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MORALITY BEFORE KNOWLEDGE

Disaster from water pollution in Indonesia: Unsustainable human interaction with the environment and its social impacts

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ABSTRACT
Background: Water is a vital global resource, available in forms such as surface water and groundwater. Human activities, particularly increased population, have led to unsustainable water use, causing pollution in rivers, lakes, and oceans. In Indonesia, water resources, including in Muara Teluk Jakarta, are polluted by organic, inorganic, chemical, and plastic pollutants, especially microplastics and debris. **Method:** This study uses a qualitative approach with secondary data from journals and water quality reports by DKI Jakarta Environmental Agency. The research involves classifying topics, analyzing human-environment interactions, and reviewing water quality data to assess pollution levels using the water quality index (WQI). The findings aim to inform effective water treatment strategies and policies for addressing water pollution in Indonesia. **Findings:** The study and data analysis of sea water quality of Muara Teluk Jakarta index trends from 2017-2023 show that conditions fluctuated in the 2017-2023 range but heavily polluted condition. These water pollution problems need appropriate and proper management to reduce pollutes and increase water quality from biological, chemical, or physical properties. Well water management with customized condition will be very effective as one of solution for clean water supply and solution for sustainable water management in Indonesia. **Conclusion**: Effective water management strategies tailored to specific local conditions are essential to mitigate pollution and improve water quality in Indonesia. Sustainable water management is crucial for ensuring clean water supplies. **Novelty/Originality of this article:** This study highlights the persistent water pollution in Muara Teluk Jakarta, particularly from plastic and chemical contaminants, and the need for technological solutions to address water quality issues. It offers a practical approach to sustainable water management by exploring innovative methods to reduce pollution and improve water quality in Indonesia.

KEYWORDS: utilization; natural resources; pollution; water management; water resources.

1. Introduction

Interaction is a reciprocal process between two or more entities in which each entity influences the other. These can be interactions between people, between people and their environment, or between different components in a system. Human life runs in the middle of the flow of life and the universe. On the way, a conflict arises between experiences that occur in human consciousness (immanent) and those that exceed human understanding or capabilities (transcendent). Human beings are faced with the task of adapting to their surrounding environment while having the ability to assess and change it (Peursen, 1988). In evaluating and interpreting their environment, both as individuals and

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as part of a social group, human beings adjust to the norms and value systems adopted. The human being, who is also a thinking being, hasperceptions and makes decisions in his interactions with the environment. This relationship between humans and the environment is not simple, but tends to be seen as a complex mechanism and is influenced by probability (Setiawan, 2010).

The understanding of the environment involves the interaction between the environment and humans that influence each other. The environment in which we live and work has an impact on our thoughts, feelings and behavior. Humans, as a result of organic evolution, have managed to survive by adapting themselves to the environment consciously, even changing it for their needs. These changes area major indication of human evolution. However, due to the complexity of cultural evolution, man as a product of organic evolution sometimes perceives the environment as something alien. The existence of a dichotomy between the body (organic evolution) and the mind (cultural evolution) results in the interesting, butlimited, understanding that the environment is what determines the human being. The relationship between humans and the environment is mutual influence, where humans are influenced by the environment and vice versa. Understanding this relationship involves paradoxes and debates that have existed from ancient to modern times (Ratnasari & Dwisusanto, 2024).

The influence of the environment on man is real, but man is not a passive entity influenced only by the environment. They have the freedom to choose and act in interaction with the environment. Humans also bring changes to the environment through the development of technology. However, the relationship between technology, the environment and people is complex and multifaceted. Lewis (2012) notes that although technological advances bring benefits, they also have the potential to pose great risks to the environment and society, for which human beings often do not take into account the environmental balance. The root of this imbalance is often a philosophical problem facing Man. With the revolution in science, technology, and capitalism, human priorities and mentalities tend to focuson existential and commodification, leading to drastic changes in the relationship between humans and the environment. In addition, the lack of awareness, understanding, and knowledge to explore technology also seems to be the cause ofless environmentally friendly activities (Pereira & Forster, 2015).

One of the most common natural resources which used by people globally and also in Indonesia is Water. Water is one of the main components that form life on Earth. According to Multazam et al. (2023), water is a basic human need. Apart from air, water is also among the most important daily needs required for the existence of living things. This natural resource is increasingly worrying about its existence from time to time. The quality of groundwater in nature varies both in space and time mainly due to the influence of human activities, rock types, topography, and also land use in that place.Water resources are a basic human need to sustain life. Water plays an important role in various needs and uses, such as domestic and industrial needs. Clean water is a basic need that cannot be replaced and abandoned, therefore processing and preserving water is absolutely necessary. High demand for water, higher living standards, low acceptable quality of resources, water pollution by urban, agriculture and industry have caused the environmental degradation (Karamouz et al., 2020). The increase of population will cause an increase in the potential amount of water use. As the population increases, the need for drinking water also increases. This increase in water demand is not accompanied by the availability of adequate raw water in quantity and quality. These environmental challenges can be attributed to rapid and unplanned urbanization involving the conversion of the land surface into impervious surfaces to accommodate a burgeoning urban population that, in turn, modulates the land surface energy balance (Duveiller et al., 2018; Imhoff et al., 2010). These urban environmental problems have direct consequences in the areas of public health and costs to society. For example, more than 166,000 people died due to heatwaves during 1998–2017, and around 6.1 million deaths around the world were attributable to diseases directly associated with air pollution in 2016. Water pollution is also a significant risk factor for human health (Babuji et al., 2023; Kumar et al., 2023; Münzel et al., 2023). Surface water environment is a major concern for water pollution control (Kumar et al., 2023; Zhou et al., 2021).

