), 29–44.

Srimurni, R. R.. (2015). *Pengolahan Limbah Cair dengan Menggunakan Biosand Filter*. Pasca Sarjana. Fakultas Teknologi Pertanian. Institut Pertanian Bogor.

Yadav, K. K., Mandal, A. K., and Chakraborty, R.. (2018). Biology of Bacterial Biofilms. *Biology of Plants Microbes*, 61-82, Book Chapter.

THE USE OF A STATIC MIXER FOR THE COAGULATION UNIT IN THE DUREN SERIBU II WATER TREATMENT PLANT

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Abstract

In the drinking water treatment plant involves a significant component i.e., coagulation, which distributed coagulants vastly and equally through rapid stirring for destabilizing colloids and suspended particles in the raw water. In water treatment plants, coagulation units are often classified into mechanical and hydraulic coagulation. This study aimed to discover the use of and in-line static mixers as coagulation in designing the Duren Seribu II Drinking Water Treatment Plant (WTP). The design criteria for coagulation unit in Duren Seribu II WTP was determined by comparing several data obtained from literature studies and evaluation of the existing conditions of Duren Seribu I WTP. Duren Seribu I WTP was evaluated by direct measurement in the field. From the results of data analysis, the design criteria appropriate for Duren Seribu II WTP, the G value is 2078.07 sec^{-1}, the detention time (td) is 4 sec, and the G.td value is 8352.19.

Keywords: *coagulation, drinking water, Duren Seribu II WTP, water treatment plant*

Introduction

Along with the population growth in Depok City, it will increase the water demand therefore the development of drinking water services are necessary. A way to conform the increasing water demands is developing a water treatment plant (Reynold & Richard, 1996). Based on RISPAM or Master Plan for Drinking Water Supply for Depok City, it is planned to develop Duren Seribu II WTP with capacity of 150 L/sec that uses Angke River as raw water source to increase the service coverage of Depok City (RISPAM Kota Depok, 2020). The WTP is planned to be built in Bojongsari District, Depok City that met the Indonesian standard drinking water quality requirements according to the Regulation of the Minister of Health Republic of Indonesia Number 492 of 2010.

On the time being, a 100 L/sec WTP named Duren Seribu I is operated to fullfil the existing water demand. It is located at Sawangan Elok Street Number 10, Duren Seribu, Bojongsari, Depok. Consider the existing WTP withdrawn its raw water from Angke River which will be used as raw water resources for the new WTP, therefore the Duren Seribu I WTP is used as a reference for design the new Duren Seribu II WTP. The existing Duren Seribu I WTP is a conventional water treatment plant consists of coagulation, flocculation, sedimentation, rapid sand filtratrion, and disinfection units. It uses in-line static mixer as coagulation unit.

The coagulation unit is a significant component in drinking water treatment, as mixing

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coagulants is dispersing coagulant uniformly throughout the basin and allowing contact between the colloids particles and coagulant for destabilizing colloids particles in raw water (Kawamura, 1991). By the time the water leaves this unit, the coagulation process has progressed sufficiently to form microfloc.

Various types of coagulation units may be generally classified as (i) mechanical coagulation uses mechanical equipment as impeller and turbine mixers, paddle mixers, by a motor with the help of electricity (Reynold & Richard, 1996), and (ii) hydraulic coagulation with gravity force as hydraulic jump, and in-line static mixers (Qasim, 2000). The degree of mixing is based on the power imparted to the water that measure as velocity gradient, considering that more input power creates greater turbulence, and greater turbulence lead to better mixing.

$$G = \sqrt{\frac{P}{\mu \times V}} \qquad (1)$$

Where G is velocity gradient (sec^{-1}), P is mixing power (watt), V is volume (m^3), μis dynamic viscocity (kg/m.s). As shown in the Equation (1), the value of G depends on the power input, the fluid viscocity, and the basin volume. The velocity gradient also related to the shear forces in the water; thus, larger velocity gradients produce appreciable shear forces. G value in-line static mixer are shown in Table 1.

The degree of mixing completion is dependent on the velocity gradient and the value of G.td, whereas td is the detention time. The magnitude of the dimensionless parameter G.td is related to the vigorous of the mixing during coagulation (mixing intensity) (Gabrielle et al., 2021). G.td value has a range of 600-10.000 (Davis, 2010).

Table 1. Design Criteria Coagulation In-Line Static Mixer

Parameter	Design Criteria	Source
Detention Time (td)	1-5 sec	(Davis,2010)
Velocity Gradient (G)	>750 sec^{-1}	(Davis,2010)
G.td Value	600-10.000	(Davis,2010)

In general, hydraulic coagulation depend on the head differential that provides hydraulic turbulence to achieve the desired velocity gradient. Static mixers are principally identified by their lack of moving parts. Typical examples include in-line static mixer, which is a type of rapid mixing which occurs in a standard pipe diameter that equipped with plates/elements that causing sudden changes in the velocity patterns as well as momentum reversals. It can break up the flow and increasing turbulence.

The advantage of using an in-line static mixer is that there are no moving parts, and no external energy sources are needed. Thus, mixing using an in-line static mixer is quite effective and the coagulation of an in-line static mixer does not require a large area (Davis, 2010). The in-line static mixer is the most compact method and is increasing in popularity. It is found that in-line static mixer is used in 65 L/sec Sindang Pasekan water treatment plant (Arief et al., 2020) and 290 L/sec Kaligarang III water treatment plant (Lestari et al., 2019).

The power consumed by static-mixing devices can be computed using the following equation.

$$P = Q \times h_L \times \rho \qquad (2)$$

Where P is mixing power (watt), Q is flow rate (m^3/sec), h_L headloss (m), ρ is water density (kN/m^3).

Headloss dissipated as liquid passes through in-line static mixer can be calculated according to the graph that determining pipe diameter and head loss per element, as shown in Figure 1. Mixing ratio of 1.5 is usually used in the design. (Davis, 2010).

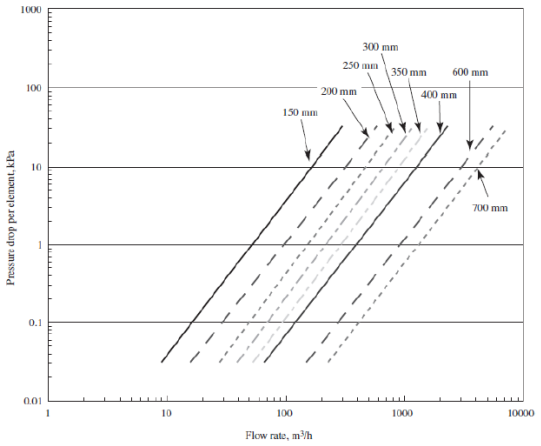

Figure 1. The Graph of Determining Pipe Diameters and *Headloss* per Element.

h_L = Total of elements × h_L per element (3)

The pipe length (L) of in-line static mixer can be obtain as follows.

L = Total of elements x mixing ratio x pipe diameter (4)

Research Methodology

The design of the coagulation unit for Duren Seribu II WTP consists of several stages:

a. Evaluation the performance of in-line static mixer which is used in the existing Duren Seribu I WTP, as follows:
   Data collection:
   - Inventory of pipeline from intake to flocculation unit (length and diameter).
   - Measure the pumping head in the intake.
   - Measure the pressure as shown in the manometer inserted after the static mixer.

   Performance evaluation:
   - Calculate headloss occuring in the static mixer using the head differential between pumps and manometer.
   - Evaluate mixing power (P), velocity gradient (G), and G.td value.

b. Literature review,
   The literature review was conducted to provide such a useful information in the design of coagulation unit of Duren Seribu II WTP, i.e:
   - Guidelines for water treatment pant design,
   - The condition of the planning area,
   - Related researchs in the area of mixing and coagulation.

c. Design of coagulation unit, as follows:
   - Jartest analysis to select the proper coagulant and determine its doses.
   - Evaluate and select the value of velocity gradient (G), time detention (td), and G.td.
   - Spesify pipe diameter from intake to flocculation unit that fullfil the velocity requirement.
   - Calculation of the headloss occurs in the in-line static mixer using graph developed by Davis (2010) as shown in Figure 1.
   - Calculate the required length of in-line static mixer using equation (4).

Results and Discussion

Existing Coagulation at Duren Seribu I WTP.

In designing a WTP, it is necessary to reference an existing WTP for estimating (i) the water treatment unit that can be used, (ii) the water treatment process can be operated optimally, to produce water that meets the quality of drinking water. The evaluation performance of the coagulation unit carried out at Duren Seribu I WTP with a design capacity of 250 L/sec. The schematic of coagulation unit Duren Seribu I WTP can be seen in Figure 2.

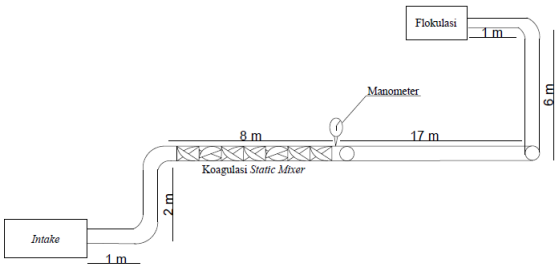

Figure 2. Schematic of Coagulation Unit of Duren Seribu I WTP.

The type of coagulation used by the Duren Seribu I WTP is in-line static mixer, where this system does not use a machine, but uses a plate that causes mixing power. The coagulant used by the Duren Seribu I WTP is aluminum sulfate with a dose of 30.68 mg/L. Aluminum sulfate coagulant that has been diluted will be injected to the coagulation unit using a dosing pump.

The coagulation in-line static mixer at Duren Seribu I WTP has a diameter of 400 mm and a pipe length of 8 m. The head of pump at the intake is 30.8 m, and the manometer measurement is 24 m. Thus, the headloss value obtained on the static mixer pipe is 6.77 m or equivalent to 0.677 bar.

The volume in the in-line static mixer is 1 m^3 with a discharge at the time of observation of 50 L/sec which is less than design capacity of 250 L/sec. This existing operational condition gives detention time (td) value of 20.10 second. The mixing power (P) can be estimated using water density value of 996.81 kg/m^3 and headloss of 6.77 m as mentioned above, resulted the mixing power of 3324.32 Nm/sec. Then, it followed by resulted the value of G (velocity gradient) = 1944.94 sec^{-1} and G.td = 39,086. The detention time (td) and G.td value obtained have not met the design criteria of Davis (2010).

In spite of that, the quality of the water produced based on tubidity parameter found in the reservoir of Duren Seribu I WTP is 0.74 NTU. It shows that the existing WTP has fulfilled the drinking water standard according to the Minister of Health Republic of Indonesia Number 492 of 2010 based on turbidity parameter below 5 NTU. In the existing conditions, the td and G.td values in coagulation do not conform the design criteria. However, it does not cause problems during operation because the flocs that were formed are quite large and dense. Accordingly, the in-line static mixer of Duren Seribu I WTP is adopted as coagulation unit in the new Duren Seribu II WTP.

Design of Coagulation Unit at Duren Seribu II WTP.

The schematic of coagulation unit Duren Seribu II WTP can be seen in Figure 3, where the 400 mm diameter with 17.95 m pipe length transmit water from intake to flocculation unit. The in-line static mixer has a diameter of 400 mm and length of 5 m.

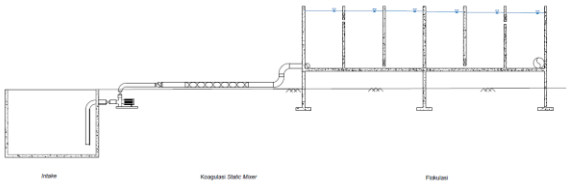

Figure 3. Schematic of Coagulation Unit Duren Seribu II WTP.

Calculation the in-line static mixer dimensions starts with calculating the headloss value. Based on the graph of the pressure drop for pipe diameters between 150 mm to 700 mm (used 400 mm), discharge of 540 m^3/h, resulting in headloss value of each element is 2 kPa = 1.02 m, as shown in Figure 4.

