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Email: ml.pasca@unpak.ac.id

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GUEST EDITORIAL

The importance of education and role of educational institutions in climate change mitigation and achieving UN SDG 13 "Climate Action"

DOLLY PRIATNA[1,*], SHUJAUL MULK KHAN[2]

[1]Graduate School of Environmental Management, Pakuan University, Jl. Pakuan Kotak Pos 452, Bogor 16129, Indonesia
[2]Department of Plant Sciences, Quaid-i-Azam University, Islamabad Capital Territory 15320, Pakistan

[*]Corresponding author: *dollypriatna@unpak.ac.id*

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ABSTRACT

Climate change is a long-term shift in weather patterns driven by natural and human activities, leading to global warming and extreme weather events. Education - both formal and informal, plays a crucial role in climate change mitigation by enhancing awareness, fostering critical thinking, and promoting sustainable practices. It equips individuals with the knowledge and skills necessary to understand the complexities of climate change and engage them in informed decision-making. Education also promotes innovation and solutions, supports policy and advocacy, builds resilience, and empowers vulnerable populations. Climate change mitigation strategies align with Sustainable Development Goal 13 (SDG 13) "Climate Action", but they also present synergies and trade-offs with other SDGs. Large-scale implementation of technologies can positively impact economic growth and job creation, but environmental issues linked to mineral extraction can detract from other SDGs. Careful management is essential to balance these interactions and minimize trade-offs. Educational institutions play a crucial role in achieving Sustainable Development Goal 13 (SDG 13) by fostering knowledge, research, advocacy, and sustainable practices. They contribute to climate education and awareness through curriculum development, research and innovation, leadership and institutional action, policy advocacy, capacity building, community engagement, ethical and sustainable values education, and monitoring and reporting. Higher education institutions can integrate climate change education into curricula, equipping students with the necessary skills to address environmental challenges. They can also promote global citizenship and empower individuals to contribute to climate solutions. By incorporating multidisciplinary approaches, educational institutions can bridge gaps in climate education and promote innovative solutions to mitigate climate impacts.

Keywords: *climate action, climate change, educational institutions, sustainable development*

INTRODUCTION

Climate change is an event of significant and long-term alterations in weather patterns, including shifts in temperature, precipitation, and wind, which can occur over decades or longer (Belić, 2006) at regional or global scale. It is driven by both natural processes, such as volcanic activity and solar irradiance variations, and anthropogenic factors, particularly the emission of greenhouse gases from human activities like deforestation and industrial processes (Jaramillo & Mendoza-Ponce, 2022; Priatna & Monk, 2023a). These changes disrupt the Earth's energy balance, leading to phenomena such as global warming, which has resulted in an increase in average temperatures and more extreme weather events. According to Khan et al. (2014), landscape dynamics associated with anthropogenic activities and global climate change will likely reduce the ecosystem services associated with natural biodiversity. Education can be understood as a multifaceted process that encompasses the systematic transmission of knowledge, skills, values, and cultural practices, aimed at personal and societal development. It is characterized by the interaction between educators and learners, fostering a normative learning environment that enhances individual responsibility and community engagement (Dasopang, 2022). Education serves as a planned series of actions designed to improve behaviour and competencies, bridging gaps between existing skills and desired outcomes (Zebaloğlu, 2024). Furthermore, it plays a crucial role in personality formation, awakening latent potentials and shaping life paths (Vladimir, 2018). Philosophically, education is viewed as a moral enterprise, emphasizing the importance of nurturing better individuals and fostering ethical considerations in knowledge transmission (Jackson, 2011). While traditional definitions often equate education with formal schooling, it is essential to recognize its broader implications, including socialization and the cultivation of human capital (Lawrence, 2009).

Education plays a pivotal role in climate change mitigation by enhancing awareness, fostering critical thinking, and promoting sustainable practices. It equips individuals with the knowledge and skills necessary to understand the complexities of climate change and to engage in informed decision-making. Climate change education (CCE) is essential for developing ethical frameworks and scientific understanding, which are crucial for preventing and adapting to climate impacts (Tripathy et al., 2024). Moreover, while education is often framed as a tool for adaptation in national climate pledges, its potential for mitigation is increasingly recognized, particularly in higher education settings that can catalyse local emission reductions through innovative governance and service-learning approaches (Goritz & Kolleck, 2024). The urgency of integrating climate education across all sectors is underscored by the need for immediate action against environmental threats, advocating for a collaborative approach to empower global citizenship and address shared challenges (Riaz et al., 2024).

The education component in climate change mitigation is critically important for several reasons:

1. Raising Awareness
   - Informed Decisions: Education helps individuals understand the science behind climate change, its impacts, and the urgency of action. This knowledge empowers people to make informed decisions in their daily lives, from reducing energy consumption to supporting sustainable policies.
   - Behavioural Change: Awareness of the causes and consequences of climate change can motivate individuals and communities to adopt more sustainable behaviors, such as recycling, conserving water, and reducing carbon footprints.
2. Promoting Innovation and Solutions
   - Cultivating Expertise: Education systems that emphasize environmental sciences, engineering, and sustainability create a generation of experts who can develop innovative technologies and strategies for mitigating climate change.
   - Research and Development: Higher education institutions often lead in research that contributes to new methods of reducing greenhouse gas emissions, renewable energy technologies, and adaptation strategies.
3. Supporting Policy and Advocacy
   - Informed Advocacy: Educated citizens are more likely to engage in advocacy and support policies that address climate change. They are better equipped to understand the implications of policy decisions and to push for regulations that protect the environment.
   - Public Participation: A well-educated populace can more effectively participate in democratic processes, ensuring that climate change remains a priority in public policy.
4. Building Resilience
   - Community Adaptation: Education can teach communities how to adapt to the effects of climate change, such as extreme weather events, by implementing local solutions and resilience-building strategies.
   - Youth Engagement: Educating young people about climate change ensures that future generations are prepared to continue the fight against it. Engaged youth are more likely to become activists, innovators, and leaders in the movement for a sustainable future.
5. Global Collaboration
   - Shared Knowledge: Education facilitates global collaboration by spreading knowledge and best practices across borders. It helps build international networks of researchers, policymakers, and activists working together to tackle the global challenge of climate change.
   - Cultural Shifts: Education can drive cultural shifts toward more sustainable lifestyles globally, fostering a collective responsibility to protect the planet.
6. Empowering Vulnerable Populations
   - Climate Justice: Education is crucial in addressing the disproportionate impact of climate change on vulnerable populations. It provides the knowledge and tools needed to advocate for climate justice and equitable solutions.

CLIMATE CHANGE MITIGATION AND UN SDG 13 (CLIMATE ACTION)

Climate change mitigation strategies significantly align with Sustainable Development Goal (SDG) 13 "Climate Action" (Anshari et al., 2023), but they also present both synergies and trade-offs with other SDGs. For instance, a study in Sweden identified that large-scale implementation of technologies like electric vehicles and renewable energy can positively impact economic growth and job creation (SDG 8) while also supporting sustainable industrialization (SDG 9) (Elbert, 2023; Ahlbäck et al., 2024). However, it also highlighted negative impacts, particularly concerning environmental issues linked to mineral extraction, which can detract from other SDGs (Ahlbäck et al., 2024). Moreover, research indicates that industrialization and trade, while beneficial for poverty reduction (SDG 1), can adversely affect climate goals (SDG 13) due to increased carbon emissions (Khan et al., 2024). Conversely, synergies were found between climate actions and water-related SDGs, suggesting that coordinated policies can enhance overall sustainability (Rimba et al., 2024). Thus, while climate mitigation can foster progress across multiple SDGs, careful management is essential to balance these interactions and minimize trade-offs (Xiao et al., 2024).

THE ROLE OF EDUCATION IN HELPING TO ACHIEVE SDG 13

Sustainable Development Goal (SDG) 13, "Climate Action", focuses on taking urgent action to combat climate change and its impacts (Priatna & Monk, 2023b) . Educational institutions are vital in achieving this goal by fostering knowledge, research, advocacy, and sustainable practices. Here's how they contribute:

1. Climate Education and Awareness
   - Curriculum Development: Integrating climate change education into school and university curricula helps students understand the science behind climate change, its causes, impacts, and the importance of mitigation and adaptation strategies.
   - Awareness Campaigns: Institutions can organize awareness programs, seminars, workshops, and campaigns to educate students and the wider community about climate action and the significance of SDG 13.
2. Research and Innovation
   - Advancing Climate Science: Universities and research centres play a crucial role in advancing the scientific understanding of climate change, contributing to data collection, modelling, and analysis that inform climate policies and actions.
   - Innovation in Mitigation and Adaptation: Research institutions can drive innovation in areas such as renewable energy, sustainable agriculture, and climate-resilient infrastructure, which are essential for achieving SDG 13.
3. Leadership and Institutional Action
   - Sustainable Campus Operations: Educational institutions can lead by example by adopting sustainable practices on their campuses, such as energy efficiency, waste reduction, water conservation, and the use of renewable energy sources.
   - Carbon Neutrality Goals: Some universities aim to achieve carbon neutrality, demonstrating a strong commitment to climate action and serving as role models for other institutions and the community.
4. Policy Advocacy and Collaboration
   - Engagement with Policymakers: Educational institutions can influence climate policy by providing evidence-based research, participating in policy dialogues, and advocating for stronger climate action at local, national, and global levels.
   - Collaborative Networks: By participating in national and international networks, such as the UN's Global Universities Partnership on Environment and Sustainability (GUPES), educational institutions can share best practices and collaborate on climate initiatives.
5. Capacity Building and Skill Development
   - Training Programs: Educational institutions offer training programs and courses that equip students and professionals with the skills needed to work in climate-related fields, such as environmental science, climate policy, and sustainable development.
   - Empowering Future Leaders: By fostering leadership skills and a sense of responsibility, educational institutions prepare the next generation to take active roles in climate action and sustainability efforts.
6. Community Engagement and Outreach
   - Local and Global Community Projects: Institutions can engage in projects that directly address climate change impacts in local communities, such as reforestation, clean energy initiatives, and climate resilience programs.
   - Public Education: Universities and schools often serve as hubs for public education on climate change, offering resources, hosting public lectures, and engaging with local communities to promote climate action.
7. Promoting Ethical and Sustainable Values
   - Values and Ethics Education: Beyond technical knowledge, educational institutions instill values of environmental stewardship, social responsibility, and global citizenship, motivating students to pursue sustainable lifestyles and careers.
   - Cultural Change: By embedding sustainability into the campus culture, educational institutions can create a community of individuals committed to long-term climate action.
8. Monitoring and Reporting
   - Tracking Progress: Institutions can contribute to the monitoring and reporting of climate action by developing and utilizing indicators to track progress towards SDG 13 at local, national, and global levels.
   - Data Sharing: They can also share research and data with governments, NGOs, and international bodies, supporting global efforts to achieve SDG 13.

THE ROLE OF EDUCATIONAL INSTITUTIONS

Through promoting awareness, knowledge, and workable solutions, educational institutions play a critical role in establishing climate change mitigation agendas that are in line with Sustainable Development Goal 13 (SDG 13). By incorporating climate change education (CCE) into curricula, higher education institutions (HEIs) can serve as agents of change for sustainable development by providing students with the tools they need to tackle environmental issues (Suteki et al., 2023; Yusuf et al., 2024). Especially in environments with limited resources, this integration is crucial for fostering a sense of global citizenship and enabling people to contribute to climate solutions (Riaz et al., 2024). Additionally, HEIs can successfully handle complex climate concerns and improve organizational learning by utilizing sustainable reporting methods (Tripathy et al., 2024). In countries like India, educational policies are evolving to incorporate multidisciplinary approaches that bridge gaps in climate education, thus promoting innovative solutions to mitigate climate impacts (Saini & Grover, 2023). Educational institutions can play a vital role in reducing carbon emissions via engagements of their students (Ali et al., 2022; Ali et al., 2023). Through improved carbon sequestration, the sustainable use and preservation of plant biodiversity in montane habitats are essential to mitigating the effects of climate change. A study conducted in the western Himalayas by Khan et al. (2013) demonstrates that ecosystems with higher plant diversity have the capacity to retain much more carbon, demonstrating the intrinsic relationship between biodiversity and carbon storage (Heriyanto et al., 2020; Heriyanto et al., 2021; Heriyanto et al., 2022; Priatna et al., 2022).

CONCLUSION

Beyond its effects on the environment, climate change has an impact on resource availability and economic stability in both rural and urban parts of society. Education, then, is the result of the dynamic interaction between gaining knowledge, developing oneself, and contributing to society. Therefore, education is an essential tactic in the fight against climate change, not only a supporting one. In conclusion, education is essential to mitigating climate change it is not merely a supplementary factor. It gives people and society the information, abilities, and drive necessary to combat climate change in the present and the future.

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Analysis of flood-prone areas in DKI Jakarta Province using Clustering Method

RANDY DAFFA ADITYA*, MUHAMMAD ABDUL AZIZ HABIBI

Politeknik Statistika STISS, Jl. Otto Iskandardinata No.64C-1, Jatinegara, Kota Jakarta Timur, Jakarta 13330, Indonesia

Corresponding author: *212112306@stis.ac.id*

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ABSTRACT

The objective of this research is to ascertain the patterns and organization of flood-affected areas in Jakarta. The dataset of flood incidents in the DKI Jakarta Province in 2020 served as the data source for this study. The research employed three methods: K-Means, K-Medoid, and Hierarchical Clustering. Of these, Hierarchical Clustering produced the best grouping in comparison to the other methods. The findings of the study show that the flood-affected areas in DKI Jakarta are classified into three groups: safe (cluster 1), moderate (cluster 2), and vulnerable (cluster 3). The districts of Cengkareng, Jatinegara, and Pulogadung are among the vulnerable areas.

ABSTRAK

Tujuan penelitian ini adalah untuk mengetahui pola dan penataan wilayah terdampak banjir di Jakarta. Dataset kejadian banjir di Provinsi DKI Jakarta tahun 2020 dijadikan sebagai sumber data penelitian ini. Penelitian ini menggunakan tiga metode: K-Means, K-Medoid, dan Hierarchical Clustering. Dari ketiga metode tersebut, Hierarchical Clustering menghasilkan pengelompokan terbaik dibandingkan dengan metode lainnya. Temuan penelitian menunjukkan bahwa wilayah terdampak banjir di DKI Jakarta diklasifikasikan menjadi tiga kelompok: aman (kluster 1), sedang (kluster 2), dan rentan (kluster 3). Kecamatan Cengkareng, Jatinegara, dan Pulogadung termasuk wilayah yang rentan.

Keywords: *clustering, flood, Jakarta, vunerable*

INTRODUCTION

Flooding is a natural phenomenon that can occur throughout the globe. Settlements in floodplain areas are the main cause of flood damage (Istiadi & Priatna, 2021). Jakarta is Indonesia's capital city, and it is dealing with a number of issues. Poverty, inequality, and environmental concerns are all issues that both the government and society must address. Flooding is an environmental concern that has received a lot of attention. Major floods in 2002, 2007, 2013, and 2014 resulted in direct and indirect economic damages worth trillions of rupiah (Bappenas, 2007; Ward et al., 2013). Although flooding is not a new phenomenon, the extent of the damage has escalated considerably over the last decade.

Based on Figure 1 above, it is evident that each year, the number of neighborhoods (RW) affected by floods in Jakarta generally ranges between 200 and 300. These numbers tend to increase each year, with the exception of 2020. In 2020, the number of affected neighborhoods was exceptionally high due to extremely high rainfall (377 mm/day on January 1, 2020), causing widespread flooding across Jakarta. Nevertheless, the increasing number of neighborhoods affected by floods indicates that the damage caused by floods will continue to escalate each year.

This increase is associated with a myriad of factors, both physical and socio-economic. Physical factors include land subsidence, low drainage or storage capacity in Jakarta's rivers and canals due to blockage by waste and sediment eroded from upstream, as well as climate change. Socio-economic factors involve rapid population growth and changes in land use, leading to the development of economic assets in flood-prone areas (Budiyono, 2016). Climate change is also a major contributor to the frequent flooding in Jakarta (Douglass *in* Lyons, 2015; Fuchs in Salim et al., 2019). Climate change disrupts the schedule and intensity of rainfall, causing high sea levels and leading to floods and land subsidence (Padawangi & Douglass, 2015). This situation is exacerbated by Jakarta's poor drainage system and the

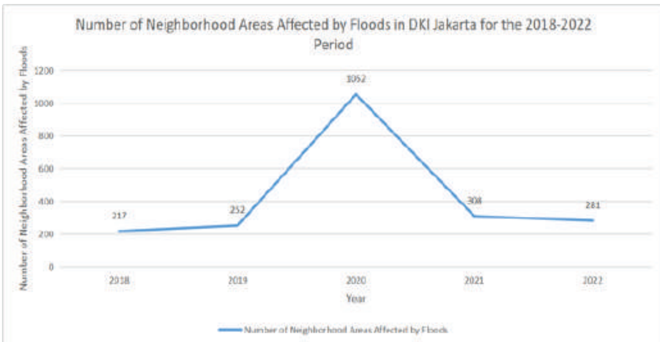

Figure 1. Graph of the number of neighborhood units (RW) affected by floods in DKI Jakarta for the period 2018-2022.

limited natural water absorption areas, preventing the efficient flow of water from other areas, rainwater, and seawater, resulting in overflowing drainage systems and rivers that cause floods (Lyon, 2015). Poor drainage maintenance combined with climate change causes Jakarta to experience floods annually (Napier, 2021; Padawangi & Douglass, 2015; Salim et al., 2019).

In addition to physical factors, socio-economic factors also influence flooding in Jakarta (Budiyono, 2016). This is partly due to Jakarta's status as the capital and economic center of Indonesia. The influx of people moving to or living in Jakarta has led to the construction of numerous buildings (Padawangi & Douglass, 2015). The proliferation of buildings has replaced many water absorption areas, resulting in an ineffective water absorption and drainage system in Jakarta (Padawangi & Douglass, 2015). This has made Jakarta increasingly vulnerable to flooding. The situation is further aggravated by the numerous illegal buildings along riverbanks and the significant amount of waste clogging the city's drainage system (Padawangi & Douglass, 2015).

Given these circumstances, flood management and prevention have become crucial programs in Jakarta. However, if the government does not prioritize the areas that need immediate flood management, their efforts may not be effective. Therefore, identifying the neighborhoods frequently affected by floods is essential to facilitate disaster mitigation and find solutions to address flooding. By knowing the flood-prone areas, those regions can better prepare themselves, thereby minimizing casualties and damage (Duykers et al., 2023).

Based on the explanation above, this research aims to identify the patterns and clustering of floods in Jakarta. Flood clustering is necessary because floods generally inundate multiple areas simultaneously, implying that some regions may be more vulnerable to flooding than others. By clustering flood-affected areas in Jakarta, it is hoped that disaster mitigation processes and flood management solutions can be implemented more easily and efficiently.

METHODS

Data Source

This research uses secondary data obtained from the website of data.jakarta.go.id, provided by the Provincial Government of DKI Jakarta. The data on this website is a compilation from various agencies such as the Badan Pusat Statistik (BPS), Badan Nasional Penanggulangan Bencana (BNPB), Dinas Kesehatan Provinsi DKI Jakarta, and other agencies. The dataset consists of 902 observations and includes attributes such as the administrative area where the flooding occurred, neighborhood units (RW), the number of RW, neighborhood associations (RT), households (KK) affected by the flood, water level, the number of affected households, number of refugees, number of fatalities, and the flood period. The collected data is cross-sectional with the unit of analysis being sub-districts in DKI Jakarta in the year 2020.

Methodology

The method used in this research is K-Means Clustering to discover and group data, enabling better insights into flooding in the DKI Jakarta area. K-Means clustering is one of the classic methods in unsupervised learning. This method is used to divide n units of observation into k groups or clusters so that each cluster has an average value as close as possible (Alashwal et al., 2019). The notion of similarity can be expressed in very different ways, depending on the research objectives, specific domain assumptions, and prior knowledge about the issue (Grira et al., 2004).

As the name suggests, K-Means Clustering requires prior information about how many clusters will be generated according to previous information or research (Sinaga & Yang, 2020). The value of k will then be initialized into the dataset of n observations to generate a number of clusters along with their members and the average values of each cluster. In summary, the following is the procedure for using K-Means Clustering (Alashwal et al., 2019).

1. Initialize k cluster centers.
2. Calculate the distance between each observation and the cluster center observation points.
3. Assign all points to the cluster whose center is at the minimum distance from all cluster centers.
4. Recalculate the positions of the k centers as the mean of the clusters.
5. Recalculate the distance between each data point and the newly calculated centers. Repeat steps 3 and 4 until all data points are assigned to the samecluster (data points also do not move).

The K-Means Clustering method was chosen because it has been proven effective in grouping data into specific clusters or groups according to the research objectives. K-means clustering has been extensively studied with various extensions in the literature and applied in various substantive fields (Sinaga & Yang, 2020). The advantage of this method is its ability to learn data in an unsupervised manner, meaning data without target variables (Alashwal et al., 2019). This is highly suitable for this research on flood clustering in the DKI Jakarta area. However, this method also has a drawback, namely, its heavy reliance on the value of k initialized by the researcher. Therefore, researchers must be cautious in determining the number of clusters to ensure optimal clustering results.

In the use of K-Means Clustering, other methods such as K-Medoid and Hierarchical Clustering are sometimes necessary. This is because K-Means Clustering is highly affected by outliers that can disrupt the data (Kaur et al., 2014). This is due to the calculation method of K-Means Clustering itself, which calculates based on the distance between the values of elements in a group and the group's average (Medellu & Nugaraha *in* Herman et al., 2022). Therefore, the K-Medoid method emerged as an alternative clustering method by selecting the most central value within each cluster (Kaur et al., 2014). The process works as follows: from numerous data points, a number of medoids are selected randomly, where groups are formed with elements most similar to the representative values. After these clusters are formed, new medoids are selected that better represent the formed groups. This continues until no medoids change their positions (Vishwakarma et al., *in* Herman et al., 2022). The K-Medoid method provides results that are more resilient to outliers and more robust, although the algorithm becomes more complex, and the number of clusters formed still heavily depends on the researcher's decisions (Kaur et al., 2014; Herman et al., 2022).

Hierarchical Clustering is a clustering method that involves either merging or splitting existing groups and specifying the order of cluster merging or splitting (Shetty & Singh, 2021). A tree or dendrogram is used to display hierarchical clusters. Hierarchical clustering can be performed in two ways: bottom-up (Agglomerative Hierarchical Clustering) or top-down (Divisive Hierarchical Clustering). Large clusters are divided into smaller clusters, and small clusters from large clusters are merged into one (Shetty & Singh, 2021). The steps to form top-down clustering are:

1. Start with all data points as individual clusters.
2. After each iteration, remove the "outlier" from the least cohesive cluster.
3. Repeat the second step, stopping when each example is in its own single cluster.

The steps of agglomerative (bottom-up) clustering formation are:

1. Begin by considering each data point as its own single cluster.
2. After each iteration of Euclidean distance calculation, merge two clusters with the minimum distance.

Repeat the second step, stopping when there is one cluster containing all examples.

RESULT AND DISCUSSION

Descriptive Statistics

Here is a summary of the description regarding flood impact data in DKI Jakarta Province used in the study.

