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Analysis of swamp irrigation water quality for agricultural areas: Case study DIR Polder Kaludan, Hulu Sungai Utara Regency

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ABSTRACT

The Kaludan Polder Swamp Irrigation Area (DIR) plays a crucial role in supporting swamp farming and controlling flooding in the Hulu Sungai Utara Regency. However, activities in the upstream and surrounding areas of the polder have the potential to degrade the quality of water entering the irrigation system. Therefore, water quality evaluation is necessary to ensure compliance with quality standards and the sustainability of its use. This study aims to analyze water quality spatially along the Kaludan Polder DIR network and determine water quality status based on the quality standards stipulated in Government Regulation of the Republic of Indonesia Number 22 of 2021. The methods used include sampling at six points representing the estuary, midstream, and outlet sections of the irrigation network, as well as laboratory analysis of 12 physical and chemical parameters: TSS, TDS, pH, DO, BOD, COD, nitrate, nitrite, iron, cadmium, manganese, and copper. Water quality status was further determined using the Storet method and the Pollution Index. The results showed that TSS and COD values in the estuary and midstream sections still exceeded quality standards and were classified as lightly polluted, while at the outlet section, all parameters met quality standards. This pattern indicates that the Kaludan Polder DIR system functions as a natural purification system through sedimentation and degradation of organic matter. Overall, the water quality in the Kaludan Polder DIR remains suitable for use as an irrigation water source with sustainable management.

INTRODUCTION

Water is one of the most critical natural resources in the agricultural sector because it directly affects plant growth, soil health, and agronomic yields. Poor irrigation water quality, such as high salt content, high sodium ratio, or heavy pollutants, can lead to soil salinization, reduced soil structure permeability, detrimental osmotic stress for plants, and significant yield reductions, thus limiting water availability to plants and triggering abiotic stress in modern agricultural systems. Several studies have also shown that increased salinity or sodium ratio in irrigation water is correlated with decreased productivity of crops such as rice and cotton, and limits the plant's ability to effectively uptake water through its roots, ultimately reducing biomass and yield (Vranešević

et al., 2025). Furthermore, a systematic review of water quality indices for agricultural use emphasizes the importance of measuring parameters such as electrical conductivity, pH, sodium ions, as well as indices developed by the FAO or USSL to assess the suitability of water use for various commodities, and this is a crucial part of sustainable water management planning to support food security (Johnston et al., 2024).

South Kalimantan Province has the authority to manage swamp areas, some of which are still semi-technical swamps whose water management has not yet been fully implemented. One of them is in Amuntai Tengah District and Banjarang District, Hulu Sungai Utara Regency, which has the Kaludan Polder Swamp Irrigation Area with an area of 1,440 Ha based on (Ministry of Public Works and

Housing of the Republic of Indonesia Regulation No. 14/PRT/M/2015 Concerning Criteria and Determination of Irrigation Area Status, 2015). The Kaludan Polder DIR still requires better management related to the regulation of the water system and planting patterns. This swamp irrigation area is expected to be optimally utilized to increase agricultural production in supporting the fulfillment of food needs and the government's food self-sufficiency program.

The Amuntai Tengah and Banjang sub-districts are areas where the primary source of income is farming. However, water quality issues often trigger weed growth in swampy areas, even in agricultural areas. Weeds constitute a primary limitation within agroecosystems, frequently absorbing nutrients more rapidly and in larger amounts than cultivated crops, thereby serving as a significant obstacle to sustainable agricultural production by directly competing with crops for essential resources such as light, water, and soil nutrients, ultimately leading to considerable reductions in yield and crop quality (S. Kumar et al., 2024). In 2016, the Ministry of Environment and Forestry created a map of water quality status across Indonesia by taking 539 sampling points in 84 major rivers across the country. In Hulu Sungai Utara Regency, the Nagara River in Pelampitan Ulu Village has a score of -88 with a severe quality status, the Nagara River in Jarang Kuantan Village has a score of -77 with a severe quality status, and the Nagara River in Banyu Tajun Pangkalan Village has a score of -76 with a severe quality status (Kurniawan et al., 2016).

Water quality analysis for irrigation systems includes measuring physical parameters such as Total Suspended Solids (TSS), where TSS reflects the amount of organic and inorganic particles suspended in water and contributes to turbidity, so that high particle concentrations can reduce light penetration, affect water infiltration into the soil, accelerate sedimentation in irrigation channels and disrupt the function of the irrigation system and plant health if it exceeds the threshold set for agricultural use (Adjovu, Stephen, & Ahmad, 2023; Hamim et al., 2025; Zulkifli & Mohd, 2025). Next is the Total Dissolved Solid (TDS) parameter, which is a measurement of dissolved organic substances that can be filtered per unit volume remaining from water evaporation. High TDS

concentrations in water can increase conductivity and reduce dissolved oxygen. TDS originating from organic substances is produced by the decay of biological materials such as roots, leaves, and stems of plants found in water (Adjovu, Stephen, James, et al., 2023). Then pH, or potential of Hydrogen, or better known as the degree of acidity, is used to state the level of acidity and freedom of a solution. pH measurement is considered a basic parameter that reflects the concentration of hydrogen ions in a solution, because pH is a graphic measure that shows the level of acidity or alkalinity of a solution, so that when the pH value is below 7 the water shows acidic properties, above 7 is basic or alkaline, and close to 7 is neutral, and the normal pH range for irrigation water is generally between the international standard range to ensure that there is no nutrient imbalance or damaging effects on the soil and irrigated plants (Benaissa et al., 2024).

The next parameter is Dissolved Oxygen (DO) defined as the concentration of oxygen gas dissolved in water expressed in units of mg/L, and because DO is the main indicator of the ability of water to support the metabolic processes of aquatic organisms as well as the formation and decomposition of organic matter, DO concentration is influenced by a number of physical factors such as water temperature, salinity, and atmospheric pressure that regulate the solubility of the gas as well as biological factors including photosynthetic activity by aquatic plants and oxygen consumption through organism respiration or degradation of organic matter, so that changes in these factors can cause significant variations in measured DO levels which in turn impact the health of aquatic ecosystems and overall water quality (Du et al., 2024; W. Liu et al., 2024; F. Zhang et al., 2025). Next is Biological Oxygen Demand (BOD) which is a measure of the amount of dissolved oxygen required by aerobic organisms, especially bacteria and other microorganisms, to biochemically decompose and oxidize organic matter contained in a water sample under certain aerobic conditions, so that the higher the level of organic matter available, the greater the oxygen requirement consumed, which indicates the level of organic pollution in the water body or aquatic system being tested (Cruz-Vivar & Hansen, 2025; Vigiak et al., 2019; X. Zhang et al., 2025) and Chemical Oxygen Demand (COD) is a water quality parameter that indicates

the amount of oxygen needed to oxidize organic matter contained in water through chemical reactions, so that the COD value is often used to describe the level of organic pollution in a water body (Saputri et al., 2023).