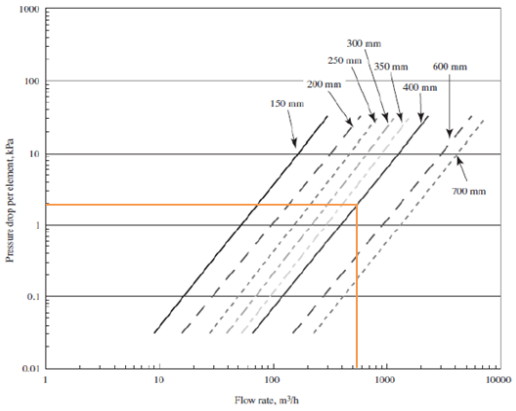

Figure 4. The Pipe Diameters and Headloss per Element for Q 150 L/sec or 540 m^3/h

Total headloss (h_L)

h_L = Total of element × h_L per element

= 8 × 2 kPa

= 16 kPa = 1.63 m

The lenght of static mixer (L)

L = 8 × 1.5 × 0.40 m

= 5 m

Volume static mixer (V)

$V = \frac{1}{4} \times \pi \times D^2 \times L$

$= \frac{1}{4} \times 3.14 \times (0.4\ m)^2 \times 5\ m = 0.60\ m^3$

Detention time (td)

$td = \frac{V}{Q} = 4\ sec$

The detention time (td) obtained meets the design criteria of Davis, 2010 and several researchs related to the coagulation in the pipe, i.e 5.4 sec is found in Sindang Pasekan WTP (Arief et al., 2020), and 5.2 sec is used in Kaligarang III WTP (Lestari et al., 2019).

Mixing power (P) imparted in this static mixer is calculated using equation (2) above:

P = 0.15 m³/sec × 1.63 m × 9987 kN/m^3

= 2442 kW

The velocity gradient (G) resulted can be calculated using equation (1), i.e.:

$$G = \sqrt{\frac{2442\ W}{9.38 \times 10^{-3}\ kg/m.sec \times 0.60\ m^3}}$$

= 2078.07 sec-^{1}

G.td value = 2078.07 /sec × 4 sec

= 8352.19

The resulted velocity gradient is within the range of the existing Duren Seribu I WTP i.e. 1944.94 sec^{-1} and 3183.09 sec^{-1} is found in Solear WTP (Ramdhan et al., 2019).

G.td value obtained has met the design criteria of Davis, 2010 with a range of 600-10000 and similar to Cipageran WTP that resulted 6746.6 as its G.td value (Sani et al., 2019).

The proposed design of coagulation unit Duren Seribu II WTP can be seen in Figure 5. Coagulant to be used is aluminum sulfate that consistent with the existing Duren Seribu I WTP. The jartest experiment with Al_2O_3 content of 17% results an optimum dose of 15 mg/L which is twice the average dose of the existing Duren Seribu I WTP i.e 30.68 mg/L of aluminum sulfate that contain 5% of Al_2O_3.

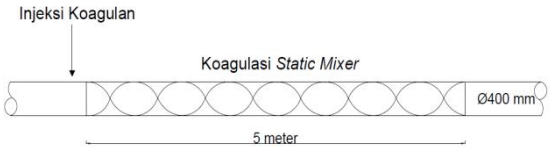

Figure 5. Coagulation Plan Design

Based on the existing Duren Seribu I experience above, an average dosages of 30.68 mg/L aluminum sulfat (5% Al_2O_3) will be added to the new Duren Seribu II WTP.

Conclusions

Based on the Duren Seribu I WTP performance evaluation, it can be concluded that several design parameters do not meet the design criteria standard such as the detention time (td) and G.td value in the coagulation in-line static mixer. Nonetheless, the production water has fulfilled as the quality of drinking water standard according to the Regulation of the Minister of Health Republic of Indonesia Number 492 of 2010. Therefore, the evaluation of existing parameters in Duren Seribu I WTP can be used as a reference for planning a new water treatment plant Duren Seribu II.

References

Arief I., Tazkiaturrizki, and Winarni. (2020). Performance Evaluation of Sindang Pasekan Water Treatment Plant. *International Journal of Scientific & Technology Research*, *9*(3), 1385-1389.

Davis, M. L., (2010). *Water and Wastewater Engineering*. McGraw-Hill, Inc. Facilities (2nd ed.). John Wiley & Sons, Inc.

Gabrielle H., Kusumadewi, R. A., and Ratnaningsih. (2021). Optimisation of Degreemont Water Treatment Package on Kedung Halang Water Treatment Plant,

Bogor, West Java. *IOP Conference Series: Earth and Environmental Science* 894.

Kawamura, S. (1991). *Integrated Design of Water Treatment Facilities*. New York: John Willey & Sons, Inc.

Lestari, S. A., Tazkiaturrizki, and Winarni. (2019). Evaluasi Ipa Kaligarang III sebagai Dasar Penentuan Kriteria Desain Ipa Pudakpayung di Kota Semarang. *Seminar Nasional Cendekiawan ke 5 Tahun 2019*.

Peraturan Kesehatan Republik Indonesia 492/MENKES/PER/IV/2010. (2010). *Persyaratan Kualitas Air Minum*.

Qasim, S. R., & Motley, G. Z. (2000). *Water Works Engineering: Planning, Design, and Operation*. Prentice-Hall, Inc.

Ramdhan, F., Siami, L., and Winarni. (2019). *Optimalisasi Instalasi Pengolahan Air Minum Solear, PDAM Tirta Kerta Raharja -Kabupaten Tangerang. Seminar Nasional Pembangunan Wilayah dan Kota Berkelanjutan.*

Reynold & Richard. (1996). *Unit Operation and Processes in Environmental Engineering*. Boston.

Reynolds, T. D. (1982). *Unit Operation and Processes in Environmental Engineering*. California: Brook/Cole Engineering Division.

RISPAM (Rencana Induk Penyediaan Air Minum) Kota Depok. (2020). Penysunan Review Rencana Induk Sistem Penyediaan Air Minum (RISPAM) Kota Depok. Depok: Badan Perencanaan Pembangunan Derah (BAPPEDA) Kota Depok.

Sani, I. K., Kusumadewi, R. A., and Winarni. (2019). The Use Of Multi-Criteria Analysis in Selecting Water Treatment Units in Sadu Water Treatment Plant, Bandung District, West Java Province, *Indonesia. Journal of Community Based Environmental Engineering and Managemen*,. *3*(2).

COMMUNITY CONCEPTIONS AND PERCEPTIONS OF CLIMATE CHANGE MITIGATION AND ADAPTATION IN TERNATE

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Abstract

The community's input on climate change issues in the city of Ternate is urgently needed. The purpose of this study is to document how the people of Ternate City understand and respond to issues of climate change mitigation and conditions. This study used a community-based participatory research method involving 30 people consisting of community members, teachers, lecturers, and students. Focus group discussions (FGD) and photovoices were conducted to obtain data on causes, impacts and solutions to climate change problems in the city of Ternate. The research results confirmed that the people in the city of Ternate feel the negative impacts of climate change in the city, such as reduced water sources, loss of plant vegetation (for example: mangroves, sago and sea grass), reduced marine habitats, floods and landslides at several points, increased sea level. The main causes of climate change in the city of Ternate are the establishment of non-environmentally friendly development policies, the lack of public knowledge and awareness of climate change adaptation, and the lack of regional regulations at the city to village levels related to environmental issues. The solutions offered by the community are very diverse but according to the community, the government and young people need to conduct education, mitigation, and adaptation to climate changes in the city of Ternate.

Keywords: *adaptation community perception, climate change, mitigation*

Introduction

Climate change is a major problem for countries around the world including Indonesia. Climate change not only has an impact on ecological conditions, but on the entire structure of human life. Research into climate change continues to be conducted around the world using remote sensing technology and satellite imaging. The results show that the impact of climate change on environmental damage continues to increase (IPCC 2018, 2020, Gabrys 2016). This increase is due to increased emissions of greenhouse gases such as carbon dioxide (CO2), methane (CH4) and nitrogen oxides (N2O) that have been produced since the pre-industrial era to the present day. In addition, environmentally negligent development increases the temperature of the earth. IPPC data suggests that the earth's average temperature periodically increases by 1 °C due to the emission of greenhouse gases (IPCC, 2018, 2020).

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The increase in the earth's temperature has a negative impact on climate change. According to the 2019 UNCCS report, climate change has resulted in droughts, floods, hurricanes, storms, heat waves, forest fires, landslides, etc. Based on a research report by the Center for Research on the Epidemiology of Disasters (CRED), every year cases of natural disasters in the world increase significantly. In 2018, 315 cases of natural disasters resulting from climate change were reported, including 16 cases of drought, 26 cases of extreme temperatures, 127 cases of floods, 13 landslides, 95 cases of storms and 10 cases of forest fires. The number of people affected by natural disasters in 2018 was 68.5 million, with floods, storms, and droughts accounting for 94% of the total people affected.

In Indonesia, climate change has led to the occurrence of natural disasters such as landslides, floods, flash floods, earthquakes, tsunamis, tidal waves, tornadoes, volcanic eruptions, forest fires to drought (BPS, 2018). People in North Maluku also experience the impact of climate change. The results of Indonesia's disaster risk index analysis in 2020 indicate that North Maluku is in the category of "prone" to disasters such as earthquakes, volcanic eruptions, tsunamis, floods, landslides, forest fires, drought, extreme waves, abrasion, and extreme weather. North Maluku's disaster-prone index (IRBI) in 2020 reached 144.81, which is categorized as high (IRBI, 2020). Of the nine districts/cities in North Maluku, six have a high IRBI, and four have a moderate IRBI, including the City of Ternate.

Ternate is included in the disaster-prone area because of its hilly and sloping topography. Ternate also has many active volcanoes. In addition, the limited land area has resulted in development centered on urban coasts. This land conversion has an impact on climate change in Ternate City. Some of the impacts that the people in the city have experienced include lava floods, flash floods, high sea waves, land abrasion and coastal abrasion.

Abrasion and landslides are among the significant problems threatening coastal areas in subdistricts on Ternate Island. These natural disasters can occur due to the nature of the island's territory, which tends to be sloping, hilly and mountainous. The topography of such an area increases the potential for landslides. The effects of the Ternate landslides have been exacerbated by beach reclamation on Ternate Island, which has been carried out from 2006 to the present. Beach reclamation has resulted in sea level rise, soil erosion and beach abrasion.

Coastal abrasion also damages plants on the coast of Ternate Island. Beach abrasion can even damage homes on the beach. Therefore, young people need to undertake mitigation and adaptation to climate change in Ternate City.

The increase in disaster risks due to climate change at global, national, and local levels has led to social and economic problems, as climate change is estimated to have the most severe impacts on human populations, especially children in disaster-prone areas (areas with very poor ecological conditions) (Landrigan PJ, Stegeman JJ, Fleming LE, et al, 2020; Crate and Nuttall 2009). Cultural issues related to climate change have also become popular among the public and have been disseminated through various information, digital and social media (Scott Allan Orr, Jenny Richards & Sandra Fatorić, 2021, Lowe et al. 2006; Stokol et al. 2009).

The climate change issues are important to discuss. Research related to public conceptions and perceptions of climate change is needed to increase and encourage public involvement in solving climate change problems. Based on this explanation, there are two objectives in this research, namely: 1) to determine public understanding of climate change issues in Ternate City; and 2) to determine public

perceptions of climate change mitigation and adaptation in Ternate City.

Research Methodology

This qualitative research employed a community-based participatory approach to explore and describe people's conceptions and perceptions of problems, impacts and solutions for climate change mitigation and adaptation in Ternate City. This method was used to facilitate collecting and presenting data or information sourced from the local community. This study involved 30 people from different backgrounds.

Research Location

The current study was conducted in a village named Rua on the Ternate Island, Ternate.

Tools and Materials

The study's data were obtained through focus group discussion (FGD) and photovoice. Data analysis is carried out inductively, from data exploration, data reduction, and data classification to data construction.

The FGD technique was chosen because data and information can be obtained quickly together by discussing specific questions about the causes, effects and consequences of climate change and their solutions. The FGD activities were carried out with the support of a facilitator who acted both as a facilitator and as a motivator for the participants. The log supported the moderator, whose task was to collect and record all data. FGD was used as a practical approach to identify and analyze problems, causes and strategies for climate change mitigation and adaptation. The objectives of conducting the FGD are 1) to identify and rank the main climate change issues in Ternate City based on community perceptions; 2) identify and understand the main causes and drivers of climate change; 3) identify and understand several potential climate change mitigation and adaptation strategies.

Results and Discussion

The findings reveal that all participants in this study are aware of the concept of climate change and their perceptions of the impact of climate change on their region. The majority of participants believed that climate change was happening in their region, with dire consequences. On average, their arguments were similar, but in some ways, their perspectives differed, allowing them to complement each other.

