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Water quality in Indonesia: The role of socioeconomic indicators

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Abstract: Population growth and the construction of settlements and industrial estates continue to increase at an unprecedented rate that has created gains and losses on environmental quality. The trend of population growth shows a declining trend but is not directly proportional to the fluctuating water quality index over the past ten years. The study uses secondary data with the quantitative approach using the panel data Fixed Effect Model (FEM) with Generalized Least Squares (GLS) to examine socioeconomic indicators in 34 provinces on water quality in Indonesia. Through analysis in this study shows that explanatory variables of the number of population and population density have a negative and significant effect on water quality in Indonesia of 4.69 and 1.95—ceteris paribus. The control variables of the number of establishments of micro and small scale manufacturing industry, and a group of workers, GRDP per capita, and realization of foreign direct investment show negative and significant results on water quality in Indonesia. It indicates that environmental management in Indonesia experiences a higher pressure from the utilization of ecological resources compared to efforts to improve the environment itself. Whereas household control variables of households and improve sanitation, the volume of water distributed by water supply establishment and the squared of GRDP per capita show positive and significant results on water quality in Indonesia, which shows that this is evidence of the government's success in managing the environment better.

Keywords: water quality, socioeconomic, population, population density, environment

JEL Classification: Q25, Q53, Q56

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1. INTRODUCTION

Water has a vital role in the fulfillment of human life and as a survival medium for aquatic environmental organisms that live in it. Water needs are related to two aspects, namely quantity and quality. Factors affecting water quality are determined by nature and non-nature. Natural factors of water quality are influenced by climate, lithology, geology, vegetation, and time, which means that chemical elements in groundwater occur because of interactions between groundwater as a solvent for chemical components found in rocks and environmental conditions from the formation of rocks groundwater storage. Human activities influence non-natural factors of water quality in densely populated areas in an area, through household activities, industry, agriculture, animal husbandry, mining, power generation, and forestry field practices. The activity is assumed that the higher the complex human and industrial activity, the higher the level of pollution, which affects aquatic ecosystems and proper sanitation and access to safe drinking water for human consumption.

The reasonable standard of clean water for the international community that is used for household purposes is around 20 liters per person per day (De Buck et al., 2015). At the international level, the right to the availability of water and sanitation is strengthened in the United Nations Declaration of Human Rights to Water and Sanitation (2010). In general, the declaration explains that human rights over water and sanitation are fundamental to the realization of a dignified life (United Nations General Assembly, 2010; United Nations-Water, 2013). Likewise, in the Sustainable Development Goals (SDGs) target, the fulfillment of the right to water and sanitation is set in the sixth goal, which is to guarantee the availability and management of clean water and sustainable sanitation for all. The target is expected to be achieved by 2030 universally access to the fulfillment of the right to clean water and proper sanitation.

For Indonesia, to create a prosperous community in the provision of access to clean water and proper sanitation services, a 100 - 0 - 100 programs have been implemented by the Ministry of Public Works and Housing is expected that by 2019 Indonesian people will have 100% access for decent drinking water, 0 slums and 100% access to sanitation according to the direction of the National Medium-Term Development Plan III. To support the realization of the 100 - 0 - 100 program, environmental quality is needed that can provide optimal support for human survival, which is comfortable in the environment in which it lives. The availability of clean water is very closely related to population conditions in an area. Socioeconomic indicators are very influential in ecosystems, including water quality[1]. The importance of socioeconomic information inherent in water quality has increased rapidly over the past few years. Previous studies have shown that the level of socioeconomic development may be a reliable indicator of, and determinants of, the level of water quality. Declining water quality is a significant challenge in the context of urban development and population growth, especially in settings without adequate wastewater management (Luo et al., 2019).

In the study conducted Radhika et al. (2013) explained that surface water availability in Indonesia was 3,906,476 m^3 per year with the highest percentage in Kalimantan 34%, Papua 27%, Sumatera 22%, Sulawesi 8%, Moluccas%, Java 4%, Bali and Nusa Tenggara 1%. The clean water crisis has remained a global issue in recent years. The United Nations Development Programme (2004) and the United Nations Educational, Scientific, and Cultural Organization (2006) report state that the global water crisis occurs not only in the supply of clean water which continues to decrease, but also shows the government's failure to manage sustainability living environment. The existence and management of freshwater have become an entire endeavor, both in terms of supply and sustainable distribution. The United Nations World Water Development Report (2018) states that in 2050 nearly 3.6 billion people will experience a shortage of clean water. Increasing demand for water, reducing water resources, increasing water pollution are triggered by uncontrolled population growth and economic growth.

Good environmental quality has been developed since 2009 by the Ministry of Environment by making the Environmental Quality Index (EQI) at the national and provincial levels as a reference for all parties in measuring the performance of environmental management and protection, which consists of three assessment components, namely the Water Quality Index (WQI); Air Quality Index (AQI); Land Cover Quality Index (LCQI). The Environmental Quality Index (EQI) and its three components are calculation on a scale from 0-100. The lower the value of 100, the higher the protection measures that must be taken by the central and regional governments in preserving environmental sustainability in the region.

The Ministry of Environment and Forestry's report in 2018 showed that the national WQI was well-ranked with a value of 72.77. In the last ten years in the span of this study that the WQI showed fluctuating results. It was noted that in 2017, the national WQI was 58.68, and the province that contributed the highest decrease in the WQI was Banten Province by 44.02%, indicates that there had been water problems in terms of both quantity and quality. The decline in the quality of clean

[1] **Social indicators:** population, population density, percentage of household and improve sanitation, and the volume of water distributed by water supply establishment. **Economic indicators:** GRDP per capita, squared of GRDP per capita, foreign direct investment, and the number of establishment of micro and small scale manufacturing industry, and a group of workers.

water in Indonesia is most dominant due to the pollution load from fecal Coliform and biochemical oxygen demand (BOD), this shows that the burden of water pollution from domestic waste, sanitation, livestock, agriculture, plantation, and industrial activities has not been handled well.

The phenomenon shows that the pollution of clean water quality is not only caused by natural factors such as climate, geology, lithology, vegetation, and time but also by non-natural factors, namely complex human activities in a densely populated residential area. Chu & Yu (2002); and Kemp (2004) said that population growth had brought environmental damage through various kinds of development, such as large-scale agriculture, urbanization, and industrialization, whose waste management does not meet operational standards. Population growth supported by a wasteful lifestyle and advancing technological developments has resulted in hazardous and toxic waste, which results in environmental damage. Population growth requires facilities and infrastructure to support all activities of human life. The increase in population has had consequences for the expansion of residential areas that affect water quality and the environment in general.