Based on Table 1, it is known that on average there are seven RW (neighborhood units) affected by floods, with a minimum of one RW and a maximum of 15 RW, and a resulting standard deviation of 3.527. Furthermore, there are on average 14.95 RT (household units) affected, with a minimum of 1 RT and a maximum of 46 RT. The standard deviation of the number of affected RT is 11.889. Regarding the variable of the number of affected households (KK), on average there are 394.41 households affected by floods, with a minimum of 0 and a maximum of 3762 households. The standard deviation value is 727.334. In terms of the variable of the number of affected individuals, there are on average 1414 individuals affected by floods, with a minimum of 0 and a maximum of 13450 individuals, and the standard deviation is 2446.895. As for the water level, the average height is 87.05 cm, with a minimum of 20 cm and a maximum of 180 cm. The standard deviation value is 40.35. For the duration of inundation, floods typically last for an average of 0.3182 days, with a minimum of 0 days and a maximum of 2 days. The standard deviation is 0.561. Lastly, for the variable of the number of minor injuries, on average there are 811.79 individuals sustaining minor injuries, with a minimum of 0 and a maximum of 4461 individuals. The standard deviation is 1036.664.

Table 1. Summary of descriptive statistics.

Variables	Mean	Minimum	Maximum	Standard Deviation
Number of Neighborhood Association (RW) affected	7	1	15	3.527
Number of Community Unit (RT) affected	14.95	1	46	11.889
Number of Household (KK) affected	394.41	0	3762	727.334
Number of Individuals affected	1414	0	13450	2446.895
Water Level (cm)	87.05	20	180	40.350
Inundation Duration (day)	0.3182	0	2	0.561
Number of Minor Injuries	811.79	0	4461	1036.664

Data Preprocessing

Data preprocessing is a crucial phase in data analysis as it has the potential to influence the final results of the analysis or models built. This process can be customized and depends on the type of data and the objectives of the analysis or models to be achieved. The stages of data preprocessing include several steps, namely data cleaning, data transformation, and data reduction.

Before processing the data, data cleaning is performed first. Data cleaning is a stage where data is filtered to ensure its accuracy, consistency, completeness, and readiness for analysis. In this study, data cleaning focuses on checking for missing or empty values (missing values) in the dataset. After that, a check for missing values is performed. The result is that there are no missing values in the dataset.

After the completion of data cleaning, the process continues with data transformation. This data transformation will change or modify the data from its original format to another format for a specific purpose. Data transformation is done to ensure that the data to be analyzed or processed meets the existing needs. This change is made because there are changes in units and dimensions in the data, so standardization with z-score is necessary.

The final stage of data preprocessing is data reduction. Data reduction is the process of reducing the amount of irrelevant, excessive, or redundant data in a dataset. The goal is to reduce unnecessary analysis complexity, save time and resources in data processing, and improve the efficiency and quality of data analysis. In this data reduction process, KMO (Kaiser-Meyer-Olkin) and PCA (Principal Component Analysis) analyses will be conducted. KMO is the abbreviation for the Kaiser-Meyer-Olkin Measure of Sampling Adequacy, which is used to assess the adequacy of the data sample used in factor analysis or PCA. PCA, on the other hand, transforms linear combinations of the original attributes into several principal components, selected based on their contribution to the variation in the data. These components provide a more concise representation of the original data, combining information from several original attributes that contribute most to the variation in the data. By using these reduced attributes, data analysis can be performed more efficiently while still retaining the important information represented by these principal components.

In this dataset, the variables for the number of deaths, number of missing persons, number of severe injuries, and the value of losses all have a value of 0, so it was decided to remove them. After that, KMO analysis is performed to determine its value. If the MSA value is more than 0.5, then the attribute can be retained. Whereas if it is less than 0.5, then the attribute will be removed. Then from the output, the overall MSA value obtained is 0.74, while the MSA value for each retained variable is listed in Table 2.

Table 2. MSA Score for each variables.

Variables	MSA Score
Number of Neighborhood Association (RW) affected	0.82
Number of Community Unit (RT) affected	0.83
Number of Household (KK) affected	0.63
Number of Individuals affected	0.64
Water Level (cm)	0.90
Inundation Duration (day)	0.67
Number of Minor Injuries	0.89

K-Medoid Clustering Method

The optimal number of clusters to be used in the K-medoid method can be determined using Elbow Plot visualization. Additionally, the determination of the optimal number of clusters can also be observed using Connectivity, Silhouette, and Dunn indices. The Elbow Plot and indices can be seen in Figure 2 and Table 3.

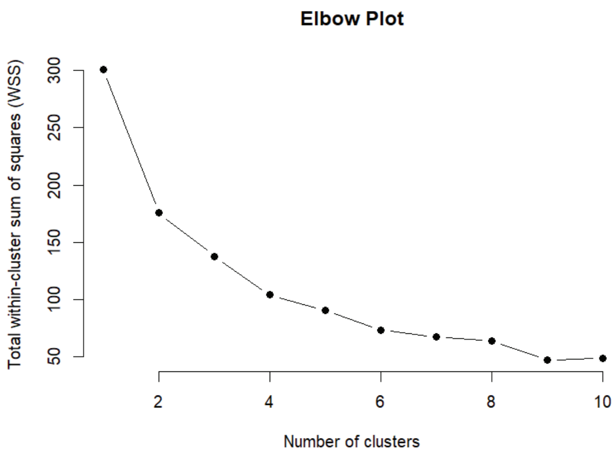

Figure 2. K-Medoid method's elbow plot.

Table 3. K-Medoid validity index value.

Validation Measures	k=3	k=4	k=5
Connectivity	15.3218	19.3032	20.8365
Dunn	0.1342	0.1601	0.2273
Silhouette	0.2793	0.3056	0.3098

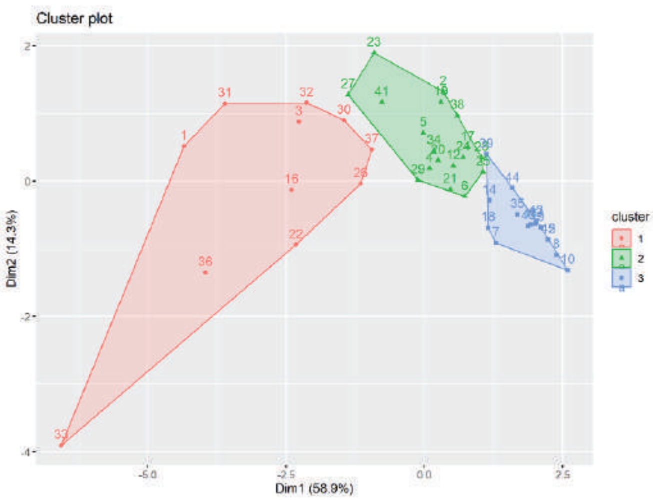

Figure 3. Cluster Plot using K-Medoid algorithm.

Based on Table 3, the smallest Validation Measure Connectivity value is found in cluster 3, thus it can be concluded that the optimal number of clusters in the K-Medoid method to be used is 3 clusters. Visualization of the clustering results with k = 3 is shown in Figure 3 and Figure 4.

Based on the choropleth map in Figure 4, the distribution of flood-prone area clusters is divided into 3 groups. The first cluster consists of 11 districts, the second cluster consists of 18 districts, and the third cluster consists of 15 districts.

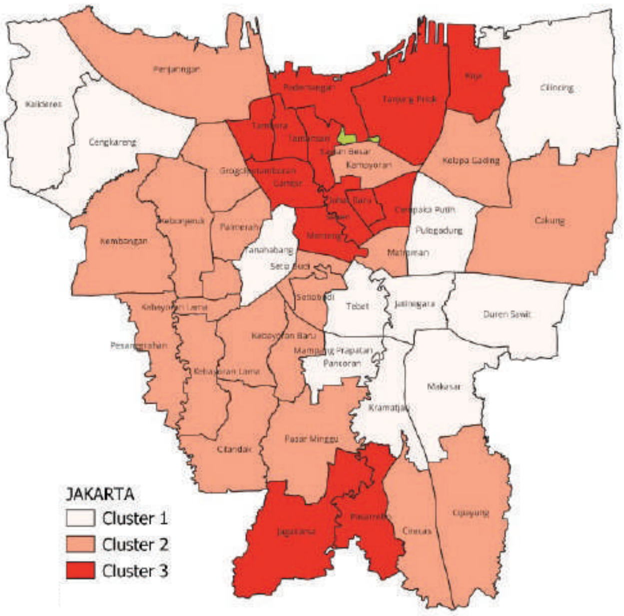

Figure 4. Mapping of flood-prone cluster regions in Jakarta using the K-Medoid method.

K-Means Clustering Method

The optimal number of clusters to be used in the K-means method can be determined using Elbow Plot visualization. Additionally, the determination of the optimal number of clusters can also be observed using Connectivity, Silhouette, and Dunn indices. The Elbow Plot and indices can be seen in Figure 5 and Table 4 below.

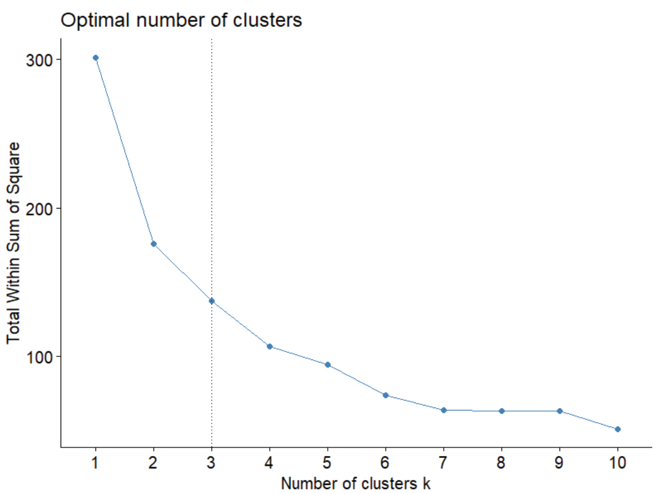

Figure 5. K-Mean Method's elbow plot.

Table 4. K-Means validity index value.

Validation Measures	k=3	k=4	k=5
Connectivity	14.6790	20.8071	21.9869
Dunn	0.3342	0.3542	0.3976
Silhouette	0.4005	0.3671	0.3573

Based on Table 4, the smallest value of Validation Measure Connectivity and the largest Dunn value are found in cluster 3, indicating that the optimal number of clusters for the K-Mean method to be used is 3 clusters. The visualization of the clustering results with k = 3 is shown in Figure 6 and Figure 7.

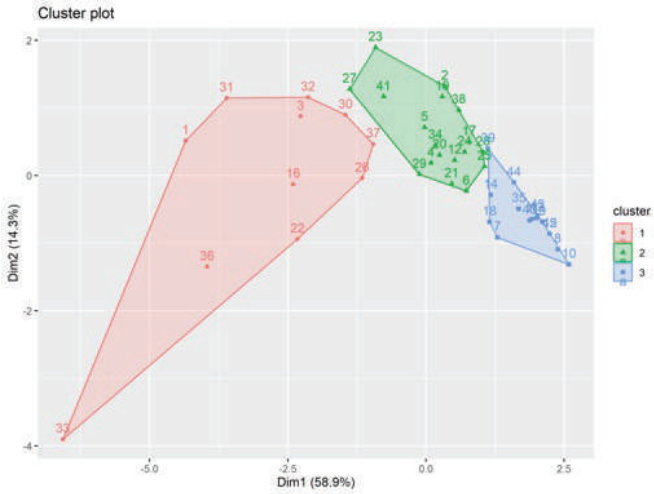

Figure 6. Cluster plot using K-Means algorithm.

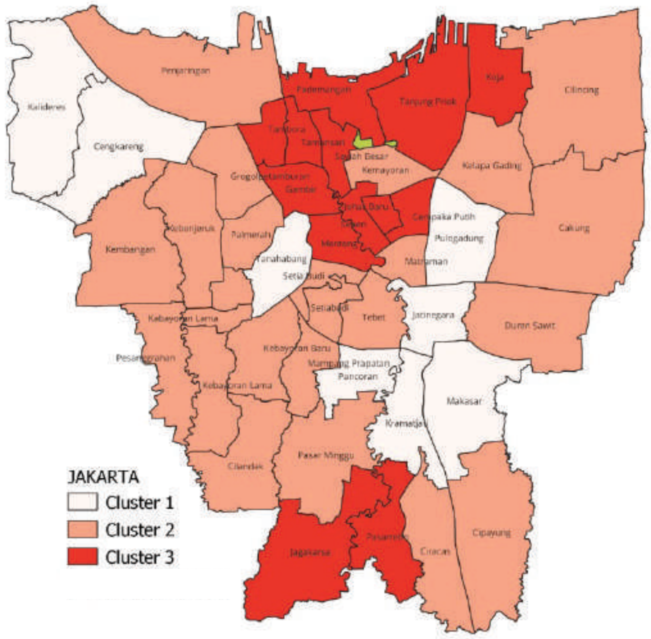

Figure 7. Mapping of flood-prone cluster regions in Jakarta using the K-Means method.

Based on the choropleth map using the K-Means method in Figure 7, the distribution of flood-prone cluster areas is divided into 3 groups. The first cluster consists of 8 districts, the second cluster consists of 21 districts, and the third cluster consists of 15 districts.

Hierarchical Method Clustering

In hierarchical clustering, the initial step is to select the best model. Model selection is done by examining the cophenetic correlation values of each available method.

The model with the highest cophenetic correlation value will be considered the best. Information regarding the cophenetic correlation values can be found in Table 5 below.

Table 5. Cophenetic correlation coefficient.

Methods	Correlation Coefficient
Single	0.8821
Complete	0.7999
Average	**0.9123**
Ward	0.6259

Based on the evaluation of the cophenetic correlation coefficient, the average linkage method stands out with the highest correlation compared to other alternatives, thus being selected for the clustering process. The determination of the number of clusters in the average linkage method is done through cluster validity testing first. In this study, internal validity testing is conducted using the Connectivity, Silhouette, and Dunn indices. The optimal number of clusters can be identified from the Silhouette and Dunn index values approaching 1, as well as the Connectivity value decreasing. Detailed values of internal validity indices are listed in Table 6.

Table 5. Cophenetic correlation coefficient.

Validation Measures	k=3	k=4	k=5
Connectivity	9.6341	10.6520	19.8119
Dunn	0.4275	0.4275	0.3356
Silhouette	0.4501	0.4128	0.3564

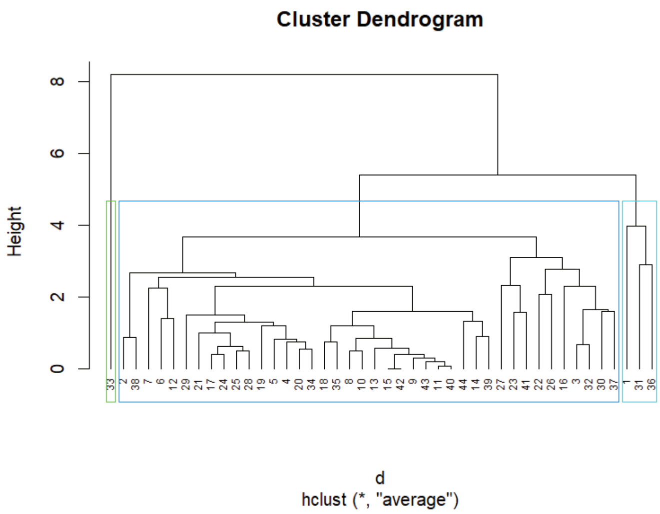

Figure 8. Dendrogram cluster using the average linkage method.

Based on Table 6, the smallest value of the Validation Measure Connectivity, and the largest values of Dunn and Silhouette, are found in cluster 3. Therefore, it can be concluded that the optimal number of clusters in the average linkage method to be used is 3 clusters. Visualization of the clustering results with k = 3 can be seen in Figure 8 and Figure 9.

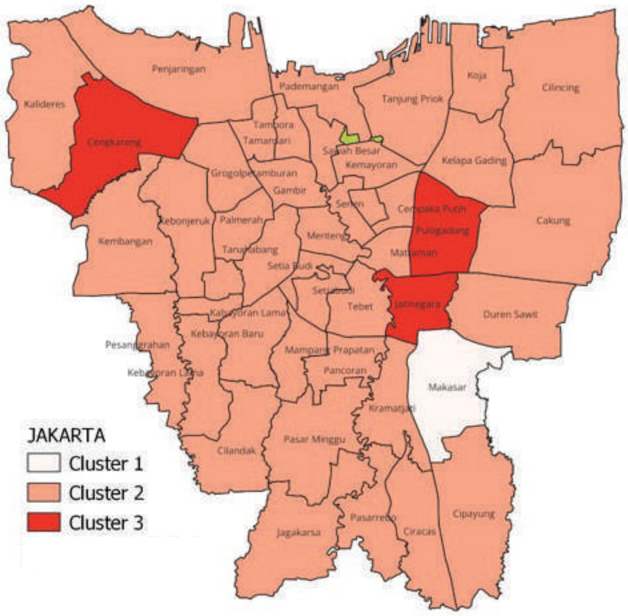

Figure 9. Mapping of flood-prone cluster regions in Jakarta using the average linkage method.

Based on the choropleth map using the Average Linkage method in Figure 9, the distribution of flood-prone cluster areas is divided into 3 groups. The first cluster consists of 1 district, the second cluster consists of 40 districts, and the third cluster consists of 3 districts.

Comparison between K-Medoid, K-Means, and Average Linkage Clustering Method

After conducting the clustering process using three different methods, the three methods will be compared to see which one is the best to use. To compare the three methods, the criteria are based on the Connectivity index, Dunn index, and Silhouette index. The best method is determined by which method has the smallest Connectivity value and the largest Dunn and Silhouette values. The comparison of the three clustering methods can be seen in the following Table 7.

Table 7. Validation index comparison for three utilized clustering method.

	Clustering Methods (k=3)		
Validation Measures	K-Medoid	K-Means	**Average Linkage**
Connectivity	15.3218	14.6790	**9.6341**
Dunn	0.1342	0.3342	**0.4275**
Silhouette	0.2793	0.4005	**0.4501**

Based on Table 7 above, it can be observed that the Average Linkage method yields the most optimal values of Connectivity, Dunn, and Silhouette indices compared to the K-Medoid and K-Means methods. Subsequently, based on the clustering results, the characteristics of each cluster are obtained based on the variables initially used in Table 8.

Table 8. Characteristic comparison for each cluster.

Variables	Cluster 1	Cluster 2	Cluster 3
Number of Neighborhood Association (RW) affected	10	6.6	**12.33**
Number of Community Unit (RT) affected	26	13.2	**34.667**
Number of Household (KK) affected	3762	200.125	**1862.333**
Number of Individuals affected	13450	784.15	**5800.667**
Water Level (cm)	115	82.85	**133.667**
Inundation Duration (day)	**2**	0.275	**0.333**
Number of Minor Injuries	2738	610.8	**2849.667**

Based on the comparison in table 8, cluster 3 exhibits high characteristics in terms of the variables of the number of affected neighborhoods (RW), the number of affected communities (RT), the number of affected households (KK), the number of affected individuals, water level, and the number of minor injuries. Meanwhile, the area with the longest duration of inundation is found in cluster 1. The grouping of areas based on their clusters is presented in Table 9.

Table 9. Inter-cluster area distribution.

Cluster Type	City	District
1 (Safe)	East Jakarta	Makassar
2 (Moderate)	West Jakarta	Grogol Petamburan, Kalideres, Kebon Jeruk, Kembangan, Palmerah, Taman Sari, Tambora
	Central Jakarta	Cempaka Putih, Gambir, Johar Baru, Kemayoran, Menteng, Sawah Besar, Senen, Tanah Abang
	South Jakarta	Cilandak, Jagakarsa, Kebayoran Baru, Kebayoran Lama, Mampang Prapatan, Pancoran, Pasar Minggu, Pesanggrahan, Setiabudi, Tebet
	East Jakarta	Cakung, Cipayung, Ciracas, Duren Sawit, Kramat Jati, Matraman, Pasar Rebo
	North Jakarta	Cilincing, Kelapa Gading, Koja, Pademangan, Penjaringan, Tanjung Priok
	Seribu Islands	Kepulauan Seribu Selatan, Kepulauan Seribu Utara
3 (Vunerable)	West Jakarta	Cengkareng
	East Jakarta	Jatinegara, Pulogadung

CONCLUSION

According to the average linkage method, flood-affected areas in DKI Jakarta are divided into 3 clusters: safe (cluster 1), moderate (cluster 2), and vulnerable (cluster 3). Areas categorized as vulnerable include the districts of Cengkareng, Jatinegara, and Pulogadung. The results of this study can be used for evaluation by the government, especially the Jakarta Provincial Government, to improve drainage infrastructure and related water channels to minimize losses and reduce casualties in the future.

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A comprehensive study on electricity utilization and CO_2 emissions in Sami Laris Swalayan, Cilacap, Indonesia

AULIA RACHMA YULIANI, MEGA MUTIARA SARI, I WAYAN KOKO SURYAWAN*

Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Jakarta 12220, Indonesia

Corresponding author: *i.suryawan@universitaspertamina.ac.id*

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ABSTRACT

In today's world, with an increased focus on environmental awareness and sustainability, mitigating carbon footprint has emerged as a crucial goal for businesses across various sectors, including supermarket chains. This research centers on Sami Laris Swalayan, a prominent and widely recognized supermarket chain, to comprehensively analyze its electricity utilization patterns and the corresponding carbon dioxide (CO_2) emissions. By delving into electricity utilization data spanning a specific period, this study identifies peak demand periods, explores energy-efficient opportunities, and assesses the potential for integrating renewable energy sources. The research underscores the significance of reducing CO_2 emissions, advocating sustainable energy practices within the supermarket chain, contributing to environmental conservation efforts, and fostering a culture of responsible energy management. The investigation begins with a thorough analysis of Sami Laris Swalayan's electricity utilization, seeking to understand the varying trends and patterns in energy consumption. The data above shows the fluctuating electricity consumption of the company, with the highest figure recorded in April, reaching 26,965 kWh. The high electricity usage is attributed to the total operational hours from 09:00 to 21:00 and the addition of other facilities such as the accessory room, bakery outlet, and coffee outlet. In contrast, the lowest consumption was observed in February, with 23,796 kWh, which was influenced by the implementation of Large-Scale Social Restrictions (PSBB) at the end of January 2021. During this period, the operational hours were shortened from 09:00 to 19:00, leading to a decrease in electricity consumption the following month.

ABSTRAK

Dalam era modern ini, dengan fokus yang semakin meningkat pada kesadaran lingkungan dan keberlanjutan, mengurangi jejak karbon telah menjadi tujuan krusial bagi bisnis di berbagai sektor, termasuk rantai supermarket. Penelitian ini berfokus pada Sami Laris Swalayan, sebuah rantai supermarket yang terkemuka dan dikenal luas, untuk melakukan analisis komprehensif terhadap pola penggunaan listrik dan emisi karbon dioksida (CO_2) yang terkait. Dengan menggali data penggunaan listrik selama periode waktu tertentu, penelitian ini bertujuan untuk mengidentifikasi periode permintaan puncak, mengeksplorasi peluang hemat energi, dan menilai potensi integrasi sumber energi terbarukan. Penelitian ini menekankan pentingnya mengurangi emisi CO_2 dan mendorong praktik energi berkelanjutan di dalam rantai supermarket, sehingga ikut berkontribusi pada upaya konservasi lingkungan dan menumbuhkan budaya pengelolaan energi yang bertanggung jawab. Penelitian ini dimulai dengan analisis mendalam terhadap penggunaan listrik Sami Laris Swalayan, dengan tujuan untuk memahami tren dan pola variasi dalam konsumsi energi. Data di atas menunjukkan konsumsi listrik perusahaan yang fluktuatif, dengan angka tertinggi tercatat pada bulan April, mencapai 26.965 kWh. Tingginya penggunaan listrik disebabkan oleh total jam operasional dari pukul 09:00 hingga 21:00 dan penambahan fasilitas lain seperti ruang aksesoris, outlet roti, dan outlet kopi. Sebaliknya, konsumsi terendah diamati pada bulan Februari, sebesar 23.796 kWh, yang dipengaruhi oleh penerapan Pembatasan Sosial Berskala Besar (PSBB) pada akhir Januari 2021. Selama periode ini, jam operasional dipersingkat dari pukul 09:00 hingga 19:00, mengakibatkan penurunan konsumsi listrik pada bulan berikutnya.