Climate change was a major issue for communities with the agreement that environmental degradation has impacted climate change. In the FGD sessions, the community members described their deteriorating environmental conditions such as erratic weather patterns, flooding, and local environmental problems that affected the way people lived in the city. Of the many opinions put forward by the community, four main issues that were often found in discussions about climate change in Ternate City are: 1) erratic weather changes; 2) reduced water sources; 3) contamination of groundwater and seawater; and 4) sea level rise leading to abrasion in coastal areas. Reduced water sources was one of the four issues that received the most attention during the FGDs. The following are excerpts from the presentation of the DW-1 FGD.

"The environmental conditions in the city of Ternate have undergone changes, including frequent abrasion of the coastal environment, conversion of forest land as a source of water to become community settlements and service industries. These changes caused the extinction of mangroves and seagrass beds, which have high carbon absorption. These environmental changes occurred at several points in the City of Ternate, such as in the Kota Baru Sub-District and the Kastela Sub-District. I will show you some photos of changes in the topography of the

mangrove forest and the impact felt by the community"

The opinion of DW-1 is in line with that of MM-1, who stated that:
"Ternate is a very small island whose water source comes from the hills. When it rains, the water settles in the lowland areas with mangrove forests, forming swampy areas that serve as a water source for the people of Ternate city, such as akegaale water in Sangaji Village which is the center of the regional drinking water company in Ternate. However, the non-environmentally friendly development impacts on the conversion lands for mangrove, sago or nipa. This activity has a major influence on the water shortage in the city of Ternate. We are already feeling the impact, I don't know how it will affect us in the future."

The discussion then developed and shifted to the factors that affect the reduction of water sources in the city of Ternate. The participants mentioned that reduced water sources in the city of Ternate could be caused by the loss of mangrove, nipa and seagrass vegetation at several points, as happened in Akegaale in the Sangaji Village, the coastal areas in the Jambula and Kastela sub-districts, the Ngade Lake area and the Talaga Ici lake area in Takome sub-district, the coastal areas in Gambesi and Sasa sub-districts, Toboko and Kota Baru areas (MC-1).

The vegetation loss is the result of land conversion into residential areas, urban development areas, offices, tourist areas, schools, and steam power plants. The FGD participants presented their arguments using photos taken directly at their observation sites. Figure 1, 2, and 3 show the condition concerning mangrove area.

Figure 1. The condition of the remaining mangroves before development

Figure 2. The conversion of mangrove land into urban areas

Figure 3. Rob floods in Ternate's residential areas because of the conversion of mangrove lands

The photos above prove that mangrove vegetation changes have occurred in Mangga Dua Village, Central Ternate District. The remaining mangrove forests (Figure 1) have been converted into residential areas and roads and ports have been upgraded (Figure 2). The effects of this land conversion are now felt by residents, namely the appearance of Rob flooding in coastal areas in Manga Dua Village (MC-2).

Through photovoice, MC-3, who is also an environmental activist, said that one of the factors causing environmental damage in the city of Ternate is the spatial planning of the city of Ternate, which does not endorse nature reserves (meaning that the development planning in the city of Ternate has not yet no preference shown for the environment). In addition, the lack of public knowledge and awareness about the function of natural vegetation also leads to environmental damage (UP-1).

All community members recognized that maintaining mangrove vegetation and protecting

their environment from damage was very important for their survival in the present and for the survival of future generations. Several community members explained in detail how the recent weather events had impacted their lives, most of whom are residents of the coastal area of Ternate. They directly experienced floods, rising sea levels, reduced water sources, reduced marine habitats such as fish (MM-2). They then decided that the problem of climate change was a joint responsibility of the government, society, community, educators and all members of society. Mitigation and adaptation strategies then became the theme of FGD's second session.

In the second session, the community members suggested that the best way to mitigate and adapt to climate change was to develop an environmentally sensitive mindset in society (IN-1). According to them, education was important to build public awareness. Through education, the community will have knowledge about how to use renewable energy and at the same time have an awareness that is reflected in their attitudes and behavior on a daily basis towards the environment. In addition, several community members suggested that there was a need for favorable policies related to climate change issues, from the top level to the sub-village or neighborhood association level (UPI-2). Household waste management and organic farming systems were also proposed as climate change mitigation and adaptation (IN-1). These community member's suggestions align with Wardekker (2021) opinion, which states that environmental conditions can be maintained by building community resilience, educating the community to be disaster resilient and developing a resilient community.

This empirical research provides unique insights into how people conceptualize and discuss climate change and its impact on their communities. Most of the FGD participants in this study had no background in the environmental field, but they were environmentalists. The FGDs conducted in this study focused on public opinion about the causes, impacts, and strategies for mitigating climate change. There were common and different perspectives on conceptualizing climate change, levels of concern, and mitigation and adaptation measures.

The current study results show that climate change is happening and, if not addressed quickly, will continue to hamper national policy responses to global problems. These results indicate how society conceptualizes climate change. The results of this study are expected to help guide policy development as well as the development of effective community engagement. The results of this study are also expected to contribute to risk communication and awareness strategies in the community. This study supports the findings of Buys et al. (2012) and Wardekker (2021) who argue that public participation and support is crucial to ensure adaptation to climate change. In line with this, Fisher et al (2022) propose that translating people's knowledge and perceptions of climate change may enable the development of resilience strategies. Such actions can help governments and stakeholders develop relevant joint policies and enhance institutional understanding of local physical processes and climate change impacts.

Conclusions

The people in the city of Ternate feel the negative impacts of climate change in the city, such as reduced water sources, loss of plant vegetation (for example: mangroves, sago and sea grass), reduced marine habitats, floods and landslides at several points, increased sea level. The main causes of climate change in the city of Ternate are the establishment of non-environmentally friendly development policies, the lack of public knowledge and awareness of climate change adaptation, and the lack of

regional regulations at the city to village levels to environmental issues.

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References

Azizah & Banowati. (2015). Pelaksanaan Sekolah Lapangan Iklim (Sli) dalam Memberikan Pemahaman Mitigasi Dan Adaptasi Perubahan Iklim Pada Petani di Kelurahan Banyurip Ageng Kecamatan Pekalongan Selatan. *Jurnal Edu Geography*, 3(6).

Badan Pusat Statistik Indonesia. (2018). Data Jumlah Desa dengan Risiko Bencana Tiga Tahun Terakhir. Badan Pusat Statistik Indonesia.

Buys, L., Miller, E., & Megen, K. V. (2012). Conceptualising Climate Change in Rural Australia: Community Perceptions, Attitudes and (in) Actions. *Reg. Environ Change, 12*, 237-248.

Carlie D. T. (2020) Children's constructive climate change engagement: Empowering awareness, agency, and action. *Environmental Education Research*, 26(4), 532-554, DOI: 10.1080/13504622.2019.1675594

Chawla, L., & Heft, H. (2002). Children's Competence and the Ecology of Communities: A Functional Approach to the Evaluation of Participation. *Journal of Environmental Psychology 22*(1–2), 201–216. doi:10.1006/jevp.2002. 0244

Crate, S. A., & Nuttall, M. (2009). *Anthropology and Climate Change: From Encounters to Actions*. Walnut Creek, CA: Left Coast Press.

David, R & Amy Cutter-Mackenzie-Knowles. (2020). A Systematic Review of Climate Change Education: Giving Children and Young People a 'voice' and a 'hand' in Redressing Climate Change. *Children's Geographies*, *18*(2), 191-208, DOI: 10.1080/14733285.2019.1614532

Dalelo, A. (2011). Global Climate Change in Geography Curricula for Ethiopian Secondary and Preparatory Schools. *International Research in Geographical and Environmental Education*, 20(3), 227–246

Ekpoh, U. I., & Ekpoh, I.J. (2011). Assessing the Level of Climate Change Awareness among Secondary School Teachers in Calabar Municipality, Nigeria: Implication for Management Effectiveness. *International Journal of Humanities and Social Science*, 1(3), 106–110.

Fisher, M.R., Bettinger, K.B., Lowry, K., Lessy, M.R., Salim, W., & Foley, D. (2022). From Knowledge to Action: Multi-Stakeholder Planning for Urban Climate Change Adaptation and Resilence in the Asia-Pasific. *Socio-Ecological Practice Research, 4*, 339-353.

Gabrys, J. (2016). *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet*. Minneapolis: University of Minnesota Press.

Hatmojo, D.S. (2020). Efektivitas Pelaksanaan Penyuluhan Pengendalian Perubahan Iklim Dan Kehutanan di Madrasyah Aliyah Aulia Cendekia Palembang. *Jurnal Ilmiah Management Agribisnis*, *1*(1).

Hicks, D., & Holden, C. (2007). Remembering the Future: What Do Children Think? *Environmental Education Research 13*(4), 501–512. doi:10.1080/1350462070158159

Indeks Rawan Bencana Indonesia, 2020 (http://mpbi.info/irbi/indeks_risiko_bencana_indonesia/)

Intergovernmental Panel on Climate Change. (2020). *Climate Change 2020: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland: IPCC.

Intergovernmental Panel on Climate Change. (2018). *Climate Change 2018: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva, Switzerland: IPCC.

Kagawa, F., & Selby, D. (2012). Ready for the Storm: Education for Disaster Risk Reduction and Climate Change Adaptation and Mitigation. *Journal of Education for Sustainable Development* 6 (2), 207–217.

Lahay, R.J, Koem, S., & Nasib, K. (2020). Adaptasi Perubahan Iklim Berbasis Masyarakat Melalui Pendekatan Ekosistem di Desa Ilodulunga Kabupaten Gorontalo Utara. *Jurnal Penelitian dan Pengabdian Kepada Masyarakat UNSIQ, 7*(2), 170 – 178

Landrigan P.J, Stegeman J.J, & Fleming, L.E, (2020). Human Health and Ocean Pollution. *Ann Glob Health, 86(*1), 151. doi:10.5334/aogh.2831

Lowe, T., Brown, K., Dessai, E., de Franca Doria, M., Haynes, K & Vincent, K. (2006). Does Tomorrow Ever Come? Disaster Narrative and Public Perceptions of Climate Change. *Public Understanding of Science*, 15, 435–457.

McNeill, J. R., & Engelke P. (2014). *The Great Acceleration: An Environmental History of the Anthropocene Since 1945*. Cambridge, MA: Harvard University Press.

Monroe, M. C., R. R., Plate, A., Oxarart, A., Bowers, & Chaves, W.A. (2017). Identifying Effective Climate Change Education Strategies: A Systematic *Review of the Research. Environmental Education Research*, 25(6), 791–812. doi:10.1080/13504622.2017.1360842.

Ramadhani, R.M. (2020). Implementasi Program Sekolah Aman Bencana di Sekolah Menengah Kejuruan Negeri 4 Balikpapan Kalimantan Timur. *Jipsindo*, 2(7).

Sari, P.N., Aprisina, J., & Jannah, M. (2019). Pembinaan Masyarakat Menuju Kampung Peduli Iklim untuk Pencegahan Masalah Kesehatan dan Bencana di Jorong Jambu Air, Kec. Banuhampu, Kabupaten Agam. *Jurnal Warta Pengabdian Andalas*, 26(3), 151-160.

Scott A.O, Jenny R., & Sandra, F. (2021) Climate Change and Cultural Heritage: A Systematic Literature Review (2016–2020), *The Historic Environment: Policy & Practice*, DOI: 10.1080/17567505.2021.1957264.

Stokols, D., S. Misra, M. G., Runnerstrom, & Hipp, J.A. (2009). Psychology in an Age of Ecological Crisis: From Personal Angst to Collective Action. *American Psychologist*, 64(3), 181–193.

Syamsuddin, Alaa, & Ahyana (2020), Penerapan Pengurangan Resiko Bencana Menuju Sekolah Aman Bencana di Madrasah Aliyah Negeri 1 Mataram. *Jurnal Pengabdian Pada Masyarakat*, 5(2). DOI: 10.30653/002.202052.303.

Tarmana, D., Ulfah, A (2021). Peningkatan Pemahaman Informasi Iklim Melalui Sekolah Lapang Iklim (sli) bagi Petani. *Jmm (Jurnal Masyarakat Mandiri)*, 5(2), 798-809.