Nitrate (NO_3^-) is widely acknowledged as the predominant inorganic nitrogen species in aquatic ecosystems, while nitrite (NO_2^-) is an important intermediate form produced during nitrification and denitrification reactions. Because both NO_3^- and NO_2^- are key components of the environmental nitrogen cycle that reflect nutrient dynamics, agricultural runoff influence, and biogeochemical transformations under varying physicochemical and biological conditions, their concentrations in water bodies are routinely measured as essential indicators of nitrogen pollution and ecosystem health (based on studies of nitrogen cycling and nitrate dynamics in aquatic environments) (Niu et al., 2021; K. Wang et al., 2025). Iron (Fe) is a naturally occurring metal element characterized by its presence in ferrous (Fe^{2+}) and ferric (Fe^{3+}) forms. Because Fe plays a central role in biogeochemical and ecological processes, including redox cycling, nutrient transformation, and interactions with organic and inorganic constituents, it is important to understand the role of Fe in aquatic ecosystems. Inorganic compounds, their concentration and speciation in water bodies are routinely assessed in water quality studies to understand their impact on ecosystem function, biogeochemical cycles, and potential toxicity to aquatic organisms when present in excess (Chen et al., 2025).

Cadmium (Cd) is characterized in environmental science as a non-essential heavy metal with no biological function in living organisms and is known for its high toxicity even at low concentrations. Therefore, when Cd enters aquatic and terrestrial ecosystems, it persists due to its non-biodegradability and causes detrimental effects on biological systems (Lee et al., 2025). Manganese (Mn) is a redox-active transition metal that readily changes oxidation states and easily interacts with ions and ligands in water due to its reactive nature, and therefore its chemical behavior and dissolved forms are important considerations in environmental and water quality studies (X. Wang et al., 2024). Copper (Cu) functions as an essential micronutrient at low concentrations. However,

excessive levels of Cu in soil and water can cause phytotoxicity by disrupting physiological and biochemical processes in plants, thus posing a significant risk to plant survival and development (V. Kumar et al., 2021). These parameters need to be considered because each can provide an idea of the suitability of water for various types of plants. Accurate knowledge of water quality parameters and their implications enables farmers to make informed decisions regarding irrigation management, adjust farming practices to minimize risks of water pollution and nutrient imbalances, and implement appropriate strategies to preserve water resources and sustain crop productivity in agricultural systems (Anyango et al., 2024).

With the analysis of water quality in the Kaludan Polder Irrigation Area (DIR), it is hoped that appropriate solutions can be found to reduce the negative impacts of water pollution and optimize the use of water resources for agriculture. This will not only increase agricultural yields but also protect the sustainability of natural resources for future generations. Effective and sustainable water management in agricultural systems is critical for ensuring long-term food security, as comprehensive control of water resources, including quality and availability, enables the resilience of crop production to environmental pressures, supports efficient use of water inputs, mitigates water scarcity risks under climate change, and ultimately underpins the continued sustainability of food production systems (Dahal et al., 2026; Teweldebrihan & Dinka, 2025). Therefore, this study aims to assess the irrigation water quality status in the Kaludan Polder Irrigation Area (DIR), Hulu Sungai Utara Regency, using selected water quality parameters to support sustainable irrigation management.

MATERIALS AND METHODS

The location of this research is located in the Swamp Irrigation Area (DIR) of the Kaludan Polder in Amuntai Tengah District and Banjarang District, Hulu Sungai Utara Regency, South Kalimantan, with an area of 1,440 ha, based on (Ministry of Public Works and Housing of the Republic of Indonesia Regulation No. 14/PRT/M/2015 Concerning Criteria and Determination of Irrigation Area Status, 2015) can be seen in Figure 1 Kaludan Polder.

Hydrotopographically, the Kaludan Polder DIR is divided into 3, namely the embankment lowland with an area of 219.9986 ha, the middle lowland with an area of 690.5895 ha, and the deep lowland with an area of 315.6647 ha. Factors that determine the hydrotopographic conditions are the

highest water level (MAT) and the ground surface elevation conditions in the field, which can change at any time. The functional area of the Kaludan Polder DIR is 832.3260 ha, while the functional area and standard area are 1241.9881 ha. The Kaludan Polder DIR is presented in Figure 1.

