Water Quality Index of The Kusan River Watershed Using The IKA-INA (Modified Indonesian Water Quality Index) Method in Tanah Bumbu Regency

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ABSTRACT

The Kusan River Watershed (DAS) is one of three major watersheds in Tanah Bumbu Regency. Quoted from the '2024 Tanah Bumbu Regency Environmental Quality Monitoring Report', the water quality of the Kusan River shows moderate pollution at the middle point and mild pollution at the upstream and downstream points. Indications of a decline in water quality due to industrial, mining, agricultural and domestic waste disposal have become a significant environmental problem in this region. This study focuses on the application of the IKA-INA method to analyse water quality in the Kusan watershed, with the aim of providing a comprehensive overview of the water conditions in the river. Water samples were collected at 11 surface water points in the Kusan River Watershed. The number of monitoring points was selected based on the spatial representation of water bodies in accordance with Minister of Environment and Forestry Regulation No. 27 of 2021, which emphasises the selection of points based on the function of water bodies, potential pollutants, and the purpose of water quality monitoring. The WQI Kusan Watershed values show spatial variation between river segments. The highest WQI was recorded in the downstream Kusan Watershed (77.63), while the lowest was in the Mangkal Api Hilir River (66.39). Sub-watersheds such as the Pendamaran River show an increase from upstream to downstream, while the Bakarangan River is relatively stable. The WQI Kusan Watershed in 2025 in stage II or the final stage is classified as good because the index range is $70 \leq i \leq 90$ with an WQI of 73.51.

Keywords: Water Quality Index, IKA-INA Method, Kusan River Watershed

INTRODUCTION

Rivers play a vital role in supporting life, both ecologically and socio-economically, providing direct benefits to the surrounding communities. A River Watershed (DAS) is a land area that forms a single unit with a river and its tributaries, functioning to collect, store, and naturally channel water from rainfall to lakes or the sea. Its land boundaries are defined by topographical divides, while its sea boundaries extend to the waters still influenced by land-based activities.

The Kusan River Watershed (DAS) is one of three major watersheds in Tanah Bumbu Regency, which consists of the Satui Watershed, Batulicin Watershed, and Kusan

Watershed. The Kusan River Watershed is a river system with a length of approximately 182 kilometres, spanning five sub-districts: Kusan Hulu Sub-district, Teluk Kepayang Sub-district, Kuranji Sub-district, Kusan Tengah Sub-district, and Kusan Hilir Sub-district.

Quoted from the '2024 Tanah Bumbu Regency Environmental Quality Monitoring Report', the water quality of the Kusan River shows moderate pollution at the middle point and mild pollution at the upstream and downstream points. Indications of a decline in water quality due to industrial, mining, agricultural and domestic waste disposal have become a significant environmental problem in this region. This situation necessitates targeted management efforts based on scientific data to maintain the sustainability of watershed functions.

Government Regulation No. 22 of 2021 explains that water quality is the condition of water at a specific time and place that is measured and/or tested based on specific parameters and methods in accordance with the provisions of laws and regulations. The determination of river water quality is regulated by quality standards as attached in Appendix VI of this Regulation. Water Quality Standards are measures of the limits or levels of living organisms, substances, energy, or components that are present or should be present and/or pollutants whose presence in water is tolerated.

Water quality can be determined using the Pollution Index (PI) and National Sanitation Foundation Water Quality Index (NSF-WQI) methods. However, these two methods have weaknesses, such as producing moderate data that is not accurate, as well as limited parameters and inflexibility. These weaknesses present an opportunity for Indonesia to develop these methods so that they can be applied to determine water quality in Indonesia.

The Indonesian Modified Water Quality Index (IKA-INA) is one of the results of water quality index development carried out at the Centre for Quality Research and Development and the Ministry of Environment and Forestry laboratory using a compilation method based on the NSF-WQI compilation method, which uses the Delphi method in decision-making for parameter selection, weighting and sub-index curve compilation.

IKA-INA was developed to formulate a water quality index adjusted to the needs of water quality assessment in Indonesia, so that all components of IKA-INA, such as the selection of water quality parameters, the weighting of water quality parameters, and the formulation of sub-index curves, are the result of processing primary data from water sector panelists in Indonesia (Ratnaningsih et al, 2020). Artiningrum & Saeful (2023) explain that the IKA-INA method has several advantages, specifically that it is contextual to Indonesian conditions, refers to national quality standards, is more practical, and is more relevant to watershed management.