In the last decades, a growing number of studies have examined the accumulation of heavy metals in coastal areas, with a focus on mercury (Hg) in America, cadmium (Cd) in China and India, plumbum (Pb) in western Europe and Australia. Chromium (Cr) and copper (Cu) worldwide, prompted by an increase in anthropogenic pressure arising from land-based activity (Li et al., 2022). Pb, Cr, and Cd are non-essential metals that have an unknown biological function, are toxic, persistent, and accumulate in organisms (Fatima et al., 2020). A recent study by Watanabe et al. (2020) explained the relationship between cancer mortality and Cd exposure in the Japanese population. Cd is also known to be responsible for cancer, DNA mutations, reproductive abnormalities, infertility, enamel development, dental caries, and bone metabolism disease (Rasin et al., 2025). Pb affects the health of the liver, bones, kidneys, nerves, brain, circulatory system, neurological system disorders, and reproductive organs (Fatima et al., 2020; Zaynab et al., 2022).

Increasing demand for water, higher standards of living. Recent comprehensive studies underscore the far-reaching impacts caused by human actions, highlighting issues such as climate change, water pollution, resource depletion, and ecological decline (Zhou & Gu, 2024; Guo & Lin, 2016). Researches show that uncontrolled environmental damage will have a negative impact on the world's climate system, which will not only impact the environment and human health, but can also give rise to major socio-economic challenges (Bolan et al., 2024). This clearly shows that there is a complex interaction between human actions and the environment as a result of human dependence on natural resources to meet their needs.The town's rapid spatial expansion and population growth have created a noticeable disparity, especially concerning water supply and quality. Despite the town's physical growth, the corresponding expansion of water supply services or improvement in water quality has not kept pace with the increasing demands of the growing population.

Since, the water used in many activities such as drinking, cooking, bathing and cleaning or other daily activities. So, this paper will discuss specifically about human interaction with water as one of natural resources, water pollution and its impact to social life in Indonesian society. As a result, this paper can be use as one of reference for study of water condition in Indonesia. The study will produce qualitative condition and information of Indonesia water resources as study for better sustainable human interaction with water resources. Furthermore, this paper will be significant for academic purposes in terms of water pollution and its social impact in Indonesia.

2. Methods

The The materials used in this paper are materials related to water resources in Indonesia, their use and the damage caused by the actors involved in it, be it the government, industrial companies and the community.This research uses a qualitative approach by collecting secondary data in the form of monitoring data from Journal, Jakarta water quality parameters in 2023 carried out by the DKI Jakarta Provincial Environmental Agency and related agency in Indonesia. The method used in this paper using a qualitative approach to methods explanatory by applying the study literature with the aim of identification, analysis and evaluation process critically and systematically on relevant research. The primary Data used comes from trusted books or journals through digital searches. The stages used in this paper are the classification process of research topics in accordance with the discussion of papers with sub-topics, which include: The stages used in this research are the process of classifying research topics in accordance with the discussion of the paper with sub-discussions, which include: 1) Human Interaction with the Environment, 2) Water Resources 3) Collection of data from water quality monitoring and 4) Collection data and studies from previous scientific journals that are relevant to analyzing an event including the impact on public health. The water quality index is a mathematical mechanism for calculating water quality data into simple terms, for example good condition, lightly polluted, moderately polluted and heavily polluted. Water quality classes are defined depending on the physical, biological and chemical parameters measured in addition to the water used for purposes such as drinking water, water for agriculture, water for industry. This index data is important to describe the general water quality status which can be very helpful in choosing appropriate water treatment techniques to overcome contamination problems.

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3. Results and Discussion

Jakarta, the capital of Indonesia, is currently encountering various difficulties connected to global challenges such as climate change, rapid urbanization, and environmental deterioration. In Jakarta, a multitude of challenges converge, encompassing recurrent flooding intensified by rising sea levels and diminished green spaces, land subsidence stemming from excessive groundwater extraction, substantial air pollution emitted by vehicular and industrial emissions, traffic congestion aggravated by a densely populated urban landscape, critical solid waste management dilemmas with limited sustainable disposal avenues, the urban heat island effect elevating city temperatures compared to surrounding areas, and water pollution compromising the quality of life for millions of residents, further exacerbated by limited access to clean water sources. These complex issues underscore the imperative for comprehensive and sustainable strategies to mitigate the city's environmental and urban challenges while ensuring the well-being and health of its inhabitants. During the Jakarta flood of 2020, over 173,000 individuals had to be evacuated, 66 lives were lost, more than 60% of residential areas were submerged, and the economic damages surpassed US$700 million (Indra et al., 2022). The research conducted by (Purba et al., 2023) provides important findings, revealing that about 45-90% of Jakarta's shallow groundwater is polluted with Escherichia coli (E. coli) bacteria. This contamination stems from untreated household waste, which includes detergents, bathing water, home industry activities, cooking, cleaning, and outdoor activities. The study by Syuhada et al. (2023) provides essential statistics on air pollution in Jakarta, revealing it causes over 7,000 negative health effects in children, more than 10,000 deaths, and over 5,000 hospitalizations each year. Additionally, research by (Zulfikri, 2023) that the levels of particulate matter and nitrogen dioxide in Jakarta surpass the World Health Organization's guidelines, highlighting the critical nature of the city's air pollution problem. These challenges underscore the urgent need for comprehensive and sustainable solutions to address Jakarta's urban and environmental issues, safeguarding the well-being of its residents and ensuring the city's resilience in the face of ongoing global changes.