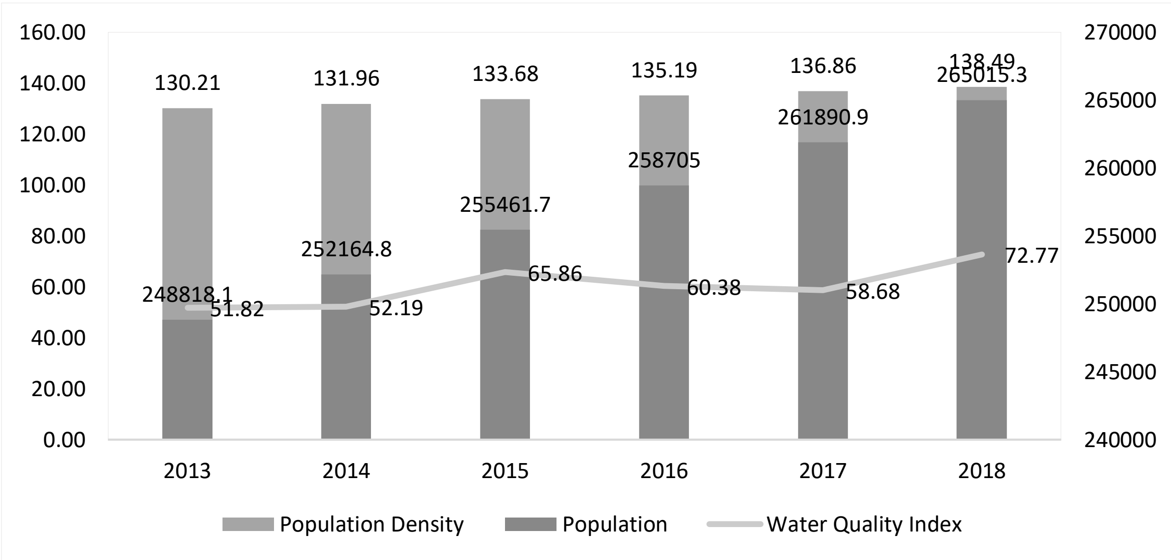

Figure 1. Population Density, Population, and Water Quality Index in Indonesia, 2013-2018
Source: Central Bureau of Statistics, Ministry of Environment and Forestry, Author's Calculation

Based on the data, in 2013, Indonesia's population was 248.8 million, and in 2018 it had increased by 1.19% to 265 million. The lowest WQI scores occurred in 2013 (51.82) in 2014 (52.19) and 2017 (58.68). The urbanization factor has become the cause of the concentration of population in various regions of Indonesia in search of a better life and employment. In 2013 the population density was 130.21 people per km^2 land of the area. Every year after that, it continued to increase, namely in 2018, as the end of the research year was 138.49 people per km^2 land of the area. Population growth and high population density have contributed negatively to the quality of the environment, especially the quality of clean water in Indonesia. The phenomenon is a fascinating subject for research related to the influence of socioeconomic indicators on water quality in Indonesia.

2. LITERATURE REVIEW

Water Quality Index (WQI) is one of the forming components of the Environmental Quality Index (EQI) compiled by the Ministry of Environment and Forestry. WQI is needed to see how well the quality of water consumed by the community is suitable for daily needs or other activities. Ratnaningsih et al. (2018) said that WQI gives a single value to the quality obtained from the integration of several constituent parameters at a specific time and location. Based on the Decree of the Minister of State for the Environment No. 115/2003, that one of the methods for determining of the WQI is the river water pollution index (PIj) method. The formula for calculating the river water pollution index is as follows:

$$PI_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)^2_M + \left(\frac{C_i}{L_{ij}}\right)^2_R}{2}} \quad (1)$$

Where: P_{ij} is the Index of river water pollution (j), which is a function of C_i/L_{ij}. C_i stated the concentration of water quality parameters to i, and L_{ij} noted the level of water quality I said in the water quality standard j. In this case, the designation used is the classification of class I water quality standards based on Government Regulation No. 82/2001 on the management of water quality and control over pollution. Index of river water pollution based on PI_j are as follows:

- Water Quality Index = 100 for $PI_j \geq 1$
- Water Quality Index = 80, for $PI_j \geq 1$ and $PI_j \leq 4.67$ is the PI_j from class II quality standards against class I),
- Water Quality Index = 60, for $PI_j \geq 4.67$ and $PI_j \leq 6.32$ (6.32 is the PI_j of the class III quality standard for class I),
- Water Quality Index = 40, for $PI_j \geq 6.32$ and $PI_j \leq 6.88$ (6.88 is the PI_j of the class IV quality standard against class I),
- Water Quality Index = 20, for $PI_j \geq 6.88$

Empirical studies of socioeconomic indicators on water quality have been carried out in various countries and regions. The research conducted by Ito (2005) statistically examined the relationship between population size and population growth on water quality, with a focus of research on 44 cities in China. After testing the independent variables of government efforts and socioeconomic conditions, the results of the regression analysis show that population size and population growth have a negative and significant impact on water quality. The results of this study indicate that domestic wastewater treatment systems in 44 cities in China cannot accommodate population size and population growth. Liu & Chen (2006) conducted a study using time series data on changes in population, economic growth, climate change, water volume, and quality and changes in land use to study the relationship between factors in watershed Tarim, Xinjiang, China is drying up. The results of this study show that rainfall and flow from upstream continue to increase, but the flow in the Tarim River has decreased significantly over the past three decades. Implies that population growth, climate change, expansion of cultivated land, economic growth has negatively affected water quality in the Tarim River, Xinjiang, China.