MATERIALS & METHODS

The study was conducted in Tanah Bumbu Regency, focusing on the Kusan River Watershed. Water samples were collected at 11 surface water points in the Kusan River Watershed. The number of monitoring points was selected based on the spatial representation of water bodies in accordance with Minister of Environment and Forestry Regulation No. 27 of 2021, which emphasises the selection of points based on the function of water bodies, potential pollutants, and the purpose of water quality monitoring. The following are the research monitoring points.
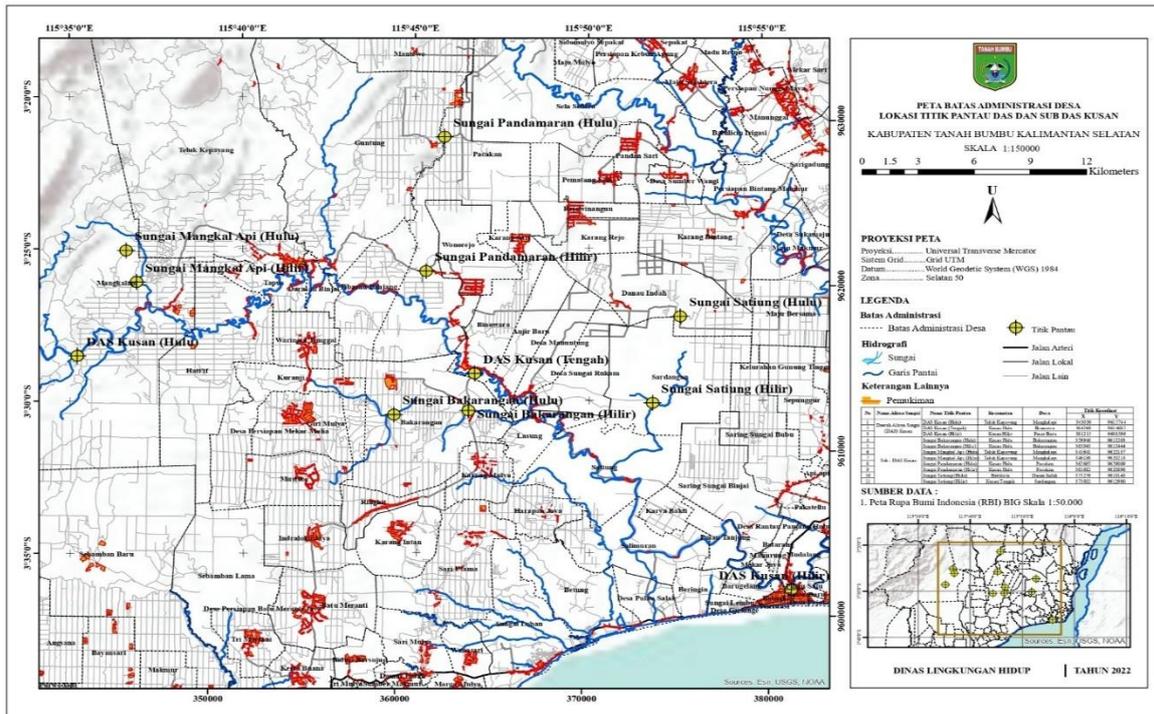
Figure 1. research monitoring points

The Water Quality Index calculation is performed by converting the laboratory test data of selected water quality variables, which have different measurement units, into sub-index values (Ii) without units. The Ii value is obtained by converting each parameter to a scale of 0 to 100 using the sub-index curve equation. The mathematical equation for the IKA-INA sub-index curve with the NSF-WQI combination can be seen in Table below.