3.1 Water resources, utilization, pollution and social impacts in Indonesia

Indonesia, in Southeast Asia, is the world's largest archipelagic country, comprising over 17,000 islands, including five large islands (Java, Sumatra, Sulawesi, part of Borneo, and New Guinea). Indonesia has a population of 268 million as of 2019 (BPS, 2020). As a tropical country straddling the equator, Indonesia has two seasons: rainy and dry. BMKG (2021) reported three rainfall patterns in the rainy season (monsoonal, equatorial, and local). The monsoonal rainy season generally occurs from October to March, when the monsoonal wind blows from the Pacific Ocean to Australia. This different season will effect to water condition and supply in Indonesia.

Water is one of the main components that form life on Earth. According to Multazam et al. (2023), water is a basic human need. Apart from air, water is also among the most important daily necessities required for the existence of living things. This natural resource is increasingly worrying about its existence from time to time. The quality of groundwater in nature varies both in space and time mainly due to the influence of human activities, rock types, topography, and also land use in that place. According to Sunarsih et al. (2023) stated that water is one of the most important factors for the life of every creature to maintain its life. Water has many benefits for washing, cooking, bathing, and drinking. There are 18 sampling parameters for monitoring used to determine water quality based on the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017 concerning environmental health quality standards and water health requirements for sanitary hygiene purposes, namely odor, TDS, turbidity, taste, temperature, color, iron, detergent, total pesticides, chloride, hardness ($CaCO_3$), manganese, nitrate as N, nitrite as N, pH, cyanide, total coliform, and e. coli. Coli.

There are some researches that has been conducted to see the condition of water resources, especially of its use and pollution in Indonesia. Al Afghani & Sari (2022) conducted research on well water, focusing on its usage by residents of Cikedokan Village for sanitary hygiene purposes. Despite the utilization of clean water from boreholes, there was a lack of information regarding the water's quality and dissolved solids content. Therefore, there was a need to assess the quality of borehole water, with a particular focus on hardness levels as a chemical parameter. The study utilized the Inductively Coupled Plasma method to determine the content of Ca_2+ and Mg_2+. Sampling was conducted at 15 coordinate points, revealing that 73.33% of the samples fell within the medium hardness criteria (50-150 mg/L), 20% fell within the soft criteria, and one sampling point indicated hard water with a value of 162 mg/L. Laboratory testing for sulfate parameter resulted in 51.3 mg/L. Overall, the analysis concluded that the majority (93%) of the clean water samples from the 15 locations met the quality standards outlined in the Minister of Health Regulation Number 32 of 2017. Utami et al. (2020) conducted research to evaluate the use of utilization data, runoff modeling, and effect prediction to determine pesticide pollution in the Citarum River using predicted and measured concentrations in the Citarum pollution regimes. A significant advantage of this new approach is its independence from measured concentration data, which is often difficult to obtain in resource-constrained regions such as Indonesia. This method was used to prioritize 31 agricultural pesticides used in the Upper Citarum River Watershed in West Java, Indonesia. The ranking of pesticides based on projected concentrations was generally in line with the ranking derived from concentrations obtained through passive sampling. Predictions indicated negligible human health risks from individual pesticide intake through river water consumption, but significant aquatic risks (e.g. PEC/PNEC N1) were estimated for profenofos (5.2. E+01), propineb (3.6.E+01), chlorpyrifos (2.6.E+01), carbofuran (1.7.E+01), imidacloprid (9.4.E+00), methomyl (7.6.E+00), and chlorpyraniliprop (3.6.E+00). To protect the aquatic environment, water managers are advised to implement measures to reduce the use and runoff of these pesticides in the UCRB. In addition, screening assessments can be improved by conducting further effect studies on specific pesticides and mixtures, along with validating projected water concentrations through targeted measurements. Dewi et al. (2015) conducted a study focused on addressing issues within the Upper Citarum River Basin by gathering hydrological data. The Citarum River, situated in West Java, Indonesia, faces annual flooding during the rainy season owing to its location in mountainous highlands. Understanding the flood characteristics is crucial for preempting and minimizing flood-related damages. However, local regions often lack sufficient hydrological data. Hence, they proposed an approach utilizing satellite-derived rainfall data to estimate flood-prone areas. To replicate the significant flood event of 2010, they employed the Rainfall-Runoff-Inundation (RRI) Model, comprising two-dimensional models for rainfall-runoff and inundation. Input data encompassed a 15-second HydroSHEDS Digital Elevation Model (DEM) and satellite-derived hourly rainfall data (GSMaP), validated against daily observation records. The simulation outcomes were compared against discharge data observed at the Nanjung water level gauge station and the inundation area noted by the Upper Citarum Basin Flood Management (UCBFM) Team in 2010. While the simulated inundation area closely resembled the observed area, disparities in simulated discharge emerged due to uncertainties in observed discharge data and insufficient data for simulation purposes.

Furthermore, a study was conducted by Sule et al. (2025) on the Citarum watershed, identified as one of Indonesia's super critical watersheds due to severe environmental degradation. Acknowledging the intricate interplay among rural, urban, riverine, farmland, and forest ecosystems within the Citarum watershed, a holistic or ecosystem-based approach to its management was embraced. As part of comprehending this approach, an initial investigation into environmental toxicology in the Citarum watershed yielded significant findings. Elevated levels of nitrogen and phosphorus compounds in river water pose a eutrophication risk in the lower stretches of Saguling Lake. The rapid proliferation of the aquatic weed Eichhornia crassipes within Lake Saguling presents a substantial challenge, affecting the lake's diverse functions as a hydropower dam, fishing ground, tourist attraction, and source of drinking water. Environmental assessment has uncovered the presence of toxic substances, including metals and organochlorine pesticides. These pollutants pose a genuine threat to the sustainable development of aquaculture activities in Saguling Lake, which serves as a vital economic lifeline for rural communities. To provide actionable insights for policymakers regarding environmental management in the Citarum watershed, particularly concerning environmental toxicology (including the identification, fate, and impacts of toxic compounds in the environment), there is an urgent need to enhance capacity and knowledge through national and international collaborations. These findings underscore the necessity of adopting a comprehensive strategy and fostering cooperation at various levels to address the complex environmental challenges confronting the Citarum watershed.