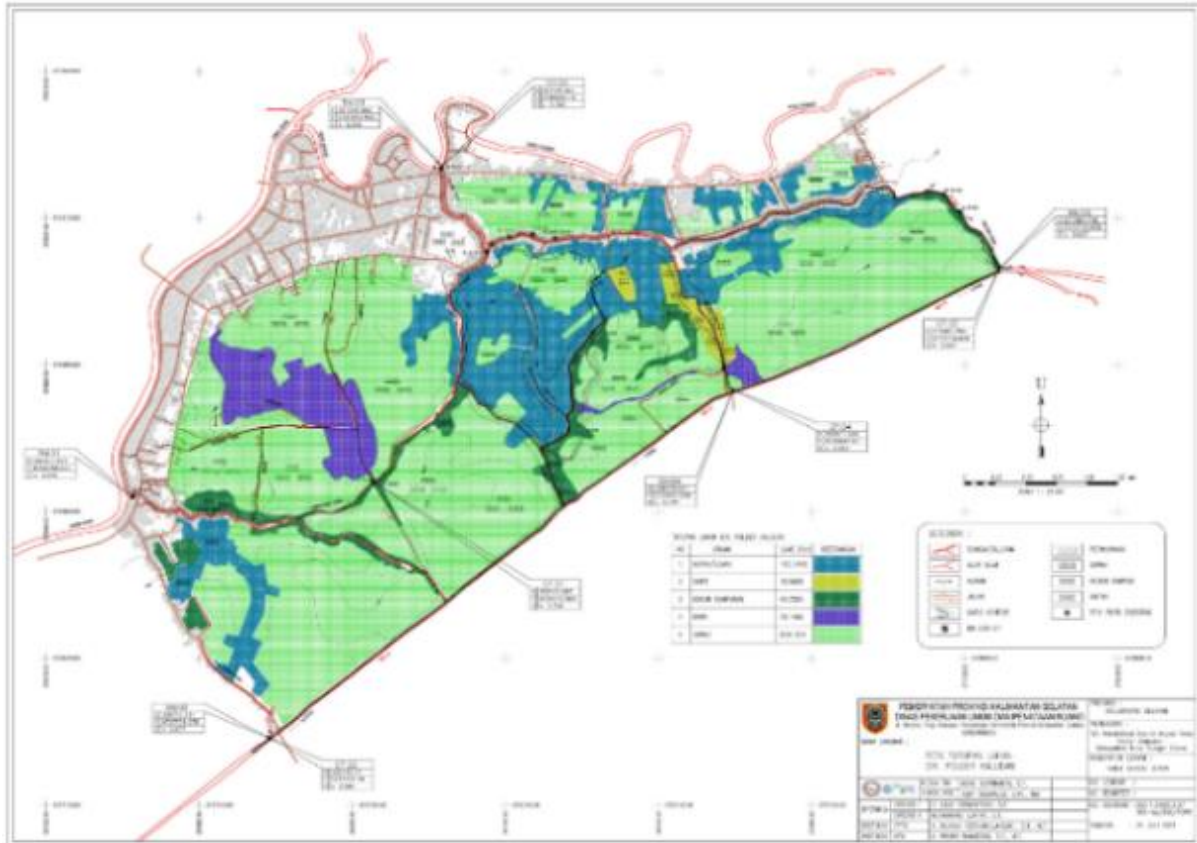


Figure 1. Description of the DIR Polder Kaludan land at the water sampling point

The primary data in this study are water samples taken directly at the Kaludan Polder DIR, Amuntai Tengah District, and Banjarm District, Hulu Sungai Utara Regency, South Kalimantan. On December 23, 2025, the sampling time was during the day, and the weather was clear. Based on reports from the Class I South Kalimantan Climatology Station (Staklim) BMKG on December 22, 2025,

the weather in the North Hulu Sungai Regency area was moderate rain. The sampling points were at the estuary, with 2 sampling points, the Central part, with 2 sampling points, and at the outlet of the Kaludan Polder DIR, also with 2 sampling points. The distribution of sampling location points is presented in Figure 2.



Figure 2. Sampling Coordinate Points

Water quality testing was conducted at the Banjarbaru Public Health Laboratory Center for the parameters of Total Suspended Solid (TSS), Total Dissolved Solid (TDS), pH, Dissolved Oxygen (DO), BOD, COD, Nitrate as N (NO₃), Nitrite as N (NO₂) and at the Banjarbaru Industrial Standardization and Services Center for the parameters of detergent, iron (Fe), Cadmium (Cd),

Manganese (Mn), and Copper (Cu). The test results were then evaluated using the Storet Method and Pollution Index, and compared with the results, with the Water Quality Criteria based on Class (Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001 Tentang Pengelolaan Kualitas Air Dan Pengendalian Pencemaran Air, 2001).

Table 1. Storet Method Water Quality Classification

Class	Water Quality Status	Score	Description
Class A	Excellent	0	Meets quality standards
Class B	Good	-1 s/d -10	Light contamination
Class C	Fair	-11 s/d -30	Moderate contamination
Class D	Poor	-31	Heavily contaminated

Source: Ministry of Environment of the Republic of Indonesia Decree No. 115 of 2003 Concerning Guidelines for Determining Water Quality Status, 2003

Table 1 shows the water quality classification, divided into four classes based on the US-EPA (Environmental Protection Agency)'s scoring system using the Storet Method. This method can identify parameters that meet or exceed water quality standards. In principle, the Storet method compares water quality data with water quality standards tailored to its intended use to determine water quality status.

Table 2. Evaluation of PI Value

Pollutant Index (PI) Value	Status
$0 \leq PI \leq 1,0$	Meets quality standards (good condition)
$1,0 < PI \leq 5,0$	Lightly contaminated
$5,0 < PI \leq 10,0$	Moderately contaminated
$PI \geq 10$	Severely contaminated

Source: Ministry of Environment of the Republic of Indonesia Decree No. 115 of 2003 Concerning Guidelines for Determining Water Quality Status, 2003

Table 2 shows the four levels of water quality: meeting quality standards, lightly polluted, moderately polluted, and heavily polluted, based on the Pollution Index (PI). Water quality management based on the Pollution Index (PI) can provide input to decision-makers to assess the quality of water bodies for a specific purpose and to take action to

improve quality if there is a decline due to the presence of pollutants.

RESULTS AND DISCUSSION

Laboratory Test Results

Water samples collected in the field were then tested at the Banjarbaru Public Health Laboratory Center. The test results are shown in Table 3.

Table 3. Test Results for Sample Points at the Estuary, Middle, and Outlet of the Kaludan Polder DIR

No	Parameter	Unit	Test Results					
			Inlet zone 1	Inlet zone 2	Intermediate reach 1	Intermediate reach 2	Outlet zone 1	Outlet zone 2
1	TSS	mg/L	67	51	70	<8 [#]	<8 [#]	<8 [#]
2	TDS	mg/L	110	90	94	72	62	88
3	pH	-	7,27	7,00	7,16	6,68	6,66	7,55
4	DO	mg/L	8,8	6,2	7,9	7,8	7,3	8,7
5	BOD	mg/L	1,8	<0,93 [#]	1,1	<0,93 [#]	<0,93 [#]	1,1
6	COD	mg/L	25,1	<13,1 [#]	26,5	29,6	<13,1 [#]	14,0
7	Nitrate (NO3-)	mg/L	2,56	3,11	3,41	5,19	2,73	2,35
8	Nitrite (NO2-)	mg/L	0,0286	0,0273	0,0271	0,0130	0,0154	0,0151
9	Iron (Fe)	mg/L	<0,138 [#]	<0,138 [#]	0,11	0,15	0,12	<0,138 [#]
10	Cadmium (Cd)	mg/L	<0,001 [#]	<0,001 [#]	<0,001 [#]	<0,001 [#]	<0,001 [#]	<0,001 [#]
11	Manganese (Mn)	mg/L	<0,046 [#]	<0,138 [#]	<0,046 [#]	<0,046 [#]	<0,046 [#]	<0,046 [#]
12	Copper (Cu)	mg/L	<0,095 [#]	<0,138 [#]	<0,095 [#]	<0,095 [#]	<0,095 [#]	<0,095 [#]