Wardekker, A. (2021). Contrasting the Framing of Urgan Climate Resilience. *Sustainable Cities and Society, 75, 103258, 1-13.*

AIR QUALITY MONITORING AND ANALYSIS IN TASIKMALAYA CITY

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Abstract

Within the national scope, based on Government Regulation no. 47 of 1997 concerning the National Spatial Plan, the City of Tasikmalaya which is included in the East Priangan Region is included in the mainstay area. Where Tasikmalaya City functions as a Regional Activity Center (PKW) city. One result is the increased volume of traffic in the area. One of the impacts of motor vehicle traffic activity is air pollution. Air pollution is defined as the contamination of the atmosphere by gases, liquids or by-products in such concentrations and periods that can harm human health/life, and or create discomfort. The method used in conducting the research was in the form of monitoring ambient air parameters which were carried out at 10 points, spread across community activity centers in Tasikmalaya City. Based on the research that has been done, it can be concluded that the parameters Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Oxidants (O_3), Dust (*TSP*), Ammonia (NH_3) and Hydrogen Sulfide (H_2S) at 10 the testing location still meets the required quality standards based on PP RI No. 41 of 1999. Meanwhile, the results of noise level measurements have exceeded the noise level quality standards, so that treatment is needed in the form of implementing sound emission rules and localizing industrial pollutant sources.

Keywords: *air pollution, ambient air, city air quality, vehicle emissions, noise levels*

Introduction

Tasikmalaya City was inaugurated as an autonomous region on October 17, 2001, containing a logical consequence of demands for increased government services to the community. This is in line with the objective of forming the Tasikmalaya Autonomous City which is stated in Law Number 10 of 2001 concerning the formation of the Tasikmalaya City (Salman, 2021).

As an autonomous region, Tasikmalaya City has autonomous authority in planning and implementing development according to its needs and potential. This also includes environmental management and protection, one of which is air quality in Tasikmalaya City (Kuncoro et al, 2020).

According to Government Regulation no. 41 of 1999 concerning Air Pollution Control, the definition of ambient air is free air on the earth's surface in the troposphere which is within the jurisdiction of the Republic of Indonesia which is needed and affects the health of humans, living things and other elements of the environment.

The activities of living things cause the composition of natural air to change. If the change in natural air composition exceeds a

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certain concentration which causes the ambient air to be unable to fulfill its function, then the air is said to be polluted.

In an effort to maintain the quality of the ambient air so that it can provide a carrying capacity for living things to live optimally, prevention and/or control of air pollution and restoration of air quality are carried out.

Air pollution is the entry or inclusion of substances, energy and/or other components into the ambient air by human activities, so that the quality of the ambient air drops to a certain level which causes the ambient air to be unable to fulfill its function (Kadyarsi, 2006). Today's air pollution is increasingly a cause for concern, along with the increasing activities of transportation, industry, offices and housing which contribute quite a lot to air pollution (Pariyanto, 2015), (Catleya et al, 2021), (Mulyatna et al, 2019). Polluted air can cause health problems, especially disorders of the lungs, blood vessels, and eye and skin irritation. Air pollution due to dust particles can cause chronic respiratory diseases such as bronchitis, pulmonary emphysma, bronchial asthma and even lung cancer. Air pollutants in the form of gases can directly enter the body to the lungs and be absorbed by the circulatory system (Latif et al, 2006).

Ambient Air Parameters indclude Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Oxidants (O_3), Particulate and Noise. Air pollution by Sulfur Oxide (SO_x) is mainly caused by two colorless sulfur oxide gas components, namely Sulfur Dioxide (SO_2) and Sulfur Trioxide (SO_3). SO_2 has a characteristic sharp odor and is not flammable in air, while SO_2 is a non-reactive gas.

SO_x pollution causes irritation of the respiratory system and eye irritation, and is harmful to the health of the elderly and people with chronic cardiovascular respiratory system diseases. Besides affecting human health, $SOx_{pollution}$ is also harmful to animal health and can damage plants.

SO_2 is the main contributor to acid rain. Once in the atmosphere, SO_2 undergoes conversion to SO_x which then becomes H_2SO_4. At night or in humid conditions or during rain, SO_2 in the air is absorbed by the alkaline water droplets and forms sulfate in the droplets. Burning fossil fuels, such as oil and coal and other materials containing sulfur will produce both forms of sulfur oxides; SO_2 is always formed in large quantities, while the SO_3 that is formed varies from 1 to 10% of the total SO_x (Rizqiyah and Rosyida, 2021).

Nitrogen Dioxide (NO_2) and nitrogen monoxide (NO) are the most widely known groups of nitrogen oxides (NO_x) as air pollutants. NO is an odorless and colorless gas, while NO_2 has a sharp odor and is reddish-brown in color. Nitrogen oxides such as NO and NO_2 are harmful to humans. NO_2 is toxic, especially attacks the lungs, which causes difficulty breathing in asthma sufferers, coughs in children and the elderly, and various respiratory system disorders, and reduces visibility.

Nitrogen oxides are also major contributors to smog and acid deposition. Nitrogen oxides react with volatile organic compounds to form ozone and other oxidants such as *peroxyacetylnitrate* (*PAN*) in photochemical *smog*, and with rainwater to produce nitric acid and cause acid rain. Wet (acid rain) and dry acid deposition (when NOx_{gas} forms nitrate aerosol particles and is deposited on the earth's surface) can harm plants, agriculture, aquatic ecosystems and forests. Acid rain can flow into lakes and rivers and leach heavy metals from the soil and change the chemical composition of the water. This can eventually degrade and even destroy aquatic life.

Oxidants are compounds that have oxidizing properties, their effect on health is interfering with the respiratory process and can cause eye irritation. Apart from causing adverse impacts on human health, ozone pollutants can cause

economic losses due to wear and tear of materials (textiles, rubber, wood, metal, paint, etc.), decreased agricultural yields and damage to ecosystems such as reduced biodiversity. Airborne oxidants include ozone (more than 90%), Nitrogen Dioxide, and Peroxyacetylnitrate (*PAN*). Because most of the oxidant is ozone, ambient air monitoring is expressed as ozone levels.

Particulates are solids or liquids in the air in the form of smoke, dust and vapor with very small diameters (ranging from <1 micron to 500 microns), which can stay in the atmosphere for a long time. Besides disturbing aesthetics, small particles in the air can be sucked into the respiratory system and cause respiratory disorders and lung damage.

Particles that are sucked into the respiratory system will be set aside depending on their diameter. Large particles will be stuck in the upper respiratory tract, while small particles that can be inhaled (*inhalable*) will enter the lungs and remain in the body for a long time. Inhalable particles are particles with a diameter below 10 microns (PM_{10}), which are known to increase mortality due to heart and respiratory diseases, at concentrations of 140 µg/m^3 can reduce lung function in children, while at concentrations 350 µg/m^3 can aggravate the condition of patients with bronchitis. The toxicity of *inhalable particles* depends on their composition.

Inhalable particles can also be secondary particulates, namely particles formed in the atmosphere from combustion gases that undergo physical-chemical reactions in the atmosphere, for example sulfate and nitrate particles which are formed from SO_2 *and* NOx_{gases}. Generally the secondary particles are 2.5 µ or less in size. The major proportions of $PM_{2.5}$ *are ammonium nitrate*, ammonium sulfate, sodium nitrate and secondary organic carbon. These particles are formed in the atmosphere with a slow reaction so they are often found as transboundary air pollutants that are transported by wind movements to places far from their sources. $PM_{2.5}$ secondary particles can cause a more dangerous impact on health not only because of their size which allows them to be inhaled and penetrate deeper into the respiratory system but also because of their chemical nature (Rivaldi, 2021), (Mulyono et al, 2019).

The noise level is known through the results of direct measurements in the field. Noise is unwanted sound or sounds that can cause harm to human health and environmental comfort. Noise can also be defined as unwanted sound, annoying sound or annoying sound (Syaiful, 2015), (Syaiful, 2020). Noise level is a measure of sound energy expressed in units of decibels A, abbreviated as dB(A) (Wahyuni et al, 2019).

Pollutant sources that have the potential to increase noise parameters include (Kusuma, 2002):

a. Moving sources , namely the exhaust sound of 2- wheeled and 4 -wheeled motorized vehicles .
b. sources , namely small and large industrial activities,
c. Daily community activities (markets, households).

Research Methodology

The research was carried out by taking direct samples 2 (two) times. in 10 (ten) locations spread across the Tasikmalaya City area, shown in Figure 1 and Table 1. The data collection flowchart is shown in Figure 2.

Table 1. Air Quality Monitoring Locations

No.	Location	*Sampling* Point	Coordinate
1	Jl. KHZ. Mostofa (A)	In front of Asia Plaza Mall	07°20'35.9"S 08°13'02.6"E
2	Jl. KHZ. Mustafa (B)	Home Yogya Dept. Store	07°19'52.4"S 108°13'10.1"E
3	Jl. Hospital (C)	In front of SMA Negeri 1 Tasikmalaya	07°19'56.3"S 108°13'25.0"E
4	Jl. Brigadier General Wasita Kusumah (D)	In front of Permata Bunda Hospital	07°17'14.8"S 108°11'46.2"E

No.	Location	*Sampling* Point	Coordinate
5	Jl. Yudanegara (E)	In front of Hotel Santika	07°19'33.4"S 108°13'01.8"E
6	Jl. Otto I Scandardinata (F)	In front of SMP Negeri 1 Tasikmalaya	07°19'35.3"S 108°13'24.3"E
7	Jl. Siliwangi (G)	In front of Siliwangi University	07°20'56.3"S 108°13'20.2"E
8	Jl. RE Martadinata (H)	In front of SMA Negeri 2 Tasikmalaya	07°18'07.36"S 108°12'12.38"E
9	Jl. Ir. H. Juanda (I)	In front of the Budiman Pool	07°18'24.4"S 108°12'12.7"E
10	Jl. Dr. Sukardjo (J)	In front of the Word Meatballs	07°19'12.9"S 108°13'12.6"E

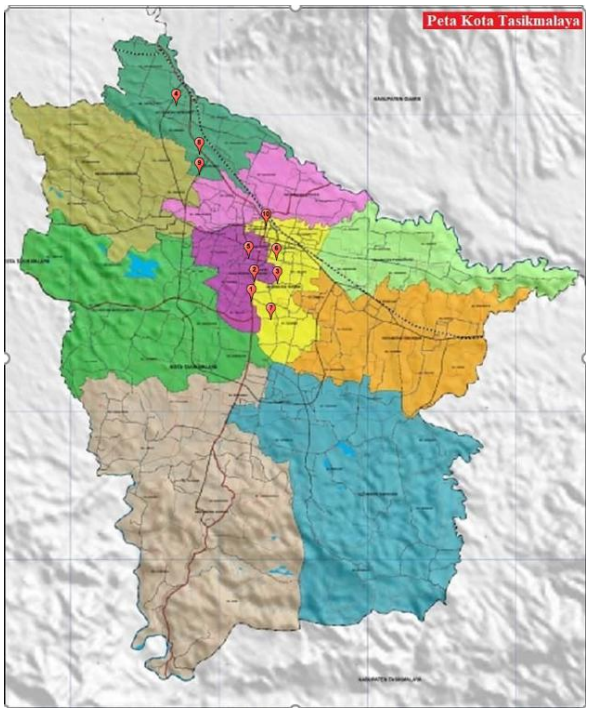

Figure 1. Distribution of Sampling Points in the City Taikmalaya

Results and Discussion

Results of Air Quality Monitoring

Air quality monitoring is carried out at 10 (ten) *sampling points* . The conditions at the time of measuring air quality and noise were on sunny days without rain, the temperature ranged from 29 ºC - 31 ºC. At the sampling location there is a lot of mobility of motorized vehicles carried out by the community and there is also a lot of potential for dust because the sampling is done during the dry season (Kusminingrum and Gunawan, 2008), (Listyarini, 2021).

All monitoring results are shown in the Tables 2-11. The test results explained that the value still met the allowable air quality standards. Even so, at almost all noise inspection points exceeding the quality standard, it is hoped that all people will continue to pay attention to both environmental conditions and the use of transportation facilities, as well as the good condition of motorized vehicles, so that the problem of exhaust emissions due to traffic will not occur.