Keywords: *electricity utilization, carbon footprint, CO_2 emissions, sustainable energy practices, supermarket chains*

INTRODUCTION

Recently, there has been a growing awareness and emphasis on environmental sustainability, prompting a heightened concern about the impact of electricity consumption on greenhouse gas emissions (Snigdha et al 2023, Uddin et al 2022, Noviarini et al., 2022). Supermarket chains, as major electricity consumers, have a significant role to play in addressing this issue (Valaskova et al., 2021). Among them, Sami Laris Swalayan stands out as a prominent player, necessitating a thorough investigation into its energy consumption patterns and subsequent carbon dioxide (CO_2) emissions. The commercial sector, of which supermarket chains are a pivotal component, accounts for a considerable share of electricity usage (Yuliani et al., 2023). Utilizing energy-intensive equipment, such as refrigeration systems, lighting, and air conditioning, significantly releases CO_2 emissions within these establishments (Suamir & Tassou, 2013). Understanding the electricity consumption patterns and emission factors specific to supermarket operations is imperative to address this issue effectively. Armed with this knowledge, the research aims to devise efficient and targeted strategies to mitigate the environmental footprint of supermarket chains. By examining the electricity utilization and CO_2 emissions within Sami Laris Swalayan, this research sheds light on its impact on the environment and its potential contributions to climate change. The findings are expected to provide valuable insights into the energy consumption patterns unique to supermarkets and the associated CO_2 emissions. With this information, stakeholders can adopt sustainable energy practices to minimize the ecological consequences and foster a more environmentally responsible approach to energy management within Sami Laris Swalayan.

The significance of this research lies in its potential to prompt meaningful change in energy consumption practices within the supermarket chain industry. Analyzing the electricity utilization data and the subsequent CO_2 emissions of Sami Laris Swalayan, researchers can pinpoint areas for improvement and propose practical solutions to reduce its environmental impact. Furthermore, the research outcomes can serve as a benchmark for other supermarket chains, encouraging adopting sustainable energy practices across the sector. In this research, an in-depth analysis of the electricity utilization patterns in Sami Laris Swalayan will be conducted, aiming to gain a comprehensive understanding of the supermarket chain's energy consumption behaviors.

Moreover, the research will explore energy-efficient opportunities within Sami Laris Swalayan. Scrutinizing electricity utilization data, the study will pinpoint areas where energy-saving measures can be implemented effectively. These could include optimizing lighting systems, HVAC (heating, ventilation, and air conditioning) units, refrigeration systems, and other energy-intensive equipment used within the supermarket chain. Identifying energy-efficient opportunities will not only lead to cost savings for the business but also contribute to reducing the overall CO_2 emissions associated with electricity consumption Furthermore, the research aims to assess the potential for adopting renewable energy sources within Sami Laris Swalayan. The study will offer valuable recommendations for the supermarket chain to transition towards cleaner and sustainable energy practices by evaluating the feasibility of integrating solar panels, wind turbines, or other renewable energy technologies. The incorporation of renewable energy sources would not only reduce the carbon footprint but also enhance the resilience and long-term sustainability of the business. The primary objective of this research is to emphasize the significance of reducing CO_2 emissions within Sami Laris Swalayan. By quantifying the carbon emissions associated with electricity utilization, the study will create awareness of the environmental impact (Lannelongue et al., 2021l; Lacoste et al., 2019) of the supermarket chain's energy consumption. This will prompt stakeholders to recognize the urgency of adopting sustainable energy practices to minimize their carbon footprint.

METHODS

Data Collection

The research methodology will collect data from Sami Laris Swalayan's, Cilacap, Indonesia (Figure 1) energy records and utility bills to obtain accurate electricity utilization data. Emission factor data will be sourced from reliable environmental agencies and energy providers. By applying the emission factor to electricity utilization, the research will calculate the CO_2 emissions. Using electricity utilization data as secondary data for this research holds significant importance for several reasons. Firstly, electricity utilization data is readily available from utility companies and official records, ensuring easy access and saving valuable time and resources compared to collecting primary data through surveys or monitoring. Secondly, this secondary data can cover a considerable period, providing historical trends and seasonal variations in energy consumption and offering valuable insights into long-term changes.

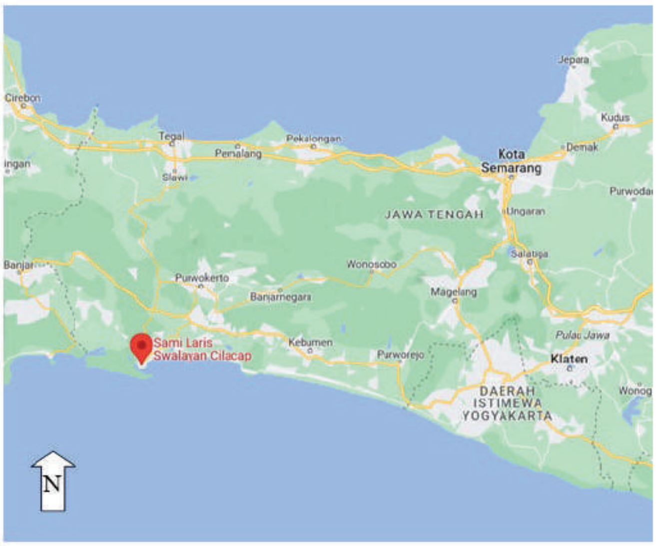

Figure 1. Study site in Sami Laris Swalayan (Google Map 2021)

Moreover, electricity utilization data encompasses various residential, commercial, and industrial sectors, allowing for a comprehensive analysis of electricity consumption patterns across different areas (Noviarini et al., 2022). As the data is derived from metered readings and detailed billing information, its accuracy and precision are ensured, enhancing the reliability of the research findings. Additionally, the large sample size provided by standardized electricity utilization data allows for statistically significant analysis and a more comprehensive understanding of electricity consumption trends.

LPG Applications in Vehicles

Calculating the carbon footprint in the electricity aspect is based on the average monthly electricity consumption accumulated into the annual electricity consumption. The carbon emissions generated in the energy sector are calculated using the equation based on the Greenhouse Gas (GHG) Inventory and Monitoring and Verification report by the Ministry of Environment and Forestry (2017) (Adinugroho et al., 2019; Noviarini et al., 2022), as follows:

$$\text{GHG Emissions/Absorption} = DA \times FE \quad (1)$$

Where:
DA = data on human or development activities that result in GHG emissions or absorption.
FE = GHG, emission or absorption factor, indicating the amount of emissionst/absorption per unit of activity performed.

The emission factor for the Java-Madura-Bali Interconnection System (Jamali) is crucial to this research because it provides a standardized value representing the amount of carbon dioxide (CO_2) emissions produced per unit of electricity generated (per megawatt-hour, MWh) in that specific electricity system (Table 1). This emission factor is critical in calculating the carbon footprint of electricity consumption in the Sami Laris Swalayan supermarket chain. Furthermore, this emission factor provides a benchmark to compare the environmental performance of different electricity systems or energy sources. It enables researchers, policymakers, and businesses to identify areas where emissions can be reduced and prioritize adopting cleaner and more sustainable energy practices.

Table 1. Emission factor.

System	Emission factor	Unit
Sistem Interkoneksi Jawa-Madura-Bali (Jamali)	0.877	Ton CO_2/MWh

Source: (Dewi et al., 2021)

RESULT AND DISCUSSION

Electricity Utilization

Electricity usage can be quantified by measuring its consumption and demand. Various factors can affect electricity consumption, including the amount used, typically measured in kilowatt-hours per month. On the other hand, peak demand is expressed in kilowatts (kW) per month or for other equipment within the previous year's range. The data on electricity aspects are obtained from secondary sources held by the company. The specified period for analysis is from January 2021 to April 2021, as electricity usage in previous years was not consistently monitored, leading to incomplete record-keeping. The power capacity of the electricity used is 82,500 watts. Figure 2 illustrates the company's electricity consumption patterns during the mentioned time frame.

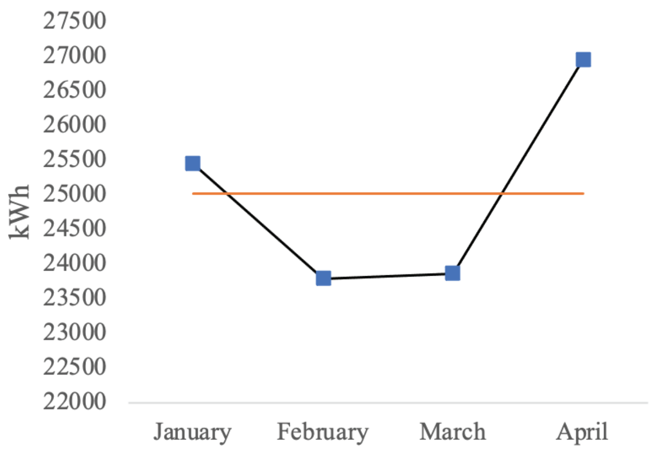

Figure 2. Graph of electricity consumption for January 2021 to April 2021

The data above shows the fluctuating electricity consumption of the company, with the highest figure recorded in April, reaching 26,965 kWh. The high electricity usage is attributed to the total operational hours from 09:00 to 21:00 and the addition of other facilities such as the accessory room, bakery outlet, and coffee outlet. In contrast, the lowest consumption was observed in February, with 23,796 kWh, which was influenced by the implementation of Large-Scale Social Restrictions (PSBB) at the end of January 2021. During this period, the operational hours were shortened from 09:00 to 19:00, leading to a decrease in electricity consumption in the following month.

The data for calculating carbon emissions is based on the highest consumption, which is 26,965 kWh, representing the overall electricity usage. The implementation of PSBB policies directly caused a decrease in demand, including the national electricity needs. Electric energy consumption experienced a decline due to PSBB's restrictions on business and industrial activities (BPTT, 2020). China also experienced a decrease in consumption, along with advancements in renewable technologies, as COVID-19 reduced energy and CO_2 emissions between 1.5% and 2% per year (Razmjoo et al 2021). One of the most noticeable effects of COVID-19 restrictions was the substantial reduction in traffic and industrial activities. With fewer vehicles on the roads and factories operating at reduced capacity or shutting down temporarily (Suhardono et al 2023), emissions from vehicles and industries significantly decreased. During lockdowns, the demand for energy also changed. Commercial establishments, including supermarkets like Semilaris Swalayan, operated with altered hours and capacity restrictions. Many people worked from home, leading to reduced energy consumption in office buildings and commercial spaces (Tavakoli et al., 2023; Sari et al., 2023b; Septiariva & Suryawan 2023).

Monitoring and understanding electricity consumption patterns and trends is paramount for companies and regions. It enables operational efficiency by optimizing schedules, workforce shifts, and resource allocation based on peak demand periods. Additionally, closely tracking electricity usage allows for better cost management and financial planning, as companies can identify periods of high usage and implement measures to reduce consumption, leading to cost savings. Furthermore, electricity consumption is closely linked to environmental impact and carbon emissions. Analyzing consumption data helps companies adopt more sustainable practices, reducing their carbon footprint. It also ensures compliance with regulations and policies to promote energy efficiency and environmental conservation. For utilities and energy providers, understanding consumption patterns is crucial for infrastructure planning, grid stability, and anticipating future demand. Moreover, electricity consumption is an economic indicator, reflecting changes in industrial activity and overall economic performance. During crises, such as the COVID-19 pandemic, tracking consumption changes aids in developing strategies for managing energy demand and ensuring resilience. In conclusion, monitoring and analyzing electricity consumption data have far-reaching implications for enhancing energy management efficiency, sustainability, and resilience.

Carbon Footprint

Table 2 presents essential information regarding electricity utilization, emission factor, and CO_2 emissions, offering insights into the environmental impact of electricity consumption. The recorded electricity utilization of 26,965 kWh/m reflects the monthly electricity consumed. The emission factor 0.877 indicates that approximately 0.877 kilograms of CO_2 are emitted for every kilowatt-hour of electricity consumed. Consequently, the calculated CO_2 emissions amount to 23,648.305 kg CO_2/m. This data illustrates the direct correlation between electricity consumption and CO_2 emissions, emphasizing the significance of adopting energy-efficient practices and cleaner energy sources to mitigate environmental consequences. A high emission factor suggests a substantial reliance on fossil fuels for electricity generation, underscoring the need for transitioning to renewable energy sources. By prioritizing energy efficiency, promoting renewable energy adoption, and implementing supportive policies and regulations, (Suryawan & Lee, 2023; Suryawan et al., 2023; Mukeshimana et al., 2021; Ngan et al., 2019) we can collectively work towards reducing the environmental impact of electricity consumption and fostering a more sustainable future.

Table 2. Emission from electricity used in Sami Laris.

Electricity utilization (kWh/m)	Emission Factor (kg CO_2/kWh)	Emission (kg CO_2/m)
26965	0,877	23648.305

Sami Laris Swalayan should prioritize energy efficiency initiatives to optimize electricity usage. This may include upgrading lighting systems to energy-efficient LED bulbs, adopting smart energy management systems for HVAC and refrigeration units, and ensuring regular equipment maintenance to improve their energy performance. Sami Laris Swalayan also should be identifying peak demand periods, the supermarket chain can develop load management strategies to distribute electricity usage more evenly throughout the day. This may involve adjusting operational hours, encouraging customers to shop during off-peak hours, or optimizing equipment usage during peak periods. Considering the feasibility of integrating renewable energy sources (Suryawan et al., 2023; Sari et al., 2023a; Suryawan et al., 2022), such as solar panels or wind turbines (Yendaluru et al., 2020; Chauhan & Saini, 2016), can significantly reduce Sami Laris Swalayan's reliance on fossil fuels and lower its overall carbon emissions. The supermarket chain should explore partnerships with renewable energy providers or invest in on-site renewable energy generation.

Sami Laris Swalayan can adopt sustainable procurement policies to source energy-efficient equipment and products with lower carbon footprints. Partnering with suppliers committed to eco-friendly practices can further contribute to reducing the environmental impact (Suryawan & Lee, 2023; Ngan et al., 2019; Sharma et al., 2023) of the supermarket chain's operations. Procuring energy-efficient equipment and products (Hua & Wang 2019; Wang et al., 2019; Sharma, 2022), Sami Laris Swalayan can directly reduce its energy consumption and, consequently, its carbon emissions. This proactive approach aligns with global efforts to combat climate change and demonstrates the supermarket's commitment to environmental responsibility.

CONCLUSION

In conclusion, this comprehensive study on electricity utilization and CO_2 emissions in Sami Laris Swalayan has provided valuable insights into the supermarket chain's energy consumption patterns and environmental impact. The study also highlighted energy-efficient opportunities within Sami Laris Swalayan, showcasing areas where implementing energy-saving measures could lead to cost savings and reduced CO_2 emissions. This emphasizes the significance of adopting sustainable energy practices to minimize the supermarket chain's carbon footprint and contribute to environmental conservation.

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Evaluation of the Cipalabuan River's water quality and measures for reducing water pollution in the Sukabumi Regency

ANNISA RACHMAWATI*, DOLLY PRIATNA, ROSADI

Graduate School of Environmental Management, Pakuan University, Jl. Pakuan Kotak Pos 452, Bogor 16129, Indonesia

Corresponding author: *annisrachmawati21@gmail.com*

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ABSTRACT

The Cipalabuan River serves as an ecosystem that provides habitat for many species and as a source of water for industry, agriculture, and drinking. However, growing industrial and residential activity poses a threat to the amount and quality of river water. The river has recently contributed to both liquid and solid waste, which has lowered the quality of the river's water. The Cipalabuan River flows through the city center from upstream to downstream, collecting pollutants from the discharge of local activities along the river's course, including liquid and solid waste. By monitoring and computing the water's quality at a certain location and time, this study seeks to ascertain the current state of water quality. In order to create a sequential explanatory design, a mixed method approach was used, mixing quantitative and qualitative methodologies in parallel. Water quality in the Cipalabuan River is influenced by a number of factors, including the actions of those who use the river as a disposal site, public ignorance of the need to control pollution, competing interests in the management of water resources, and a lack of cooperation between authorized agencies in the management of natural resources and the control of water pollution.

ABSTRAK

Sungai Cipalabuan berfungsi sebagai ekosistem yang menyediakan habitat bagi banyak spesies dan sebagai sumber air untuk industri, pertanian, dan minum. Namun, meningkatnya aktivitas industri dan pemukiman menimbulkan ancaman terhadap kuantitas dan kualitas air sungai. Akhir-akhir ini sungai tersebut menghasilkan limbah cair dan padat sehingga menurunkan kualitas air sungai. Sungai Cipalabuan yang mengalir melalui pusat kota dari hulu ke hilir mengumpulkan zat-zat pencemar yang berasal dari buangan aktivitas masyarakat di sepanjang aliran sungai, termasuk limbah cair dan padat. Dengan memantau dan menghitung kualitas air pada lokasi dan waktu tertentu, penelitian ini berupaya mengetahui kondisi kualitas air saat ini. Untuk membuat desain penjelasan sekuensial, pendekatan metode campuran digunakan, yang memadukan metodologi kuantitatif dan kualitatif secara paralel. Kualitas air di Sungai Cipalabuan dipengaruhi oleh beberapa faktor, antara lain tindakan pihak yang memanfaatkan sungai sebagai tempat pembuangan sampah, ketidaktahuan masyarakat akan perlunya pengendalian pencemaran, persaingan kepentingan dalam pengelolaan sumber daya air, dan kurangnya sumber daya manusia. kerjasama antar instansi yang berwenang dalam pengelolaan sumber daya alam dan pengendalian pencemaran air.

Keywords: *AHP, Pollution Index, river quality, sequential explanatory, water pollution control, water quality*

INTRODUCTION

The growing population has an impact on the industrial sector and the rise in household activities (Wardhana, 2004; Zhou, 2009). Both significantly increased the demand for clean water. Thus, controlling water sources in order to meet the demand for clean water urgently needs to be done. The management of this water source should strike a balance between the environment's supply of clean water and human need for it. The river is a clean water source that humans use most frequently (Mulyanto, 2007).

In order to assess the degree of pollution in river water, the water quality must be assessed by measuring and computing the water's quality at a certain location and time using the prescribed methodology (Herlambang, 2006; Agustiningsih, 2012) . Measurement results can be used as a guide to determine which metrics go above the required level of quality.

Indonesia’s Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management governs the protection and management of water quality. It defines water pollution as the presence of influent discharges or other components into water bodies originating from human activities that cause the Water Quality Standard to exceed the threshold (Rahayu et al., 2013).

Sukabumi Regency, the Cipalabuan River is a surface water source that traverses the city center. The Cipalabuan River flows through the city center as it moves from upstream to downstream, bringing with it solid and liquid waste that is discharged from nearby community activities and serves as a source of pollution (Said, 2006).

The Cipalabuan River needs to be treated properly because of its concerning quantity and quality conditions. Various interested parties must work together to regulate river water quality to minimize the effects on the community and the environment (Effendi, 2003; Suripin, 2004; Campo et al., 2010).

One of the measures to prevent water pollution is the implementation of river water quality management, which ensures that the water's natural characteristics are maintained and that its designated quality is met. In an effort to avoid and manage water pollution and to restore water quality, it is also vital to control water pollution to make sure that the quality of the water conforms with the requirements (Pohan et al., 2016).

Thus, according to Yetty et al. (2011) by creating an effective water pollution control strategy, it is imperative to manage water quality and control water pollution to guarantee the availability of clean water sources and the quality of water that will be used for human activities both now and in the future.

METHODS

Sequential Explanatory

The research employed a mixed method approach or sequential explanatory design which is research by combining quantitative methods and qualitative methods in parallel (Sugiyono, 2012). Quantitative methods are used to analyze the results of river water quality measurements and weighting criteria for river water pollution control strategies (Hadi, 2007).

Location

The study was conducted in the Cipalabuan River basin, which encompasses the upstream, middle, and downstream monitoring points of the river, in the Palabuhanratu District of Sukabumi Regency. The location of the upstream monitoring point is at the Cipalabuan I Bridge at coordinate point 06⁰59'14.87" South and 106⁰32'41.09" East. The location of the middle monitoring point is at the Cipalabuan II Bridge, Pangsor Village, at the coordinate point 06⁰58'32.26" South and 106⁰33'19.61" East. The location of the downstream monitoring point is at the Ojolali Bridge at the coordinate point 06⁰59'20.8" South and 106⁰34'14.8 East.

The water quality requirements in Appendix VI of Government Regulation 22 of 2021 concerning the Implementation of Environmental Protection and Management are compared with the results of river water quality tests to analyze and interpret the measures. The Pollution Index calculation method, which makes reference to the Environmental Quality Index Regulation of the Minister of Environment and Forestry Number 27 of 2021, is used to determine the current state of water quality (Priyambada et al., 2008; Yuliastuti, 2011).

The formulation of a water pollution control strategy is prepared based on the results of field observations in the study areas, discussions and in-depth interviews with experts who have the capacity and competence in the field of water pollution control (Rahmawati, 2011). The experts involved in this study consisted of 1). Head of West Java Province Water Resources Management Center, 2). Head of Pollution Control and Environmental Damage Division of DLH Sukabumi Regency, 3). Environmental Impact Controller Junior expert/Sub-coort for Prevention of Pollution and Environmental Damage, 4). Lecturer/researcher from LPPM Muhammadiyah University of Sukabumi.

The Analytical Hierarchy Process (AHP) method is then used to formulate strategic concerns in order to determine the criteria and strategies for controlling water pollution (Saaty, 2008).

RESULT AND DISCUSSION

Summary of laboratory test results

Table 1. Summary of laboratory test results for the quality of Cipalabuan River water in the dry season.

No.	Parameter	Unit	Quality Standard of River Water (PP 22/2021)				Test Results - 29 September 2022		
			Grade 1	Grade 2	Grade 3	Grade 4	Up Stream	Middle Stream	Down Stream
1	TSS	mg/L	40	50	**100**	400	**54**	**56**	**58**
2	pH		6-9	6-9	6-9	6-9	7.84	7.52	8.12
3	COD	mg/L	10	**25**	40	80	14	15	16
4	BOD	mg/L	2	3	**6**	12	**6**	**6**	**6**
5	DO	mg/L	6	4	3	**1**	**3.11**	**2.97**	**2.67**
6	NO3	mg/L	10	**10**	20	20	2.8	2.9	2.9
7	Total Phosphate	mg/L	0.2	0.2	0.2	**0.5**	**0.44**	**0.47**	**0.48**
8	Fecal Coliform	MPN/100L	100	**1,000**	2,000	2,000	550	550	600

Source: Analysis results, 2023

Table 2. Laboratory test results for the quality of Cipalabuan River water in the rainy season.