Table 1. Mathematical Equation of Curve Sub-Index IKA-INA Combination Results

Parameters	Sub-Index IKA-INA Combination Curve Equation	Designated for
DO	$y = -0{,}6574x^2 + 10{,}157x + 7E{-}15$	DO≤2
	$y = -0{,}023x^3 - 0{,}9933x^2 + 26{,}124x - 30{,}173$	DO≤7
	$y = -1{,}9524x + 109{,}67$	DO≤8
	$y = -5{,}8985x + 141{,}24$	DO≤8,5
	$y = 8{,}0809x^3 - 227{,}43x^2 + 2101{,}2x - 6300{,}1$	DO≤11
Fecal coliform	$y = -0{,}004x^3 + 0{,}2471x^2 - 5{,}2535x + 102{,}14$	FC≤30
	$y = 3E{-}09x^4 - 4E{-}06x^3 + 0{,}0019x^2 - 0{,}3953x + 67{,}962$	FC≤500
	$y = -0{,}014x + 36$	FC≤1000
	$y = -0{,}002x + 24$	FC≤5000
	$y = -0{,}0008x + 18$	FC≤10000
	$y = -0{,}0002x + 12$	FC≤20000
	$y = 5E{-}23x^2 - 0{,}0001x + 10$	FC≤40000
	$y = 6$	FC≤50000
COD	$y = 0{,}0204x^2 - 1{,}4479x + 99{,}614$	COD≤20
	$y = -2{,}9803x + 138{,}43$	COD≤25
	$y = -0{,}9054x + 86{,}555$	COD≤50
	$y = -0{,}0055x^2 + 0{,}2907x + 40{,}428$	COD≤100
	$y = 0{,}0088x^2 - 2{,}4487x + 171{,}57$	COD≤150
pH	$y = 0$	pH≤1
	$y = -0{,}0375x^5 + 0{,}5379x^4 - 1{,}8352x^3 + 0{,}1667x^2 + 7{,}8273x - 6{,}7143$	pH≤7
	$y = -4x + 116$	pH≤8
	$y = -0{,}463x^3 + 19{,}155x^2 - 263{,}07x + 1200{,}4$	pH≤13

BOD	y = -0,25x3 + 4,0952x2 - 26,726x + 118,14	BOD≤7
	y = 6E-05x4 - 0,0067x3 + 0,3286x2 - 8,3016x + 90,378	BOD≤32
Total Phosphate	y = -80x + 100	TP≤0.1
	y = 246,13x3 - 304,86x2 + 30,477x + 91,909	TP≤0.8
	y = 0,0924x6 - 1,8787x5 + 15,365x4 - 64,708x3 + 148,85x2 - 184,6x + 126,81	TP≤5
	y = -0,0463x3 + 1,4524x2 - 14,882x + 56,921	TP≤10
	y = 2,5x2 - 57,5x + 332	TP≤12
TSS	y = x + 78	TSS≤2
	y = 0,1458x + 79,708	TSS≤50
	y = 87	TSS≤60
	y = -4E-16x2-0,1x+93	TSS≤100
	y = -0,08x + 91	TSS≤150
	y = -3E-05x2 - 0,1145x + 96,81	TSS≤450
	y = -0,18x + 121	TSS≤500
	y = -11x + 5531	TSS≤501
	y = 20	TSS≤2000
NO₃	y = -x + 97	NO3≤1
	y = 0,6989x2 - 12,05x + 107,32	NO3≤6
	y = 0,0714x2 - 3,4111x + 78,091	NO3≤15
	y = -1E-16x3 + 0,0071x2 - 1,3929x + 62,214	NO3≤40
	y = 4E-16x2 - 0,8x + 50	NO3≤50
	y = 0,02x2 - 2,5x + 85	NO3≤60
	y = 0,0029x2 - 0,5571x + 30,114	NO3≤100
	y = -2x + 203	NO3≤101
	y = 1	NO3≤200

Source: **Ratnaningsih et al**, (2020).

The sub-index curve may be linear or non-linear. The Delphi method was used in determining the index based on the weight (Wi) and sub-index (Ii) of eight main water quality parameters, namely pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Fecal Coliform, Nitrate (NO₃), Total Phosphate, and Total Suspended Solids (TSS), which are expressed by the following formula:

$$WQI = \sum_{i=1}^{n} (Wi \times Ii)$$

Information:
WQI : Water Quality Index
Wi : Parameter weight up to i
Ii : Sub-index value for the i-th
n : Number of water quality parameters
The weight values of water quality parameters in the IKA-INA system are presented in Table below.

Table 2. IKA-INA Calculation Parameter Weight

No	Parameters	Weight
1	DO	0.167
2	Fecal Coliform	0.157
3	COD	0.14
4	pH	0.137
5	BOD	0.133
6	Total Phosphate	0.1
7	Nitrate	0.081
8	TSS	0.086
	Total	1

Source: Ministry of Environment and Forestry, (2024)

Meanwhile, the overall water quality index for the Kusan watershed can be obtained using the following formula:

$$WQI\ Kusan\ Watershed = \sum_{i}^{n} \frac{WQI\ Monitoring\ Points}{Number\ of\ Monitoring\ Points}$$

After the Water Quality Index calculation results are obtained, the IKA-INA results are compared with the new classification of IKA-INA criteria in the table below:

Table 3. Water Quality Index Category Classification

Index Range	Category
$90 \leq i \leq 100$	Excellent
$70 \leq i \leq 90$	Good
$50 \leq i \leq 70$	Average
$25 \leq i \leq 50$	Poor
$0 \leq i \leq 25$	Very poor

RESULTS

The Water Quality Index (WQI) is an important indicator for assessing the overall quality and condition of aquatic ecosystems. The WQI is designed to simplify various water quality parameters into a single, easy-to-understand index value, thereby facilitating decision-making in water resource management. Water Quality Index (WQI) data for the Kusan watershed and sub-watershed can be seen in the following table.