Source: Primary data from laboratory analysis, 2025

The test results in Table 3 show an improvement in water quality from the estuary to the outlet in the Kaludan Polder DIR system. TSS and TDS concentrations tended to be higher at the estuary and middle reaches, then decreased significantly at the outlet (<8 mg/L for TSS). In estuarine systems, total suspended solids (TSS) often form a turbidity maximum zone where concentrations are elevated near the mid-estuary and mouth due to the convergence of riverine and tidal flows, and then decline seaward as particles settle out of suspension and are deposited along the flow path, indicating natural sedimentation and filtering processes occurring along the longitudinal profile (Lins et al., 2024). The pH value was relatively stable and in the neutral range (6.66–7.55), while the DO showed good conditions (6.2–8.8 mg/L) and tended to increase at the outlet, reflecting the net effect of natural aeration through turbulent mixing and gas exchange with the atmosphere along the flow path, indicating better

oxygenation conditions as the water moved towards the DIR outlet (Zhong et al., 2021). BOD and COD parameters were generally higher in the estuary and middle reaches, then decreased at the outlet, reflecting increased input of organic pollutants and subsequent oxidative degradation processes as the water flows through populated or agricultural areas before its quality deteriorates further along the river flow (Y. Liu et al., 2024). Nitrate and nitrite concentrations fluctuated with the highest values in the middle reaches and decreased at the outlet, reflecting the ongoing transformation and removal of nitrogen processes such as nitrification, denitrification, dilution, and biological assimilation along the flow path (Su et al., 2024). Meanwhile, most heavy metals (Fe, Cd, Mn, Cu) are below the LOQ, so they are not dominant pollutants. Overall, the Kaludan Polder DIR system functions as a natural water quality improvement system before the water is used or released.

Water Quality Evaluation with Quality Standards

The test results were then compared with the Water Quality Standards for Rivers and Similar Areas (Government Regulation No. 22 of 2021 Concerning the Implementation of Environmental Protection and Management, 2021) (Appendix VI Class II). Class II was chosen because polder waters

function as water bodies that collect and channel runoff and have the potential to be used for fisheries, irrigation, and limited domestic needs.

1. Inlet Zone of DIR

The results of the comparison of water samples from the estuary or inlet point with river water quality standards are explained in Figures 3, 4, and 5.

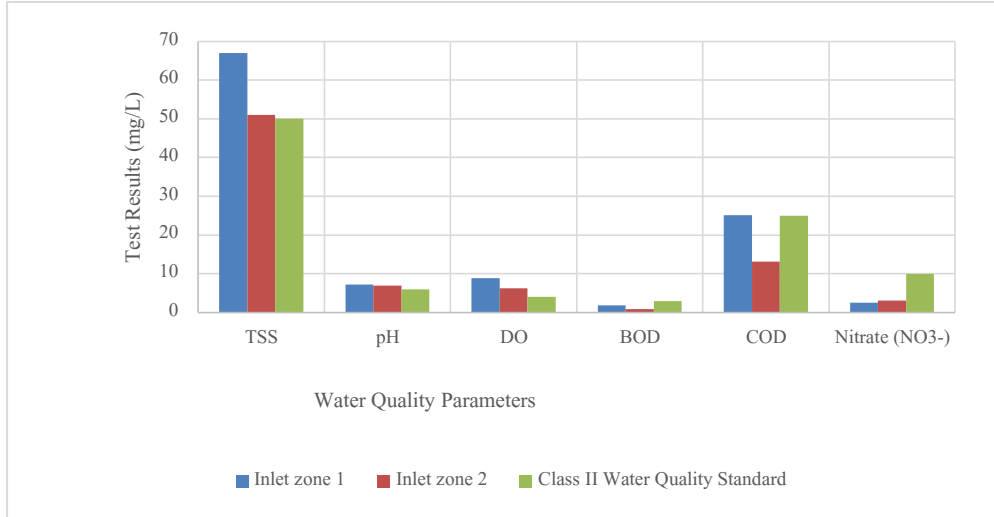


Figure 2. Comparison of Estuary Point Results with River Water Quality Standards (TSS, pH, DO, BOD, COD, and Nitrate Parameters)

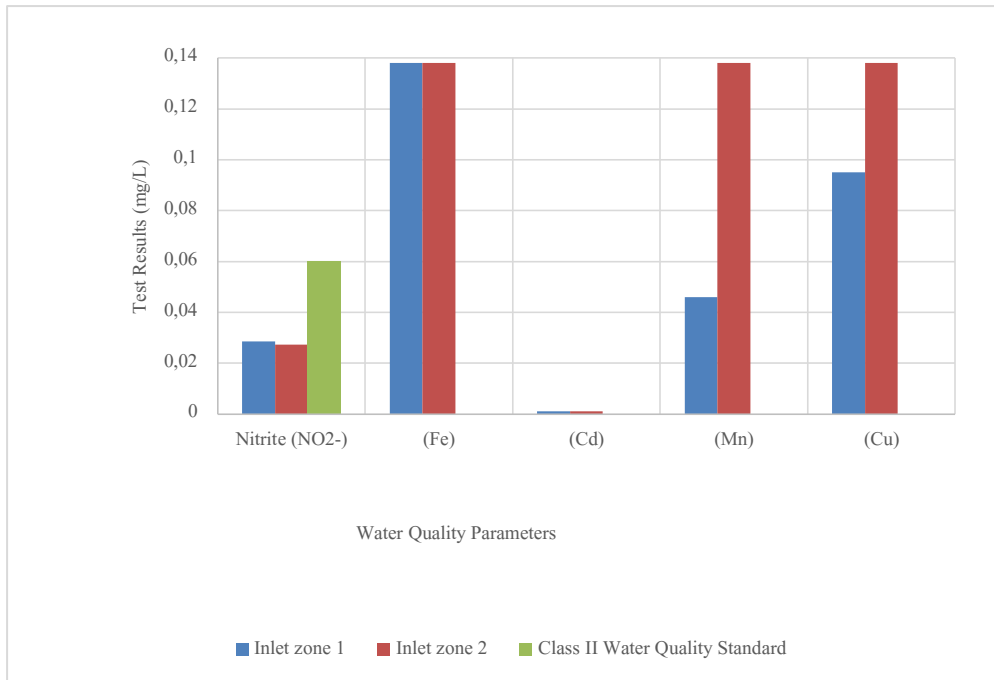


Figure 3. Comparison of Estuary Point Results with River Water Quality Standards (Nitrites, Iron, Cadmium, Manganese, and Copper Parameters)