No.	Parameter	Unit	Quality Standard of River Water (PP 22/2021)				Test Results - 29 September 2022		
			Grade 1	Grade 2	Grade 3	Grade 4	Up Stream	Middle Stream	Down Stream
1	TSS	mg/L	40	50	**100**	400	**51**	**53**	**56**
2	pH		6-9	6-9	6-9	6-9	7.74	7.15	7.26
3	COD	mg/L	10	**25**	40	80	**14**	**14**	**15**
4	BOD	mg/L	2	3	**6**	12	**6**	**7**	**6**
5	DO	mg/L	6	4	3	**1**	**2.87**	**02.45**	**2.49**
6	NO3	mg/L	10	**10**	20	20	**2.9**	**3.4**	**3.7**
7	Total Phosphate	mg/L	0.2	0.2	0.2	**0.5**	**0.45**	**0.5**	**0.54**
8	Fecal Coliform	MPN/100L	100	**1,000**	2,000	2,000	**550**	**550**	**600**

Source: Analysis results, 2023

Four of the eight parameters tested —TSS, BOD, DO, and total phosphate—did not meet the necessary quality standards (Harson, 2010) in the results of the Cipalabuan River water quality test, which was conducted during both the dry and rainy seasons (Tables 1 and 2).

The results of tests conducted in the dry season and the rainy season are not much different. However, the pollutant parameter concentration values tend to be higher in the dry season test results compared to the rainy season test results. This can happen because during the rainy season there is dilution of the rainwater flow so that it affects turbidity. Based on monitoring points, the value of pollutant concentrations is getting higher downstream, as illustrated in the following graph (Figure 1 and Figure 2).

Calculation of the water quality Pollution Index in the Cipalabuan River is obtained by calculating based on the equation in the calculation example. The results obtained for the 3 (three) location points tested during the dry season are presented in the following figures below (Figure 3 and Figure 4).

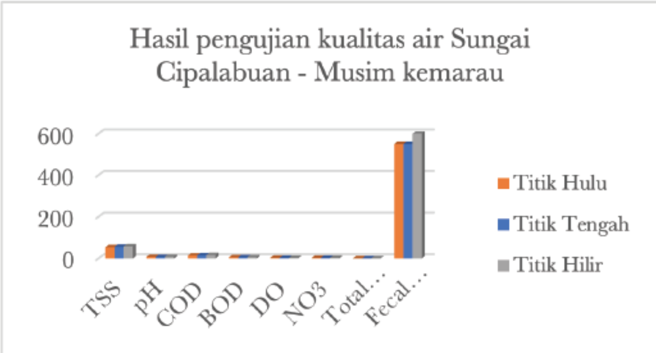

Figure 1. Results of testing the quality of Cipalabuan River water in the dry season.

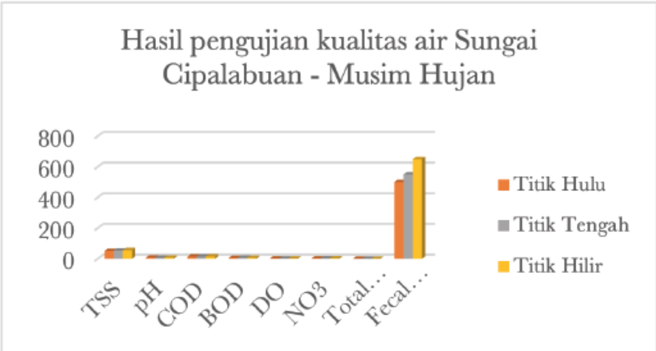

Figure 2. Results of testing the quality of Cipalabuan River water in the rainy season.

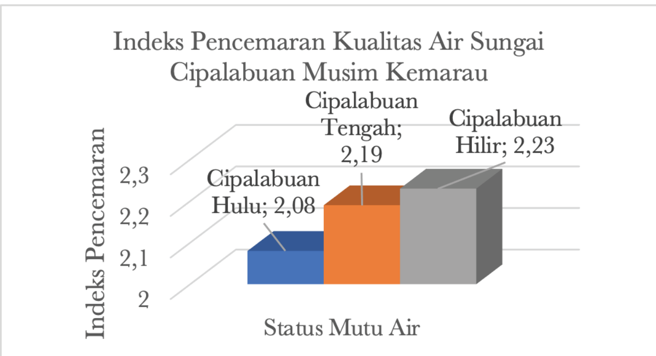

Figure 3. Results of testing the quality of Cipalabuan River water in the rainy season.

Based on the results of the calculation of the pollution index on the Cipalabuan River for the upstream, midpoint and downstream points with a total of three monitoring points, and carried out as much two times the measurement period, which represents the dry season and the rainy season, it can be seen that the water quality status at each monitoring point is in the status of slightly polluted.

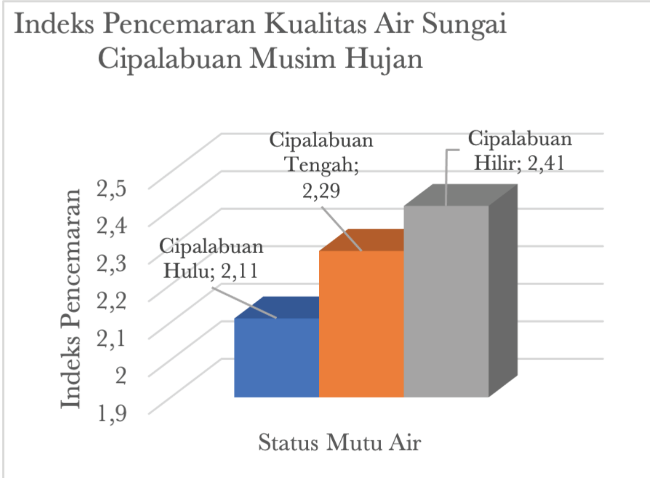

Figure 4. Pollution index of Cipalabuan River water quality in the rainy season.

Cipalabuan River water quality conditionsat each monitoring point is in a lightly polluted status. And the value of the Cipalabuan Saungai Water quality index is 50Based on the Water Quality Index category, it is known that the range 50 ≤ x ≤ 70 is in the medium category. In addition, the classification of water use in the Cipalabuan River is classified as class 3 forWater that can used for fresh water fish, livestock, irrigation and/or other similar purposes.

Table 3. Criteria and strategy for controlling Cipalabuan River water pollution.

Criteria		Strategy
Economy	A1	Determination of water class
	A2	Providing data and information about river water quality
	A3	Integration of watershed management into spatial planning
Social	A4	The synergy between authorized agencies
	A5	Public education regarding controlling water pollution
	A6	Increased public participation
Environment	A7	Conservation of upstream river areas
	A8	Development of community santiation infrastructure
	A9	Water quality monitoring and supervision

Source: Analysis results, 2023

Determination of alternatives and criteria in the Cipalabuan River Water Pollution Control Strategy is carried out based on the formulation of data from field observations, results of discussions and in-depth interviews, as well as grouping criteria, which are then synthesized and formulated into several strategic issues as follows (Table 3).

The hierarchical weighting framework in the Cipalabuan River water pollution control strategy is as follows (Figure 5).

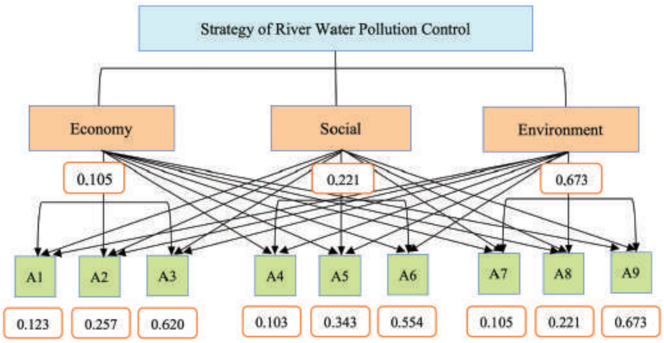

Figure 5. Hierarchical weight of the Cipalabuan River water pollution control strategy.

From the results of the assessment using the AHP method for the three criteria in efforts to control water pollution (Figure 6), it is known that environmental criteria have the highest ranking with a priority value weight of 0.673 and a consistency ratio of 0.06 which is less than the maximum limit of ten percent (10%) or 0.1, so that the results of the analysis of priority grouping criteria show that hierarchical consistency is acceptable.

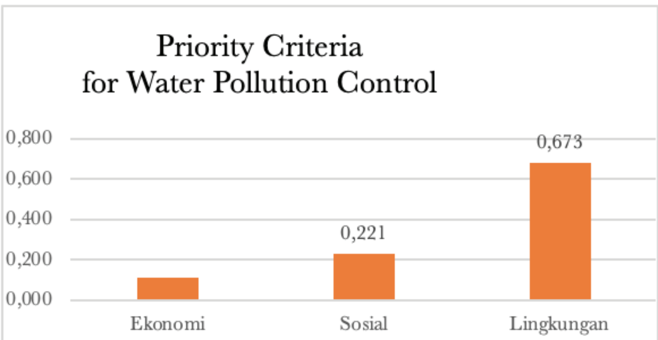

Figure 6. Priority criteria for water pollution control strategies.

Based on the results of the priority assessment analysis for each criterion (Table 7), it can be seen that from the economic criteria, the one with the highest priority value is A3 with a weight value of 0.620, namely the strategy for integrating watershed management into spatial planning (Asdak, 2010; Tchobanoglous, 2013; Pambudi, 2022). For social criteria, the value that gets the highest priority is A6 with a weight value of 0.554, with a strategy to increase community participation. And for environmental criteria, A9 with a weight value of 0.673 is a priority criterion with a strategy for monitoring and supervising water quality (Purnomo, 2010).

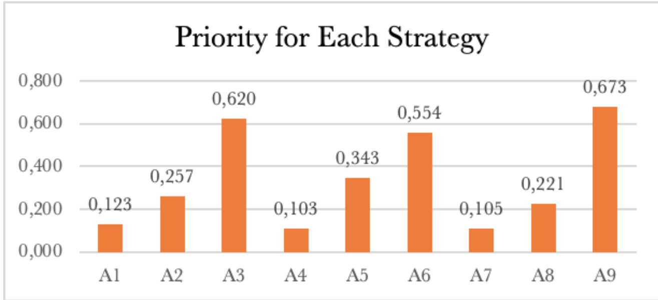

Figure 7. Priority of each strategy.

From the results of the assessment analysis using the AHP method, it shows that 3 (three) main priorities are alternatives in the water pollution control strategy as an effort to manage the water quality of the Cipalabuan River, including:

1. Integration of watershed management into spatial planning;
2. Increasing community participation;
3. Water quality monitoring and control.

CONCLUSION

At every monitoring location, the water quality of the Cipalabuan River is considered to be slightly contaminated. Cipalabuan Saungai Water has a quality index value of 50. It is known that the range $50 \leq x \leq 70$ falls into the medium group based on the Water Quality Index category (Purnomo, 2010). Additionally, water that can be utilized for irrigation, cattle, freshwater fish, and/or other comparable uses is categorized as class 3 water usage in the Cipalabuan River.

The following factors affect the water quality of the Cipalabuan River: 1. the actions of those who view the river as a disposal area; 2. a lack of public education regarding water pollution control; 3. divergent interests in the management of water resources; 4. a lack of cooperation between authorized agencies in the management of natural resources and the control of water pollution; and 5. the absence of a concerted effort by multiple parties to address pollution and environmental damage.

The main priorities that become alternatives in the Water Pollution Control Strategy as an effort to manage the water quality of the Cipalabuan River include: 1). Integration of watershed management into spatial planning; 2). Increased community participation; 3). Water quality monitoring and control.

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Development of cultural spatial concepts for the preservation of local culture and the environment in the ecotourism area of Tamansari Village

YUSI FEBRIANI*, YUDI FIRMANSYAH

Faculty of Engineering, Pakuan University, Jl. Pakuan, Tegallega, 16143, Indonesia

Corresponding author: *yusifebriani@unpak.ac.id*

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ABSTRACT

Areas designated as strategic tourism areas are those where tourism serves as the primary industry or has the potential to do so, as well as has a significant impact on one or more factors, such as the development of the economy, society, and culture, as well as the preservation of natural resources, the ability of the environment to support human habitation, and defense and security, through putting into practice the idea of ecotourism development, which is responsible tourism to natural areas that promote environmental preservation and enhances the well-being of locals. With a focus on local wisdom and a microcosm of Sundanese culture connected to Tamansari Village, the concept plan for developing the village's tourism areas combines ecotourism and local wisdom.

ABSTRAK

Kawasan yang ditetapkan sebagai kawasan pariwisata strategis adalah kawasan yang pariwisatanya berfungsi sebagai industri utama atau mempunyai potensi untuk itu, serta mempunyai dampak penting terhadap satu atau lebih faktor, seperti perkembangan ekonomi, masyarakat, dan budaya, serta serta pelestarian sumber daya alam, kemampuan lingkungan hidup untuk mendukung tempat tinggal manusia, serta pertahanan dan keamanan, melalui penerapan gagasan pengembangan ekowisata, yaitu pariwisata yang bertanggung jawab terhadap kawasan alam yang memajukan pelestarian lingkungan dan meningkatkan kesejahteraan. penduduk setempat. Dengan fokus pada kearifan lokal dan mikrokosmos budaya Sunda yang terhubung dengan Desa Tamansari, konsep rencana pengembangan kawasan wisata desa ini memadukan ekowisata dan kearifan lokal.

Keywords: *Ecotourism, environment preservation, local wisdom, West Java*

INTRODUCTION

Ecotourism means a model of nature tourism in natural areas with the aim of enjoying its natural beauty and supporting conservation efforts and increasing the economic income of the local community. (Hutanpedia, 2023). Some ecotourism activities can be carried out by visiting a village that has natural and cultural charms that are still preserved. According to Simanjuntak et al. (2021) and Panderi et al. (2022), a region's ecotourism industry can be built on its biophysical features as well as its people's everyday lives. Examples of this include nature tourism (Sofiyudin et al., 2021), research nature tourism, and culturally-based nature tourism (local wisdom). Tamansari Village, Tamansari Sub-district, is a village that is not only directly adjacent to the TNGHS area, but most of its area is within the TNGHS area (Indonesia Geospatial Information Agency (BIG) Earth Shape Map 2016). Of the total area of approximately 1,580.79 ha, almost 63.86% of Tamansari Village is within the TNGHS Forest Area. Calobak Village is located in RW 08 Hamlet 3 of Tamansari Village which is directly adjacent to the Gunung Halimun Salak National Park Area. Some residents in RW 08 earn a living as pohpohan farmers and honje farmers who are planted in the TNGHS utilisation zone. The TNGHS area has very high biodiversity, this is very potential to become a tourism resource that is worth developing and becomes its own attraction into a natural tourism area. The potential for abundant natural tourism resources in the Dusun 3 area is a major consideration in determining the location of the Tamansari Village flagship tourism area development plan. In the area, the Tamansari Village government owns Village treasury land which is located right in the Calobak Village Area Rt 04 Rw 08 with an area of 2.4Ha Coordinates 6°39'56.68‘ South latitude and 106°44'32.95’ East longitude. The area is bordered to the east by residential housing, to the north and west by cultivated land and to the south by Mount Salak.

The geographical position is right at the foot of Mount Salak and is only ±14km from Bogor city centre. Topographical conditions vary with some having slopes from gentle to steep. Traversed by lava flow paths that form rivers with water originating from Mount Salak springs. The uniqueness of the landscape and topography is a characteristic that cannot be found in other areas. The back to nature tourism trend has changed the focus of world tourism towards nature tourism. This provides a great opportunity for areas that have high natural resources. However, the development of the area is expected to maintain environmental sustainability and local wisdom so that it can become its own characteristics in the development of the regional concept (Rusmana, 2018).

CULTURAL SPATIAL CONCEPT

The development concept that highlights the value of Sundanese culture is the main alternative in the development of the spatial concept where in Sundanese society it is known that the tritangtu or the concept of 3 worlds is often found in traditional Sundanese villages (Rusmana, 2018).

Figure 1. Philosophical concept in Sundanese traditional buildings (Rusmana, 2018).

From this philosophical concept (Figure 1), it is interpreted into; 1) The upper world is the leuweung (forest) cover, 2) The middle world is the life of the community, and 3) The lower world is the world of the end of life.

Concept of Space

The application of the cosmos of the Sundanese universe (Figure 2), becomes the philosophy of the spatial concept in the development of the area. This spatial concept consists of 3 zones, namely:

a) The upper world which is a *leuweung tutupan* which has the concept of agroforestry must be maintained and preserved for balance in the relationship between humans and nature, both of which are God's creations, so that they must protect each other as a form of gratitude for their gifts. *Leuweung tutupan* or *leuweung geledegan* literally means old forest, which is a forest that is still dense with various types of large and small native plants, complete with all the animals that inhabit it. This type of forest should not be touched by humans at all. This type of forest according to custom should not be destroyed because it is considered a protector of life or a source of life, essentially a source of water (*hulu cai'*).

b) The middle world is the zone of human life. In the social zone between humans and humans. In the zone seen from the concept of yard in every Sundanese traditional settlement.

c) The underworld is a prohibition zone whose designation is a zone of relationship between humans and God, where humans will eventually return to the Creator.

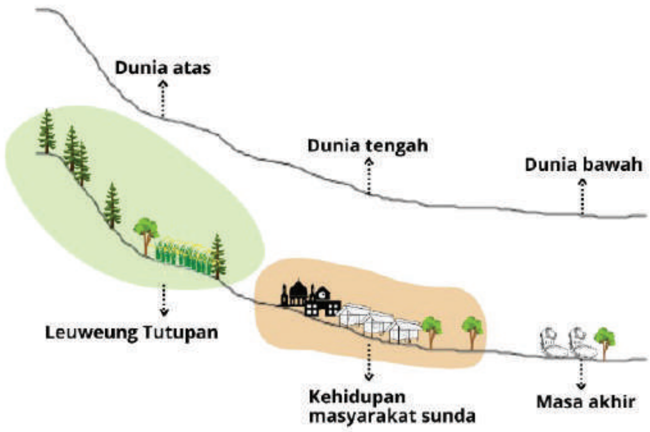

Figure 2. Landscaping concept based on zoning.

Yard Concept

The yard pattern is the basis for the development of the Sundanese yard concept. This concept provides a philosophy of life for Sundanese people who utilise the resources in the yard for their daily needs (Arifin, 2013). Figure 3 shows that the Sundanese community yard concept is one example of a sustainable green space on a small scale.

The space in the concept consists of:

a. *Buruan* is the front yard which is a zone of processing and storage of foodstuffs. In addition, there is also a children's playroom and the types of plants used are ornamental and fruit plants that function as a welcome area.

b. *Pipir* is a side yard that contains service spaces in the daily activities of the community, such as bathing, washing, wells. In this space there are also fish ponds, beds for production plants and medicinal plants. As well as firewood storage as one of the traditional lives of cooking with firewood.

c. *Kebon* is a space whose overall function is a production zone. In this space there are vegetable production plants, industrial plants and livestock. In this zone the results are for daily needs and as a result of production that is sold to increase family income.

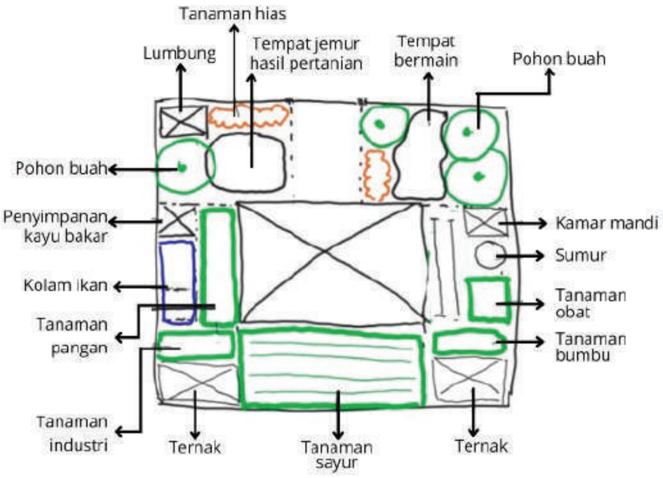

Figure 3. Illustration of the yard pattern.

Yard Concept

The concept of tourism in Taman Sari village is the concept of Sundanese culture by displaying the life of Sundanese people both in cosmological layout and spatial patterns of daily life (Figure 4 and 5). Yasmine & Subekti (2021) suggested that the planned tourist space displays several Sundanese cultural attractions consisting of:

1. Museum of Sundanese cultural life that displays the vernacular side of Sundanese society. Consists of traditional houses and their yards.
2. Sundanese traditional house which is the management zone of the area. This zone provides the appeal of traditional Sundanese architecture.
3. Amphitheatre becomes the centre of the tourist space. This zone will provide the attraction of Sundanese art, in the form of art performances. Dance, traditional music, puppet shows.
4. Another attraction is the overnight tour package consisting of a camping ground area. The tour packages offered are independent camping, glamping, and home stays in traditional houses.
5. There is a water source on the site, a resource that can be developed as one of the tourism potentials. Attractions provided in the form of a bathing area.
6. In addition, nature tourism is also offered in the form of trekking to the leuweung tutupan area. This nature tourism provides education on the ecosystem in the forest.

The planning concept is adjusted to the existing conditions of the site (Nugrahatama, et al., 2024), where the welcome area which is the entrance to the area is in the north and the site is increasingly complex towards the inside by being limited by the *leuweung* (forest) cover area to the north as a boundary between the tourist area and the National Park area.

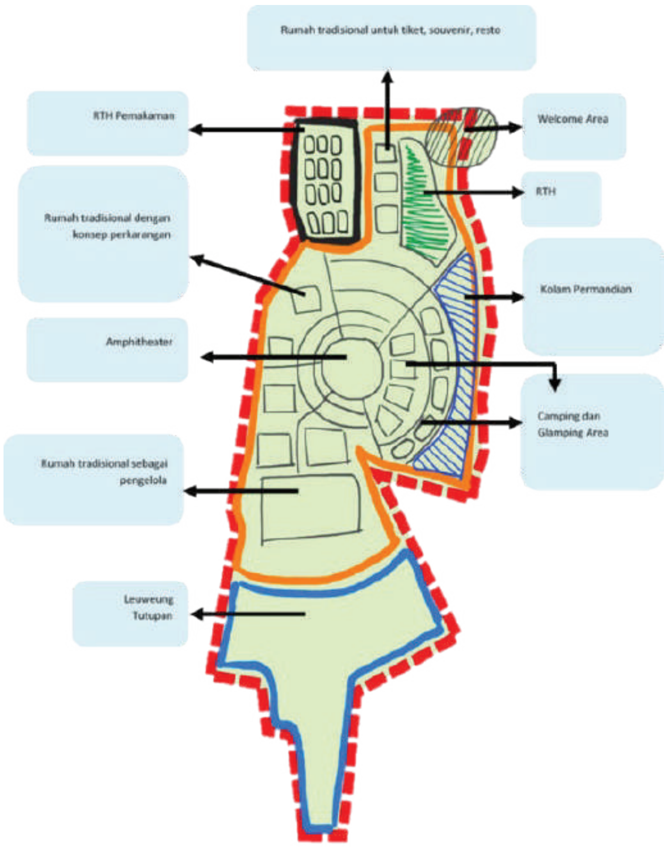

Figure 4. Ecotourism concept plan.

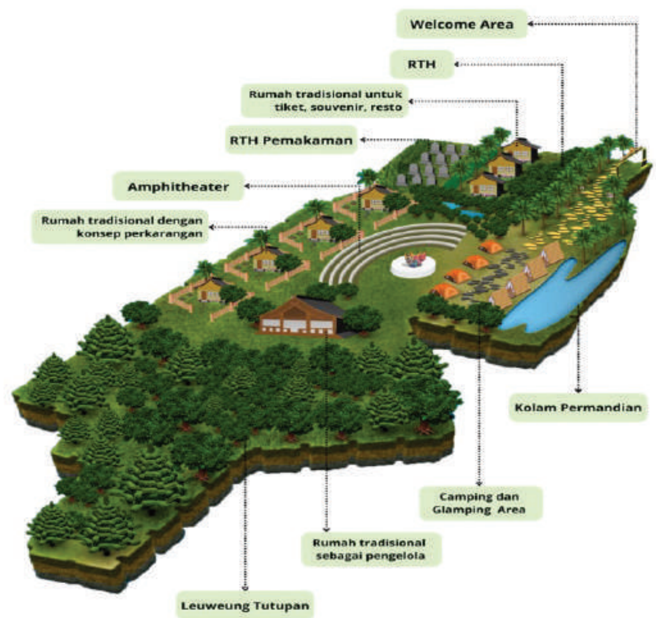

Figure 5. Ecotourism Concept Plan in Taman Sari Village.