Duh et al. (2008) examined the impact of the development of large cities in the world and population growth on water and air quality. The study found that the migration of people from villages to cities hurts the quality of the environment in major cities in the world. Increasing the population from villages to cities will lead to an increase in residential buildings, thereby reducing green open areas, increasing the volume of household waste, water, and air pollution. Juma et al. (2014) investigated the effects of population growth, economic growth, and poorly planned water catchment management on water quality in Lake Victoria, Kenya. They were confirmed by an increase in water vegetation using moderate resolution imaging spectroradiometer (MODIS) image analysis from 2000-2012. The results of his research found that in general, the rapid population growth, economic growth, and industrialization of water catchment areas with inadequate waste management have led to an increase in the volume of urban waste discharged into the lake region and the environment in the Lake Victoria, Kenya. One of the main factors causing lake water pollution is unplanned or poor waste management policies and services.

The study of the relationship between economic growth, trade around rivers, population, and two indicators of water quality in the four main rivers in South Korea was conducted by Choi et al. (2015) using the Environmental Kuznets Curve (EKC). The results of this study indicate that national economic growth is accompanied by changes in environmental and industrial policies that drive water quality improvement. The relationship between biochemical oxygen demand and GDP in Geum and the Nakdong River and between chemical oxygen demand and GDP in the Yeongsan River and Nakdong supports the Kuznets curve environment hypothesis. In general, the turning point for improving water quality occurs at a later stage of economic development for industrial pollution rather than biological pollution. A study conducted by Liyanage & Yamada (2017) on population growth in environmental quality in Sri Lanka shows that there is a distance that must be maintained between densely populated areas and other areas around 2,375 meters to maintain the quality of groundwater that can be consumed by people with proper consumption status for purposes household and others. Settlements around watersheds must be kept at a distance of around 2,672 meters so that water quality is maintained for the sustainability of ecosystems and aquatic organisms that live in rivers.

Zhang et al. (2017), examining the effects of the urbanization process on water quality, shows that land use and changes in industrial structure, energy consumption, and changes in population structure during rural urbanization have an essential influence on the safety of rural drinking water. In rural Beijing, the level of rural drinking water qualifications has a significant positive relationship or limit with urbanization parameters, such as total electricity consumption, live electricity consumption, tertiary industry growth rates, and annual GDP growth rates. There is an excellent relationship between urban-rural Beijing's level and a comprehensive water quality index, and a comprehensive water quality index is closely related to the factors of value-added growth rates by residential construction areas, secondary and tertiary industries, annual GDP growth rates, and total electricity consumption.

Chen et al. (2018) conducted a study to evaluate economic growth, industrial structure, and water quality in the Xiangjiang River Basin in China based on a spatial econometric approach. This study extracted water quality data from 42 environmental monitoring stations in the Xiangjiang River Basin region. Then, match 42 monitoring stations with the corresponding districts according to map coordinates. The results of this study indicate that GDP per capita has a direct effect on COD_{Mn} and NH_3-N, that GDP per capita has a significant overflow effect on water quality in adjacent areas. The impact of primary industry on COD_{Mn} and NH_3-N is not significant, which indicates that the increase in the primary industry output in one region has no effect on water quality in the adjacent region. The impact of industry and population density on COD_{Mn} is not significant. However, NH_3-N is significant, which implies that the industrial output and population density has a positive impact on NH_3-N pollution in adjacent areas but does not have an effect on COD_{Mn}.

Boretti & Rosa (2019), in their study, discussed the relationship between exponential growth in global population and GDP to water scarcity, which is the result of competitive water demand, water resources, and water pollution. Population growth and economic growth until 2050 will be robust and uneven in the world, with the highest growth rates in third world countries. This study looks at the effects between population growth and economic growth on a global scale and countries such as Pakistan, India, Bangladesh, Angola, Malawi, and Uganda. The results of this study indicate that population growth and economic growth will ultimately drive water scarcity and quality in the future.

Li et al. (2019) conducted a study on the impact of socioeconomic development on rural drinking water safety (RDWS) in China. China's rapid socioeconomic development generates significant benefits for the safety of rural drinking water in China. However, the by-products associated with this development, such as water shortages, environmental pollution, and excessive water demand, seriously threaten the current and future RDWS in any country. The findings of this study are GDP per capita, rural per capita annual net income, percentage of the rate contribution to GDP from primary and secondary industry, per capita water resources, and urbanization rate show positive and significant results on RDWS in China. Meanwhile, population density, rate of natural increase, the total volume of water supply, water consumption of 10 thousand RMB GDP, and discharge standard-meeting rate of industrial wastewater show negative and significant results on RDWS in China.

The study of water pollutant emissions by Zhou et al. (2019) in 339 cities at the city level in China from the perspective of spatial spillover effects by conducting univariate and bivariate spatial autocorrelation analyzes. The results show that economic agglomeration can effectively reduce water pollutant emissions, and a 1% increase in economic agglomeration can cause a reduction in COD emissions by 0.117% and NH_3-N emissions by 0.102%. Other findings from this study are GDP per capita, emission intensity, population, secondary industries, and urbanization levels can increase water pollutant emissions. These findings show that as economic activity increases, the effects of external abundance from capital investment, production technology, and emission reduction processes become more apparent, increasing the efficient use of regional resources and energy and promoting improvement in the regional water environment.

Empirical studies on the socioeconomic role of water quality in Indonesia in research Kustanto (2020) said that population growth and foreign direct investment harm water quality in 33 provinces in Indonesia by 0.04—ceteris paribus. Also, another finding in this study is that the amount of water supplied by the water company and household access to proper sanitation shows positive and significant results, and this needs to be optimized as a form of government success in improving welfare through the clean water program. From the various phenomena and empirical studies, the purpose of this study is to look at the impact of socioeconomic indicators on water quality in Indonesia. The quality of clean and healthy water is an essential requirement for the survival of human beings and other living things. An assessment of water quality is an important thing to do so that it can know whether the water in an area is suitable to support the needs of humans and living things in the area.

3. MATERIALS AND METHODS

The data in this study is secondary data using a panel data method consisting of 34 provinces in Indonesia as a cross-section and time series for ten years during 2009-2018, sourced from the Central Bureau of Statistics and the Ministry of Environment and Forestry. Panel data is a combination of time series and cross-section data to improve the accuracy of model estimation (Gujarati & Porter, 2009). There are several advantages obtained by using panel data estimation techniques. First, panel data can accommodate the heterogeneity of the variables included in the model. Secondly, being able to combine time series data and cross-section information that can overcome what arises when a variable occurs. Third, minimizing the bias generated by individual aggregations due to more research data units (Baltagi, 2015).