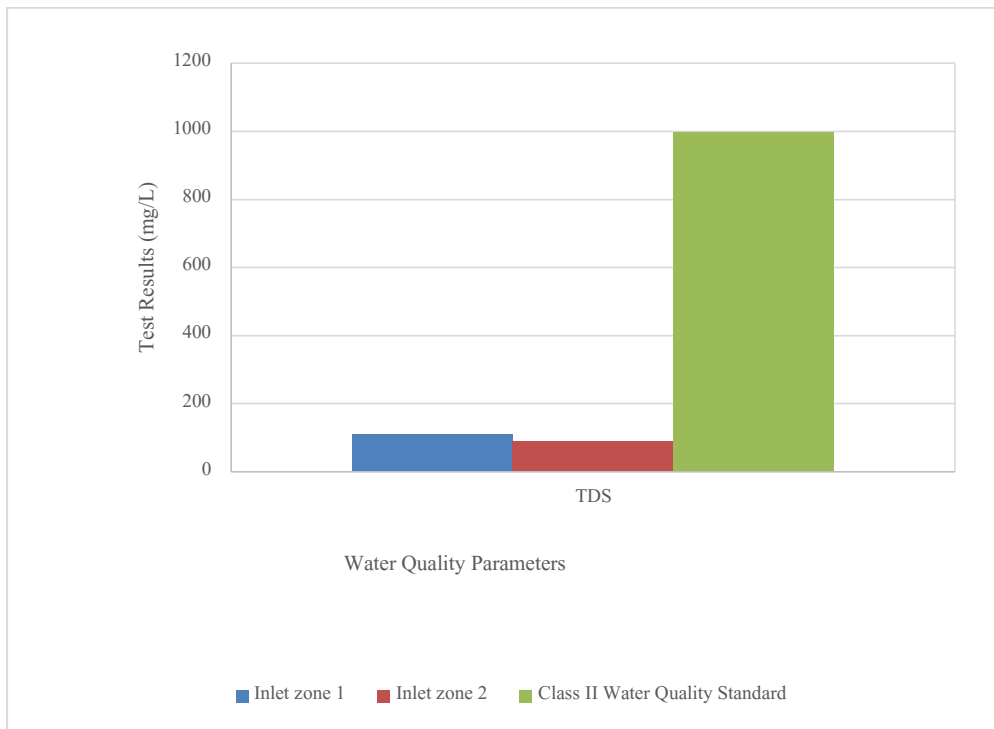


Figure 4. Comparison of Estuary Point Results with River Water Quality Standards (TDS Parameters)

Based on the results of the Kaludan Polder water quality tests shown in Figure 3, Figure 4, and Figure 5, most parameters important for agriculture, such as pH (7.00–7.27), DO (6.2–8.8 mg/L), BOD (1.8 and <0.93 mg/L), TDS (90–110 mg/L), and nitrate and nitrite levels, are still within the quality standards stipulated in Government Regulation No. 22 of 2021, making the water generally suitable for use as an irrigation water source. The neutral pH supports the availability of nutrients in the soil, while the low BOD and nutrient values indicate that the water does not contain excessive organic matter and nitrogen, which can damage soil structure or trigger weed and algae growth in irrigation channels. The TSS values in both samples, 67 mg/L and 51 mg/L, exceeded the quality standard, indicating high levels of silt and sediment particles. This condition has the potential to clog soil pores, reduce porosity and water infiltration rates, and accelerate blockages in irrigation channels and distribution systems. These combined effects can cause siltation, reduce irrigation efficiency, and cause physical stress and stress on plant roots,

thereby reducing growth and yield (Albalasmeh et al., 2022; Ashie et al., 2024). Furthermore, the COD value in the Muara 1 sample (25.1 mg/L) was right within the quality standard threshold, indicating relatively high organic and chemical content. If water with high COD is used continuously for irrigation, it can modify the physical and chemical properties of the soil and cause physiological disorders in plants, including inhibition of photosynthesis, oxidative stress, and decreased biomass when these compounds accumulate in plant tissues due to repeated irrigation (Ashie et al., 2024; Ishfaq et al., 2023). Although the water of the Kaludan Polder is still considered suitable for agriculture, sediment and pollutant load control are still needed to maintain sustainable agricultural land productivity.

2. Intermediate Reach of DIR

The results of the comparison of water samples from the middle point of the DIR with river water quality standards are explained in Figures 6, 7, and 8.

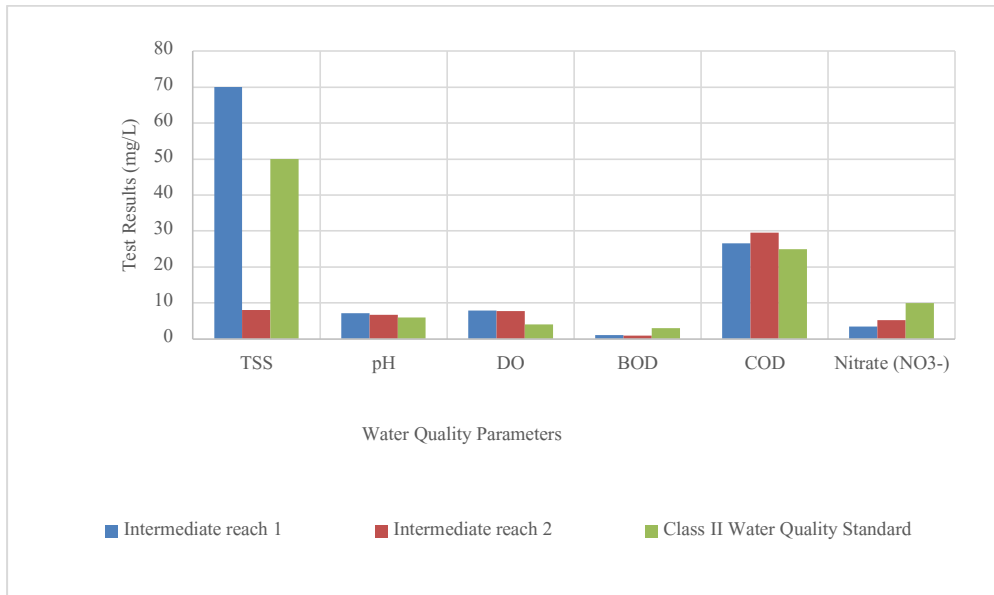


Figure 5. Comparison of Midpoint Results with River Water Quality Standards (TSS, pH, DO, BOD, COD, and Nitrate Parameters)