Table 2. Results of Air Pollution Laboratory Tests on Jl. KHZ. Mostofa (A)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm^3	3.56	3.69	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm^3	1.91	1.82	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm^3	8.53	7,26	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm^3	88	85	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	2.8 x 10^{-6}	2.6 x 10^{-6}	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.16	0.15	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	73.2 ^	72.5 ^	70	Kep-48/MENLH/11/1996

Table 3. Results of Air Pollution Laboratory Tests on Jl. KHZ. Mustafa (B)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	6,72	6,60	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	5.95	6,84	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm ^{3}	2.36	2.49	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	108	110	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	2.5 x 10 $^{-6}$	2.7 x 10 $^{-6}$	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.095	0.091	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	74.1 ^	73.8 ^	70	Kep-48/MENLH/11/1996

Table 4. Air Pollution Laboratory Test Results on Jl. Hospital (C)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	3.38	3,24	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	1.85	1.65	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm ^{3}	8,17	6,22	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	88	85	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	2.7 x 10 $^{-6}$	2.5 x 10 $^{-6}$	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.23	0.18	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	**73.0 ^**	**72.0 ^**	70	Kep-48/MENLH/11/1996

Table 5. Laboratory Test Results for Air Pollution on Jl. Brigadier General Wasita Kusumah (D)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	2.72	2.69	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	2.82	2.88	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm ^{3}	5.79	5,51	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	62	66	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	2.9 x 10 $^{-6}$	2.8 x 10 $^{-6}$	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.087	0.075	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	69,2	**70.5 ^**	70	Kep-48/MENLH/11/1996

Table 6. Air Pollution Laboratory Test Results on Jl. Yudanegara (E)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	6,82	7,49	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	3.61	3.68	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm ^{3}	3.71	3,33	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	95	88	230	*Direct Reading*
Odor						

1	Hydrogen Sulfide (H_2S)	Ppm	3.1×10^{-6}	3.8×10^{-6}	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.17	0.16	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	**73.8 ^**	**71.1 ^**	70	Kep-48/MENLH/11/1996

Table 7 Air Pollution Laboratory Test Results on Jl. Otto I Scandardinata (F)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	4.82	4.80	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	5,15	5,68	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm ^{3}	7,22	7,16	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	64	68	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	2.7×10^{-6}	2.3×10^{-6}	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.15	0.19	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	**75.0 ^**	**80.2 ^**	70	Kep-48/MENLH/11/1996

Table 8. Air Pollution Laboratory Test Results on Jl. Siliwangi (G)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	5,25	4,17	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	4.88	4.56	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	6.85	8,17	6,32	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	75	86	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	2.5×10^{-6}	2.8×10^{-6}	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.21	0.18	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	**73.2 ^**	**74.3 ^**	70	Kep-48/MENLH/11/1996

Table 9. Air Pollution Laboratory Test Results on Jl. RE Martadinata (H)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	7,15	6,73	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	4.56	4,24	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm ^{3}	3,18	3.64	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	105	108	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	3.1×10^{-6}	2.5×10^{-6}	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.15	0.11	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	**72.0 ^**	**76.2 ^**	70	Kep-48/MENLH/11/1996

Table 10. Air Pollution Laboratory Test Results on Jl. Ir. H. Juanda (I)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	7.51	8.49	400	SNI 19-7119.2-2005

2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	2.93	2.25	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm ^{3}	8.75	8,15	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	78	85	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	3.2 x 10 $^{-6}$	2.8 x 10 $^{-6}$	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	0.06	0.06	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	**74.1 ^**	**77.8 ^**	70	Kep-48/MENLH/11/1996

Table 11. Air Pollution Laboratory Test Results on Jl. Dr. Sukardjo (J)

No.	Parameter	Unit	Test result		Quality standards	Reference Method
			Period I	Period II		
Chemistry						
1	Nitrogen Dioxide (NO_2)	µg/Nm ^{3}	4,12	4,22	400	SNI 19-7119.2-2005
2	Sulfur Dioxide (SO_2)	µg/Nm ^{3}	4,11	3.63	900	SNI 19-7119.7-2005
3	Oxidants (O_3)	µg/Nm ^{3}	6,45	6,37	235	SNI 19-7119.8-2005
Physics						
1	Dust (TSP)	µg/Nm ^{3}	81	66	230	*Direct Reading*
Odor						
1	Hydrogen Sulfide (H_2S)	Ppm	2.1 x 10 $^{-6}$	2.65 x 10 $^{-6}$	0.02	JIS K-108
2	Ammonia (NH_3)	Ppm	2.6 x 10 $^{-3}$	2.6 x 10 $^{-3}$	2	SNI 19-7119.2-2005
Noise						
1	Noise	dB	**71.8 ^**	**72.4 ^**	70	Kep-48/MENLH/11/1996

From the test results it can be seen that the parameters Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Oxidants (O_3), Dust (*TSP*), Ammonia (NH_3) and Hydrogen Sulfide (H_2S) at 10 test locations still meet the required quality standards (Republic of Indonesia Government, 1999). The results of measuring dust parameters from the 10 measurement locations ranged from 56µg/Nm 3 ^{to} 110µg/Nm ^{3} . The smallest concentration of dust was found at the test location (10), namely Jl. Dr. Sukardjo (07°19'12.9"S 108°13'12.6"E) of 56 µg/Nm ^{3} , while the highest dust concentration was found at location 3, namely on Jl. Hospital (07°19'56.3"S 108°13'25.0"E) of 70.2 µg/Nm ^{3} . When compared with the quality standards based on Government Regulation of the Republic of Indonesia No. 41 of 1999, the dust content at all sampling locations is still below the quality standard set at 230 µg/m ^{3} .

The results of noise level measurements at 3 (three) activity locations ranged from 69 - 78 dBA so that they exceeded the 60 dBA quality standard (Ministry of Environment of the Republic of Indonesia, 1996). This is because the activity location is on a road that is quite busy with motorized vehicles. When compared with Kep-48/MENLH/11/1996 concerning Noise Level Standards (Allocation of Government Areas and Public Facilities), the noise parameters at all air sampling points are above the required quality standard.

Conclusions

The results of monitoring the quality of emissions from immovable sources in Tasikmalaya City are still below the predetermined quality standards. This condition needs to be maintained so that emissions released from businesses/activities do not pollute the air.

References

Catleya, F., Yustiani, Y.M. & Hasbiah, A.W. (2021). Tingkat Pencemaran Udara CO Akibat Lalu Lintas dengan Model Prediksi Udara Skala Mikro di Jalan Sudirman, Jakarta. *Infomatek: Jurnal Informatika, Manajemen dan Teknologi, 23*(1), 55-58.

Kadyarsi, I. (2006). Mapping Air Quality in Surakarta. *Geography Forum, Vol. 20(1).*

Kuncoro, AH, Mellyanawaty, M., Sambas, A., Maulana, DS, & Mamat, M. (2020). Air Quality Monitoring System in the City of Tasikmalaya based on the Internet of Things (IoT). *Journal of Advanced Research in Dynamical and Control Systems , Vol . 12(2),* 2473-2479.

Kusuma, IGBW (2002). Device to reduce exhaust emissions on motorcycles, cars, outboard motors and stationary combustion engines. *Makara Journal of Technology , 6* (3), 147108.

Kusminingrum, N., & Gunawan, G. (2008). Pollution Air due to Motorized Vehicle Activities in Road Urban Island Java And Bali. *Journal Road Bridge, 25(3).*

Latif, MT, Othman, MR, & Johnny, Z. (2006) Study of air quality in Bandar Kajang, Selangor. *Malaysian J. Anal. Sci , 10,* 275-284.

Listyarini, S., Warlina, L., Sambas, A. (2021). Air Quality Monitoring System in South Tangerang Based on Arduino Uno: From Analysis to Implementation. *IOP Conference Series: Materials Science and Engineering, 1115(1), 012046.*

Ministry of Environment of the Republic of Indonesia (1996). *Kep-48/MENLH/11/1996 concerning Noise Level Standards (Allocation of Government Areas and Public Facilities)*

Mulyatna, L, Yustiani, Y.M. & Sidik, A. (2019). Uji Efektivitas Ionizer BBM terhadap Penurunan Emisi Gas Karbon Monoksida dan Hidrokarbon pada Mobil dengan Sistem Karburator. *Infomatek: Jurnal Informatika, Manajemen dan Teknologi, 21*(1), 61-68.

Mulyono, GS, Fatmawati, D., Hidayati, N., & Sunarjono, S. (2019). Analysis of Noise and Air Pollution at Muhammadiyah 1 Kartasura Middle School Due to Traffic Flows (Jl. Ahmad Yani Kartasura).

Pariyanto, A. (2015). Prediction of Noise Levels and Emissions of Vehicle Exhaust on Jalan Jenderal Sudirman - Sukoharjo". Muhammadiyah Surakarta university.

Republic of Indonesia Government Regulation No. No. 41 of 1999 concerning Control of Air Pollution.

Rizqiyah, T., & Rosyida, I. (2021) Cluster Analysis of Highway Ambient Air Quality Levels in Central Java in 2018. In *PRISMA, Proceedings of the National Mathematics Seminar,* 4, 560-564.

Rivaldi, RA. (2021). *Relationship of PM2.5 Temporal Distribution with Meteorological Factors and Trajectory Tracking of PM 2.5 with the Hysplit Model in Bandung City".* (Doctoral dissertation, Bandung National Institute of Technology).

Salman, N. (2021). Strategy of Ecoregion Protection and Management, Case Study of Tasikmalaya City. *Journal of Community Based Environmental Engineering and Management, 5*(1), 23-32.

Syaiful, S. (2015). Noise Pollution Resistance Level in Front of RSIA Sentosa Bogor". *Astonjadro: CEAESJ , 4*(2), 57-61. 2015.

Syaiful, S., & Akbar, L. (2020). Analysis of the Influence of Traffic Speed on Noise Generated by Motorized Vehicles". *Astonjadro: CEAESJ , 4*(1), 13-19. 2020.

Wahyuni, S., Yustiani, YM., Juliandahri, A. (2018). Analisis Tingkat Kebisingan Lalu Lintas Jalan Cihampelas dan Jalan Sukajadi Kota Bandung. *Journal of Community Based Environmental Engineering and Management, 2*(1), 9-12.

ANALYSIS OF THE LOAD CARRYING CAPACITY OF BOD AND COD POLLUTANTS IN THE KRUKUT RIVER

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Abstract

Krukut River is one of the rivers that has an important role to support the activities of the residents of Jakarta City. Krukut River has a length of 44.3 km. In 2015 the Krukut River was the target of a master plan for improving river water quality in Jakarta by Regional Environmental Management Agency (BPLHD) DKI Jakarta but in fact there was a decline in river water quality due to increasing population growth so that monitoring activities are needed. The purpose of the study is to identify the polluting sources of the Krukut River, analyze the water quality of the river, determine the pollutant load. The research parameters used are Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Sampling in the Krukut River was carried out using the grab sampling method in September, October, November 2021 divided into 9 segments consisting of 9 non-point sources and 5 point sources. Non-point sources of pollutants are obtained from domestic waste dominated by residential areas, as well as food stalls, point source of pollutants are obtained from drainage channels, Mampang River, Ciliwung River, Cideng Channel and Krendang River. Pollutant load carrying capacity for BOD and COD concentrations in the Krukut River were respectively 292.896-622.592 kg/day and 2440.8-13521.6 kg/day. The pollutant load for BOD and COD concentrations in the Krukut River were respectively 2601.3-13792.2 kg/day and 3139.1-16542.6 kg/day.

Keywords: *BOD, COD, carrying capacity, Krukut River, pollutant load*

Introduction

Krukut River is one of the rivers that has an important role to support the activities of the residents of Jakarta City (Rachmawati, 2017). Krukut River has an area of 84.54 km^2 and a river length of 44.3 km which flows in Situ Citayam, Cipayung, Depok City which is located in Pluit Reservoir, Penjaringan, North Jakarta. In 2015 the Krukut River was the target of the master plan for improving river water quality in Jakarta by Regional Environmental Management Agency (BPLHD) DKI Jakarta, but in fact the quality of the Krukut River water is decreasing along with the increasing number of people in DKI Jakarta and the increasing number of industrial and household activities that contribute to the decline in the water quality of the Krukut River (Rachmawati et al., 2020).

The decline in the water quality of the river goes along with the growth of its population and activity. Wastewater entering through drainage channels comes from settlements and other activities around the riverbanks. The water quality of a river can be determined by measuring several parameters of water pollutants. it is necessary to study the carrying capacity of pollutants in the Krukut River to determine the capacity of the water source

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against the influx of waste, both point sources and non-point sources. From the perspective of the causes of water pollution, with the improvement of point source pollution control capabilities, the problem of non-point source pollution has become increasingly prominent, and has become the main reason for the deterioration of environmental water quality in many areas (Zhang et al., 2014).