Panel data estimation can use two approaches, namely through the Fixed Effect Model (FEM) and Random Effect Model (REM) approaches. FEM introduces heterogeneity between subjects by giving each entity its intercept (Gujarati & Porter, 2009). Panel data estimation uses the FEM using the dummy variable technique to capture intercept differences. This estimation model is often referred to as Within Group (WG) and Least Square Dummy Variable (LSDV) techniques. FEM can be expressed in the form of an equation as follows:

$$Y_{it} = \alpha_i + \lambda_i + \beta X_{it} + \varepsilon_{it} \; for \; i = 1, \dots N \; and \; t = 1, \dots T \quad (2)$$

There are two kinds of ε_{it} components, namely one-way and two-way. One-way is marked by the ε_{it} the component contains individual-specific effects and random errors. In contrast, two-way is marked by the ε_{it} component, which contains individual-specific effects, random errors, and time effects.

The Random Effect Model (REM) approach estimates panel data in which interruption variables may be interconnected between time and between individuals. The intercept is accommodated by an error term, and the benefits can eliminate heteroscedasticity. REM is known as an error component model (ECM) or generalized least square (GLS) technique. REM can be stated in the form of an equation as follows:

$$Y_{it} = \alpha_i + \beta X_{it} + \lambda_{it} + \varepsilon_{it} \; for \; i = 1, \dots N \; and \; t = 1, \dots T \quad (3)$$

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To determine the best model estimation between the FEM and the REM does not appear to be modifying the subject Hausman test can be performed, which is statistical testing as a basis for consideration of choosing whether to use the FEM or the REM.

Based on the data obtained, the decline in water quality is one of the problems faced by big cities in Indonesia. River water as a source of clean water is polluted due to uncontrolled household waste and industrial area waste. This phenomenon is interesting to observe, considering that during 2009-2018 the population and population density in Indonesia continued to increase, which resulted in a decrease in the water quality index. In 2009-2012 the water quality index score continued to grow, whereas after that fluctuated, namely in 2013 (51.82) in 2014 (52.19) and 2017 (58.68) (see Figure 1). Thus, it is suspected that the decline in the WQI is a negative impact of population growth and population density that occurs in big cities in Indonesia.

Table 1. Description of Variables

Variables	Abbreviation	Measurement	Database
Dependent Variable			
Water Quality Index	WQI	Water Quality Index	Ministry of Environment and Forestry
Explanatory Variables			
Population	POP	The number of population in 34 provinces in Indonesia	Central Bureau of Statistics
Population Density	DEN	The Population density in 34 provinces in Indonesia	Central Bureau of Statistics
Control Variables			
Micro and Small Enterprises	MSE	The number of establishments of micro and small scale manufacturing industry, and a group of workers	Central Bureau of Statistics
Sanitation	SAN	Percentage of the household by province and improved sanitation	Central Bureau of Statistics
Drinking-Water	WATER	The volume of water distributed by water supply establishment by province	Central Bureau of Statistics
GRDP per capita	GRDP	GRDP per capita at 2010 constant market prices by province	Central Bureau of Statistics
Squared GRDP per capita	$GRDP^2$	Squared of GRDP per capita at constant market prices by province	Central Bureau of Statistics
Foreign Direct Investment	FDI	Foreign direct investment realization by province	Central Bureau of Statistics

Source: Author's, 2020

The model in this study was modified from the research model Ito (2005) with the following equation:

$$Water_{it} = \beta_0 + \beta_1 Growth_{it} + \beta_2 Controls_{Jit} + \varepsilon_{it} \quad (4)$$

Where water is water quality, explanatory variables, namely population and population growth, and control variables is domestic wastewater treatment, facilities, a project to reduce wastewater, and investment in wastewater treatment, cultivated land treatment per capita, industrial company, GDP per capita, and squared GDP per capita. Modification in equation (4) of the research model Ito (2005) uses control variables in the form of government efforts and social and economic environment adjusted to the availability of data in provinces in Indonesia, the size of the Indonesian government's efforts in managing water quality is proxied using data on the percentage of the household and improved sanitation, and the volume of water distributed by water supply establishment.

Socioeconomic conditions for water quality in Indonesia are proxied using data on the number of establishments of micro and small scale manufacturing industry, and a group of workers, the realization of foreign direct investment, GRDP per capita, and squared GRDP per capita. Control variable functions included in this study as a tool to get a robust model. The difference dependent and independent variable units in this study are transformed into a natural logarithm (ln) so that the regression data is usually distributed. The equation model in this study is as follows:

$$WQI_{it} = \beta_0 + \beta_1 Pop_{it} + \beta_2 DEN_{it} + \beta_3 SAN_{it} + \beta_4 WATER_{it} + \beta_5 lnSME_{it} + \beta_6 lnGRDP_{it} + \beta_7 GRDP^2{}_{it} + \beta_8 lnFDI_{it} + \varepsilon_{it} \quad (5)$$

Where: WQI_{it} is water quality index, POP_{it} is the number of population, DEN_{it} is Population density, SAN_{it} is the percentage of the household by province and improved sanitation, $WATER_{it}$ is the volume of water distributed by water supply establishment by province, $lnSME_{it}$ is the number of establishments of micro and small scale manufacturing industry, and a group of workers, $lnGRDP_{it}$ is GRDP per capita at 2010 constant market prices by province, $GRDP^2{}_{it}$ is squared of GRDP per capita at 2010 constant market prices by province, $lnFDI_{it}$ is foreign direct investment realization by province, β_0 is the intercept of the regression line, β_1 - β_8 is the slope of the regression line, i is the number of cross-section data of 34 Provinces in Indonesia, t is the period of 2009-2018, ε is the error term. The operationalization of variables in the study is needed so that there is no double meaning to study so that measurements can be carried out appropriately.

4. RESULTS AND DISCUSSION

Water is an essential part of the growth and development of life, not only humans but also other living things. Provision of clean water services in Indonesia has been guaranteed in the 1945 Constitution of The Republic of Indonesia Article 33 paragraph 3, the land, the waters, and the natural resources within shall be under the powers of the State and shall be used to the most significant benefit of the people. Furthermore, in article 1 paragraph 3 of Law No. 11 of 1974 on Water Resources, the definition of water is all water contained in and or originating from water sources, both above and below ground level, not included in this sense water contained in the sea. Therefore, water quality management policies must pay attention to all group interests regardless of their socioeconomic status.