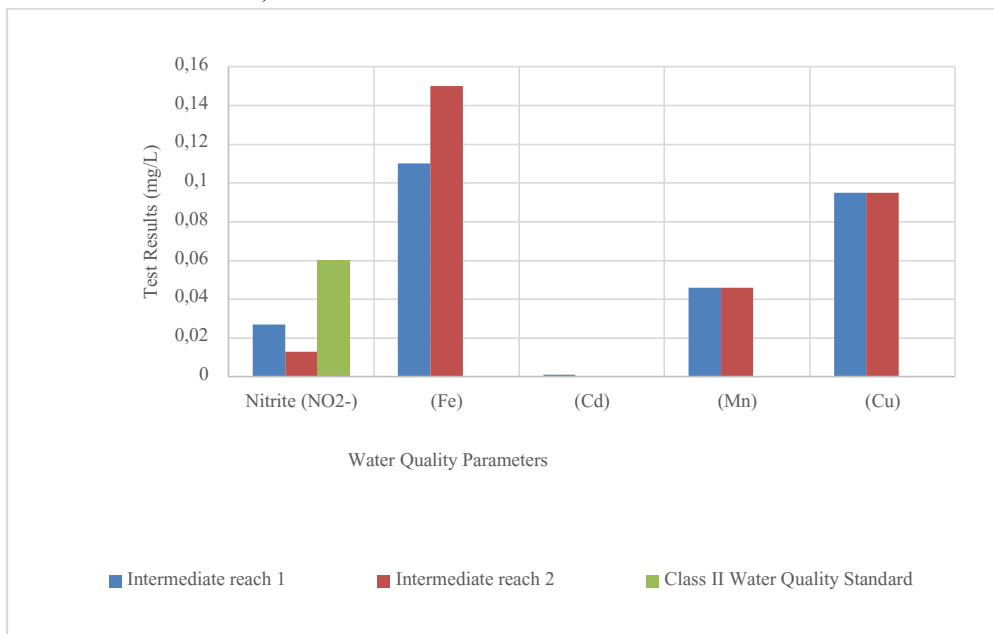


Figure 6. Comparison of Midpoint Results with River Water Quality Standards (Nitrite, Iron, Cadmium, Manganese, and Copper Parameters)

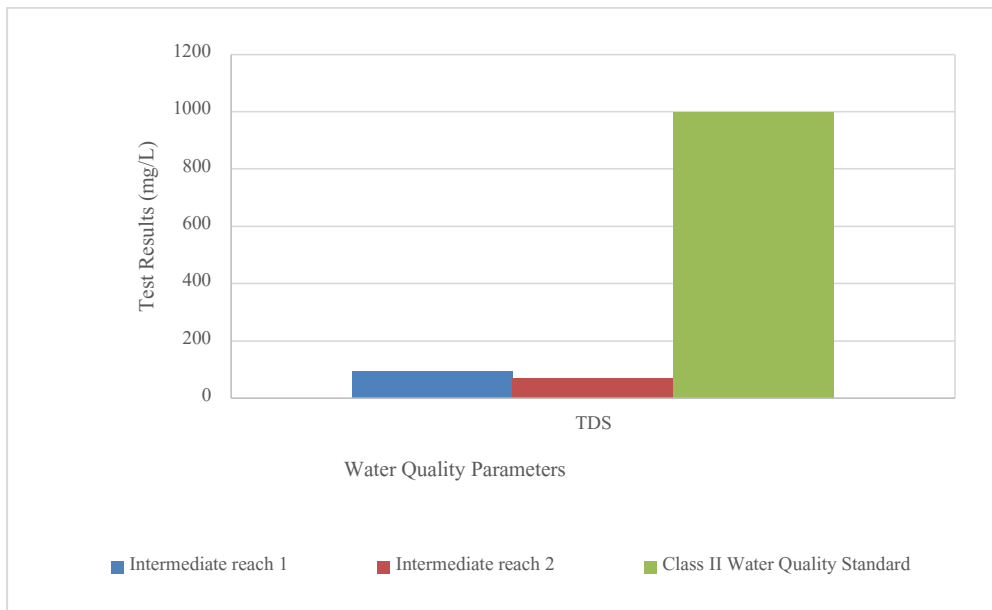


Figure 7. Comparison of Midpoint Results with River Water Quality Standards (TDS Parameters)

Based on the results of the Kaludan Polder water quality tests shown in Figure 6, Figure 7, and Figure 8, it was found that most chemical parameters such as pH (6.68–7.16), DO (7.8–7.9 mg/L), BOD (1.1 and <0.93 mg/L), TDS (72–94 mg/L), and nitrate and nitrite still meet quality standards, so that in general the water is still suitable for use to support agriculture and aquatic life. The TSS value in the Middle 1 sample of 70 mg/L exceeded the quality standard, indicating a high sediment content in the water, potentially causing channel siltation and reducing the efficiency of irrigation water flow (Albalasmeh et al., 2022; Ashie et al., 2024). The COD value in both samples (26.5–29.6 mg/L) also exceeded the quality standard, indicating a relatively high content of oxidized organic and chemical materials. This

condition can reduce irrigation water quality because these pollutants have the potential to disrupt plant growth, reduce soil fertility, and increase the risk of hazardous substance accumulation in agricultural land (Ashie et al., 2024; Ishfaq et al., 2023). Thus, although the general water quality of the Kaludan Polder is still quite good, the high TSS and COD values indicate the need for water quality management so that the polder's function as a water provider for agriculture can remain optimal and sustainable.

3. Outlet Zone of DIR

The results of the comparison of endpoint or outlet water samples with river water quality standards are explained in Figures 9, 10, and 11.