Research Methodology

The study was conducted from September to November 2021. The scope of the study area is the Krukut River from upstream in Cipayung, Depok City to downstream in Penjaringan, North Jakarta along 44,3 km. Research to determine the carrying capacity of the Krukut River pollutant load is divided into three stages, namely preparation for implementation, and analysis.

Sources of pollutants that have the potential to pollute the river are in the data through preliminary surveys and observations during sampling. The results of identifying the source of pollutants are then tabulated and analyzed descriptively. The sources of pollutants identified can be related to the state of water quality of the Krukut River. Identification of waste can be seen in **Table 1**.

Table 1. Identify sources of polluters

Characteristic	Point Source	Non Point Source
Domestic Waste	Household Waste Stream	Residential wastewater
Non-Domestic Waste	Industrial Wastewater, Hotel, and Motor Wash	

Sampling was carried out at 14 sampling points, namely 9 sampling points at non-point sources and 5 sampling points at point sources. Source of Pollutants Point source is a source of pollution that is discharged through a special location point using a gutter or discharge directly to the surface of a body of water. Non point source or source is not necessarily a waste stream originating from residential areas in general Sampling location can be seen in **Table 2**.

Table 2. Sampling Location

Point	Location	Upstream	Downstream	Coordinate	
		(km)	(km)	LS	BT
1	Jl. Pinggir Setu, Depok		44.30	6° 26.593'S	106° 47.995'T
2	Jl. Cagar Alam, Depok	44.30	42.16	6° 24.231'S	106° 48.490'T
3	Jl. Tridarma Raya, Jakarta Selatan	42.16	42.04	6° 18.305'S	106° 48.551'T
4A	Jl. KHM Naim III, Jakarta Selatan	36.92	36.69	6° 15.775'S	106° 48.681'T
4	Jl. Cemp III, Jakarta Selatan	42.04	36.92	6° 15.766'S	106° 48.686'T
5A	Jl. Poncol 3, Jakarta Selatan	34.2	34.07	6° 14.020'S	106° 49.054'T
5	Jl Puspa II, Jakarta Selatan	36.69	34.2	6° 13.899'S	106° 49.010'T
6A	Jl. Tenaga Listrik, Jakarta Pusat	29.80	29.61	6° 12.056'S	106° 48.912'T
6	Jl. Tenaga Listrik, Jakarta Pusat	34.07	29.80	6° 11.880'S	106° 48.614'T
7A	Jl. Kebon Sirih, Jakarta Pusat	25.04	24.99	6° 10.913'S	106° 48.988'T
7	Jl. Jati Baru Raya, Jakarta Pusat	29.61	25.04	6° 10.910'S	106° 48.873'T
8A	Jl. Perniagaan Raya, Jakarta Barat	19.19	5.37	6° 8.499'S	106° 48.408'T
8	Jl. Pekojan Raya, Jakarta Barat	24.99	19.19	6° 8.474'S	106° 48.472'T
9	Jl. Inspeksi 281-257, Jakarta Utara	5.37		6° 7.460'S	106° 48.130'T

Sampling refers to SNI 6989.57:2008 on Water and Wastewater – Section 57: Surface water sampling methods. In this study, sampling was carried out by grab sampling, namely samples taken directly from the water body being monitored, sampling with this method was carried out once per point and directly examined. Sample water was taken with a horizontal type water sampler and tools that have been sterilized first. After taking water with a water sampler, the sample water was put into a 1-liter jerry can and then the jerry can was numbered according to the sampling location. The jerry can was then placed in styrofoam containing dry ice so that it remains durable to be taken to the Environmental Laboratory of

Trisakti University for analysis as much as 2 times (duplo). Sampling was carried out at 14 points on the Krukut River which was carried out 1 time in September, October, and November 2021.

Result and Discussion

Measurements of the characteristics of the Krukut River during III Peride, namely in September, October, and November 2021 when the weather is clear. Characteristic of the Krukut River can be seen in **Table 3**.

Table 3. Characteristics of the Krukut River

Point	Measurement Location	River Width (m)	River Water Depth (m)	River Cross-sectional Area (m^2)	Flow Rate (m)	Flow Discharge (m^3/detik)	Elevation
1	Jl. Pinggir Setu, Depok	4.62	1.2	5.58	0.28	1.56	78
2	Jl. Cagar Alam,Depok	5.56	1.14	6.34	0.24	1.51	33
3	Jl. Tridarma Raya, Jakarta Selatan	3.81	1.23	4.67	0.25	1.18	20
4A	Jl. KHM Naim IIIB,Jakarta Selatan	1.95	0.38	0.741	0.086	0.46	11
4	Jl. Cemp III, Jakarta Selatan	8.15	1.34	10.98	0.18	1.97	11
5A	Jl. Gatot Subroto Kav 14	7	1.31	9.17	0.083	0.76	8
5	Jl. Puspa II No 46, Jakarta Selatan	18.37	0.75	13.72	0.22	3.03	8
6	Jl. Tenaga Listrik, Jakarta Pusat	34.74	1.47	31.5	0.11	3.36	6
6A	Jl. Tenaga Listrik, Jakarta Pusat	6	0.91	8.84	0.2	1.74	6
7A	Jl. Jati Baru Raya, Jakarta Pusat	8	0.81	6.51	0.09	0.56	3
7	Jl. Jati Baru Raya, Jakarta Pusat	12.76	1.44	18.33	0.15	2.69	3
8A	Jl. Perniagaan Raya, Jakarta Barat	13.38	1.72	23.05	0.16	3.77	2
8	Jl. Pekojan Raya, Jakarta Barat	17.6	1.13	19.95	0.14	2.81	2
9	Jl. Inspeksi 281-257,Jakarta Utara	30.69	1.53	47.1	0.13	6.28	1

The width of the river ranges from 1.95 – 34.,74 m with a river depth between 0.75 – 1.72 m. The current speed ranges from 0,083 - 0.28 m/s so that the rated discharge ranges from 0.46 – 6.28 m^3/s. River discharge is influenced by the speed of the river flow current and the cross-sectional area of the river, the value of the river discharge is obtained from the speed of the flow current × the cross-sectional area of the river, while the value of the cross-sectional area of the river is obtained from the calculation of the river width×river depth, fluctuations in the Krukut River discharge can be seen in **Figure 1**.

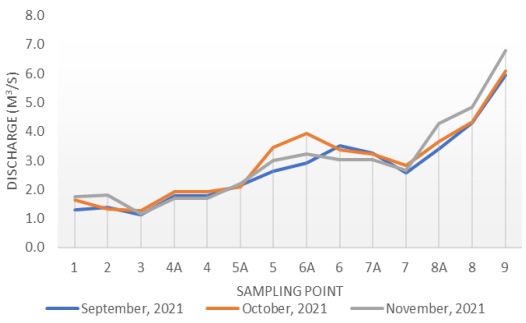

Figure 1. Krukut River Discharge Fluctuations

The results of the Grogol River sample water analysis for 3 periods, namely September October, and November 2021 using water quality standards in PP No.22 of 2021. The quality of river water tested is physics (turbidity, electrical conductivity, and water temperature) and chemistry (pH, dissolved oxygen, chemical oxygen demand, biological oxygen demand). River water quality data can be seen in **Table 4**.

Table 4. Quality of Krukut River

Point	Temperature Air (°C)	DHL (µmhos/cm)	Turbidity (NTU)	pH	DO (mg/L)	BOD (mg/L)	COD (mg/L)
	Quality Standards of Government Regulation Number 22 of 2021						
	Deviation 3 From natural	-	-	6 - 9	Class 2 :>4	Class 2:>3	Class 2:>25
1	26.3	124.5	10.7	6.5	5.8	27.7	34.1
2	26.3	137.7	23.3	6.6	6.2	24.1	30.9
3	27.0	313.1	24.0	6.9	4.5	33.0	40.5
4A	26.7	244.2	28.7	7.1	5.3	28.6	35.2
4	27.3	217.0	24.3	7.2	5.3	28.3	33.1
5A	28.0	215.6	18.3	7.0	4.5	30.3	38.4
5	28.3	232.6	22.3	7.3	5.3	24.2	27.6
6A	29.0	373.2	41.3	6.9	3.0	33.8	40.5
6	29.3	401.5	43.0	6.5	3.1	31.2	35.2
7A	30.3	395.6	42.0	7.3	2.8	22.1	32.0
7	31.3	435.8	32.7	6.9	3.0	22.5	28.8
8A	29.7	514.4	30.3	6.5	1.5	24.4	28.8
8	30.3	539.1	32.7	6.8	3.8	21.6	25.6
9	29.3	519.1	31.0	6.5	2.0	21.4	30.9

The water temperature of the Krukut River ranges from 26°C–32°C. The water temperature of the Krukut River is influenced by altitude, air circulation time, discharge, depth and the presence of pollutants in the water and water temperature greatly affects the amount of dissolved oxygen in the water.

Electrical Conductivity (DHL) obtained from observations for three periods, the DHL parameters from upstream to downstream experience an up and down state and at Point 7A to Point 8 it increases. The DHL parameter in the Krukut River was in the range of values of 116.4 µmhos/cm – 557.4 µmhos/cm.

The turbidity in the Krukut river ranges from 8 – 47 NTU. The high turbidity in photosynthesis is disturbed, which leads to disturbances in other vegetation in water.

The results of pH value analysis in the 3-period measurement were obtained on average in period 1 of 6.9, in period 2 of 6.9 and period 3 of 6.8. Each sampling point in 3 periods did not show a significant difference and still entered the range of pH values in the quality standard, namely 6-9.

The dissolved oxygen value in period 1 was recorded at 4.021 mg/L, in period 2 it was 3.95 mg/L and in period 3 it was 4.019 mg/L. The highest DO concentration during monitoring was recorded in period 1, which was 4.021 mg/L and the highest DO concentration during monitoring was recorded in period 1 which was 4.021 mg/L and the lowest point 8A was 1.35 mg/L.

BOD_5 concentration results from the analysis in 3 periods. The highest concentration value was recorded during the monitoring period 1 that point 6 of 38.9 mg/L while the lowest concentration was during the month to November at point 3 of 7.80 mg/L which was tested in the rainy season.

The concentration of COD values in the Krukut River during the 3 sampling periods ranges between 22.4 mg/L – 44.8 mg/L, COD concentrations from upstream to downstream tend to increase and decrease.

The sampling location has several confluences of water flows, namely the Krukut tributary that enters the Krukut River water body, therefore, it is necessary to measure the mass balance to determine its magnitude. Here are the concentrations of the mixtures in **Table 5.**

Table 5. Mixing Concentrations

Point	Debit	COD data	BOD data	C COD	C BOD
	(m^3/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
4A	0.13	35.2	28.57	33.20	28.32
4	1.97	33.1	28.30		
5A	0.76	38.4	30.27	29.75	25.43
5	3.06	27.6	24.23		
6A	3.36	40.5	33.83	38.71	32.92
6	1.74	35.2	31.17		
7A	0.54	32.0	22.10	29.33	22.46
7	2.69	28.8	22.53		
8A	3.77	28.8	24.37	27.43	23.19
8	2.81	25.6	21.60		

After the calculation of the mixed concentration of each confluence of rivers and drainage channels. Therefore, the calculation of the capacity of polluting loads on the Krukut River is carried out. BOD and COD polluting load capacity are respectively shown in **Tabel 6** and **Tabel 7**.

Table 6 BOD Polluting Load Capacity

Segment	BOD Polluting Load	BOD Capacity
	kg/day	kg/day
1	3733.6	404.4
2	3449.0	391.4
3	2730.6	305.9
4	2601.3	292.9
5	5919.6	671.3
6	7562.1	863.1
7	6621.0	759.5
8	9191.2	1070.5
9	13792.2	1622.6

Table 7 COD Polluting Load Capacity

Segment	COD Polluting Load	COD Capacity
	kg/day	kg/day
1	4600.6	3369.6
2	4139.1	3261.6
3	3290.0	2548.8
4	3139.1	2440.8
5	7135.7	5594.4
6	9106.7	7192.8
7	7965.9	6328.8
8	11028.1	8920.8
9	16542.6	13521.6

The pollutant load capacity is determined based on the difference between the existing pollutant load in the river and the permissible pollutant load, namely the concentration of each water quality parameter according to the water class in the quality standard (Hossain et al., 2010). The calculation results use BOD and COD parameters in the Krukut River which are compared with the water quality standards of PP No.22 of 2021 in Appendix VI for class II rivers. Suppose the carrying capacity of the pollutant load is determined based on the difference between the pollutant load in the river and the allowable pollutant load. In that case, that is, the concentration of each water parameter in the quality standard. The difference can be negative or positive. If the difference between the pollutant load and its carrying capacity is negative, the pollutant load needs to be reduced. If the difference between the pollutant's load and its carrying capacity is positive, then it can be said that the river is still able to accommodate a certain amount of load before it exceeds its carrying capacity. BOD and COD excess are respectively shown in **Tabel 8** and **Table 9**.