In this discussion, descriptive statistics on the variables used in this study will be presented during the period 2009-2018. The dependent variable in this study is the water quality index. In contrast, the independent variables are the population, population density, the number of the establishment of micro and small scale manufacturing industry, and a group of workers, percentage of the household and improved sanitation, the volume of water distributed by water supply establishment, GRDP per capita, squared of GRDP per capita, and foreign direct investment.

The WQI in 2009-2018 has an average score of 55.42. Provinces with the highest WQI scores were North Sumatera and Lampung in 2010 with a score of 100.00, while the lowest were East Kalimantan, Papua, West Papua, West Nusa Tenggara, and East Java with a score of 0.00. In general, provinces that have low biochemical oxygen demand (BOD) and chemical oxygen demand (COD) and Coliform have low WQI. However, if the BOD and COD are below the quality standard, and Coliform is above quality standard, the WQI will be higher. The WQI is generated from monitoring river water quality in 34 provinces in Indonesia, which is the main inter-provincial river at 97 rivers and 629 monitoring points. River water quality monitoring is carried out on priority rivers (State Budget/Deconcentration Fund) and river State Budget.

Table 2. Descriptive Statistics

Variables	Obs.	Mean	Median	Maximum	Minimum	Std. Dev.
WQI	306	55.42	57.11	100.00	0.00	23.47
POP	306	8260514	4363500	48683700	743900	10700324
DEN	306	448.50	123.34	8089.49	13.68	1268.12
lnSME	306	10.80	10.92	13.85	7.33	1.23
SAN	306	58.85	59.85	91.13	12.39	16.06
WATER	306	96733.60	33294.00	712996.00	2955.00	136283.00
lnGRDP	306	10.29	10.19	12.02	9.11	0.56
$GRDP^2$	306	2100000000	713000000	27500000000	81315306	4240000000
lnFDI	306	5.25	5.50	8.87	-1.61	2.03

Source: Author's Calculation

Water, especially river water, has a vital and strategic role in the survival of living things. River water has become a source of drinking water for some households in Indonesia. Also, river water is a source of raw water for various activities such as processing, agriculture, plantation, animal husbandry, and power generation. On the other hand, river water becomes a place for the disposal of various wastes so that they are polluted, and their quality decreases and is unfit for human consumption. Because of this role, river water has become an important indicator of environmental quality.

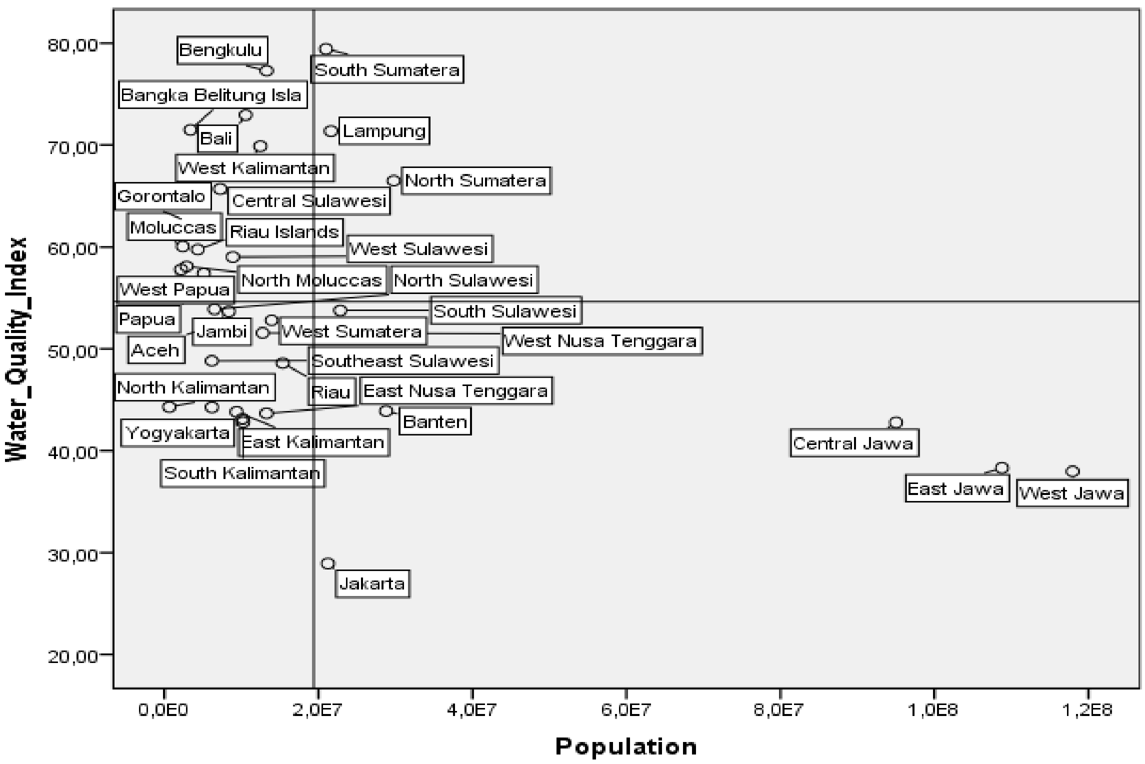

Figure 2. Distribution of Water Quality Index and Population in Indonesia, 2009-2018
Source: Author's calculation

Figure 2 shows that the distribution pattern of the average WQI and number of the population are in quadrant III, where WQI is below the average, and the population is also below the ordinary province in Indonesia. The population in 2009-2018 had an average of 8260514. The province with the highest population was West Java in 2010 at 48.6 million, while the lowest was in West Papua in 2010 at 743 thousand. This condition will bring the consequences of increasing living space in the form of residential areas, public facilities, industrial areas as residents' livelihood land in the area. Loss of water quality can also be caused by natural events, namely erosion in watersheds. In

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contrast, declining water quality is caused by sediment, soil, rocks, and other particles in watersheds, which are exacerbated by poor land-use conditions, and population activities produce domestic waste that results in groundwater pollution.