Marselina et al. (2022) conducted a study on the water quality index (WQI) of the Citarum River, which provides an overview of the water quality status within a specific timeframe. The implementation of daily WQI assessments can enhance public awareness regarding surface water conditions in their vicinity. As the longest and largest river in West Java Province, the Citarum River plays a vital role in both human livelihoods and the surrounding ecosystem. Hence, this study aimed to evaluate the most suitable WQI assessment method for determining the water quality of the Citarum River. This research provides an overview of the water quality status within a specific timeframe. The implementation of daily WQI assessments can enhance public awareness regarding surface water conditions in their vicinity. As the longest and largest river in West Java Province, the Citarum River plays a vital role in both human livelihoods and the surrounding ecosystem. Hence, this study aimed to evaluate the most suitable WQI assessment method for determining the water quality of the Citarum River.The researchers utilized monitoring data from four stations along the Upper Citarum, collected by the West Java Province monitoring program. They employed three assessment methods: the National Sanitation Foundation WQI (NSF WQI), the Canadian Council of Ministers of the Environment WQI (CCME WQI), and the Oregon Water Quality Index (OWQI). Analysis encompassed nine years of data, categorized by wet vs. dry months, wet vs. dry years, monitoring station, and year.Results from the NSF WQI assessment indicated that the Citarum River exhibited 'Fair' and 'Poor' water quality scores, with WQI values ranging between 38.212 and 60.903 during dry months, 49.089 and 62.348 during wet months, 42.935 and 65.696 during dry years, and 39.002 and 58.898 during wet years. The CCME WQI assessment revealed 'Fair', 'Marginal', and 'Poor' water quality classifications, with WQIs ranging between 12.683 and 31.503 during dry months, 21.231 and 33.127 during wet months, 12.134 and 28.748 during dry years, and 13.621 and 30.569 during wet years. Meanwhile, the OWQI assessment method assigned a 'Very Poor' water quality rating to the Citarum River, with WQIs ranging between 11.528 and 18.827 during dry months, 13.898 and 24.563 during wet months, 11.528 and

25.782 during dry years, and 11.528 and 15.997 during wet years.Considering these findings and the strengths and weaknesses of each method, the NSF WQI assessment method is deemed the most suitable for evaluating the water quality of the Citarum River.

Cordova et al. (2022) conducted a study focusing on macrodebris and microplastic content within the flow of the Citarum River. Their findings revealed that based on in-situ monitoring data, macro and microplastic debris along the Citarum River had already reached supercritical levels in Indonesia. Dams were identified as the areas with the highest concentration of microplastics. Plastics constituted 85% of the debris in the river, totaling 5,369 ± 2,220 items or 0.92 ± 0.40 tons per day. The researchers estimated a daily discharge of 6043 ± 567 items or 1.01 ± 0.19 tons of macro-waste, with a microplastic concentration of 3.35 ± 0.54 particles per m3 from the Citarum River to the sea. Additionally, the study found that population density and urbanization level were the primary factors determining the spatial variation of macrodebris and microplastics in the Citarum River. These findings underscore the significance of long-term monitoring for estimating debris and microplastic flow along Indonesian rivers to the global ocean, serving as a benchmark for reducing macro- and micro-waste in the environment. Plastic waste in debris and microplastic form already been one of pollution in Indonesia water resources, especially in river that already been discussed above from Cordova et al. (2022). This plastic pollution will also discussed as study case in sub chapter below as study case of water pollution in Muara Teluk Jakarta which data taken from DKI Jakarta Provincial Environmental Agency.

3.2 Study case: Water pollution in Muara Teluk Jakarta

In Jakarta, rainfall may influence the amount of plastic debris in the surface water due to run off process from in raining season. The data is taken from DKI Jakarta Provincial Environmental Agency on 2023. The area study will be carried out in the Muara Teluk Jakarta area. Jakarta is an area with a high population density, this also encourages the government to provide water resources. Groundwater used by the community must of course have sufficient discharge and good quality. High population density will lead to predicted declines in ground air quality. The decline in groundwater quality is estimated to be caused by community activities that are less wise in managing groundwater resources. Based on the results of the DKI Jakarta population census by BPS (2015), it is predicted that there will be an increase from 10.18 million people in 2015 to 10.37 million people in 2017, which means that in two years the population in DKI Jakarta is predicted to increase by up to reaching 269 people per day (Prakoso & Herdiansyah, 2019). This increase in population will then also be followed by an increase in people's need for clean water.