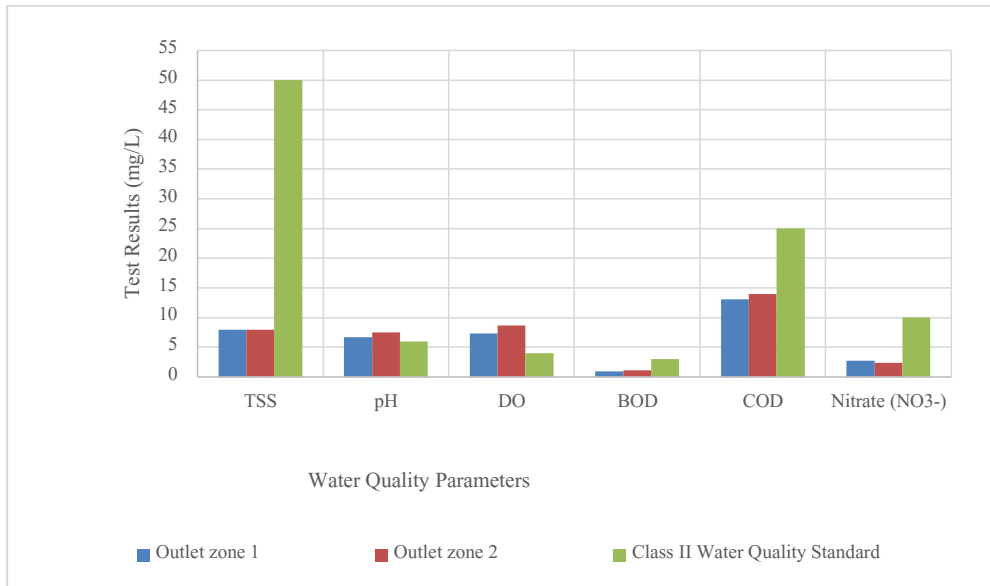


Figure 8. Comparison of End Point Results with River Water Quality Standards (TSS, pH, DO, BOD, COD, and Nitrate Parameters)

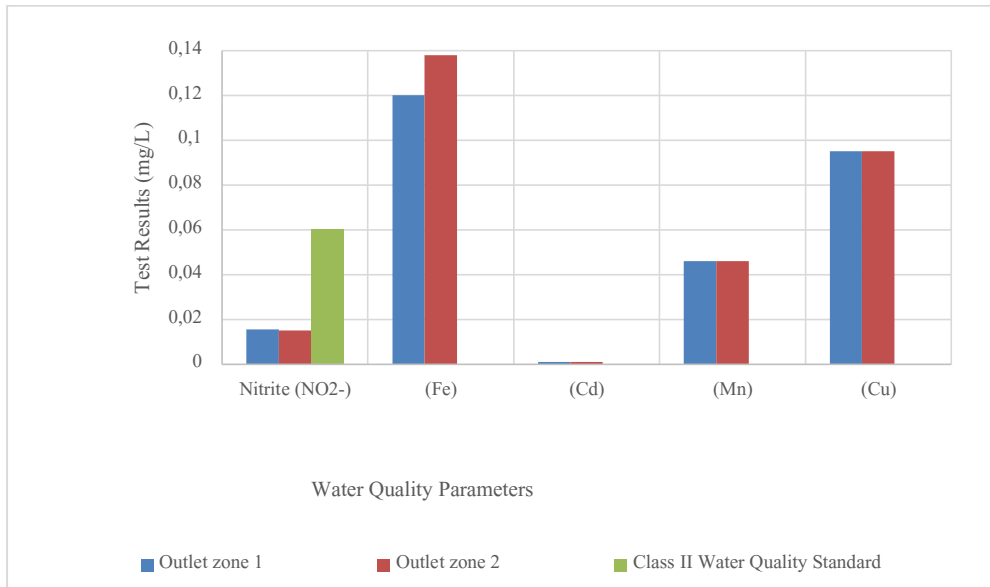


Figure 9. Comparison of End Point Results with River Water Quality Standards (Nitrite, Iron, Cadmium, Manganese, and Copper Parameters)

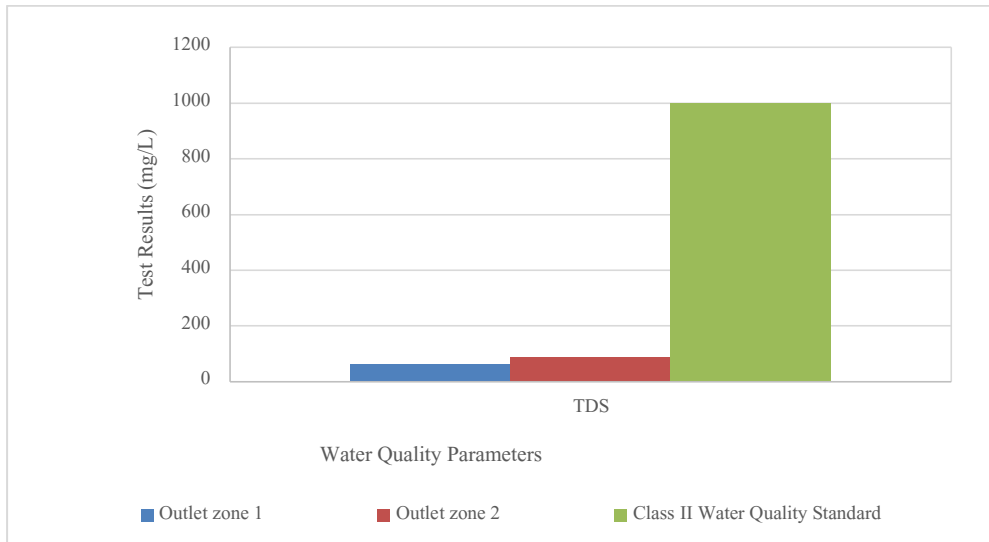


Figure 10. Comparison of End Point Results with River Water Quality Standards (TDS Parameters)

The results of the Kaludan Polder water quality testing, shown in Figures 9, 10, and 11, indicate that all key parameters meet the Class II river water quality standards stipulated in Government Regulation No. 22 of 2021. The pH value, which is in the range of 6.66–7.55, high dissolved oxygen (DO) levels (7.3–8.7 mg/L), and low BOD and COD values indicate that the waters are in good condition and free from organic pollution. Furthermore, low nitrate and nitrite concentrations indicate that the system has not experienced increased phytoplankton biomass formation associated with eutrophication, due to low inorganic nitrogen concentrations (Duque et al., 2021). Very low TSS values (<8 mg/L) indicate relatively clear water with minimal sediment, thus not potentially causing channel siltation or soil pore clogging. For the agricultural sector, this condition is very advantageous because irrigation water tends to be clearer and more physically stable, thus not clogging soil pores and allowing for good water movement within the soil profile, ultimately increasing infiltration rates and improving soil structure. This condition increases water availability in the root zone and facilitates nutrient uptake by

plants, thus supporting more optimal growth and increasing water use efficiency in sustainable agricultural systems (Darko et al., 2025). Thus, the water quality of the Kaludan Polder at points A1 and A2 is classified as very suitable for use as an irrigation water source, and it plays a positive role in supporting the productivity and sustainability of the surrounding agricultural land.