The increase in population in an area will be directly proportional to the need for clean water is increasing, including for activities in the domestic sector (residents and public facilities, industrial, and the hotel). According to the Central Bureau of Statistics that Indonesia's population projection in 2010-2035 continues to increase and is significant, namely in 2010 from 238.5 million to 305.6 million in 2035. Meanwhile, the trend of population growth rates over the period 2010-2035 shows a declining trend in 2010-2015 and 2030-2035 periods, the population growth rate from 1.38% to 0.62% per year, or an increase of 2.9 million per year. The United Nations World Water Development 2018 report has provided the latest information that at the same time, the global water cycle is increasing due to climate change, with wetter regions generally becoming wetter due to high rainfall and drier areas becoming drier due to the dry season. At present, an estimated 3.6 billion people (almost half of the global population) live in areas with potential shortages of clean water for at least one month per year, and this population could increase to around 4.8-5.7 billion by 2050.

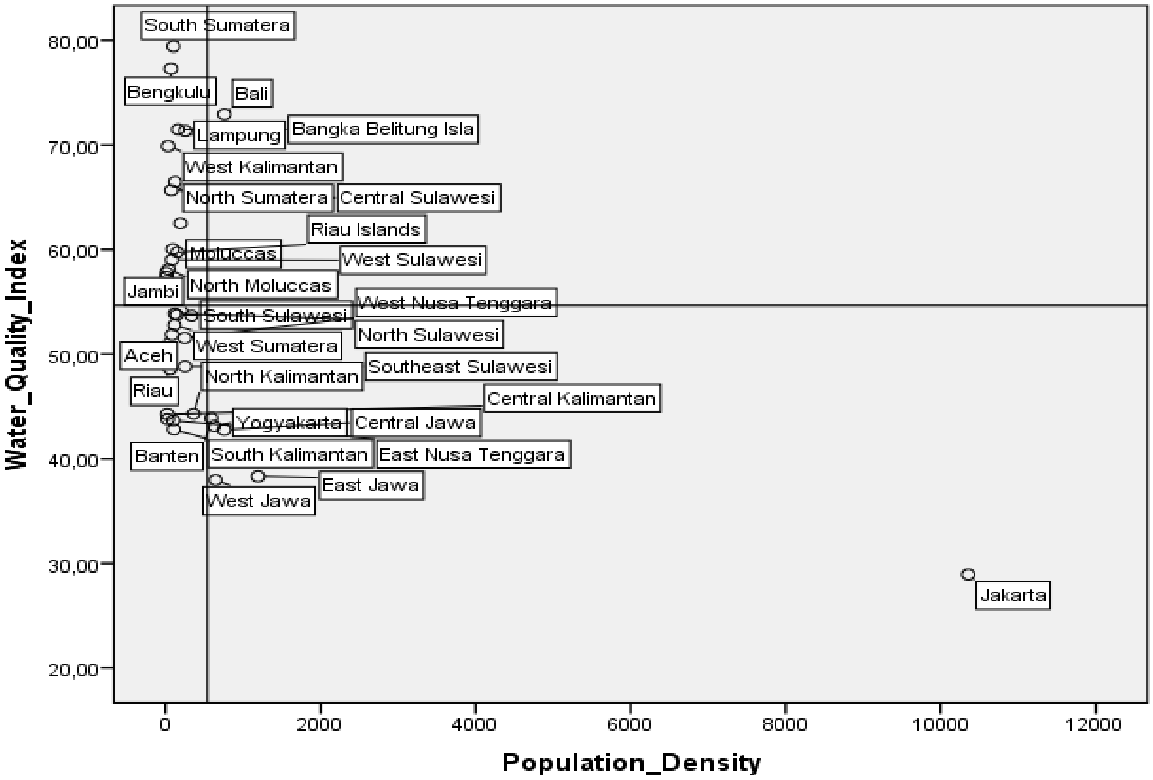

Figure 3. Distribution of Water Quality Index and Population Density in Indonesia, 2009-2018
Source: Author's Calculation

Figure 3 shows the average distribution pattern of WQI and population density in Indonesia 2009-2018. Most of the standard distribution patterns between WQI and population density are in quadrant III, where water quality is below average, and population density is also below the provincial average in Indonesia. The population density in 2009-2018 has an average of 448.50 people per km^2 of land area. The province with the highest population density was Jakarta in 2018, with 8089.49 people per km^2 of land the area, while the lowest was West Papua, with 13.67 people per km^2 of land the area. Dense population in an area caused by high population growth. Unequal distribution of population has become the cause of population density in provinces in Indonesia exceeding the carrying capacity of the environment. The impact of overcrowding is the high pressure on the environment, such as access to clean water, sanitation, and air pollution.

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The number of establishments of micro and small scale manufacturing industry and a group of workers in Indonesia 2009-2018 has an average of 10.80. The province with the number of establishments of micro and small scale manufacturing industry and a group of workers was Central Java in 2015 with a natural logarithm of 13.84 or a total of 1,030,374. The lowest was West Papua in 2012, with a natural logarithm of 7.08 or 1,194. Households that had access to proper sanitation in 2009-2018 had an average of 58.85%. The province that had the highest percentage of households with access to adequate sanitation was Jakarta in 91.13%, while the lowest was East Nusa Tenggara in 2009 at 12.39%. The volume of water supplied by drinking water companies in 2009-2018 has an average of 96,733.60. The province with the highest volume of the water provided by the drinking water company was East Java in 2018, amounting to 712,966 m^3, while the lowest was West Papua in 2009, totaling 2,955 m^3.

The GRDP per capita in 2009-2018 has an average in the form of natural logarithms of 10.29 or IDR35,348,700. The province with the highest GRDP per capita was Jakarta in 2018 in the form of natural logarithms of 12.01 or IDR165,863,000, while the lowest was East Nusa Tenggara Province in 2009 in the form of natural logarithms of 9.10 or IDR9,017,000. The Squared of GRDP per capita in 2009-2018 had an average of 2100000000. The province with the highest squared of GRDP per capita in 2010 was Jakarta in 2018 with IDR275,105,347, while the lowest was East Nusa Tenggara in 2009 amounted to IDR81,315,306. The realization of foreign direct investment in 2010-2018 has an average in the form of natural logarithms of 5.25 or USD749.3 million. The province with the highest foreign direct investment realization was West Java in 2013 in the form of natural logarithms of 8.87 or USD7129.9 million, while the lowest was West Papua in 2009 in the form of natural logarithms of 0 or USD1.0 million.