Table 8 BOD Excess

Segment	BOD	BOD Quality Standards	BOD Excess
	(mg/L)	(mg/L)	
1	27.70	3	89%
2	24.10	3	88%
3	32.97	3	91%
4	28.32	3	89%
5	25.43	3	88%
6	32.92	3	91%
7	22.46	3	87%

Segment	BOD	BOD Quality Standards	BOD Excess
	(mg/L)	(mg/L)	
8	23.19	3	87%
9	21.43	3	86%

Table 9. Excess COD

Segment	COD	BOD Quality Standards	COD Excess
	(mg/L)	(mg/L)	
1	34.13	25	27%
2	30.93	25	19%
3	40.53	25	38%
4	33.20	25	25%
5	29.75	25	16%
6	38.71	25	35%
7	29.33	25	15%
8	27.43	25	9%
9	30.93	25	19%

Based on the results of measurements of BOD and COD parameters in **Table 8** and **Table 9**, the value obtained exceeds the quality standard. The difference between the excess BOD and COD was 86%-91% and 9%-38% respectively. Excess pollutants are caused by an increase in the population and a large number of activities over time.

Conclusions

Residential areas dominate potential non point sources of pollutants in Krukut, be it housing or villages, in addition, the existing sources of potential pollutants are also caused by restaurants, shops, and other domestic activities. The water quality of the Krukut River for BOD parameters ranges from 21.43 mg/L – 32.97 mg/L while COD ranges from 27.43 mg/L – 40.53 mg/L. According to PP No.22 of 2021, Class II River Water Quality Standards have a BOD value of 3 mg/L so that the BOD parameters exceed the quality standards and the quality standard value of class II for COD is 25 mg/L, so the COD parameters exceed the quality standards.

References

BPLHD DKI Jakarta (Badan Pengelolaan Lingkungan Hidup) DKI Jakarta. 2015. Buku Status LingkunganHidup Daerah DKI Jakarta Tahun 2015.

Hakki, W. (2015). Dampak Pemanfaatan Bantaran Sungai terhadap Kualitas Lingkungan di Kelurahan Pasar Krui. Universitas Lampung.

Hossain, M.D., Hanafi, M.M., Talib, J. & Jol, H. (2010). Effects of Nitrogen, Phosphorus and Potassium Levels on Kenaf (Hibiscus cannabinus L.) Growth and Photosynthesis under Nutrient Solution. *Journal of Agricultural Science*, 2(2), 49-57.

Irsanda, P. G., Karnaningroem, N., Bambang, D. (2014). Analisis Daya Apung Beban Pencemaran Kali PalayaranKabupaten Sidoarjo dengan Metode QUAL2KW, Surabaya: Institut Teknologi Sepuluh Nopember.

Muliawan, A. K., Kusumadewi R. A., Fachrul M.F. (2022). Analysis of Contaminant Load Capacity of Nitrate and Phosphate in Krukut River. *Journal of Community Based Environmental Engineering and Management*, *6*(2), 65-72.

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Rachmawati, I. P., Riani, E., & Riyadi, A. (2020). Water quality status and load pollution Krukut River, DKI Jakarta. *Jurnal Pengelolaan Sumberdaya dan Lingkungan*, *10*(2), 220-233.

Zhang, W., Hongjie, Ji, Kolbe, H., et al. (2014). China's Agricultural Non point Source Pollution Situation Estimation and Control Countermeasures II: Agricultural Non point Source Pollution Status and Control in European and American Countries. Chin. *Agric. Sci*., *37*(7), 1018–1025.

PROBLEM AND PROJECT-BASED LEARNING AS AN EFFECTIVE ENVIRONMENTAL EDUCATION (EE) METHODS: A CASE OF TEXTBOOK DEVELOPMENT IN MEDAN CITY SCHOOLS

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Abstract

Environmental education (EE) is a tool for educating people about the environment, and EE textbooks are an essential resource for this purpose. This book was created by a group of elementary, middle, and high school teachers in the Medan City area who had yet to gain experience in textbook writing. A combination of problem and project-based learning (PBL and PjBL) by triggering teachers to develop a textbook for EE was carefully conducted. The project took three years, during which the teachers worked on conceptualizing and setting goals, selecting themes, creating the content, and designing teaching materials. Initially, the teachers conducted a poll which acted as a PBL approach to identify the most pressing environmental issues faced by the people of Medan City. This poll showed that waste management was the most crucial issue, followed by problems related to rivers, wastewater, waste disposal, and floods. The teachers then wrote chapters as a part of the PjBL approach for the EE book based on the identified issues and aligned with the EE curriculum. Over three years, the teachers tested the book with their students, evaluated the results, and revised it accordingly. The final questionnaire results showed that the experience of creating an EE book was valuable to the teachers and inspired them to consider making more EE resources in the future.

Keywords: *Deli River; environmental education; environmental leader; problem-based learning; project-based learning*

Introduction

The urgency of addressing global environmental challenges has led educational institutions to re-evaluate their curricula and incorporate environmental education (EE) into their programs. Integrating EE into formal education has become increasingly important as the impact of human activity on the planet becomes more apparent (Reid, 2019). EE and sustainable development are now considered essential components of a well-rounded education. The goal of EE in education is not only to increase awareness of environmental issues but also to equip students with the skills and knowledge they need to create positive change in the world (Fekih Zguir et al., 2021). By incorporating EE into the programs, students can be ready to act as leaders of change who will be responsible for addressing global environmental challenges.

EE is a multifaceted concept that spans from basic primary education to higher education, regardless of the area of knowledge. Despite the

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absence of a simple or agreed definition for EE, it encompasses a clear and defined core that promotes the need for a behavioural change towards the environment, regardless of the teaching approach or didactic strategy utilized (Acosta Castellanos et al., 2020). There is an intricate link between the environment and various biological, physical, social, cultural, and socioeconomic factors, underscoring the importance of awareness and providing tools for sustainable decision-making (Pace et al., 2023). EE must empower students to understand the environment and generate action strategies to protect it. Many schools face the challenge of integrating the environment into their functions since EE is often ignored in several countries' primary and secondary education (Seikkula-Leino et al., 2021). Therefore, incorporating EE into schools' curricula and practices is crucial.

Problem-based learning (PBL) and project-based learning (PjBL) are two student-centered learning approaches that emphasize critical thinking, problem-solving, and real-world application of knowledge (Sukackė et al., 2022). PBL is a teaching and learning method that focuses on solving complex problems in real-life contexts. In PBL, students work collaboratively to identify problems, generate hypotheses, gather and analyze data, and draw conclusions. The instructor plays a facilitator role, guiding students through the process and providing support as needed. PBL emphasizes the development of critical thinking, problem-solving, and communication skills, as well as content knowledge (Ali, 2019; Indriyani Rachman et al., 2021; Tell and Hoveskog, 2022). PjBL, on the other hand, is an approach to teaching and learning that involves students in designing, planning, and execution of projects that are related to real-world problems or challenges. PjBL emphasizes the development of project management skills, as well as critical thinking, problem-solving, and collaboration. In PjBL, students are often given a degree of autonomy to design their projects, which may involve research, experimentation, and analysis (Aminatun and Oktaviani, 2019; Farrow et al., 2022). Both PBL and PjBL share some similarities, such as focusing on real-world problems and emphasizing collaboration and critical thinking. However, PjBL tends to focus more on the project, while PBL focuses on the problem-solving process (Sukackė et al., 2022). Both approaches are effective in promoting deep learning, engagement, and motivation in students. They are often used in STEM fields, as well as in social sciences and humanities.

Medan City is one of Indonesia's cities experiencing rapid population growth, which has resulted in a surge of environmental problems. One such issue is the pollution of the Deli River, which runs through Medan City and originates in Deli Serdang. The river suffers from water and waste pollution, as reported by (Susanti, 2018). However, low environmental awareness among the residents of Medan City makes it challenging to address these problems (Aldhila et al., 2021). The city also faces a waste problem, with waste piling up along the Deli River and in illegal dumping sites. Moreover, the city grapples with flooding, traffic congestion, and a lack of public awareness about maintaining a clean environment, among the most critical problems (I Rachman et al., 2021).

EE is one way to tackle environmental problems, but what kind of education model can effectively address the issues Medan City faces? Therefore, it is essential to create textbooks and learning media that act as part of the PBL-PjBL methods that provide guidance on EE materials and teaching techniques for educators. Unfortunately, few experienced teachers are available to write such books, and some teachers willing to write books may lack the necessary guidance. A comprehensive work project is required to produce an EE textbook from scratch. This book's production aims to help

address the shortage of teaching materials on EE and improve teachers' ability to create their own textbooks.

Research Methodology

The research project begins with problem-based learning (PBL) where the teachers invite stakeholders to generate the environmental problems. An opinion poll was conducted with 40 people: traditional stakeholders, community leaders, school principals, and teachers, including 10 elementary school teachers, 5 junior high school teachers, and 10 high school teachers. The results of this opinion poll will be processed using text mining to determine the theme of environmental problems in the field. 40 people were asked about their environmental problems, and the data were analyzed using text mining, which generated 265 words related to the environment. Therefore, to gain the teachers' knowledge related to successful implementation of EE, the teachers were invited to Japan. This effort is part of an experience exchange between the schools, teachers, and students. It is to develop a new environmental leader (EL) when they returned to Medan City. This also aimed to provide an overview and comparison of EE development in Japan and Indonesia. After the EL understand and gain an overview of EE applied in Japan, it will be easier for the EL team to formulate an environment-based curriculum adapted to the culture of the people of North Sumatra to be applied in schools. The ELs were also given training on how to learn with the plan-do-check-act (PDCA) method.

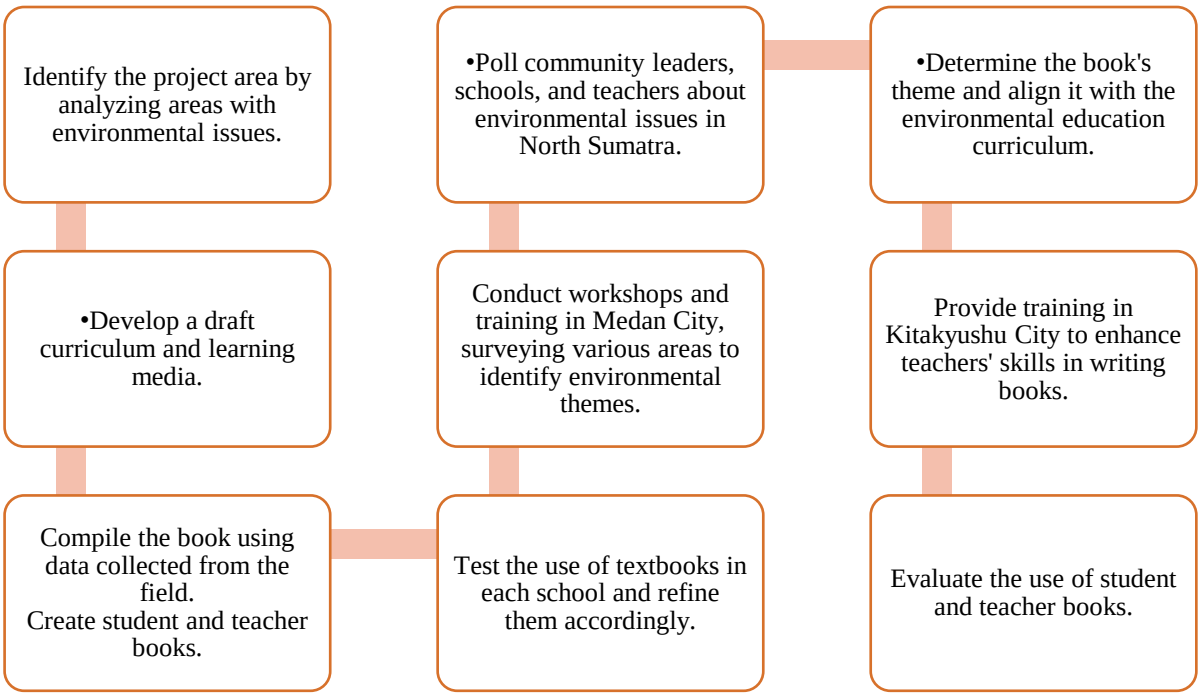

Figure 1. Methodological framework

The production of this textbook, JICA funded, is one of the initiatives under the cooperation program between the University of North Sumatra and The University of Kitakyushu. Over three years, teachers from five schools, ranging from elementary to high school, were

involved in the project to create EE textbooks. Every month, workshops were conducted to develop EE textbooks for students and teacher guidebooks. The teachers' activities were continually monitored throughout the research process, including planning, drafting, testing, and evaluation. To assess whether this project can establish a sustainable system/structure to manage EE and awareness activities for students and the community, questionnaires were distributed to 25 EL teachers. All data generated during the project are processed and analyzed using qualitative analysis. Fig. 1 provides the framework for creating EE textbooks.