Space Function:

a) The upper zone functions as a conservation area, in accordance with the concept of leuweung tutupan which means that the conservation forest area sacred to the Sundanese tribe is basically a protected forest area that functions as a soil and water protection area, plasmanutfah and wildlife. In this area visitor activities are limited to nature tourism activities such as trekking, bird watching, and some educational activities.

b) The middle zone is representative of Sundanese settlements with the imah gede as the centre of the settlement and surrounded by several houses with Sundanese architecture. Like a traditional Sundanese village, it is equipped with several cultural elements such as petirtaan, balai riung, places of worship and a large open space where traditional ceremonies are held.

c) The lower zone is the entrance to the area. In this zone there are tourist facilities that give a welcoming impression, such as restaurants and souvenir stalls. There are also other natural tourism facilities such as camping ground and glamping area. In addition to tourist facilities, there is also an end-time zone in the form of a cemetery for local residents and illustrates the underworld in Sundanese cosmology.

CONCLUSION

For a region to be developed to be both aesthetically pleasing and fundamentally sound for the three forming factors nature, people, and the Creator it must have a strong idea philosophy. We can examine the theory behind the concept in the local culture, as Sundanese cosmology is derived from the everyday lives of the people of Tamansari Village. The upper, middle, and lower zones are the three interconnected spaces that make up the concept of space. Preserving culture and using nature as a container for the area's development is the goal of the cultural idea approach.

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Carbon Dioxide (CO_2) sequestration by trees and green open space (GOS) at the campus of Pakuan University

INDARTI KOMALA DEWI*, YUSI FEBRIANI, ARIF WICAKSONO

Urban & Regional Planning Study Programme, Post Graduate School, Pakuan University, Jl. Pakuan, Bogor 16129, Indonesia

Corresponding author: *indarti@unpak.ac.id*

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ABSTRACT

Pakuan University (Unpak) as one of the largest private campuses in Bogor City, is committed to reducing greenhouse gases (GHG) emissions, especially CO_2, through green open spaces (GOS) and trees on campus. Currently, the GOS and trees on the Unpak campus have not been arranged by CO_2 sequestration as a consideration, even though the source of CO_2 on the Unpak campus apart from the number of students which is more than 15,000 people is also filled with motorized vehicles. Therefore, to participate in reducing GHG emissions, especially CO_2 in Bogor City, and create a comfortable campus, a campus GOS management strategy is needed which is based on CO_2 sequestration. This research aims to analyze the ability of existing trees and GOS to sequester CO_2. CO_2 sequestration calculations are carried out based on the area of the GOS and the sequestration capacity of the trees in the GOS. The research results show that the 6 zones on Unpak's main campus have different CO_2 sequestration capacities depending on the area of space planted with grass and ornamental bushes and the number of trees and shrubs planted. Overall, the CO_2 sequestration capacity of trees and GOS on Unpak's main campus is 282,784.89 kg per year.

ABSTRAK

Universitas Pakuan (Unpak) sebagai salah satu kampus swasta terbesar di Kota Bogor berkomitmen menurunkan emisi gas-gas rumah kaca (GRK), khususnya CO_2 melalui ruang terbuka hijau (RTH) dan pepohonan di dalam kampus. Saat ini RTH dan pepohonan di kampus Unpak belum ditata dengan mempertimbangkan sekuestrasi CO_2, padahal sumber CO_2 di kampus Unpak selain dari jumlah mahasiswa yang lebih dari 15.000 orang juga dipenuhi oleh kendaraan bermotor. Oleh karena itu, untuk ikut serta dalam penurunan emisi GRK khususnya CO_2 di Kota Bogor dan mewujudkan kampus yang nyaman diperlukan strategi pengelolaan RTH kampus yang berbasis pada penyerapan CO_2. Penelitian ini bertujuan untuk menganalisis kemampuan pepohonan dan RTH yang ada dalam menyerap CO_2. Perhitungan sekuestrasi CO_2 dilakukan berdasarkan luas RTH dan kapasitas sekuestrasi pohon-pohon yang ada di dalam RTH. Hasil penelitian menunjukkan bahwa 6 zona di kampus induk Unpak mempunyai kapasitas penyerapan CO_2 yang berbeda-beda tergantung luas ruang yang ditanami rumput dan semak hias serta jumlah pohon dan perdu yang ditanam. Secara keseluruhan, kapasitas sekuestrasi CO_2 pepohonan dan RTH di kampus induk Unpak adalah 282.784,89 kg per tahun.

Keywords: *CO_2 Sequestration, Greenhouse Gases, Green Open Space*

INTRODUCTION

Global warming and climate change have become global environmental problems that urgently need to be addressed. For Indonesia, climate change poses a formidable challenge for its people, as it is the world's fourth most populous nation and the biggest archipelagic country (Priatna & Monk, 2023). One of the factors causing climate change is an increase in the concentration of greenhouse gases (GHG) such as CO_2 in the atmosphere (Roshintha & Mangkoedihardjo, 2016; Baderan, 2017; Rachmayanti & Mangkoedihardjo, 2021; Haruna, 2020). Nature-based solutions are widely recognized as a key means of carbon removal technology, offering significant effectiveness and cost efficiency in addressing climate change (Li et al., 2023). Using the natural-based solution concept, the way to reduce CO_2 concentrations in the atmosphere is through CO_2 sequestration by plants (Ali, 2012; Zhang & Wang, 2022). Sequestration of CO2 by vegetation can be an effective alternative in reducing CO_2 concentration in the atmosphere because all parts of vegetation starting from stems, leaves, and roots store biomass from photosynthesis (Darlina et al., 2023). Plants can sequester CO_2 through the process of photosynthesis and convert it into carbohydrates for plant growth and development (Othman et al., 2019). The presence and content of chlorophyll are crucial for a plant because chlorophyll has an important role in plant biochemical processes, especially in photosynthesis (Latifa et al., 2019). The most important part of the plant in photosynthesis is the leaf (Pertamawati, 2010). The factor causing differences in chlorophyll content is differences in leaf surface width (Latifa et al., 2019). Therefore, different types of vegetation have different abilities to sequester CO_2 from the atmosphere (Mansur & Arief, 2014; Mandal et al., 2016; Othman et al., 2019) . Plants that have wide leaves can sequester CO_2 more effectively because having a wider leaf area allows for greater capture of sunlight and is efficient for photosynthesis (Latifa et al., 2021).

A campus provides sufficient land for planting vegetation, which is one solution to mitigating climate change (Sharma et al., 2021). Pakuan University (Unpak) is one of the large and influential private universities in the city of Bogor. which has a main campus area of 3,500 m^2, is certainly committed to assisting the government's efforts to reduce GHG emissions and increase the supply of oxygen (O_2) through the arrangement of GOS. Green Open Space (GOS) on campus has various functions, apart from adding to the beauty of the campus, it is also very beneficial for the civitas academics, including facilitating health and well-being by eliminating stress and allowing relaxation (Sharma et al., 2021). The GOS on campus ideally has a function that supports the activities of the civitas academics (Gandasari et al., 2021). The arrangement of GOS can add comfort because it can regulate air temperature and humidity, reduce CO_2 pollution, and increase O2. A campus that is comfortable and beautiful, because it is equipped with an organized GOS, will make civitas academics more productive. Currently, there is no data and information available regarding the distribution and condition of GOS and trees on the Unpak campus related to the sequestration of CO_2. Therefore, research is needed to analyze the sequestration of CO_2 by trees and GOS on the Unpak campus.

METHODS

Location of Research

The research was conducted at the main campus of Pakuan University, Jalan Pakuan No. 1, Tegallega, sub-district of Central Bogor on 6^0 35' 59" S and 106^0 48' 41" E. The area of Pakuan University's main campus is 35,000 m^2. For analysis, the Unpak's main campus is divided into 6 observation zones, namely: Zone 1 (SPs – Management - Mandiri - Accounting); Zone 2 (UKM – BNI - Accounting); Zone 3 (Vocational – GPS- Back of Rector office); Zone 4 (FISIB - FKIP); Zone 5 (FMIPA); and Zone 6 (Front of Rector Office -FH). Figure 1.

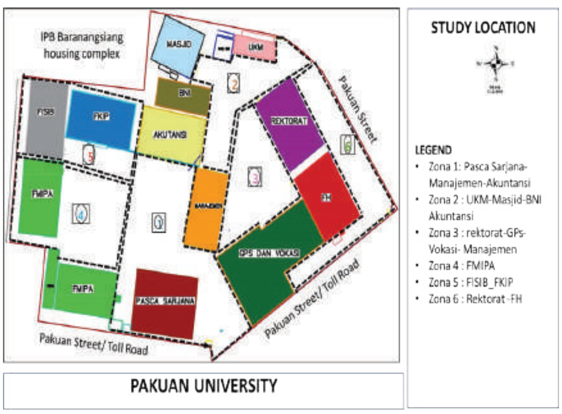

Figure 1. Location of the study.

Data

This study used primary and secondary data. Primary data was obtained by observing and measuring the area of GOS and collecting data on trees/shrubs and ornamental bushes, while secondary data was obtained from documents and websites. The data required and how to search and source the data are shown in Table 1.

Table 1. Data required and source.

No	Data	Data Search Technique
1	Number and type of trees/shrubs	Field observations, interviews, and literature
2	Bushes and grass area	Measurement
3	Name of tree/shrub	Literature
4	Sketch of the main campus of Pakuan University	Document, Unpak website
5	Unpak main campus area	Unpak website

Analysis

Each type of plant has a different rate of CO_2 sequestration due to differences in plant physiology (Mansur & Bayu Arief, 2014). Calculation of CO_2 sequestered uses the formula: Total amount of CO_2 sequestered, equal to CO_2 sequestration rate per tree/shrub multiplied by the number of trees/shrubs (Suryaningsih et al., 2015). Next, to calculate the amount of CO_2 sequestration by trees/shrubs, use Table 2.

Table 2. CO_2 Sequestration Rate by Trees and Shurbs.

Species	CO_2 Sequestration Rate (Kg/Tree-Y)
Alpukat (*Persea americana Mill*) [1)]	113
Angsana (*Pterocarpus indicus*) [2)]	2,804.93
Asem Jawa (*Tamarindus indica*) [3]	8.48
Belimbing (Averrhoa carambola) [1)]	132
Beringin (*Ficus benjamina*) [4)]	1,917.56
Beringin kimeng (*Ficus Microcarpa*) [5)]	5,728.20
Bintaro (*Cerbera manghas*) [6)]	4,509
Biola cantik (*Ficus lyrata Warb*) [1]	11,919
Bougenville (*Bougainvillea spectabills*) [4)]	2.63
Bunga merak (*Caesalpinia pulcherrima*) [7)]	30.95
Bungur (*Lagerstroemia speciosa*) [7)]	160.14
Cemara laut (*Casuarina equisetifolia*) [8)]	394.20
Dadap Hijau (*Erythrina variegata*) [9)]	1,445.40
Flamboyan (*Delonix regia*) [6)]	42.20
Jamblang (*Syzygium cumini*) [5)]	4,135.99
Jambu Air (*Syzygium aqueum*) [10)]	1,543
Jambu biji (*Psidium guajava Linn*) [1]	602
Jambu Jamaica (*Syzygium malaccense*) [1]	9,419
Kamboja kuning (*Plumeria acuminate*) [6)]	220
Kelapa (*Cocos nucifera*) [4)]	804.17

Kenari (*Canarium asperum*) [11]	38,964
Kepel/Kiburahol (*Stelechocarpus burahol*) [11]	8,606
Ketapang Badak (*Terminalia catappa*) [10]	7,272
Ketapang Kencana (*Terminalia Mantaly*) [10]	689.60
Kiputri (*Podocarpus macrophyllus*) [12]	1.63
Krey Payung (*Fellicium decipiens*) [6]	404.83
Mahoni (*Swietenia mahagoni*) [14]	295.73
Mangga (*Mangifera indica*) [4]	455.52
Matoa (*Pometia pinnata*) [7]	329.76
Nangka (*Arthocarpus heterophyllus*) [11]	1,108
Nyamplung (*Calophyllum inophyllum*) [10]	2,047.56
Pakis Brazil (*Schizolobium parahybum*) [13]	52.51
Palem Bismarck (*Bismarckia nobilis*) [16]	23.91
Palem kipas (*Livistona saribus*) [17]	43.81
Palem Kuning (*Dypsis lutescens*) [9]	3.42
Palem Putri (*Veitchia merrillii*) [9]	285.58
Palem sadeng (*Livistona rotundifolia*) [13]	29.75
Pandan Bali (*Cordyline australis*) [16]	13.30
Pucuk merah (*Oleina syzygium*) [8]	1,362.88
Pulai (*Alstonia scholaris*) [8]	11,557.51
Rambutan (*Nephelium lappaceum*) [7]	2.19
Salam (*Syzygium polyanthum*) [2]	749.78
Song of India (*Dracaena reflexa*) [15]	550.30
Sukun (*Artocarpus communis*) [6]	815.19
Tanjung (*Mimusops elengi Linn*) [11]	4,856

Source: [1] (Santoso et al., 2021); [2] (Misni et al., 2015); [3] (Febriansyah et al., 2022); [4] (W. O. D. M. Lestari et al., 2021); [5] (Sharma et al., 2021); [6] (Suryaningsih et al., 2015); [7] (Dahlan, 2008); [8] (Untajana et al., 2019); [9] (Roshintha & Mangkoedihardjo, 2016); [10] (Darlina et al., 2023); [11] (Lailati, 2013); [12] (Gharge & Menon, 2017); [13] (Milantara & Gustin, 2023); [14] (Othman et al., 2019); [15] (Pasaribu & Tangahu, 2016); [16] (Wesport, 2022); [17] (Dinas Lingkungan Hidup Kota Surabaya, 2017).

The CO_2 sequestration rate for each type of GOS cover is different. The CO_2 sequestration rate in GOS with ornamental bushes cover is 131.99 kg/m^2-year, while GOS with grass cover is 28,803 kg/m^2-year (Dinas Lingkungan Hidup Kota Surabaya, 2017). The amount of CO_2 sequestered on the GOS cover is equal to the rate of CO_2 sequestration multiplied by the area of the GOS cover (Suryaningsih et al., 2015).

RESULT AND DISCUSSION

Trees and Shrubs Sequestration

On the Unpak main campus, there is GOS in the form of a garden with ornamental bushes and trees/shrubs, a field with grass and trees/shrubs, as well as a box planter with ornamental bushes and shrubs. The area of the Unpak main campus is 35,000 m^2 with a GOS of 1,090.11 m^2 (3.11%). Based on Law No. 26 of 2007 about Spatial Planning, the GOS of the campus of Unpak is a private GOS. Provision on the Green Coefficient (KDH), by Bogor City Regulation No. 6 of 2021 about Amendments to Bogor City Regulation No. 8 of 2011 about Regional Spatial Planning (RTRW) Bogor City 2011-2031, is 10% of campus area. Thus, the area of GOS on the main campus, which is only 3.11% of the campus area, is still very small. This certainly affects the amount of CO_2 sequestration.

On Unpak's main campus are 45 species of trees and shrubs were identified with a total number are 208 trees and shrubs. The CO_2 sequestration rate for each tree is not the same, so a large number of trees/shrubs does not automatically cause a high amount of CO_2 sequestration. The zone with an abundance of trees is Zona 1 with 47 trees/shrubs, but CO_2 sequestration is 32,842.70 kg/y lower than zone 4 which has 45 trees/shrubs with CO_2 sequestration of 70,664.57 kg. This is because in Zone 4, the CO_2 sequestration rate of existing trees/shrubs is higher than in Zone 1. One example is a tree with the highest sequestration rate is Ficus lyrata Warb (11,919 kg/tree-year), Alstonia scholaris (11,557.5 kg/tree-year), and Syzigium cumini (4,136 kg/tree-year). The total CO_2 sequestered by all the trees in a year on Unpak's main campus is 220,960.53 kg or 220,960 tons. The average, CO_2 sequestered by an individual tree/shurb on Unpak's main campus is 1.06 tons per year (Table 3).

Table 3. CO_2 sequestration by trees/shrubs at Unpak's main campus in 2023.

Zone	Number of Trees/Shrubs	CO^2 Sequestration (kg/y)
Zone 1: SPs-Mjn -Mandiri-Acc	47	32,842.70
Zone 2: UKM-BNI-Acc	31	17,174.18
Zone 3 : Vokasi-GPS	35	25,497.47
Zone 4 : MIPA	45	70,664.57
Zone 5 : FISIB-FKIP	36	19,114.71
Zone 6 : Rector's Office-FH	24	55,666.91
Total amount	208	220,960.53

Source: Analysis 2023

Green Open Space with Covered by Ornamental Bushes and Grass

CO_2 sequestration on Unpak's main campus, besides trees, was also identified by the area of GOS covered by ornamental bushes and grass. The total CO_2 sequestration on Unpak's main campus by the GOS that is covered by ornamental bushes (294.85 m^2) and grass (706.50 m^2) is 61,824.34 kg/year. Zone 6 is the zone with the largest area of GOS with ornamental bushes because in this zone there are 11 forms of elongated GOS planted with ornamental bushes. Even though Zones 4 and 5 are the zones with the most extensive GOS planted with grass, the amount of CO_2 sequestration is smaller than in Zone 6 where the GOS is covered by ornamental shrubs. This is because the CO_2 sequestration rate of grass is lower than ornamental shrubs (Table 4).

Overall the amount of CO_2 sequestration by grassy GOS, ornamental bushes GOS, and trees is 282,784.87 kg/year. The zone with the highest CO_2 absorption is

Zone 6 (81,546.05 kg/y) which comes from trees/shrubs and GOS covered with ornamental bushes. In zone 4 (80,547.97 kg/y) CO_2 sequestration comes from trees/shrubs and GOS covered with grasses. The ability to sequester CO_2 by ornamental bushes, grasses, and trees/shrubs for each zone on the Unpak campus is different, depending on the area and cover of GOS by grass, ornamental bushes, or trees and shrubs. According to ATR/BPN Ministerial Regulation no. 14 of 2022 article 4(1), one of the GOS typology classifications is space objects that function as GOS. Therefore, it is necessary to expand GOS, by creating a type of GOS in the form of a space object that functions as GOS in the form of a building surface planted with vegetation. Space objects that function as GOS are in the form of roof gardens (Lestari et al., 2018) vertical gardens (Alfaatihah et al., 2022),(Indriani et al., 2020), or planter box gardens (Widyaputra, 2020).

Table 4. CO_2 sequestration by GOS with ornamental bushes and grasses cover at Unpak's main campus in 2023.

GOS Location	Area (m^2)		CO_2 Sequestration (kg/y)		Total CO_2 Sequestration (kg)
	Grasses	Ornamental Bushes	Grasses	Ornamental Bushes	
Zone 1	17.17	18.45	494.54	2,435.51	2,930.04
Zone 2	23.52	41.97	677.32	5,539.74	6,217.06
Zone 3	1.49	39.42	42.77	5,202.64	5,245.41
Zone 4	323.36	-	9,883.40	-	9,883.40
Zone 5	409.96	-	11,808.03	-	11,808.03
Zone 6	-	195.01	-	25,740.40	25,740.40
Total	795.27	294.85	22,906.06	38,918.28	61,824.34

Source: Analysis 2023

Table 5. Total CO_2 sequestration at Unpak's main campus in 2023.

Zone	CO_2 Sequestration (kg/y)			Total CO_2 Sequestration (kg)
	Grasses	Ornamental Bushes	Trees/ Shrubs	
1. SPs-Min-Mandiri-Acc	494.54	2,435.51	32,842.70	35,772.74
2. UKM-BNI-Acc	677.32	5,539.74	17,174.18	23,391.24
3. Vokasi-GPS	42.77	5,202.64	25,497.47	30,742.89
4. MIPA	**9,883.40**	0.00	**70,664.57**	80,547.97
5. FISIB-FKIP	**11,808.03**	0.00	19,114.71	30,992.74
6. Rector's Office-FH	0.00	**25,740.40**	**55,666.91**	**81,407.31**
Total	22,906.06	38,918.28	220,960.53	282,784.87

Source: Analysis 2023

GOS of Unpak's main campus in sequestering CO_2 is not optimal because existing conditions show that the quality of the grassy GOS is not well maintained, as well as the quality of trees/shrubs and ornamental bushes. The grassy GOS as well as ornamental bushes is poorly maintained, and some trees require pruning and rejuvenation. Pruning can also improve lighting from sunlight to all parts of the plant so that the photosynthesis process can take place perfectly (Suradinata et al., 2017). A perfect photosynthesis process not only increases CO_2 absorption but also increases the amount of O_2 in the air which has an impact on improving air quality. Several trees with high CO_2 sequestration rates in main campus, for example Ficus lyrata warb, Bauhinia purpurea, Syzygium malaccense, Stelechocarpus burahol, Terminalia cattapa Linn, Syzygium cumini, Ficus Microcarpa, Mimusops elengi Linn, Pterocarpus indicus, and Calophyllum inophyllum, can be an option when rejuvenation of trees. Therefore, to increase the CO_2 sequestration capacity on the GOS of the Unpak campus, it is necessary to maintain the quality of trees, grasses, and ornamental bushes, through pruning, rejuvenation, and fertilization. Besides that, spaces in the form of hallways or corridors or building walls that still allow for planting vegetation in the form of ornamental bushes or shrubs need to be utilized optimally. Based on observations in the field, there are walls/fences that can be used as vertical gardens and corridors/aisles between buildings, as well as parking lots where plant boxes can be placed planted with ornamental bushes.

CONCLUSION

The area of GOS on the Unpak main campus is 3.11% consisting of 795.27 m^2 (grass open space), 294.85 m^2 (ornamental bushes open space), and 208 trees/shrubs with 45 species of trees/shrubs. The GOS area of the Unpak campus does not meet the Green Coefficient (KDH) criteria (10%) for the use of private space. The total CO_2 sequestration from GOS is 282,784.87 kg/year, consisting of: 22,906.06 kg/year (grassy GOS), 38,918.28 kg/year (bushies GOS), and 220,960.53 kg/year (trees). Therefore, a strategy is needed so that the arrangement of GOS in the Unpak campus can be optimal, by adding a vertical garden and planter box garden, as well as regular maintenance of trees and GOS.