One of the areas targeted for development in the northern region of Jakarta is the coastal area. City facilities and infrastructure such as international ports, industrial areas, recreation areas and residential areas have been built, which is in accordance with the mandate in DKI Jakarta Provincial Regulation Number 1 of 2012 concerning the 2030 Regional Spatial Plan which states that coastal areas are transition areas between ecosystems. land and sea which have been influenced by changes occurring on land and sea in Jakarta which functions as a center for various anthropogenic activities, such as economics, industry, trade and transportation. However, the consequences that occur as a result of these activities actually make the coastal areas in DKI Jakarta more dominant as an environment that has been managed, utilized and also "damaged" (Indrasari, 2020). Jakarta's coastal areas are widely known as tourist attractions, as well as fishing and fishing. However, various tourism and industrial potentials in this coastal area are closed and the main problems in the area have not been resolved, one of which is the problem of the availability of clean water. And the coastal area which is currently still one of the areas vulnerable to experiencing a clean water crisis is the coastal area in Muara Teluk Jakarta. One of the studies conducted by Rachmawati on the Krukut river shows that the water quality in the Krukut river is terrible, with BOD levels ranging from 2.63-9.72 mg/L, which no longer meets the water quality standards of class I and class II. Furthermore, the water in the Krukut river does not meet thecriteria to drink as raw drinking water, and the level of COD ranges from more than 25 mg/L, which does not meet the standard quality. Recently, the city is facing solid and liquid waste problems, such as limited wastewater treatment plants (WWTP) and solid waste management. Nowadays, the capacity of WWTP facilities in Joint Management Arrangement (JMA) is only 6–10%. Furthermore, among the 7100 m3 solid waste/day produced in Jakarta City, approx. 5% (350 tons/day) are not collected and possibly leak to the rivers around Jakarta City (Media Jaya, 2020). Maisalda et al. (2024) also reported dissolved metal of Hg, Cu, Zn, Ni and Pb in Jakarta Bay from 13 river flows. In line with other studies, the DKI Jakarta Environmental Agency also stated that there was an increase in the pollution index in the Kamal estuary and Cilincing Estuary from 2005 to 2022 with light to moderate pollution levels (Jakarta Environmental Agency, 2022). Situated near city, Muara Teluk Jakarta has been recognized as anessential ecosystem for fishery, tourism, and sea transportation facilities that must be conserved from environmental pollution. The objectives of the research investigate the concentration of water pollution levels in Muara Teluk Jakarta and its risks to public health.

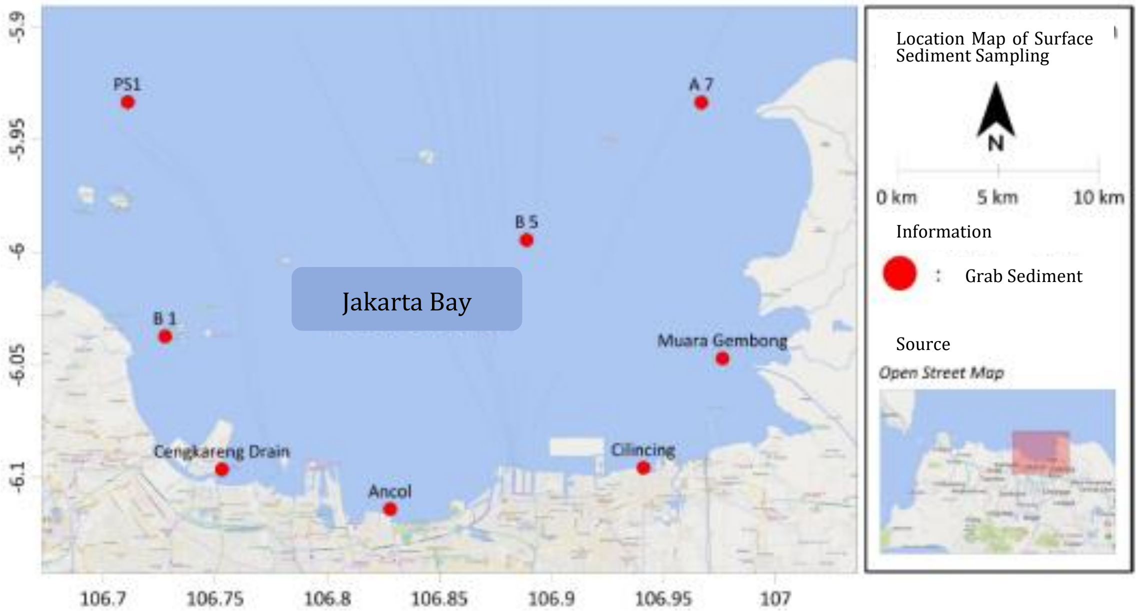

Fig. 1. Location and for water quality research point

Based on the data collected, the trend analysis of the water quality index in the estuary zone, beach and Gulf waters for the observation period 2017-2023 is presented in the tables below.

Table 1. Trends in the water quality index of tidal estuary zone for 2017-2023

Year	Kamal	Cengkareng	Angke	Karang	Pluit Pump	Ancol	Sunter	Cilincing	Marunda
2017	64.86	45.04	42.17	64.01	47.99	55.26	57.16	62.21	61.03
2018	74.03	55.42	67.48	61.39	53.01	66.91	56.20	54.26	58.45
2019	74.63	71.74	67.24	81.62	77.53	78.67	87.41	63.07	55.21
2020	40.43	-	-	64.81	48.18	-	47.77	57.97	-
2021	57.53	51.03	64.14	73.96	56.85	73.55	60.47	63.87	52.75
2022	72.27	42.89	31.06	74.26	58.64	77.79	52.79	67.81	71.75
2023	65.97	32.67	52.11	60.98	57.74	76.22	52.48	58.79	58.57

Based on Table 1, it is known that there has been a decline in water quality status since 2017. This was caused by a decrease in the percentage of water quality status since 2017 from moderate to poor status. The locations that showed the most significant changes were Cengkareng Drain, Cilincing, Pompa Pluit and Muara Angke. Changes in IKAL's status also occurred in 2019 for the better at several points including Ancol, Sunter, Muara Gembong, Pompa Pluit, Muara Karang, Cengkareng Drain and Muara Kamal. The status of IKAL in 2022 will relatively decrease in status compared to the previous year, such as in Cengkareng Drain and Muara Angke. Parameters that show large changes and fluctuations in the estuary zone are physical parameters and water fertility which include turbidity, TSS, nitrate, ammonia and phosphate.