4.1. Panel Data Analysis Result

Hausman test is a statistical test a basic for consideration of choosing the best model, whether using the fixed-effect model (FEM) or random effect model (REM) (Gujarati & Porter, 2009). If the p-value from panel data is more significant than 0.05, then H_0 cannot be rejected, and this study uses the REM estimation method. If the p-value of panel data is less than 0.05, then H_0 is rejected, and a better estimation method is used the FEM. Based on the test results, Table 2 shows that the prob. < α (0.05) or 0.00 < 0.05, the best model used is the FEM. That is, estimates using the FEM are more efficient than the random effect model, and the cross-sections selected in the study were not taken randomly.

In the FEM, intercepts between individuals are different, but these intercepts vary across time invariants. Then, in the FEM, it is assumed that there is a correlation between cross-section error and the independent variable (regressor). The FEM method does not require the assumption of a model-free from serial correlation so that the autocorrelation test can be ignored (Baltagi, 2015). As for the heteroscedasticity test, given that the data used are cross-sections, then heteroscedasticity is suspected. To eliminate the effect of heteroscedasticity, the estimator used is Generalized Least Squares (GLS), namely by doing weighting: cross-section weight on all variables. Thus, the estimated model is expected to be free from heteroscedasticity.

Furthermore, to be able to produce estimators that are Best Linear Unlimited Estimator (BLUE) models must be free from violations of classical assumptions, including heteroskedasticity test, autocorrelation, and multicollinearity. To overcome the problem of heteroscedasticity in this study does not appear to be modifying the subject, the estimation was carried out using the GLS method. Estimation results using the GLS method show the coefficient of determination (R^2) of the model with a high enough number. Based on the estimation results of Table 2, it is known that the model has a determination coefficient (R^2) of 52%; it indicates that this model can explain variations in water quality changes by 52%. In comparison, the role of other variables in defining the dependent variable is 48%.

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Table 2. Estimation Result of FEM with Generalized Least Squares

Variables	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-226.3580**	122.6587	-2.945430	0.0661
POP	-4.696555***	7.120077	-2.658402	0.0109
DEN	-1.956644***	0.030573	-3.277968	0.0236
lnMSE	-1.370502**	2.713680	-7.505035	0.0640
SAN	1.409362**	0.187647	2.181555	0.0301
WATER	5.86605**	2.722005	2.151977	0.0323
lnGRDP	-23.854443*	1.259262	-1.894319	0.0793
$GRDP^2$	6.522009***	2.755009	5.772676	0.0184
lnFDI	-1.038958***	1.049208	-7.690231	0.0230
R-squared	0.527411			
F-Statistics	7.030811***			
Hausman Test	37.02159***			

Note: Dependent variable: Water Quality Index; Significant level at *10%, **5%, ***1%; Observations = 306.
Source: Author's Calculation

Based on the estimation results of the model, the number of population (POP_{it}) has a negative and significant effect on water quality at a significant level of 1%. Every 1.000 population increase will reduce the water quality score by 4.69—ceteris paribus. With a negative relationship to water quality, this shows that the more population in a region increases, the water quality in the region will decrease. In line with the results of research Ito (2005); Liu & Chen (2006); Duh *et al.* (2008); Juma *et al.* (2014); Liyanage & Yamada (2017); Boretti & Rosa (2019); Zhou et al. (2019); and (Kustanto, 2020) concluded that high population growth has resulted in not all components of society to get access to clean water. The population growth caused by rural-urban migration and urbanization. Also, the development of various industrial companies in an area in major cities in Indonesia has become an attraction for local communities to carry out these migration activities in the hope of getting a better life in terms of income. The rapid development of cities, trade, and service activities, the growth of new housing areas. As a result, complex and varied human activities in an area will affect water quality caused by household and industrial waste in the region.

Population density (DEN_{it}) shows negative and significant results on water quality at a significant level of 1%. That is, every increase in population density of 1000 people per km^2 land of the area will reduce the water quality score by 1.95—ceteris paribus. Increased population density has opened up consequences for water quality. Relates to the volume of household and industrial waste generated that is not well managed. The results of this study are in line with Ito (2005); Liyanage & Yamada (2017); Chen et al. (2018); and Li *et al.* (2019) concludes that the higher population density in an area has an impact on increasing the burden of pollution on groundwater. For people who live in densely populated areas, groundwater is one of the primary sources of life. This relates that in the dry season, the amount of surface water in rivers, lakes, and reservoirs is reduced drastically and is followed by a decrease in water quality to a level suitable for consumption. Another consequence of the need for clean water in densely populated areas can result in a reduction of groundwater-surface conditions, which in turn will have an impact on land subsidence.

The number of establishments of micro and small scale manufacturing industry and a group of workers $(lnMSE_{it})$ shows negative and significant results on water quality at a significant level of 5%. The results of this study are in line with Ito (2005); Zhang et al. (2017); Chen et al. (2018); Li et al. (2019); and Zhou et al. (2019) that industrial companies have an impact on water quality degradation. Although growth in employment will increase and the number of small and medium-sized industrial companies, on the one hand, indicates economic progress, on the other hand, it harms the quality of clean water. For this reason, special monitoring is needed in the management of domestic and industrial waste so that the pollution of clean water around the industrial area optimally mitigated by making planned wastewater management. The percentage of the household and improved sanitation (SAN_{it}) and the volume of water distributed by water supply establishment ($WATER_{it}$) show positive and significant results on water quality at a confidence level of 5%. In study conducted by Kustanto (2020) proving that the government's performance in environmental preservation is producing positive results. However, the portion of clean water services in Indonesia has not reached 100%, and there needs to be an increase in the provision of honest water services provided by clean water companies and an increase in low-income households in disadvantaged, outermost, and foremost regions. Both of the above need to be optimized to improve the welfare and quality of life of the community.

The variable of economic growth in this study using GRDP per capita ($lnGRDP_{it}$) showed negative and significant results on water quality. This research is in line with Ito (2005); Choi et al. (2015); Boretti & Rosa (2019); and Zhou et al. (2019) that the decline in environmental quality as a negative externality of economic growth which ultimately causes many environmental problems, especially water quality. Economic growth will increase the use and utilization of natural resources. If economic growth and income targets are highest, the exploitation of natural resources will be even higher. The utilization of natural resources currently prioritizes economic benefits and has not been adequately paid attention to as a life-supporting resource. As a resource to support human life, the use of which causes a decrease in water quality directly (factory waste, sewage treatment facilities, refineries) or indirectly (domestic waste, industrial waste, insecticides and pesticides, detergents and fertilizers) affects the decrease in water quality index.