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The effectiveness of using a combination of eggshell waste and natural zeolite as an adsorbent for treating laundry waste

ELISA LISTIANTI[1,*], SUTANTO[2]

[1]Graduate School of Environmental Management, Pakuan University, Jl. Pakuan Kotak Pos 452, Bogor 16129, Indonesia
[2]Chemistry Study Programme, Faculty of Mathematic and Natural Sciences, Pakuan University, Jl. Pakuan Kotak Pos 452, Bogor 16129, Indonesia

Corresponding author: *elisa.listianti76@gmail.com*

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ABSTRACT

In Indonesia, the laundry industry is expanding extremely quickly. There are worries over the concentration of surfactants accumulated in the aquatic environment because the laundry industry has expanded into both large cities and rural regions, yet control over the disposal of laundry waste is still quite poor. In order to lessen surfactant waste in the aquatic environment, we must control laundry waste. Eggshells are not used to their full potential because of a lack of public understanding. In addition to figuring out the ideal composition of the optimum ratio of zeolite to eggshell that can lower detergent levels in laundry waste, this study attempts to ascertain how successful it is to combine chicken eggshells with active zeolite in decreasing laundry waste. In this investigation, two adsorbents were used as a treatment for synthetic laundry waste (LAS) and laundry waste. There are two iterations of each treatment. A 1: 50 ml sample of 1.0 g of adsorbent in 50 ml surfactant samples (laundry waste) was employed in this investigation. It then splits into five different treatments: Zeolite 1.0 g and chicken eggshell 0 g (A), zeolite 0.0 g and chicken eggshell 1 g (B). Chicken eggshell 0.3 g and 0.7 g of active zeolite (C), 0.5 g and 0.5 g of active zeolite (D), and 0.7 g and 0.3 g of active zeolite (E). The findings demonstrated that the detergent content decreased from 50.507 mg/L to P1 (A) 39.535 mg/L, P2 (B), 44.794 mg/L, P3 (C), 38.311 mg/L, P4 (D), 42.063 mg/L, and P5 (E) 37.396 mg/L. These results corresponded to an advisory capacity of A; 0.5484 mg/g, B; 0.2855 mg/g, C; 0.6095 mg/g, D; 0.4222 mg/g, and E; 0.6553 mg/g. The percentage efficiency of each treatment was determined to be 21.724%, B: 11.311%, C: 24.148%, D: 20.073%, and E: 25.959%. E saw the biggest drop, coming in at 37.396 mg/l. According to the study's findings, treating chicken eggshells has a 25.959% efficiency rate and an adsorption capacity of 0.6553 mg/g. The ideal mixture is 0.3 gr. of zeolite and 0.7 gr. of eggshell. Eggshell and natural zeolite are combined in the absorption process of LAS/SLS compounds, with a contact time of 30 minutes and a discharge rate of 8 ml/minute.

ABSTRAK

Di Indonesia, industri laundry berkembang sangat pesat. Ada kekhawatiran mengenai konsentrasi surfaktan yang terakumulasi di lingkungan perairan karena industri laundry telah berkembang baik di kota-kota besar maupun daerah pedesaan, namun pengendalian terhadap pembuangan limbah laundry masih sangat buruk. Untuk mengurangi limbah surfaktan di lingkungan perairan, kita harus mengendalikan limbah laundry. Cangkang telur belum dimanfaatkan secara maksimal karena kurangnya pemahaman masyarakat. Selain untuk mengetahui komposisi ideal perbandingan zeolit terhadap cangkang telur yang optimal yang dapat menurunkan kadar deterjen pada limbah laundry, penelitian ini juga berupaya untuk mengetahui seberapa sukses kombinasi cangkang telur ayam dengan zeolit aktif dalam menurunkan limbah laundry. Dalam penelitian ini digunakan dua adsorben sebagai pengolahan limbah laundry sintetik (LAS) dan limbah laundry. Terdapat dua iterasi pada setiap perlakuan. Sampel 1: 50 ml dari 1,0 g adsorben dalam 50 ml sampel surfaktan (limbah cucian) digunakan dalam penyelidikan ini. Selanjutnya dipecah menjadi lima perlakuan berbeda: Zeolit 1,0 g dan cangkang telur ayam 0 g (A), zeolit 0,0 g dan cangkang telur ayam 1 g (B). Cangkang telur ayam 0,3 g dan 0,7 g zeolit aktif (C), 0,5 g dan 0,5 g zeolit aktif (D), serta 0,7 g dan 0,3 g zeolit aktif (E). Hasil penelitian menunjukkan kandungan deterjen mengalami penurunan dari 50.507 mg/L menjadi P1 (A) 39.535 mg/L, P2 (B), 44.794 mg/L, P3 (C), 38.311 mg/L, P4 (D), 42.063 mg /L, dan P5 (E) 37,396 mg/L. Hasil ini sesuai dengan kapasitas penasehat A; 0,5484 mg/g, B; 0,2855 mg/g,C; 0,6095 mg/g, D; 0,4222 mg/g, dan E; 0,6553 mg/g. Persentase efisiensi masing-masing perlakuan ditetapkan sebesar 21,724%, B: 11,311%, C: 24,148%, D: 20,073%, dan E: 25,959%. E mengalami penurunan terbesar, yaitu 37,396 mg/l. Berdasarkan hasil penelitian, pengolahan cangkang telur ayam memiliki tingkat efisiensi 25,959% dan kapasitas adsorpsi sebesar 0,6553 mg/g. Campuran yang ideal adalah 0,3 gr. zeolit dan 0,7 gr. dari kulit telur. Cangkang telur dan zeolit alam digabungkan dalam proses penyerapan senyawa LAS/SLS, dengan waktu kontak 30 menit dan laju pelepasan 8 ml/menit.

Keywords: *adsorbent, detergent, eggshell, laundry waste, zeolite*

INTRODUCTION

The use of detergents is increasing every year along with the increasing population, meaning that the community's need for the use of detergents is increasing. Laundry services both in urban and even rural clothing are increasing. Disposal of laundry waste directly into the environment without prior treatment, can pollute the environment, especially waters.

The main content of laundry waste that can cause environmental pollution is surfactant (raw material for making detergents). Detergent ingredients are surfactants (the main ingredients of detergents) containing ± 22-30% active ingredients, active ingredients (phosphate compounds) and additives (bleaching and fragrance). Surfactants have polar groups that like water (hydrophilic) and nonpolar groups that like oil (lipophilic), so they can bind the two mixtures (Ety, 2014). The most important substances contained in detergents are ionic compounds in the form of sodium tripolyphosphate which acts as a builder and surfactant. Surfactants can be harmful to the environment because they are difficult to decompose by the environment. Excessive exposure to surfactants in humans can cause eye irritation and skin infections (Apriyani & Novrianti, 2020).

The adsorption process is widely used in industry because it has several advantages, namely it is more economical, does not cause toxic side effects and can remove organic matter. When a solution interacts with a solid adsorbent, the adsorbate molecules will transition from liquid to solid until the solution is in equilibrium with the adsorbate concentration in the solid (Himma, 2017) Freudlich and Langumuir investigated equations that could explain isothermal experimental data. A good adsorbent has a high adsorption capacity and adsorption percentage.

The adsorption capacity can be calculated using the formula:

$$qe = (Co-Ce)v/w$$

The percentage of adsorption (adsorbent efficiency) can be determined using the formula:

$$\%E = ((Co-Ce))/Co \times 100\%$$

Where:
qe = number of metal ions adsorbed (mg/g)
Co = concentration of metal ions before adsorption
Ce = concentration of metal ions after adsorption
V = volume of solution of metal ions (L)
W = number of adsorbents (g)
%E = adsorption efficiency

Adsorption is one of the efficient and effective and inexpensive methods to reduce the concentration of a contaminant. Known types of adsorbents include activated carbon, silica gel, and zeolite. In this study, a combination of 2 adsorbents will be carried out, namely eggshells and zeolite. Adsorbents that can reduce pollutants in laundry waste, one of which is eggshells. Eggshells are potential absorbent materials (Mulyati, 2018). Porous structure of eggshell rich in calcium carbonate can be used as an adsorbent for good liquid waste treatment (Li et al., 2021). Zeolite is an aluminosilicate mineral widely found in Indonesia, so it has the ability to adsorb pollutants in laundry waste well. Eggshells and zeolite have high porosity so that both combinations can be used to adsorb pollutants in laundry waste.

Handling or treatment of laundry wastewater includes the Biosand Filter method, floating treatment wetland, moving bed biofilm reactor (MBBR), electrocoagulation, sand filter, and activated carbon adsorption. This method is quite good but has not been widely applied because it is limited in land, requires a long time and requires an aerator, requires the use of electric current and electrodes. Meanwhile, micro-scale laundry entrepreneurs need a practical method that is simple, and cheap, but effective and efficient.

The activation process can increase the surface area and pore size so that it can affect adsorption performance (Fasihah, et al., 2022). Activation of chicken egg shells as adsorbents by burning at 600 °C calcination reaction occurs. The calcination process causes a change in the composition of the eggshell. In addition to changes in composition, the calcination process also causes changes in the morphology and pore structure of the eggshell (Pardede et al., 2020).

The results of research (Apriyani & Novriyanti, 2020) revealed that the use of activated carbon and zeolite without prior activation has the potential to pollute the environment.

Some of the background methods that have been described related to handling laundry waste, in this study one solution that can be applied in the community is a simple filtration method with a combination of *zeolite* and eggshell. Based on research Fasihah et al., 2022), eggshells are effective in reducing MBAS levels where the optimum adsorbent size of 150 mesh can reduce BOD levels by 80% and MBAS levels by 38.85% and 200 mesh sizes which can reduce COD levels by 67.34%. The optimum time for reducing COD and BOD levels is at 90 minutes which can reduce BOD levels by 80% and COD levels by 74.5% and 120 minutes which can reduce MBAS levels by 35.67%.

According to (Purnamasari, 2015), natural zeolite can be used to reduce the concentration of Linear Alkylbenzene Sulfonate (MBAS) compounds in laundry waste water by 93.6 – 95.2%. The maximum decrease in the concentration of Linear Alkylbenzene Sulfonate (MBAS) compounds was achieved with the addition of

100 grams of zeolite with a decrease in MBAS concentration of 0.48 mg/L.

Based on the background above, this study aims to see the effect of using a combination of zeolite and chicken egg shells to reduce the level of laundry wastewater pollution in particular the levels of surfactant, phosphate and COD.

METHODS

Research Location

This research was conducted on laundry waste around Bantarjati, North Bogor. Sample testing was carried out at the AKA Bogor Polytechnic test laboratory and the Bogor stone mountain forestry test laboratory. The test parameters measured are Detergent (MBAS), COD and Total Phosphate. The research conducted between February and July 2023.

The research conducted uses descriptive experiments consisting of several methods that have been standardized by SNI and related journals. This research consists of 4 stages including adsorbent preparation, adsorbent quality testing, adsorbent optimization, and adsorbent application to laundry waste. Application of adsorbents (combination of eggshells and zeolite) to laundry waste with a simple filter device.

Material

The necessary materials are laundry waste water taken in one of the laundry around, eggshell, zeolite, aquades, NaOH, H_2SO_4, Benzene, buffer pillow, isopropyl alcohol, Na_2SO_4, ammonium molybdate, ascorbic acid, filter paper, potassium antimonyl tartrate, MBAS (linear alkylbenzene sulfonate), HCl, NH_4NO_3, $NaH_2PO_4.2H_2O$, buffer solution (pH 4, 7, and 10), phosphate buffer solution, $K_2Cr_2O_7$, $HgSO_4$, Ag_2SO_4, $CaCl_3$, $FeCl_3$, $MgSO_4.7H_2O$, KH_2PO_4, and NH_4Cl.

Activation of Chicken Eggshells and Zeolite

Eggshells from the Home industry of Bantarjati and Tegal Gundil regions, Bogor City, were used as biosorbent materials in this study. The eggshell is cleaned of dirt and membrane layers attached with running water, then ground and sifted using a mechanical sieve measuring 150 mesh and furnaced at 600 °C for 2 hours and then stored in a desiccator for 3 hours. *Natural zeolite* is pureed and then sifted using a sieve mechanical size 200 mesh and heated to 600 °C with a time of 2 hours and stored in the desiccator for 3 hours.

MBAS Methylene Blue Active Surfactant (MBAS) Laundry Wastewater Sample Analysis HACH .8027 Method

The principle of MBAS testing is that anionic surfactants react with methylene blue to form blue-colored ion pairs that dissolve in organic solvents. The intensity of the blue color formed was measured with a spectrophotometer at a wavelength of 605 nm. The measured absorption corresponds to anionic surfactant levels. The test procedure is in accordance with the HACH Method. The spectrophotometric method is an instrument based on Lambert's law BEER to measure a solution with a light source.

Test Procedures:

1. Insert the test sample then add 30 ml benzene and 10 ml buffer sulfate solution, insert 1 bh buffer pillow then extracted.
2. The extracted solution will be divided into two layers and then accommodated into the upper layer Erlenmeyer.
3. Once accommodated into the Erlenmeyer insert it in the spectrophotometric cuvette.
4. Enter the program number for the Detergent test parameter.
5. Rotate the wavelength appropriate for the detergent test parameters and then create a calibration curve.

Table 1. SNI adjustments.

Parameter	Method	SNI
COD	Reflux spectrophotometer	SNI 6989. 2-2009
Surfactant (detergent)	Spectrophotomete HAC H	Method 8028, surfactant anionic
Phosphate	Test phosphate levels spectrophotometrically with ascorbic acid	SNI 06.6989-31:2005

RESULT AND DISCUSSION

Zeolite and eggshell activation process

Eggshells that are clean from dirt and membrane are then dried below sunlight and smoothed use blender dry. The sieving process is carried out using a mechanical sieve of 150 mesh size. While the zeolite uses a size of 200 mesh. This sieving aims to make the eggshell more homogeneous in size and have a wider surface.

The 2 adsorbents (egg shell and zeolite) are physically activated in the muffle furnace at 600°C for 2 hours. The more surface area produced, the more pores are formed. The purpose of physical activation is to increase the adsorption trap power. According to (Napitapulu, 2009), with physical activation, it can enlarge pores, namely by breaking chemical bonds or oxidizing surface molecules so that the surface area increases and affects adsorption power.

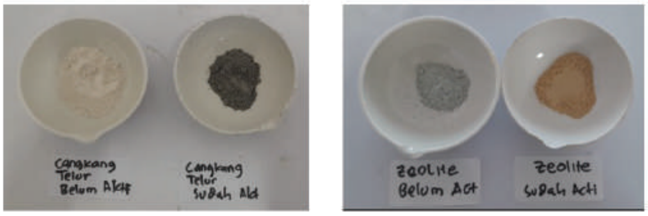

Figure 1. eggshell and zeolite before and once activated.

Based on Figure 1, you can see the difference between eggshell and zeolite before and after the activation process. Discoloration the eggshell turns black clearly because in the carbonization process the high enough hydrocarbon content in the eggshell undergoes authoring. Likewise, with activated zeolite undergoing discoloration, the purpose of physical activation is to evaporate the remaining water in the pores of the zeolite crystal, so that the surface area of the pore increases.

Basically, only the water content evaporates in the heating process, and there is no aluminum removal process or impurity separation in the zeolite structure, so there is no change in the composition of the zeolite material.

Optimization of the combination of eggshell adsorbent and zeolite

Factors that affect the adsorption process must be optimized by optimization. Determination of the optimum conditions of the adsorption process in this study is to determine the optimum weight, and the optimum concentration.

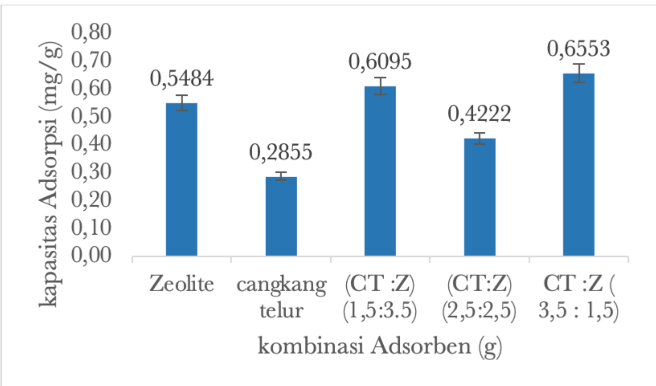

Figure 2. Optimum combination of adsorbents.

Based on Figure 2. above shows that the mass capacity of 1 g of zeolite adsorbent is greater compared to eggshell adsorbents of the same mass. Zeolite has an absorption model of silicon dioxide, ie. active groups SiO_4 and AlO_4, and in addition the largest eggshell forming component is $CaCO_3$, where this compound is included in the polar adsorbent group (Hajar, et al, 2016). Both materials also have pores that can increase their surface area.

The adsorption capacity of methylene blue increases as the mass of adsorbents on the eggshell increases, so the number of active sites on the surface of the adsorbent increases. However, under certain conditions the adsorption capacity remains or even decreases because the adsorbent is saturated due to the reduction in the number of active sites (Nurlaili et al., 2017).

The optimal ratio of eggshell and zeolite adsorption weight is 0.7:0.3 g with an adsorption capacity of 0.6553 mg/g, where the percentage of adsorption efficiency is 25.21%. This value is very different compared to zeolite and eggshell when reacted on its own. Zeolite has an adsorption capacity of 0.5484 mg/g while eggshells are 0.2855 mg/g.

Optimization of Adsorption Concentration of Laundry Waste

Determination of the optimum concentration aims to determine the adsorption capacity of the adsorbent in adsorbate and determine the optimum concentration of surfactant that can be adsorbed by the adsorbent to a saturation point thereby reducing its ability to absorb. In this study, several variations in concentration were carried out including (10, 20, 40, 80, and 100) mg / L.

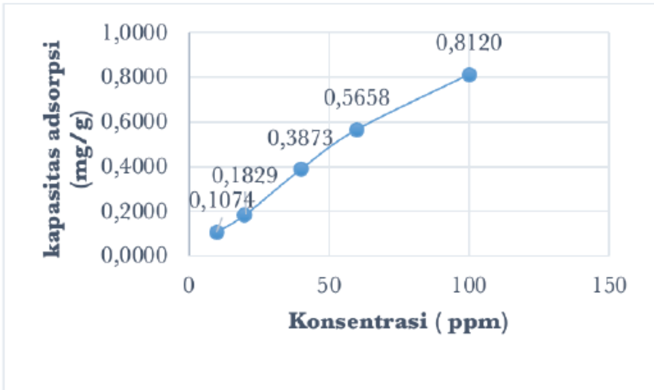

Figure 3. Optimum concentration.

Variations in the optimum concentration of adsorbents against surfactants were carried out with a weight of 3.5 grams of eggshells and 1.5 grams of zeolite and a contact time of 60 minutes and with a stirring speed of 120 rpm. Figure 3 above shows the effect of surfactant concentration on the adsorption capacity of adsorbent.

The adsorption capacity of the adsorbent increases with the increase in surfactant concentration. It refers to the active side on the surface of the adsorbent, the more active side it is. The more active sides, the higher the absorption capacity. Based on this study, the optimum concentration of eggshells and zeolite against surfactants / detergents was obtained at a concentration of 100 mg / L, with an adsorption capacity of 0.812 mg / g.

Decreased Detergent Levels After Adsorbing with Zeolite and Eggshell

The length of adsorption time affects the amount of decrease in surfactant levels in detergent wastewater samples (Figure 4). At the adsorption time that lasted for 1.5 hours, the rate of decline of SLS compounds was not too significant. The large amount of adsorbent mass in the adsorption process also affects the decrease in SLS compounds. The above is the result of anionic surfactant adsorption with fluctuations in discharge. Each discharge has different levels of surfactant.

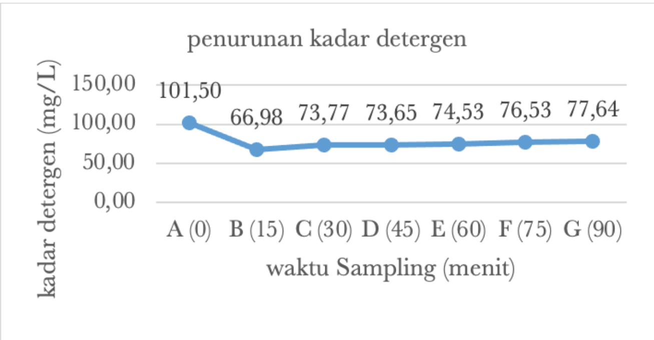

Figure 4. Decreased detergent levels flow rate 8 ml/min.

The length of adsorption time affects the amount of decrease in surfactant levels in detergent wastewater samples (Figure 4). At the adsorption time that lasted for 1.5 hours, the rate of decline of SLS compounds was not too significant. The large amount of adsorbent mass in the adsorption process also affects the decrease in SLS compounds. The above is the result of anionic surfactant adsorption with fluctuations in discharge. Each discharge has different levels of surfactant.

It can be seen from the picture that the separation is influenced by anionic surfactant (detergent) levels, this can be seen from all variations in discharge of 8 ml / minute which can provide significant surfactant reduction results. At the initial detergent level of 101.50 mg / L, and after being applied with the filtration method using a simple tool obtained at a sampling time of 15 minutes a decrease in detergent levels of 66.98 mg / L, and at the 30th minute and so on there has been an equilibrium and saturation point occurs.

The percentage of removal is around 27.32%. This is because the lower the variability of the discharge, the longer the contact time between the surfactant and the adsorbent to maximize the absorption process (Mistar et al., 2017).

Based on Figure 5. It can be seen that with an allowance rate of 18 ml / min, the content of anionic surfactant (detergent) decreases, but is less optimal than the discharge of 8 ml / minute. This is because the lower the variability of the discharge, the contact time between the surfactant and the adsorbent is longer, and vice versa the higher the discharge, the faster the contact time so that the discharge absorption process is slower and vice versa (Mistar et al., 2017).

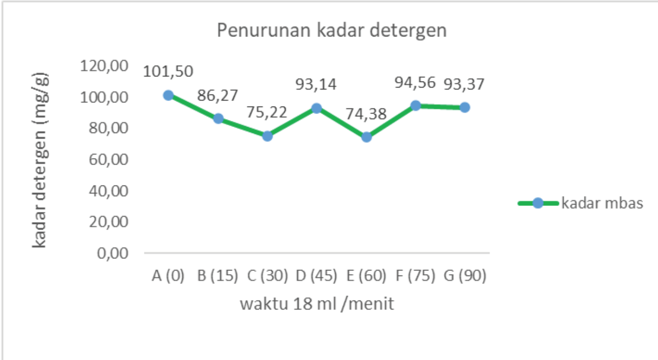

Figure 5. Decrease in detergent levels flow rate 18 ml/min.

At a discharge of 18 ml / minute shows a saturation point, which is shown at a sampling time of 60 minutes decreased after minutes 75 and 90 detergent levels rose. This shows that the higher the discharge, the less optimal the results of surfactant removal in laundry waste (Maharani, 2018). The percentage of removal of detergents is 8.24%. So it can be concluded that the optimal percentage of detergent removal is 8 ml / minute which is 27.32% at a sampling time of 30 minutes.

Effect of PO_4 Levels After Adsorbing with Zeolite and Eggshell

From Figure 6, it can be seen that the phosphate concentration dropped from the initial concentration of 51.56 ppm to 47.63 ppm which shows that phosphate is adsorbed in waste laundry with a combination of zeolite adsorbent and eggshell of 7.62% for 15 minutes at a flow rate of 8 ml / minute. But at sampling times of 30, 45, 60, 80, 75 and 90 minutes increased, this is because the adsorbent adsorption power is decreasing and the state becomes saturated. The use of eggshell adsorbents and zeolite can help lower phosphate levels in detergent waste by binding phosphate from the solution. This is in line with research by (Astuti, 2015), (Irawaty et al., 2021).

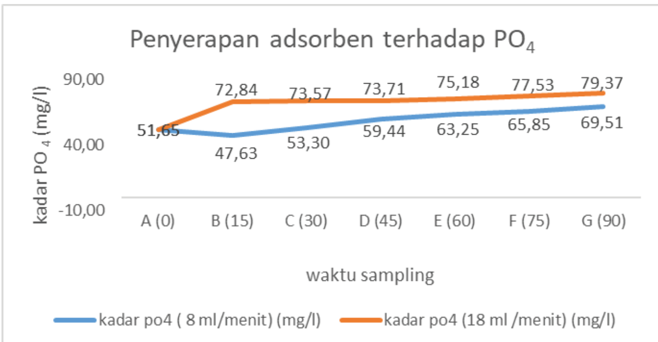

Figure 6. Adsorbent absorption against PO_4.