Referring to Table 2, it is known that all observation locations in the Estuary zone at low tide have experienced a decline in water quality status since 2017. This can be seen by the decrease in the percentage of water quality status since 2017, which is marked by an increase in the percentage of water quality with moderate to poor status. The locations that showed the most significant changes were Marunda, Muara Angke, Cengkareng Drain and BKT.

Table 2. Trends the water quality index of estuary low tide zone 2017-2023

Year	Kamal	Cengkareng	Angke	Karang	Pompa Pluit	Ancol	Sunter	Cilincing	Marunda
2017	51.37	49.61	48.71	47.47	48.79	59.08	55.40	39.47	47.33
2018	74.35	50.35	57.29	74.05	68.88	77.25	57.92	54.25	64.17
2019	62.35	64.84	55.55	82.46	78.53	82.64	83.38	72.38	57.49
2020	40.43	-	-	64.81	48.18	-	47.77	57.97	-
2021	57.53	51.03	64.14	73.96	56.85	73.55	60.47	63.87	52.75
2022	74.43	39.23	28.09	66.59	63.26	70.86	53.17	62.41	66.40
2023	70.23	43.12	45.90	51.41	49.79	74.59	66.92	65.49	69.19

Referring to the Swedish Environmental Protection Agency (SEPA) in 2000, the quality standard for copper (Cu) concentration is 15 mg/kg. Meanwhile, according to the United States Environmental Protection Agency (US-EPA) in 2004 it was 49.98 mg/kg. Based on quality standard references from these two sources, it is known that at several observation points in periods 1 and 2, the quality standards have been exceeded. As can be seen in figure 2.

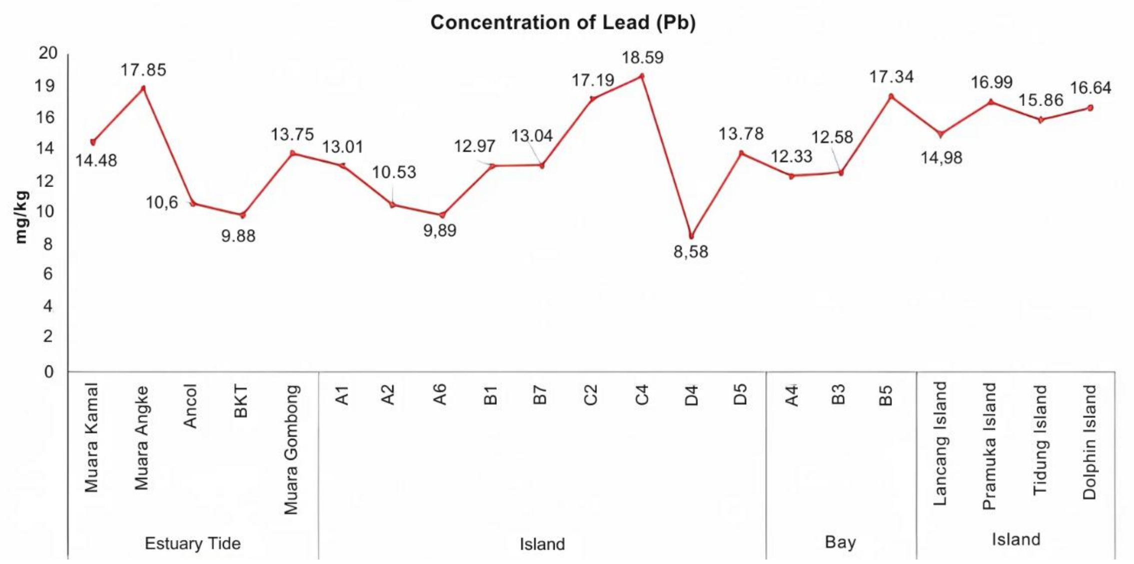

Fig. 2. Lead concentration in sediments period 1

Figure 2 above shows the concentration of lead (Pb) in the sediment of marine waters and the estuary of Jakarta Bay. Lead concentrations in period 1 ranged from 8.58-18.59 mg/kg. The highest concentration in period 1 was found at the C4 observation point at 18.59 mg/kg. Meanwhile, the lowest concentration was found at point D4 at 8.58 mg/kg.