Whereas, the next variable of economic growth using the squared of GRDP per capita ($GRDP_{it}^2$) showed positive and significant results on water quality. The results of this study are in line with Ito (2005); Choi et al. (2015); Zhang et al. (2017); Chen et al. (2018); Li et al. (2019); and Zhou et al. (2019) said that when the country first enters the stage of rapid economic growth—indicate by GRDP per capita growth—environmental degradation initially increase, but then decrease once the GRDP per capita reaches a certain threshold. Another potential analysis for the positive effect of squared of GRDP per capita is that the willingness to pay for water supply tends to increase along with increasing incomes, the higher the desire to improve health through improving the quality of the environment, especially in improving the water quality index. Also, Hutton (2013) said that additional investment in clean water and sanitation services of $1 would result in a return of investment of $4 and a positive long-term economic impact to avoid diseases such as malnutrition and diarrhea caused by water pollution.

Another finding in this study is the realization of foreign direct investment (FDI_{it}) shows negative and significant results on water quality. Supported by the results of research Ito (2005); and (Kustanto, 2020) that industrial projects from a foreign direct investment have an impact on decreasing water quality. Like two sides of a coin, the development of various industries from foreign direct investment will grow a multiplier effect on the economy of the country or region because the investment will encourage an increase in the production and consumption side. The production side of investment will provide easy access to factors of production, one of which is human resources. While in terms of consumption, the investment will automatically increase domestic economic activity. The negative thing about uncontrolled industrial development will have an impact on the quality of the environment because industrial activities in conducting production produce side wastes, both solid, liquid, and gas—generally, the waste generated by linear industrial businesses with the product it provides.

4.2. Potential Policy Option to Improve Water Quality Index

The purpose of this study is to use WQI not only to assess the situation of water quality in 34 provinces in Indonesia but also to identify socioeconomic indicators that affect WQI with the hope of further classifying appropriate response measures to support and protect WQI in the future.

- For social development, it is controlling the population growth rate (POP_{it}) and population density (DEN_{it}) accompanied by the family planning program, revitalizing the transmigration model to answer the amount of interest from the area of origin to the recipient area by developing leading commodities in the transmigration area by connecting directly to the business world, and utilizing demographic bonuses by increasing competence human resources in terms of education and skills. So that the creation of Indonesia-centric development and human capital who have the social awareness to behave friendly to the environment as a form of support for social life and environmental conditions that have an impact on improving the quality of clean water, like on Java Islands, namely Jakarta, West Java, East Java, and Central Java.

- For economic development, while the government must continue to promote economic growth $(lnGRDP_{it})$ and ensure stable financial support for the development, maintenance, and operation of clean water supply infrastructure. The government must also revise or make policies to reduce the pressure from excessive growth and support water-saving innovations in large, medium and small industrial enterprises $(lnSME_{it})$, agricultural land and plantations. Also, the government continues to strengthen the rule of law for companies investing in Indonesia through foreign direct investment schemes $(lnFDI_{it})$, especially in large industrial fields, such as mining to run Corporate Social and Environmental Responsibility (CSER) as a company's commitment to participate in sustainable economic development in order to increase the quality of life of the environment, especially the quality of clean water, both for companies, communities, and society in general.
- For water resource, the community-based environmental sanitation (SAN_{it}) a policy implemented by the government in 34 provinces in Indonesia in realizing Sustainable Development Goals 6 has been quite well implemented because the community has understood and is aware of the benefits of sanitation. The implementation of policies that must be carried out to achieve SDG 6 goals is to continue to build political will to create new national social norms in support of safely managed sanitation.
- For water consumption, having abundant water resources $(WATER_{it})$ is a factor that helps in terms of water supply in 34 provinces in Indonesia, but that is not a prerequisite for achieving high WQI. Guaranteed availability of clean water for sustainable communities for all is the goal of SDG 6. This effort must continue to be made to achieve these targets by both the government and non-governmental organizations. The implementation of the policy of the volume of water distributed by water supply establishments in 34 provinces in Indonesia is a program to control water pollution and environmental damage, and increase the population who still do not have access to safe water. The program is to achieve 100% access to safe drinking water that is safe and can be enjoyed by the people of Indonesia according to the targets of the 2015-2019 National Medium-Term Development Plan and the 2030 Agenda for Sustainable Development.

5. CONCLUSIONS

Water pollution is one of the things faced by the provinces of Indonesia. Most of the literature tends to focus on a factory or industrial and household waste and pollution from agricultural and livestock activities as a cause of water pollution. Undoubtedly true because human activities have affected water quality. The projection of the Indonesian population from the Central Bureau of Statistics shows that in the next 25 years, the population continues to increase and is significant, namely in 2010 from 238.5 million to 305.6 million in 2035. Meanwhile, the trend of population growth rates over the period 2010-2035 shows a declining trend. In the period 2010-2015 and the period 2030-2035, the rate of population growth from 1.38% to 0.62% per year. However, the above is not directly proportional to the water quality index, which shows fluctuating values. The quality of water quality has not shown a significant change (good quality trend, constant or down).

Through analysis in this study indicate that the explanatory variables of the number of population and population density have a negative and significant effect on water quality in Indonesia of 4.69 and 1.95—ceteris paribus. The control variables of the number of establishments of micro and small scale manufacturing industry, and a group of workers, GRDP per capita, and realization of foreign direct investment shows negative and significant results on water quality in Indonesia. It indicates that environmental management in Indonesia is experiencing higher pressure from the utilization of ecological resources compared to efforts to improve the environment itself. Whereas the control variables of households and improve sanitation, the volume of water distributed by water supply establishment and the squared of GRDP per capita show positive and significant results on water quality in Indonesia, which indicates that this is evidence of the government's success to manage the environment better.

Limitations in this study use provincial aggregate-level data for the 2009-2018 time span. Although the data in this study have represented all provinces in Indonesia, the availability of data in a short period causes the analysis to be limited. It is recommended that further studies can use microeconomic data such as the National Socio-Economic Survey (Susenas) or the Indonesian Family Life Survey (IFLS) and research models that are continuously being refined to produce a further analysis of socioeconomic indicators for water quality in Indonesia.

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