Table 4. Water Quality Index (IKA) Data for the Kusan River Watershed and Sub-Watershed

KUSAN Watershed	WQI 2022 II	WQI 2023 II	WQI 2024 II	WQI 2025 I	WQI 2025 II
Upstream Kusan River Watershed	82.16	66.19	75.44	50.68	74.73
Middle Kusan River Watershed	79.34	67.95	73.04	68.73	75.09
Downstream Kusan River Watershed	79.41	74.42	75.99	62.99	77.63
Upstream Bakarangan River Sub-Watershed	78.02	67.05	63.02	79.25	74.08
Downstream Bakarangan River Sub-Watershed	80.98	68.18	75.29	73.20	74.51
Upstream Mangkal Api River Sub-Watershed	81.66	76.67	78.25	77.22	79.25
Downstream Mangkal Api River Sub-Watershed	79.69	76.86	76.71	77.63	66.39
Upstream Pandaraman River Sub-Watershed	73.18	70.43	77.93	73.17	75.14
Downstream Pandaraman River Sub-Watershed	72.69	65.67	76.02	71.44	76.98
Upstream Satiung River Sub-Watershed	67.38	65.14	71.84	74.34	67.83
Downstream Satiung River Sub-Watershed	75.92	68.04	48.72	74.26	67.00
Average of WQI Kusan Watershed	77.31	69.69	72.02	71.17	73.51

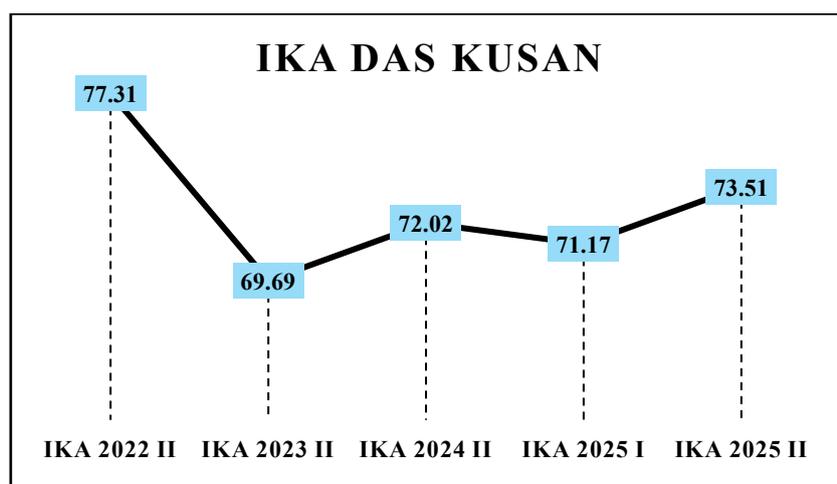**(Source: Secondary and Primary Data, 2025)**

Figure 2. Graph of WQI Watershed from 2022 to 2025

The Water Quality Index (WQI) value is directly influenced by the condition of the watershed and the presence of pollutants. A clean ecosystem contributes to a higher WQI score, which reflects better water quality (Tiwari et al., 2025). Changes in the water

quality of the Kusan watershed can be determined from the annual WQI value. The highest WQI value was recorded in 2022, reaching 77.31. In 2023, water quality declined dramatically, with an WQI of only 66.69. In 2024, water quality in the Kusan watershed showed improvement from previous conditions. The WQI value was recorded at 72.02, indicating an improvement compared to 2023. In phase I of 2025, the WQI value decreased slightly to 71.17. However, in phase II of 2025, water quality again showed a positive trend with the WQI value increasing to 73.51. This improvement is a hope for more sustainable environmental management.

DISCUSSION

The upper reaches of the Kusan River Watershed experienced a significant decline in water quality, with the WQI value falling from 82.16 in 2022 to 50.68 in phase I of 2025. In phase II of 2025, there was a recovery with an increase in the WQI value to 74.73, indicating a fairly good improvement in water quality. The middle section of the Kusan watershed showed a decline in 2023 with a WQI value of 67.95, but gradually increased to 75.09 in phase II of 2025. The downstream section of the Kusan watershed showed relatively stable water quality throughout the 2022 to 2025 period. The WQI tends to be in a good range, with the highest achievement of 77.63 in phase II of 2025.