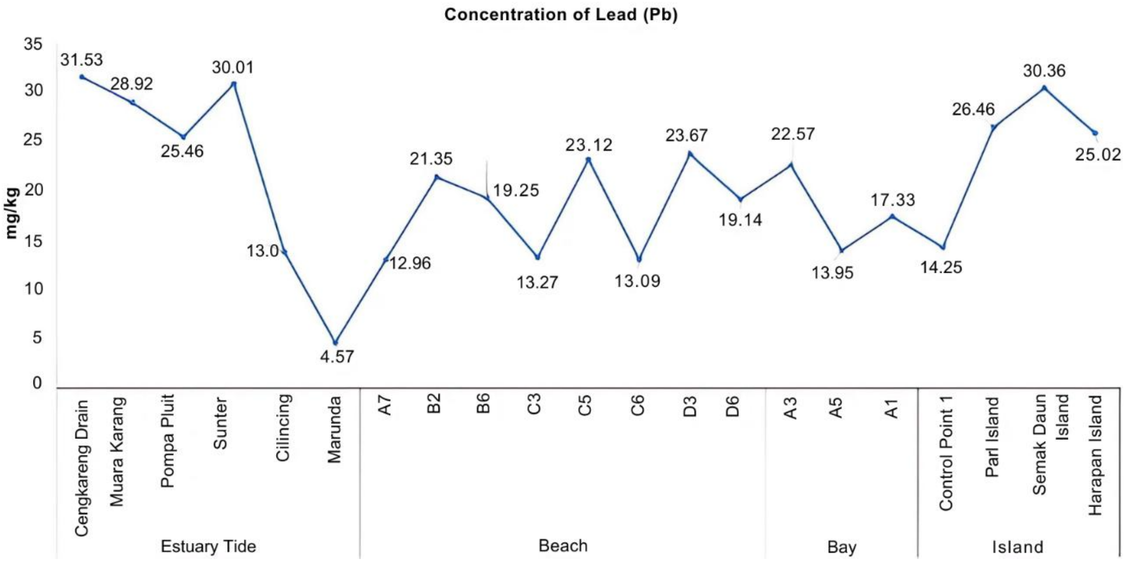

Fig. 3. Lead concentration in sediments period 2

Based on the reference for lead (Pb) concentration from the Swedish Environmental Protection Agency (SEPA) in 2000, it is 25 mg/kg. Meanwhile, the reference from the United States Environmental Protection Agency (US-EPA) in 2004 was 47.82 mg/kg. Referring to the quality standards from SEPA, it is known that the concentration of lead (Pb) in period 2 at several points has exceeded the quality standards.

The concentration of heavy metals in sediment is more constant than at sea level, which is complex and dynamic. Based on this, it is more possible to indicate the source of heavy metals in sediment compared to dissolved heavy metals. The potential sources of heavy metals in the waters of Jakarta Bay mostly come from land such as ports and industries (chemical, cat, textile and battery factories) which dispose of their waste through rivers or drainage through the estuary into Jakarta Bay (Rochyatun & Rozak, 2007; Arifin & Fadhlina 2009 in Kusuma et al., 2015). Activities at ports such as painting ships, disposing of ballast water, docking ships and refueling can contribute to the deposition of heavy metals in the water. Apart from that, loading and unloading activities of large ships in the middle of the sea also have the potential to release waste heavy metals which are then deposited in sediment in the waters of Jakarta Bay.

The accumulation of heavy metals in sediment can cause accumulation in the bodies of biota that live and feed in waters or around sediments at the bottom of waters (Permanawati et al., 2013). Based on this, all parameters of heavy metals in sediment need to be watched out for because they will pollute marine biota and have very dangerous toxic effects and can be acute/chronic which can affect the health of people who consume them. However, based on the results of laboratory analysis, the parameters that really need to be paid attention to are copper (Cu) and lead (Pb). The presence of heavy metal content in aquatic sediments is caused by the dilution process in water which is then precipitated and accumulated in the sediment (Permanawati et al., 2013). Based on this, it can be concluded that the results of the analysis of heavy metal concentrations in waters cannot be linked to the heavy metal content in sediment. The pattern of heavy metal content in sediment in 2023 cannot be seen due to differences between observation points and different periods.

Water quality and sanitation monitoring activities are regulated in Minister of Health Regulation Number 492 of 2010 concerning Drinking Water Quality Requirements, which includes sanitation inspections, water sampling, water quality testing, analysis of laboratory examination results, recommendations and follow-up. The Ministry of Health has the authority to monitor drinking water quality through Environmental Health Inspection (IKL) activities which are carried out by sanitarian staff at community health centers, environmental health cadres, or other cadres in villages who have received practical training in monitoring water quality. The adverse consequences of the accumulation of nondecomposable solid waste over an extended period can result in soil pollution. Such waste, categorized as refuse, comprises materials that have been processed into undesirable parts with no economic value after the main component has been utilized. The impacts of waste on both humans and the environment include decline in health quality, degradation of environmental quality, and societal and economic impacts. Insufficient waste management, particularly unregulated waste disposal, creates an ideal habitat for various organisms and attracts animals like flies and dogs that can transmit diseases. Potential illnesses include diarrhea, cholera, and typhoid, as viruses from waste can contaminate drinking water. Areas with inadequate waste management may also see an increase in diseases such as dengue fever. Additionally, mold and diseases transmitted through the food chain pose potential health risks. Leachate from waste seeping into drainage channels, irrigation canals, or rivers can pollute water sources. Fish and other aquatic organisms may face threats, leading to significant alterations in the aquatic ecosystem and potential extinction. The decomposition of waste disposed of in water bodies can generate organic acids and gases such as methane, which not only emit unpleasant odors but also pose explosion hazards at high concentrations. Inadequate waste management results in decreased public health and increased healthcare expenses. The accumulation of poorly managed waste disrupts the quality of life, creating unsightly and unhealthy surroundings. Furthermore, infrastructure such as drainage channels, irrigation systems, and roads may suffer disruptions due to waste infiltration, while economic activities may be hampered by pollution and visual disturbances caused by inadequate waste management.