Result and Discussion

Polling and Workshop Results

The polling resulted in six most frequent words, which were then identified: waste (48 times), disposal (21 times), carelessly (16 times), household (16 times), trash can (12 times). From the results, it can be concluded that the environmental problems faced by the community are related to household waste being disposed of in random places along the Deli River. From the interviews with EL teachers who attended the EE training in Kitakyushu, they all reported gaining new knowledge related to environmental learning, getting new ideas, and being inspired. Some argue that the success of Kitakyushu City as an environmentally friendly city is due to the power of education in schools and communities. A visit to Kitakyushu City opened new ideas, broadened teachers' insights when writing books, and made them more communicative, including using learning media. The visit to Kitakyushu City aimed to learn how the city provides EE lessons to students and the public. Fig. 2 shows the EL workshop for teachers in Kitakyushu, Japan.

Figure 2. Environmental Leader (EL) workshops for teachers in Kitakyushu Japan

Textbooks Development

In order to add insight to the teachers, several activities related to the textbook developments were done. The teachers were asked to write the material, surveys, and learn from the experiences after visiting several places such as waste banks, compost houses, wastewater treatment plants (WWTP), water supply companies, and landfills along the Deli River. The teachers also interviewed local communities, resource persons, and stakeholders. The teachers made EE books according to the areas where they teach. Table 1 shows the textbooks' themes in different levels of education. The textbooks focused on the Deli River's history, current river functions, identification of river water quality, polluted river environment, river conservation, domestic wastewater treatment, and flood.

Table 1. Thematic list of textbooks in different levels of education

No	Name of School	EE Theme
1	Elementary School first grade	The theme of this elementary school book focuses more on learning about rivers. Because this elementary school is very close to the river. History of the river, the role of the river, the function of the river, Animals and plants in the river, waste in the river, types of waste
2	Elementary School second grade	The themes for second grade of elementary schools are primarily about the history of rivers, river overflows, waste in rivers, river functions, types of rivers, the role of rivers, managing domestic waste
3	Junior High School	Middle school themes about types of rivers, the role of rivers, waste in rivers, river management, floods, wastewater, the role of the community, use of the Joukasou, visits to wastewater treatment plants (WWTP), water supply companies, and landfills, animals, and plants in the river
4	Senior High School first grade	High school theme, about the types of rivers, the role of rivers, waste in rivers, river management, floods, community role wastewater, use of joukasou, visits to wastewater treatment plants (WWTP), water supply companies, and landfills, plants and river plants, compost, biopore, floods, and the role of the community in managing green areas
5	Senior High School second grade	High school theme, about the types of rivers, the role of rivers, waste in rivers, river management, floods, community role wastewater, use of joukasou, visits to wastewater treatment plants (WWTP), water supply companies, and housing

The teacher selected a theme based on the chapter and then identified the sub-theme before creating a storyline. This activity is conducted every two months, where teachers gather and produce books based on their collected data. The photos presented in Fig. 3 depict the teachers working on creating the book, which was carried out at the Graha Kirana Building, one of the NGOs that participated in the book-making project. During the book-making process, the teacher creates an initial draft that includes an introduction, an explanation of the theme, the use of media, assignments, and evaluations.

Fig. 3. Textbook writing activities

Evaluation of Textbooks

The teacher's guidebook is a compilation of the evaluation results from the trial of student textbooks. During the trial, teachers take notes on the learning process, identify media and teaching method deficiencies, and provide feedback on assignments and evaluations. These notes are recorded and used to create the teacher's guidebook, designed to support teachers using the student EE books to teach EE.

The revision and printing process for the teacher's guidebook takes approximately 7 months. The book is valuable for other teachers to use. Following data collection through polling survey on waste problems in the field, teacher interviews were conducted after the book trial. It was discovered that the teacher wished to create textbooks on other themes and that the student knowledge test results were promising.

Through this project, the implementation of EE programs for students and the community can continuously improve their knowledge, awareness, and attitude. A test on the knowledge and attitudes of elementary, middle, and high school students was conducted. The knowledge and attitude questions were adapted from the EE textbook compiled by the teacher EL. The knowledge and attitude of elementary and junior high school students were found to be similar. However, there was a difference in knowledge and attitude scores between high school and junior high, as well as high school and elementary school.

Since the beginning of the project, the EL teacher and the Kitakyushu City team have developed a plan to create an EL book. They started by conducting an opinion poll to identify environmental problems in the Deli River and then developed a theme to be included in the textbook that aligned with the elementary, middle, and high school curriculum and EE subject matter. However, due to the pandemic, the meetings for making the textbook were held online. They have been holding weekly meetings to continue creating teaching materials, and the textbooks are expected to be finished in March 2021, followed by testing at the beginning of April. The questionnaire results show that ELs have gained an understanding of how to create textbooks, teach EE, and feel capable of being agents of change. After the completion of the student books and teacher guidebooks, questionnaires were distributed to teachers to evaluate their experience in creating the books.

Figure 4. Trial of EE Book

This EE textbook was tested for one year in each school, with 30 grade 2 students involved. The book was tested based on chapters, with weekly meetings for 2-hour lessons over the course of a year. The trial results showed increased students' knowledge after studying EE using the PBL method. One of the discussion themes in the junior high school EE book are rivers and their surroundings. Students were assigned to analyze the condition of the river using the PBL method from upstream, middle, and downstream perspectives. As a result, students drew pictures of the current and future river conditions, shown in Figure 5. The questionnaire distributed to the 25 teachers involved in making EE textbooks revealed that teachers with no prior experience writing books were interested in trying again after the training. Based on the PjBL methods done to the teachers as EL, they also gained valuable knowledge on how to make books.

Fig. 5. Students' drawings analyze the condition of the upstream, middle and downstream of a river

Incorporating elements of both PBL and PjBL can effectively provide students with a more engaging and meaningful learning experience (Wiek et al., 2014). As in this case, the teachers are trained using PBL and PjBL approaches, they are more likely to engage in the learning process. Therefore, the environmental problems can be solved by developing textbooks which are relevant to their lives and interests. Besides, teachers can create projects that are relevant and meaningful and require students to apply their knowledge and skills in real-world contexts. As environmental problems are complex, both approaches used in this research project can help them develop important communication and collaboration skills (Farrow et al., 2022; Indriyani Rachman et al., 2021; Sukackė et al., 2022).

Conclusions

The success of the project in creating teaching materials is strongly supported by the role of the school and the teachers involved in the project-based activities, which provides teachers with experience in making books. Difficulties in bookmaking activities were encountered at the beginning of the writing process. Teachers had to determine the narrative, link pictures, and select appropriate learning media. However, the teachers became more skilled in making textbooks and finding information over time. The PjBL and PBL approach was successful when the teachers as part of the EL visited Kitakyushu City and saw real examples of EE implementation. They learned how to plan, teach, and evaluate EE, especially in river-related materials. After attending a workshop on textbook creation and completing their textbooks, the teachers wanted to try creating books with other themes. This study shows that implementing PBL-PjBL approaches successfully improves the EL's environmental knowledge, especially the teachers of the Medan City schools.

References

Acosta Castellanos, P.M., Queiruga-Dios, A., Hernández Encinas, A., Acosta, L.C., (2020). Environmental Education in Environmental Engineering: Analysis of the Situation in Colombia and Latin America. *Sustainability 12*, 7239. https://doi.org/10.3390/su12187239

Aldhila, A., Warsono, H., Suwitri, S., Astuti, R.S., (2021). Management of slum settlements based on sustainable development in the Deli Watershed of Medan City. *BIRCI 4*, 2791–2799. https://doi.org/10.33258/birci.v4i2.1988

Ali, S.S. (2019). Problem Based Learning: A Student-Centered Approach. *ELT 12*, 73. https://doi.org/10.5539/elt.v12n5p73

Aminatun, D., Oktaviani, L., (2019). Memrise: Promoting Students' Autonomous Learning Skill through Language Learning Application. *Metathesis. J. Engl. Lang. Lit. Teach.* 3, 214. https://doi.org/10.31002/metathesis.v3i2.1982

Farrow, J., Kavanagh, S., Samudra, P. (2022). Exploring Relationships between Professional Development and Teachers' Enactments of Project-Based Learning.

Education Sciences 12, 282. https://doi.org/10.3390/educsci12040282

Fekih Zguir, M., Dubis, S., Koç, M., 2021. Embedding Education for Sustainable Development (ESD) and SDGs values in curriculum: A comparative review on Qatar, Singapore and New Zealand. *Journal of Cleaner Production* 319, 128534. https://doi.org/10.1016/j.jclepro.2021.128534

Pace, L.A., Saritas, O., Deidun, A., 2023. Exploring future research and innovation directions for a sustainable blue economy. *Marine Policy* 148, 105433. https://doi.org/10.1016/j.marpol.2022.105433

Rachman, I, Dewi, F.T., Simanjuntak, E., Muklis, Akmal, H., Rambe, R., 2021. Efforts to save the deli river environment with environmental education for students (study case: schools around the Deli River in Medan City Indonesia). *IOP Conf. Ser.: Earth Environ. Sci. 802*, 012055. https://doi.org/10.1088/1755-1315/802/1/012055

Rachman, Indriyani, Soesanto, Q.M.B., Matsumoto, T., Septiana, A.I., 2021. The Implementation of Problem-Based Learning (PBL) for Environmental Education in Elementary Schools: Case Study of Malang City in East Java. Presented at *the 5th Asian Education Symposium 2020* (AES 2020), Bandung, Indonesia. https://doi.org/10.2991/assehr.k.210715.067

Reid, A., 2019. Climate change education and research: possibilities and potentials versus problems and perils? *Environmental Education Research 25*, 767–790. https://doi.org/10.1080/13504622.2019.1664075

Seikkula-Leino, J., Jónsdóttir, S.R., Håkansson-Lindqvist, M., Westerberg, M., Eriksson-Bergström, S., 2021. Responding to Global Challenges through Education: Entrepreneurial, Sustainable, and Pro-Environmental Education in Nordic Teacher Education Curricula. *Sustainability 13*, 12808. https://doi.org/10.3390/su132212808

Sukackė, V., Guerra, A.O.P. de C., Ellinger, D., Carlos, V., Petronienė, S., Gaižiūnienė, L., Blanch, S., Marbà-Tallada, A., Brose, A., 2022. Towards Active Evidence-Based Learning in Engineering Education: A Systematic Literature Review of PBL, PjBL, and CBL. *Sustainability* 14, 13955. https://doi.org/10.3390/su142113955

Susanti, E., (2018). Risk Factors for Diarrhea Cases in Communities Living Along Deli River, North Sumatera. J *EPIDEMIOL PUBLIC HEALT 04*, 47–54. https://doi.org/10.26911/jepublichealth.2019.04.01.06

Tell, J., Hoveskog, M., (2022). Applied engineering education for soft skills in the context of sustainability and mobility. *IJSHE* 23, 324–336. https://doi.org/10.1108/IJSHE-07-2022-0202

Wiek, A., Xiong, A., Brundiers, K., van der Leeuw, S., (2014). Integrating problem- and project-based learning into sustainability programs: A case study on the School of Sustainability at Arizona State University. *International Journal of Sustainability in Higher Education* 15, 431–449. https://doi.org/10.1108/IJSHE-02-2013-0013