Pollution Analysis

The Storet method and the Pollution Index (IP) method are used to determine the level of water pollution by comparing the concentration of water quality parameters to the quality standards (Government Regulation No. 22 of 2021 Concerning the Implementation of Environmental Protection and Management, 2021) (Class II) and the score according to Storet and the IP value. These two methods are regulated in the Ministry of Environment of the Republic of Indonesia Decree No. 115 of 2003 Concerning Guidelines for Determining Water Quality Status, 2003. After analyzing pollution using the Storet method and the Pollution Index method, the results of the two methods are then compared, as shown in Table 4.

Table 4. Comparison of Analysis Results of Storet Method and Pollution Index Method

Sample Point	Storet Method	Classification	Pollution Index Method	Classification
Inlet Zone 1	-4	Lightly Contaminated	1,61	Light Pollution
Inlet Zone 2	-1	Lightly Contaminated	1,14	Light Pollution
Intermediate Reach 1	-4	Lightly Contaminated	1,45	Light Pollution
Intermediate Reach 2	-3	Lightly Contaminated	1,41	Light Pollution
Outlet Zone 1	0	Not Polluted	1,31	Light Pollution
Outlet Zone 2	0	Not Polluted	1,56	Light Pollution

Source: Author's analysis, 2026

Based on Table 4 of the Storet method, the water quality at Muara 1 and Muara 2 points is generally in the light pollution category, with Muara 1 showing a higher level of pollution than Muara 2. This condition is mainly influenced by TSS and COD parameters that exceed the quality standards in Muara 1, while in Muara 2, only a minor violation of TSS occurred. These results are supported by the Pollution Index method, where the IP value of Muara 1 is 1.61 and Muara 2 is 1.14, both of which are included in the light pollution category. The higher IP value in Muara 1 indicates that the pollutant load entering the Kaludan Polder DIR system is not only in the form of suspended particles, but also organic matter that affects the overall water quality. The difference in assessment between the two methods shows that the Storet method is more sensitive to individual quality standard violations, while the IP method emphasizes the cumulative condition of pollution. From an agricultural perspective, this condition indicates that the incoming irrigation water has the potential to increase turbidity, accelerate canal sedimentation, and impact the clogging of rice field soil pores if not managed properly.

In the middle section of the irrigation network, Storet analysis results still indicate a mild pollution status for both points. However, there are differences in pollutant characteristics between samples. Middle Point 1 is still affected by high TSS and COD, while in Middle Point 2, the TSS value is very low due to the sedimentation process, but COD still exceeds the quality standard. The Pollution Index method shows relatively uniform IP values, namely 1.45 for Middle Point 1 and 1.41 for Middle Point 2, indicating that overall water quality in the middle section of the system remains at a mild pollution level. This indicates that despite improvements in physical water quality (reduced TSS), the dissolved organic matter load remains a

major limiting factor. In the context of DIR Kaludan Polder agriculture, this condition indicates that the irrigation system has been effective in reducing sediment, but the organic load still has the potential to affect the soil oxygen balance. If used continuously, this condition can increase the activity of soil microorganisms, which in turn increases oxygen consumption in the root zone. This condition has the potential to reduce soil oxygen availability, cause hypoxic stress in plant roots, and disrupt physiological processes such as root respiration and nutrient uptake (Li et al., 2021; Y. Wang et al., 2018; Zhao et al., 2022).

The endpoint analysis using the Storet method showed that all water quality parameters at Endpoints 1 and 2 met the quality standards, thus classified as unpolluted. This indicates that sediment deposition, organic matter degradation, and natural water quality stabilization have occurred along the Kaludan Polder DIR flow. However, the Pollution Index method still classifies the outlet water quality as slightly polluted, with IP values of 1.31 and 1.56. This difference is due to the IP method's characteristic, which still takes into account the maximum and average ratios of parameters, such as DO and TDS, even though there are no violations of quality standards. This difference in results indicates that Storet is more appropriate for assessing compliance with quality standards, while the Pollution Index is more conservative in assessing overall environmental pressure. From an agricultural perspective, the outlet water quality is relatively safe for reuse and does not pose a significant risk to soil or plants.

Overall, a comparison of the two methods indicates that water quality in the Kaludan Polder Irrigation Area (DIR) has gradually improved from the inlet to the outlet. Light pollution conditions at the inlet and middle sections are still tolerable for agricultural activities, but still require good

monitoring and management of sediment and dissolved organic matter to prevent the accumulation of contaminants in the soil, which can reduce fertility, damage soil structure, and reduce land productivity if used repeatedly in the long term (Hmidi et al., 2025). The results of this analysis indicate that the agricultural and irrigation systems in the Kaludan Polder Irrigation Area (DIR) remain in ecohydrological balance, with self-purification processes able to offset the pollutant load from incoming water and agricultural activities as long as the load remains below the environmental carrying capacity. This finding aligns with the water quality management principles stipulated in (Ministry of Environment of the Republic of Indonesia Decree No. 115 of 2003 Concerning Guidelines for Determining Water Quality Status, 2003) and (Government Regulation No. 22 of 2021 Concerning the Implementation of Environmental Protection and Management, 2021), which emphasize that determining water quality status must consider the natural capacity of the aquatic environment to reduce pollution.

CONCLUSION

The quality of swamp irrigation water in the Kaludan Polder Irrigation Area (DIR) is generally considered suitable for agricultural activities, although some locations and parameters show mild pollution. Laboratory testing results in 2025 showed that most physical and chemical water parameters, such as pH, DO, BOD, TDS, nutrients, and heavy metals, met Class II water quality standards based on Government Regulation of the Republic of Indonesia Number 22 of 2021. The parameters that remain the main limitations are Total Suspended Solids (TSS) and Chemical Oxygen Demand (COD), particularly at the estuary and middle points of the irrigation network. Analysis of water quality status using the Storet Method and the Pollution Index Method shows graphical variations from upstream to downstream. The estuary and middle sections of the DIR are classified as mildly polluted, while the outlet section shows better conditions, even unpolluted, based on the Storet Method. This condition indicates that the swamp irrigation system still has effective natural self-purification capabilities, so that the pollutant load from incoming water and agricultural activities remains

within the limits of environmental carrying capacity.

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