3.3 Some water management technology for water quality improvement

Gemala & Ulfah (2020) conducted a study wherein they utilized black and highly concentrated brown leachate water for research purposes. The water underwent treatment via filtration employing a combination of activated zeolite and activated charcoal. The findings indicated that this combined filtration method effectively reduced the levels of BOD, COD, total nitrogen (N), total suspended solids (TSS), and pH in the leachate water across three different thicknesses. The most significant reduction in TSS, by 11.76%, was observed with a 10cm thickness. Meanwhile, the 20cm thickness exhibited the highest effectiveness in reducing pH, COD, BOD, and total nitrogen levels, demonstrating reductions of 19.6%, 22.6%, 35.5%, and 33.33%, respectively. However, for mercury (Hg) and cadmium (Cd), the filtration process across all thicknesses did not effectively decrease the levels of these heavy metals.

Ahmad et al. (2023) conducted a laboratory-scale research study aimed at reducing well water pollution and assessing the effectiveness of filter media in Fitu Village, Ternate City, utilizing both physical and chemical parameters. The physical parameters assessed included odor, total dissolved solids (TDS), turbidity, and temperature, while the chemical parameters comprised iron (Fe), manganese (Mn), and pH levels. The filter media employed consisted of silica, zeolite, activated carbon, and sand. The study utilized a sample of 180 liters of community well water.Initial laboratory analysis revealed that the raw well water in Fitu Village exhibited TDS of 1,250 mg/L, turbidity of 27 NTU, and a temperature of 25°C for physical parameters. Regarding chemical parameters, the concentration of iron was measured at 1.3 mg/L, manganese at 0.6 mg/L, and pH at 9. The filtration process involved passing water through silica sand, zeolite, and activated carbon filters.Subsequent analysis indicated a decrease in TDS to 897 mg/L, a reduction in turbidity to 24 NTU, and a temperature decrease to 24°C. Additionally, for chemical parameters, iron concentration decreased to 0.91 mg/L, manganese concentration reduced to 0.45 mg/L, and pH decreased to 7.9.The research concluded that the filtration system employing silica sand, zeolite, and activated carbon filter media effectively reduced contaminant and metal levels in the well water of Fitu Village, Ternate City.

Syuhada et al. (2021) conducted research utilizing Appropriate Technology (TTG), which comprises activated carbon, manganese, silica sand, and active zeolite. The TTG mechanism involves two main processes: oxidation of iron (II) ions through oxygen from air dissolved in water, leading to the formation of a settling colloid that settles at the bottom of a reservoir, and a filtration process to eliminate color and odor, where water from the reservoir flows into a filter tube.

The water treatment principle revolves around adsorption and ion exchange. Active sand, manganese, and natural zeolite within the filter tube act as adsorbents, absorbing heavy metals such as Pb (II), Fe (III), and Cu (II), as well as binding cations and anions responsible for water hardness, such as Ca2+ and Mg2+ dissolved in water. Meanwhile, activated charcoal within the filter tube serves as a substance for absorbing color and odor. Subsequent to passing through the filter tube, the water is then pumped or drained into a reservoir to yield clean water (the filtration results).

Furthermore, research conducted by Yofananda & Prakoso (2017) revealed that employing the Slow Sand Filter method with flow rates of 1 liter/minute and 3 liters/minute resulted in a reduction in various parameters including pH, turbidity, total dissolved solids (TDS), total hardness, Ca-hardness, and salinity, aligning with SNI standards. However, due to the small flow rate generated by this method, it still did not adequately meet the community's demand for clean water.Similarly, in 2020, Viyanti conducted research utilizing silica sand filter media and activated carbon to mitigate turbidity, TDS, hardness, and iron in well water in Pasir Sari Village, South Cikarang. The obtained data indicated that in the Silica Filter Reactor - Activated Carbon setup, there was a decrease in turbidity by 87.60%, color by 61.98%, TDS by 99.31%, pH by 2.47%, iron by 71.91%, and hardness by 94.63%. Conversely, in the activated carbon - silica sand filter reactor, the reduction percentages were as follows: turbidity by 88.17%, color by 69.01%, TDS by 99.46%, pH by 3.70%, iron by 76.40%, and hardness by 94.95%. So, by reviewing some water management above, it can be seen that by applying proper and correct water management can be very useful for improvement water quality in Indonesia. Application of appropriate technology usually applied by public or private agency to increase quality and volume of clean water for their or society activities

4. Conclusions

Water resources is one of the most important natural resources in Indonesia. But, with human interaction with this natural resources cause many bad effect to water resources. The most negative effect of human interaction with water resources are pollution in form quality decrease or depletion, organic and anorganic chemicals accumulation in water and also plastic in form microplastic and debris. The pollution already occur in rivers, lake, estuary and also ocean. One of the study case which study is about water pollution in Muara Teluk Jakarta. The results of the pollution index trend analysis from 2017-2023 show that pollution conditions in Jakarta Bay experienced a decline in the 2017-2019 period. This can be seen from the decline in the percentage of heavily polluted and moderately polluted categories. The results of the analysis of sea water quality index trends from 2017-2023 show that conditions fluctuated in the 2017-2023 range. But, the result show heavily polluted water in Muara Teluk Jakarta. Some of recent water management are already proposed to increase water quality that already successfully research by applying appropriate technology to reduce physical and chemical substances in water as methods for sustainable water utilization in Indonesia.

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Author Contribution

Conceptualization, Rendri and Widya; Methodology, Rendri; Material, Widya; Formal Analysis, Widya and Rendri; Data Curation by Widya and Rendri; Result and Discussion, Widya and Rendri; writing the original draft preparation by Widya; Review and Editing, Rendri and Widya. About the layout, Rendri contributes on creating analyzing theoretical journals, summarizing journals, writing part of the result and discussion. Widya contributes in; creating abstract, introduction, and summarizing the journal and writing the conclusion and writing part of the result and discussion. Rendri and Widya contributes in writing the references of this research.

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