The sampling time of 30 – 90 minutes of phosphate level reduction is not significant because the adsorb process requires a certain time to interact with phosphate in detergent waste.

Elevated phosphate levels after detergent waste treatment using zeolite or eggshells can occur for several reasons:

1. Desorption effect, Zeolite or eggshell may not completely bind phosphate from detergent waste. When the material is saturated with phosphate, the bound phosphate can be released back into solution when conditions change or shock occurs.
2. Imperfections of Treatment, Sewage treatment process using zeolite or eggshell may not be perfect, and some phosphates may remain dissolved in solution after treatment.

Decreased COD Levels After Adsorption with Natural Zeolite and Eggshell

COD (Chemical Oxygen Demand) analysis in detergent waste analysis is very important because it provides information on the increase in the amount of chemically oxidized organic matter in the waste sample. COD values reflect the burden of organic pollution in waste, which can have a negative impact on the environment if disposed of without adequate treatment (Figure 7). A value indicating the amount of oxygen in 1 liter of a solution of oxygenated organic compounds (Setyobudiarso, 2014).

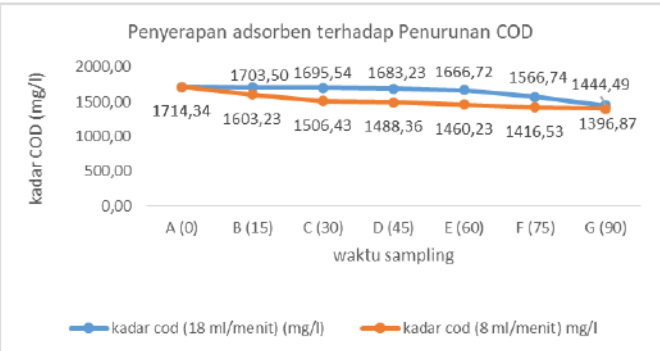

Figure 7. Adsorbent absorption against COD.

According to Mulia (2005), organic substance of COD compounds that can be processed biologically (biodegradable) and those that cannot be processed biologically (non-biodegradable). In the picture above, the initial cod content of laundry waste is 1714.34 mg / L, and the decrease in cod content after laundry waste treatment after 1.5 hours is 1397.87 mg / L or about 81.54%.

Basically, the treatment carried out causes a decrease in the COD parameters of laundry water, this can be seen from the percentage decrease in COD levels. In general, the COD number is a measure of water pollution by organic matter which can certainly be oxidized during microbiological processes, but does not necessarily cause a decrease in dissolved oxygen in waters (Setyobudiarso, 2014). Another factor that also contributes to this decrease is the flow rate adjusted to achieve a relatively long dwell time before being drained to the filter unit.

The decrease in COD levels of detergent waste after processing with eggshell adsorbents and zeolite is caused by the ability of these adsorbents to absorb organic matter resulting in high COD values. By using adsorbents it can help bind and remove potentially polluting components contained in detergent waste, thereby reducing the value of COD and its negative impact on the environment.

CONCLUSION

The results of the study found that the application of simple filtration with the optimum combination of zeolite and eggshell can reduce surfactant levels and Chemical Oxygen Demand (COD). The optimum conditions of eggshell and zeolite adsorbents in adsorbing anionic surfactants at a combination of 0.7 g eggshell and 0.3 g zeolite, flow rate 8 ml/min, and adsorption time 30 min. The maximum adsorption capacity of eggshell and zeolite adsorbent combination (0.7:0.3) against surfactants in laundry waste is 3.24 mg/g.

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Utilizing Qual2Kw software to calculate the pollution load capacity of Ciliwung River Segment IV (Depok City)

MARGAHAYU PRIANGGONO[1,*], ROSADI ROSADI[2], SUTANTO SUTANTO[2]

[1]Environment and Sanitation Agency, Depok, Jl. Raya Jakarta Bogor Km 34.5 Sukamaju Baru, Depok, Indonesia
[2]Graduate School of Environmental Management, Pakuan University, Jl. Pakuan Kotak No.1, Tegallega,Bogor 16129, Indonesia

Corresponding author: *ranggapedal@gmail.com*

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ABSTRACT

Situated in the administrative boundaries of West Java Province and DKI Jakarta Province, the Ciliwung River is a national river. Its river length is about 120 km, and its watershed area is about 425 km^3 (DAS). The population of Depok City is growing at a pace of 1.79% annually, which leads to a rise in the demand for food, clothing, and housing, among other necessities. As a result of the growth of various industrial and community residential buildings to accommodate human needs, wastewater discharge into rivers will increase and the amount of pollution entering the Ciliwung River may surpass its carrying capacity if efforts are not made to control water pollution. As a result, research must be done to ascertain Segment IV Depok City's Ciliwung River Pollutant Load Capacity utilizing a simulation model and Qual2Kw software. Primary data samples of the Ciliwung River's water and pollution sources that enter it were collected for this study, in addition to firsthand field observations. Data calibration is carried out after entering hydraulic and quality data into worksheets. In order to ensure that river flow data still satisfies class II river water quality standards, modeling is done utilizing the following sources: (1) existing data; (2) upstream data of class II river water quality standards; and (3) current conditions of river flow and trial & error pollutant source data. The findings indicated that the Ciliwung River section IV, Depok City, has a somewhat contaminated water quality. Pollutant loads for TSS and COD criteria can still be accommodated in Ciliwung River section IV, Depok City. In the meantime, the BOD criteria for carrying pollutant loads has been surpassed; therefore, to meet class II water quality regulations, the BOD pollutant load needs to be reduced by 22.58% to 37.50%.

ABSTRAK

Terletak di batas administratif Provinsi Jawa Barat dan Provinsi DKI Jakarta, Sungai Ciliwung merupakan sungai nasional. Panjang sungainya sekitar 120 km, dan luas daerah aliran sungainya sekitar 425 km^3 (DAS). Pertumbuhan penduduk Kota Depok sebesar 1,79% setiap tahunnya menyebabkan peningkatan permintaan terhadap pangan, sandang, papan, dan kebutuhan lainnya. Akibat tumbuhnya berbagai bangunan industri dan pemukiman masyarakat untuk menampung kebutuhan manusia, pembuangan air limbah ke sungai akan semakin meningkat dan jumlah pencemaran yang masuk ke Sungai Ciliwung dapat melampaui daya dukungnya apabila tidak dilakukan upaya pengendalian pencemaran air. Oleh karena itu, perlu dilakukan penelitian untuk memastikan Kapasitas Beban Pencemar Sungai Ciliwung Segmen IV Kota Depok dengan menggunakan model simulasi dan software Qual2Kw. Sampel data primer air Sungai Ciliwung dan sumber pencemaran yang masuk ke dalamnya dikumpulkan untuk penelitian ini, selain observasi lapangan secara langsung. Kalibrasi data dilakukan setelah memasukkan data hidrolik dan kualitas ke dalam lembar kerja. Untuk memastikan data debit sungai masih memenuhi baku mutu air sungai kelas II, pemodelan dilakukan dengan menggunakan sumber-sumber sebagai berikut: (1) data eksisting; (2) data hulu baku mutu air sungai kelas II; dan (3) kondisi aliran sungai terkini dan data sumber pencemar trial & error. Temuan menunjukkan bahwa Sungai Ciliwung seksi IV Kota Depok memiliki kualitas air yang agak tercemar. Beban pencemar kriteria TSS dan COD masih dapat tertampung di Sungai Ciliwung seksi IV Kota Depok. Sementara itu, kriteria BOD untuk memikul beban polutan telah terlampaui; Oleh karena itu, untuk memenuhi ketentuan mutu air kelas II maka beban pencemar BOD perlu diturunkan sebesar 22,58% menjadi 37,50%.

Keywords: *Ciliwung River, pollutant load, Qual2Kw, water quality*

INTRODUCTION

The river is a natural element that has an important role in various cultural features of a nation since ancient times. The potential availability of water, the fertility of the valley and other potentials become a magnet for humans to live around rivers. Their daily life cannot be separated from the use of the river in various ways including the engineering needed to utilize more of the potential that can be extracted from the river. (Mulyanto, 2018). Rivers have a very important role as natural resources that provide many benefits, but rivers can also pose a threat to the sustainability of human life. Various efforts made by humans make use of rivers and surrounding land such as agriculture, fisheries, irrigation, hydroelectric power, transportation and so on. Various efforts to safeguard against river hazards continue to be carried out for the welfare of mankind such as efforts to control floods, efforts to protect, prevent and deal with damage to facilities and infrastructure in river basins (Kumala, 2021).

Watershed (DAS) with a river length of ± 120 Km, the head of the Ciliwung River originates from Mandalawangi Lake on Mount Pangrango which is the peak area of Bogor Regency. The Ciliwung River flows from Puncak, Bogor Regency, crosses Bogor City, Bogor Regency, Depok City, South Jakarta, Central Jakarta and North Jakarta, empties into the Jakarta Bay. The Ministry of Environment and Forestry divides the Ciliwung watershed into 6 segments, namely segment 1 is upstream in Puncak Bogor Regency, segment 2 is in Bogor City, segment 3 is in Bogor Regency after passing through Bogor City, segment 4 is in Depok city, segment 5 located in South Jakarta City, and finally Segment 6 which is in Central Jakarta City and North Jakarta City. The increase in the population of Depok City with a growth rate of 1.79% per year based on data from Depok City in Figures 2023 from the Central Statistics Agency, this increase in population encouraging an increase in various needs for food, clothing, and boards so that various kinds of industries and residential houses emerge. The increasing number of industries and community houses around the Ciliwung watershed is expected to cause a pollution load on the Ciliwung River. The condition of the forest around the Ciliwung watershed which has decreased has also caused a lack of water absorption so that the river water discharge and its quality fluctuate.

Based on the background above, the problems in the research that the authors conducted identified the problems as follows:

1. The increase in population every year and the increase in development, human and industrial activities, the waste water discharged into water bodies / rivers is also increasing.
2. From data on the water quality status of the Ciliwung River Segment IV (Depok City) at the Onlimo Station of the Ministry of Environment and Forestry located in Depok Village, Pancoran Mas District, Depok City, it is known that the results of monitoring the water quality of the Ciliwung River have good fluctuations - slightly polluted.
3. Data on Pollution Load Capacity of Ciliwung River Segment 4 Depok City is not yet available using quality standards in accordance with Appendix VI Class II River Water Government Regulation Number 22 of 2021.

This study aims to determine the status of water quality, determine the pollutant load carrying capacity of the TSS, BOD, and COD parameters, and determine the allocation of pollutant load for the parameters TSS, BOD, and COD of the Ciliwung River Segment IV.

METHODS

Time and Location

Field observations and surface water sampling were carried out on March 7, 2023, located in the Ciliwung River segment IV, Depok City.

Tools and Materials

This study used sampling equipment and water sample testing directly or in an environmental laboratory. Data processing uses Qual2Kw Software version 5.1 and Google Earth Pro.

Sampling Methods

Primary data collection was carried out by direct observation and sampling in the Ciliwung River segment IV, Depok City, consisting of 5 points on the Ciliwung River and 2 points on tributaries as a source of pollutants entering the Ciliwung River.

Measurement Methods

The measurement method is carried out directly in the field and samples are also taken to be tested in an environmental laboratory. River distance measurement using Google Earth Pro software.

Experimental Design

This study uses descriptive quantitative research methods by collecting primary data, processing data and analyzing.

Stage of Research Activity

are then entered into the QUAL2Kw software *worksheet* with the following conditions:

1) Discharge data and quality of Ciliwung River segment IV Depok City are used as a reference for model simulation results.
2) Data on wastewater discharge entering the Ciliwung River segment IV, Depok City at point *sources* as input in *the point sources worksheet*.
3) Climatological data (air temperature, etc.) are used to determine climatic conditions along the Ciliwung River segment IV, Depok City.

The flow regarding the use of the QUAL2Kw software can be seen in Figure 1 and Figure 2 as follows:

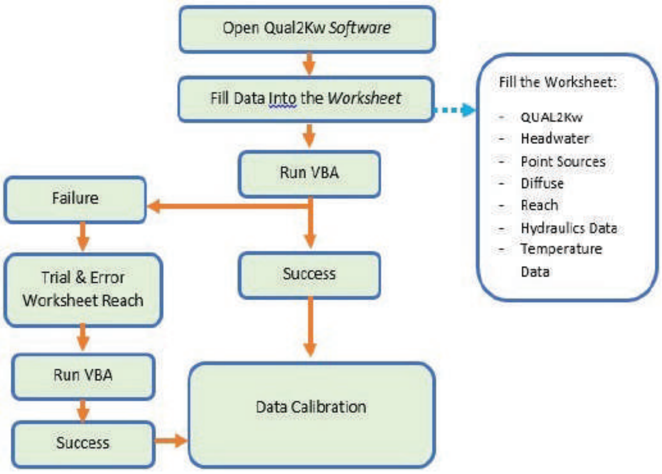

Figure 1. Use of QUAL2Kw in hydraulic data calibration.

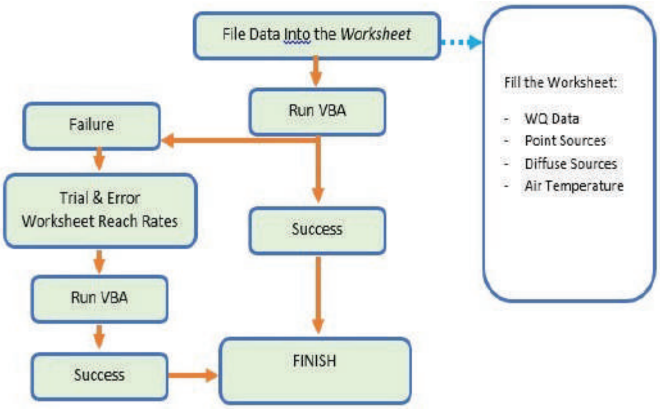

Figure 2. Use of QUAL2Kw in hydraulic data calibration.

Data Calculation and Analysis

The simulations in this study are divided into 3 simulations which will be used to obtain quality results and capacity according to the Ciliwung River Table 1. Based on Government Regulation Number 22 of 2021 concerning Implementation of Environmental Protection and Management, that if the Government has not set water quality surface water bodies, class 2 quality standard attachment VI is used in Government Regulation Number 22 of 2021 concerning Implementation of Environmental Protection and Management. Based on this, the Ciliwung River quality simulation technique is adjusted to class 2 water quality standards.

Table 1. Data simulation techniques.

No	Condition	Source of Pollutants	River Water Conditions
1	Existing	Existing	Model
2	Grade 2 quality standard	No burden	Model
3	Existing	Model	Grade 2 quality standards

The simulation used in this study is as follows:

1. Simulation 1
   In simulation 1, data on upstream water conditions and uncertain pollutant sources such as domestic waste loads are categorized as non-point sources whose discharge amount is based on the number of residents as well as point sources of pollutant sources from drainage channels and streams coming out of the Ciliwung River whose waste is directly to water bodies using existing data.
2. Simulation 2
   In simulation 2, the upstream data is adjusted to class 2 water body quality standards, while no pollutant load is considered to enter the water body. This serves to determine the self-purification process and the capacity of the river because there is no pollutant load that reduces quality.
3. Simulation 3
   In simulation 3, data on the existing Ciliwung River was carried out by conducting trial and error on pollutant sources (point sources) with the aim that along the flow of the Ciliwung River quality must meet class II water quality standards. The result of this simulation is to obtain a model for the quality of the Ciliwung River maximum pollution load with class II water quality standards.

The data is analyzed by comparing the value of the maximum pollution load with the initial (existing) pollution load, the value of the difference is the allocation of the available pollution load or which must be reduced if the existing conditions have exceeded the pollutant load capacity.

RESULT AND DISCUSSION

Ciliwung River Flow Data Segment IV

Table 2. Name tag of sampling locations.

No	Sampling Point	Coordinate	Name/Tag
1	Bridge of Pondok Rajeg - Bojong Pondok Terong	S: 6 O 26' 44.90” E:106 O 48' 46,22”	Reach A
2	GDC Bridge	S: 6 O 24' 41.40” E:106 O 49' 07,40”	Reach b
3	Cikumpa Downstream (Point Source)	S: 6 O 24' 07.66” E:106 O 49' 51,20”	Point Source 1
4	Panus Bridge	S: 6 O 23' 02.80” E:106 O 49' 54,59”	Reach C
5	Juanda Bridge	S: 6 O 23' 43.06” E:106 O 50' 20.76”	Reach D
6	Sugutamu Downstream (Point Source)	S: 6 O 22' 34.95” E:106 O 50' 32,53”	Point Source 2
7	UI Access PAL Bridge	S: 6 O 21' 16.23” E:106 O 50' 09,11”	Reach E

This study will analyze data on the Ciliwung River segment 4 along 20.89 kilometers in Depok City, starting from the border of Depok City - Bogor Regency as the upstream segment 4 of the Ciliwung River to the border of Depok City - South Jakarta City as the downstream segment 4 of the Ciliwung River. To facilitate the naming in this study, the dot naming was carried out which can be seen in Table 2. While the division of the river flow can be seen in Table 3.

Table 3. Distribution of river flows.

No	Streams	Distance from Downstream (Km)	Water Level	
			Upstream	Downstream
1	Stream 1 (Reach A - Reach B)	20.89 - 13.62	105.00	85.00
2	Stream 2 (Reach B - Reach C)	13.62 - 11.07	85.00	77.50
3	Stream 3 (Reach C - Reach D)	11.07 - 6.27	77.50	65.00
4	Stream 4 (Reach D - Reach E)	6.27 - 0.00	65.00	55.00

The distribution of river flow as in table 3 can be seen visually in Figure 3.

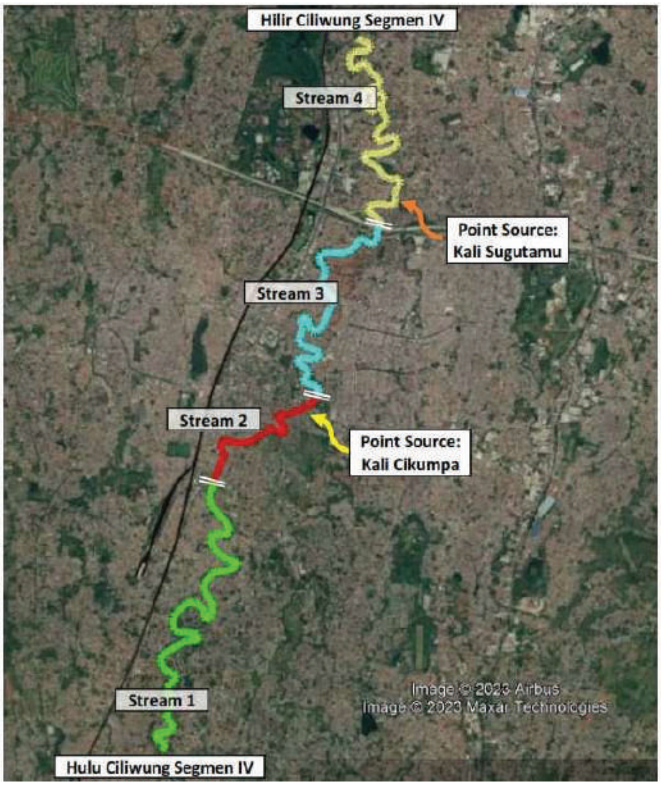

Figure 3. Distribution of the Ciliwung River Segment IV.

Description of Environmental Baseline for Research Locations

The environmental baseline provides an overview of the surrounding conditions and the condition of the river at the sampling points according to Table 3 on the Ciliwung River.

Reach point A, which is the upper reaches of the Ciliwung River segment IV, which is located between Pondok Rajeg Village and Bojong Pondok Terong Village, contains various types of plants. The riverbank area or commonly called the riverbank, around 50 to 150 meters, is filled with various kinds of plants which constitute a river buffer ecosystem to protect the river from landslides and other damage. The function of the riverbank ecosystem is to maintain the availability of groundwater, prevent flooding, windbreak, sediment catcher and as a partial cover of sunlight entering the river. The combination of humidity and atmospheric conditions makes it a comfortable place for various types of animals to breed. Plants found on the banks of the Ciliwung River include: bamboo trees, coconut trees, banana trees, melinjo trees, mango trees, breadfruit trees, kapok trees, as well as garden plants such as cassava and taro.

Reach point B is under the Grand Depok City (GDC) bridge, in this stream there are rocks in the middle of the river so that a natural aeration process occurs.

The banks of the river about 10 to 30 meters are covered with various types of trees, dominated by banbu trees on the banks of the river, besides that there are also kapok trees, coconut trees, banana trees and cassava. At this point there are still many long bamboo trees on the banks of the river which cover the banks of the river from the sunlight. The river water flow is quite clean, there is no garbage and the water looks quite clear. The GDC Bridge is a gathering place for the Ciliwung community and as a pier for rafting activities or river cruising using rubber boats which are usually carried out by the Ciliwung community together with the government or environmentalists.

Reach point C is under the Panus Bridge on the Iskandar Toll Road, at the sampling location on the bridge piers there is a water level gauge as an indicator of Jakarta's flood preparedness, which also has a monitoring post near the Panus Bridge. On the banks of the river near the Panus Bridge about 20 to 50 meters there are plants such as bamboo trees, kapok trees, coconut trees, banana trees, and jackfruit trees. At this point there are still many long bamboo trees on the banks of the river which cover the banks of the river from the sunlight. The water condition at this point looks still quite clear, but there is visible garbage stuck in the Panus bridge pillars.

Reach point D is under the Jalan Juanda toll bridge, with a riverbank of about 10 to 30 meters where various types of trees, especially bamboo, are grown, besides that there are also kapok trees, coconut trees, banana trees and various other gardens, as well as wild animals such as monitor lizards. At this point there are still many long bamboo trees on the banks of the river which cover the banks of the river from the sunlight. In this stream, the water is still quite clear. Under this bridge there is also a

Ciliwung community post and a wharf for rafting activities or river cruising.

Reach point E is under the PAL Access UI bridge, with a riverbank of about 10 to 20 meters where there are many residential areas on the riverbank. On the banks of the river are still dominated by bamboo trees, besides that there are also banana trees, kapok trees, and so on. On the bank of the river you can also see the life of yuyu (small crabs) and snakehead fish. At this point there are still long bamboo trees on the banks of the river which cover the banks of the stream from the sun.

Sampling Data and Test Results

Data from the sampling results can be seen in the Table 4.

Table 4. Field test results.

No	Sampling Point	Water Discharge (m^3/sec)	DO (mg/L)	Electrical Conductivity (µS/cm)	Air Temperature (°C)	Humidity (%)
1	Reach A	34,36	9,1	138.4	30,3	74
2	Reach b	48,20	8,4	151.0	30.5	71
3	Point Source 1	7,47	5,8	205.5	31,6	64
4	Reach C	57.85	9.0	156.8	31,2	66
5	Reach D	23.55	7,5	147,6	32,8	72
6	Point Source 2	2,26	6,6	348.9	32,1	69
7	Reach E	27,74	7,4	160.2	31,2	67

Table 5. Test results in the laboratory.

No	Sample	Temperature (°C)	TSS (mg/L)	pH	COD (mg/L)	BOD (mg/L)
1	Reach A	25.5	26,8	8.00	7,9	4,8
2	Reach b	25.0	18,4	7,73	14,7	9,2
3	Point Source 1	28.0	11,4	7,25	20,2	12.0
4	Reach C	26.0	24,7	7,42	7,2	4,2
5	Reach D	26.5	28,9	7,39	13,4	8,2
6	Point Source 2	30.0	18,4	7,44	18,7	11,2
7	Reach E	27.0	28,8	7,21	6,8	4.0

Table 6. Class II water quality standards based on Appendix IV PP RI No. 22/2021.