Water quality in the Mangkal Api Hulu River showed excellent consistency throughout the observation period. The WQI value remained at a high level, with the highest achievement of 79.25 in phase II of 2025. This stability reflects the well-preserved environmental conditions in the upstream area. The Mangkal Api Hulu River showed stable water quality until phase I in 2025, with WQI values ranging from 76.71 to 77.63. However, the WQI declined in phase II in 2025 to 66.39, indicating a disturbance in water quality in the downstream area.

Water quality in the Upstream Pendamaran River has shown considerable improvement. The WQI value in 2023 was 70.43 and continued to improve, reaching 75.14 in phase II in 2025. The Downstream Pendamaran River sub-watershed also experienced significant improvement. The IKA value, which was initially at 65.67 in 2023, increased consistently to reach 76.98 in phase II in 2025. Water quality in the upstream and downstream sections of the Pendamaran River will be in good condition in 2025.

Water quality in the Upstream Satiung River shows quite dynamic fluctuations. The WQI value was 65.14 in 2023, then increased to 74.34 in phase I of 2025, indicating an improvement in environmental conditions. However, in phase II of 2025, the WQI value dropped again to 67.83, indicating that water quality in the upper reaches is still not fully stable and requires further attention. The Downstream Satiung River experienced more extreme changes. After recording an WQI value of 75.92 in 2022, water quality declined dramatically to a low of 48.72 in 2024. Although it improved to 74.26 in phase I in 2025, the WQI value fell again to 67.00 in phase II. These fluctuations indicate that the downstream area of the Satiung River faces serious challenges in maintaining consistent water quality.

The middle of the Kusan River Basin has shown a steady upward trend since the decline in 2023, while the downstream section has remained relatively consistent in the good category, reflecting the effectiveness of environmental management. The downstream sections, the Bakarangan River and the Pendamaran River, have also recorded consistent improvements. This is closely related to water discharge, which is greater at these points. In line with the research by Das (2025), which states that high flow rates contribute to WQI, this is because high flow rates can dilute waste, resulting in a decrease in phosphate and TSS concentrations, especially at downstream points.

The Bakarangan and Mangkal Api rivers in the upstream sub-watershed recorded a significant increase, with the WQI value peaking in phase II in 2025, indicating consistent good water quality. The Pendamaran Hulu River also shows a stable upward trend. This is in line with Santika's (2024) research, which noted that at several research points, the upper reaches tended to have higher WQI values. This may be because the upstream areas have minimal human activity, so the pressure of pollutants on water bodies is relatively low (Novita et al., 2023).

Water quality in the Kusan watershed shows a promising increase in the Water Quality Index (WQI) towards the end of 2025, although with varying dynamics in each section. The upstream section experienced a sharp decline until phase I of 2025, but recovered significantly in the following phase. Research by Novita et al. (2023) states that high WQI values in the final stage indicate the effectiveness of sub-watershed management. There are challenges at points such as the upstream and downstream Satiung River and the downstream Mangkal Api River, which experienced fluctuations and a decline in water quality at the end of the period. According to Pramaningsih et al. (2023), significant fluctuations in water quality in the upstream and downstream areas are the main challenges in maintaining the WQI. The decline in WQI at several points may be due to domestic pollution and sedimentation.

According to the Water Quality Index Classification, the 2025 WQI value for the Kusan River Watershed in stage II or the final stage is classified as good because the index range is $70 \leq i \leq 90$ with a WQI of 73.51. This is in line with the research by Pramaningsih et al. (2023), which states that an index range of $70 \leq WQI < 90$ is classified as good. Aulia et al. (2023) also mention that WQI with an index value between 70-90 is classified as good, in accordance with Government Regulation No. 22 of 2021 and Ministry of Environment and Forestry standards. This indicates that the overall water quality condition of the Kusan River Watershed still supports ecological functions and limited utilisation by the community.

CONCLUSION

The WQI Kusan Watershed values show spatial variation between river segments. The highest WQI was recorded in the downstream Kusan Watershed (77.63), while the lowest was in the Mangkal Api Hilir River (66.39), indicating the influence of pollutants and anthropogenic activities. Sub-watersheds such as the Pendamaran River show an increase from upstream to downstream, while the Bakarangan River is relatively stable. The WQI Kusan Watershed in 2025 in stage II or the final stage is classified as good because the index range is $70 \leq i \leq 90$ with an WQI of 73.51. This indicates good water quality, but differences between locations need to be considered in zone-based management and conservation.

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