Name	Temperature (°C)	TSS (mg/L)	pH	DO (mg/L)	COD (mg/L)	BOD (mg/L)
Quality Standards Class II of River Water	-	50	6-9	4	25	3

Based on calculations using the Storet Method, the results show that the water quality status of segment IV Ciliwung River is lightly polluted.

Modeling using Qual2Kw software, the river water discharge model is obtained as follows.

Based on the Figure 4 from point 3 to point 4 there is a decrease in discharge, this happens because at that location there is surface water taking from the Ciliwung River as PDAM raw water.

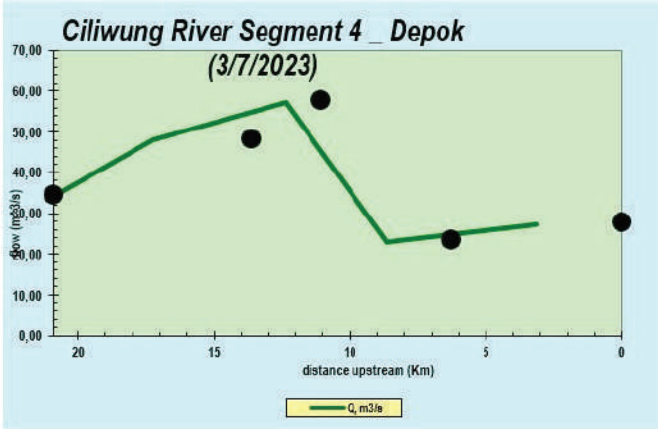

Figure 4. Results of river discharge model calibration.

Simulation 1

Based on the results of simulation 1, the graphs in Figure 5 to Figure 9 are obtained as follows:

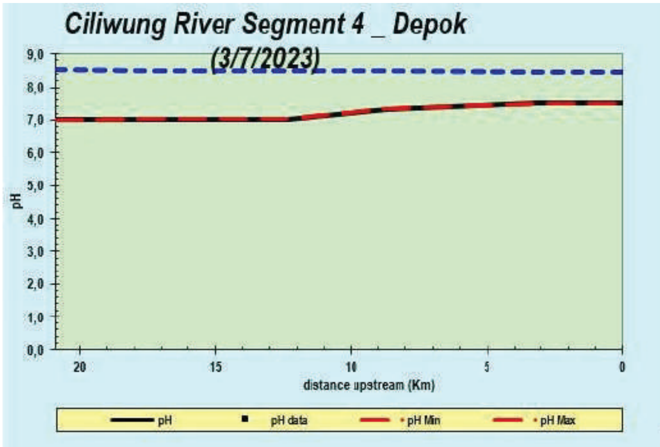

Figure 5. Graph of pH value (simulation1).

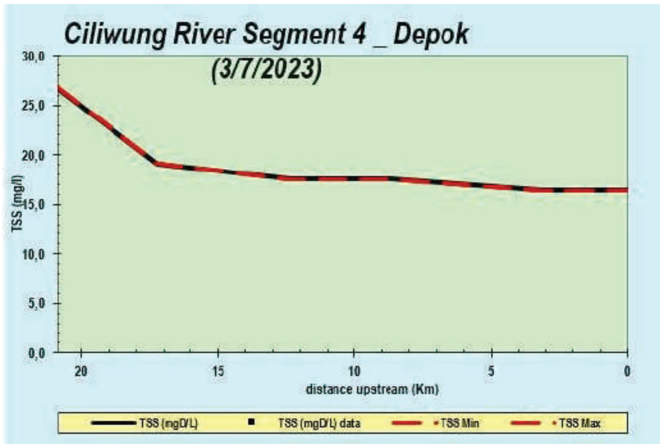

Figure 6. Graph of TSS values (simulation1).

In Figure 5 and Figure 6 it can be seen that the pH and TSS parameters meet the quality standards.

In Figure 7 it can be seen that the DO value meets the quality standard (DO value above 4 mg/l), but there is a DO value that exceeds the DO Saturated value. This can occur due to turbulence in the water during sampling.

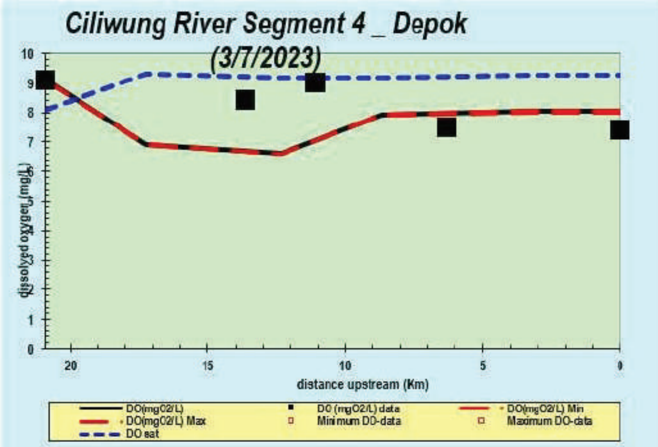

Figure 7. Graph of DO values (simulation 1).

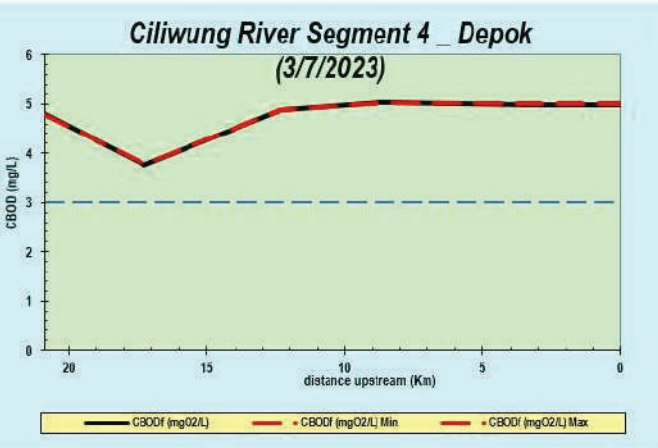

Figure 8. Graph BOD of values (simulation1).

The Figure 8 shows that the BOD value exceeds the quality standard, which is more than 3 mg/l. fluctuations occur due to pollutant loads that enter the river flow.

As for the COD value, based on Figure 9, it can be seen that the COD value fluctuates due to pollutant loads that enter the river flow, but the COD value still meets the quality standard, which is 30 mg/l.

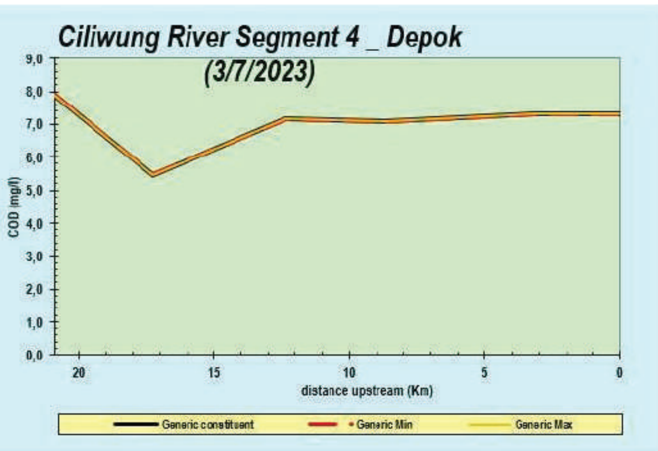

Figure 9. Graph of COD values (simulation1).

The results of simulation 1 obtained Water Quality Output data on the WQ Output sheet with the following Table 7.

Table 7. WQ output of simulation results 1.

STREAM	TSS (mgD/L)	DO (mgO2/L)	CBODf (mgO2/L)	COD (mgO2/L)
STREAMS 1	26.80	8.00	4.80	7.90
STREAMS 2	19.10	6.91	3.05	5.47
STREAMS 3	17.54	6.62	3.97	7.16
STREAMS 4	17.54	7.94	3.82	7.09
Terminus	16.37	8.03	3.13	7.30

Simulation 2

Based on the results of simulation 2, we get a graph like Figure 10 to Figure 12.

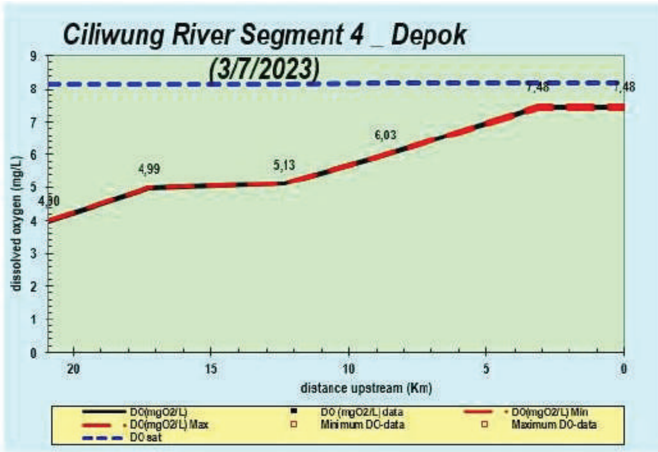

Figure 10. Graph of DO value (simulation 2).

Based on the Figure 10, it can be seen that in the absence of incoming pollutant loads, the DO value continues to increase close to the DO Saturated condition.

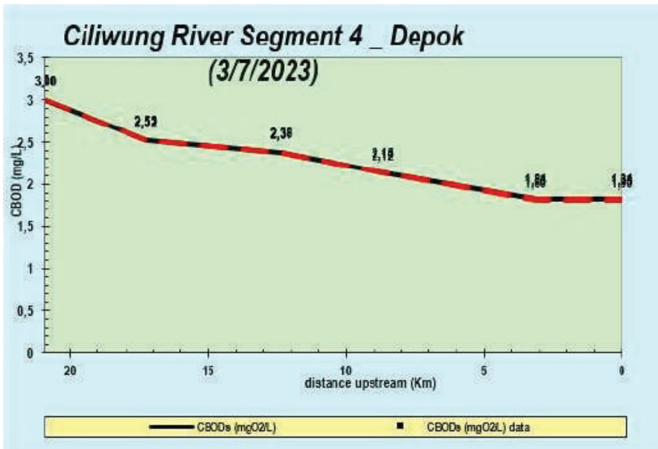

Figure 11. Graph of the BOD value (simulation 2).

Based on the Figure 11, it can be seen that in the absence of incoming pollutant loads, the BOD value will continue to decrease, this occurs due to the ability of water to *self-purify*. It can be calculated that the decrease in BOD levels along the Ciliwung River segment IV in Depok City is 38.67%.

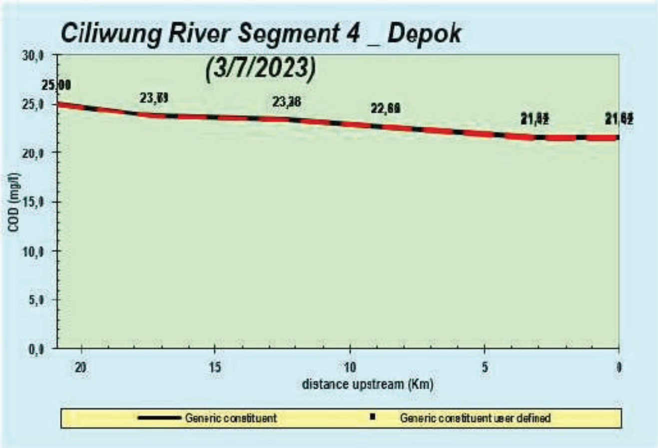

Figure 12. Graph of COD values (simulation 2).

As for the COD parameter, based on Figure 12, it can be seen that in the absence of incoming pollutant loads, the COD value will decrease and it can be calculated that the reduction in COD levels is 13.44%.

Simulation 3

Based on the results of simulation 3, the results are as follows:

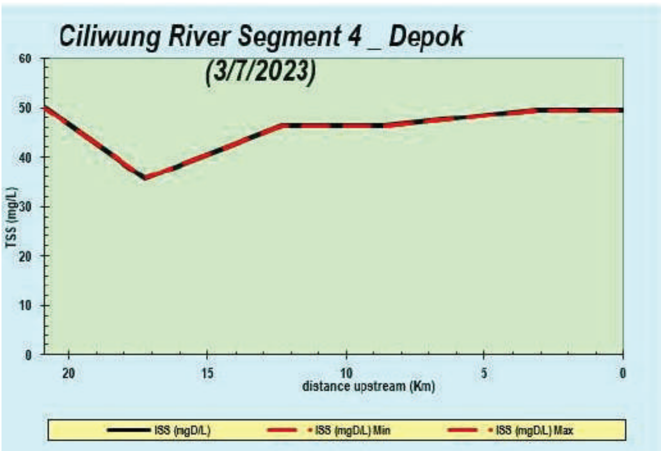

Figure 13. Graph of TSS values (simulation 3).

The Figure 13 is obtained based on *trial and error* of pollutant sources (*point sources*) where optimum conditions with the target of meeting class II water quality standards are obtained from the set point at point source 1 with a TSS concentration of 11.40 mg/l and point source 2 with a TSS concentration of 18. 40 mg/l.

Figure 14 is obtained based on *trial and error* of pollutant sources (*point sources*) where optimum conditions with the target of meeting class II water quality standards are obtained from the set point at point source 1 with a BOD concentration of 12 mg/l and point source 2 with a BOD concentration of 4 mg/1 l.

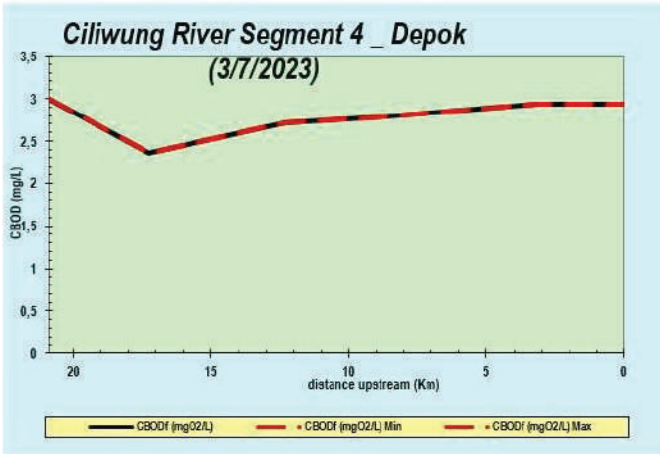

Figure 14. Graph of BOD value (simulation 3).

The simulation results for the COD parameter can be seen in the figure above obtained based on *trial and error* of pollutant sources (*point sources*) where the optimum conditions with the target of meeting class II water quality standards are obtained from the set point at point source 1, the COD concentration is 20.20 mg/l and point source 2 COD concentration of 18.70 mg/l.

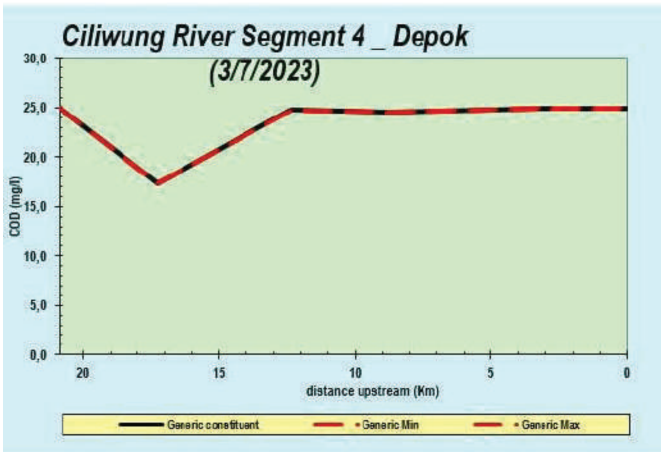

Figure 15. Graph of COD values (simulation 3).

Table 8. WQ output of simulation results 3.

STREAM	TSS (mgD/L)	DO (mgO2/L)	CBODf (mgO2/L)	COD (mgO2/L)
STREAMS 1	50.00	4.00	3.00	25.00
STREAMS 2	35.64	4.01	2.36	17.32
STREAMS 3	46.24	4.01	2.71	24.74
STREAMS 4	46.24	6.74	2.79	24.51
Terminus	49.50	7.56	2.93	24.88

Pollutant Load Capacity

Calculation of pollutant load carrying capacity using WQ Output simulation data 3 in Table 8, these results are the maximum concentrations that can be accommodated in river water flow with the target of meeting class II water quality standards, from these results to calculate the pollutant load capacity is calculated by the following formula:

Capacity Pollutant Load = Concentration x Discharge

Discharge data can be seen in Table 4, and for unit conversion in this calculation it is known that:
1 mg/second = 86.40 KG/day, so the calculation results for Pollutant Load Capacity are obtained in Table 9 as follows:

Table 9. Pollutant load capacity.

STREAM	debit (m^3/sec)	Distance (km)	TSS (kg/day)	BOD (kg/day)	COD (kg/day)
STREAMS 1	34,36	20.89 - 13.62	148435.20	8906.11	74217.60
STREAMS 2	48,20	13.62 - 11.07	148422.07	9828.17	72128.79
STREAMS 3	57.85	11.07 - 6.27	231118.62	13545.23	123656.46
STREAMS 4	23.55	6.27 - 0	94085.45	5676.87	49870.99

Pollutant Load Allocation

Calculation of pollutant load allocation using the results of simulation 1 and simulation 3, from these results it can be calculated the difference between the maximum pollutant load (simulation 3) and the pollution load of the existing initial conditions (simulation 1) in each Ciliwung River water flow with the following formula:

Pollutant Load Allocation	=	Maximum Pollutant Load	-	Existing Pollutant Load

Based on the results of Simulation 1 and Simulation 3 it can be seen that the Existing Pollutant Load can be seen in Table 9 and the Maximum Pollutant Load can be seen in Table 9, so that the concentration of pollutant load allocation can be calculated with the results shown in Table 10.

Table 10. Difference of WQ output of simulation 1 and simulation 3.

STREAM	Distance (km)	TSS (mgD/L)	CBODf (mgO2/L)	COD (mgO2/L)
STREAMS 1	20.89 - 13.62	23.20	-1.80	17.10
STREAMS 2	13.62 - 11.07	16.54	-0.69	11.85
STREAMS 3	11.07 - 6.27	28.70	-1.26	17.58
STREAMS 4	6.27 - 0	28.70	-1.03	17.42

The results above are concentrations that can still be accommodated in river water flow, from these results to calculate the allocation of pollutant loads is calculated using the following formula:

Allocatio of Pollutant Load	=	Concentration x Discharge

Discharge data can be seen in Table 4, and for unit conversion in this calculation it is known that:
1 mg/second = 86.40 KG/day, so the calculation results for Pollutant Load Capacity are obtained in Table 11.

Table 11. Allocation of pollutant loads.

STREAM	debit (m^3/sec)	Distance (km)	TSS (kg/day)	BOD (kg/day)	COD (kg/day)
STREAMS 1	34,36	20.89 - 13.62	68873.93	-5343.67	50764.84
STREAMS 2	38,2	13.62 - 11.07	68860.85	2865.65	49357.32
STREAMS 3	57.85	11.07 - 6.27	143441.96	6310.12	87876.04
STREAMS 4	23.55	6.27 - 0	58393.41	2103.94	35444.24

Based on the Table 10, it can be seen that the BOD parameter is negative (-) this indicates that the pollutant load capacity of the BOD parameter has been exceeded.

Water Pollution Control Strategy

Based on the calculation results of the pollutant load carrying capacity and load allocation, it can be seen that the pollutant load capacity of the Ciliwung River segment IV Depok City for the BOD parameter has been exceeded, so efforts are needed to reduce the pollutant load entering the Ciliwung River, especially the BOD parameter.

Strategies that can be carried out by the Government include:

1) Build a communal domestic wastewater treatment plant to treat domestic wastewater in the Ciliwung watershed area at various points where the flow empties into the Ciliwung River.
2) Relocating businesses and/or activities on the banks of the Ciliwung river into 1 location provided by the Government along with its wastewater treatment plant.
3) Returning the width of the river bank to its normal condition, which is 50 meters, and carrying out land acquisition that is in line with the river.
4) Make an inspection road on the bank of the river.
5) Conduct patrols and educate the public not to throw garbage into the river.
6) Installing CCTV cameras at several points on the Ciliwung River.
7) Doing greenery around the Ciliwung River.
8) Legal education and socialization related to water pollution control for business actors and the community.

CONCLUSION

Based on the results of the study it can be concluded that:

1. The water quality status of the Ciliwung River segment IV in Depok City is Lightly Contaminated.
2. Ciliwung River Pollution Load Capacity IV segment Depok City based on TSS, BOD and COD parameters with reference to class II river water quality, the following results are obtained:
   a) In Stream 1 (20.89 – 13.62 Km), with a discharge of 34.36 m3 / second, the pollutant load carrying capacity for the TSS parameter is 148,435.20 kg/day, the BOD parameter is 8,906.11 kg/day and the COD parameter is 74,217.60 kg/day.
   b) In Stream 2 (13.62 – 11.07 Km), with a discharge of 48.20 m3 / second, the pollutant load carrying capacity for the TSS parameter is 148,422.07 kg/day, the BOD parameter is 9828.17 kg/day and the COD parameter is 72,128.79 kg/day.
   c) At Stream 3 (11.07 – 6.27 Km), with a discharge of 57.85 m3 / sec, the pollutant load carrying capacity for the TSS parameter is 231,118.62 kg/day, the BOD parameter is 13,545.23 kg/day and the COD parameter is 123,656.46 kg/day.
   d) In Stream 4 (6.27 – 0 Km), with a discharge of 23.55 m3 / second, the pollutant load capacity for the TSS parameter is 94,085.45 kg/day, the BOD parameter is 5,676.87 kg/day and the COD parameter is 49,870.99 kg/day.
3. Allocation of Pollutant Load in Ciliwung River segment IV in Depok City based on TSS and COD parameters with reference to class II river water quality, the following results are obtained:
   a) In Stream 1 (20.89 – 13.62 Km), with a discharge of 34.36 m3 / second, the pollutant load allocation for the TSS parameter is 68,873.93 kg/day and the COD parameter is 50,764.84 kg/day.
   b) In Stream 2 (13.62 – 11.07 Km), with a discharge of 48.20 m3 / second, the pollutant load allocation for the TSS parameter is 68,860.85 kg/day and the COD parameter is 49,357.32 kg/day.
   c) In Stream 3 (11.07 – 6.27 Km), with a discharge of 57.85 m3 / second, the pollutant load allocation for the TSS parameter is 143,441.96 kg/day and the COD parameter is 87,876.04 kg/day.
   d) At Stream 4 (6.27 – 0 Km), with a discharge of 23.55 m3 / sec, the pollutant load carrying capacity for the TSS parameter is 58,393.41 kg/day and the COD parameter is 35,444.24 kg/day.

As for the BOD parameter, the pollutant load carrying capacity has been exceeded so that there is no longer any allocation of pollutant load, and efforts must be made to reduce the pollutant load for the BOD parameter as follows:

a) In Stream 1 (20.89 – 13.62 Km), with a discharge of 34.36 m3 / second, the excess pollutant load for the BOD parameter is 5,342.67 kg/day.
b) In Stream 2 (13.62 – 11.07 Km), with a discharge of 48.20 m3 / second, the excess pollutant load for the BOD parameter is 2,865.65 kg/day.
c) In Stream 3 (11.07 – 6.27 Km), with a discharge of 57.85 m3 / second, the excess pollutant load for the BOD parameter is 6,310.12 kg/day.
d) In Stream 4 (6.27 – 0 Km), with a discharge of 23.55 m3 / second, the excess pollutant load for the BOD parameter is 2,103.94 kg/day.

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