

Development and Validation of the Rational Water Quality Index (RWQI): A Health Risk-Based Dynamic Weighting Framework for Water Quality Evaluation of Lake Sentani, Papua

Bambang Suhartawan^{1*}, Daawia²

¹ Environmental Engineering Study Program, TSP, Jayapura University of Science and Technology

² Department of Biology, Faculty of Mathematics and Natural Sciences, Cenderawasih University

ARTICLE INFO

Article history:

Received January 04 2026

Received in revised form February 20, 2026

Accepted March 20, 2026

Available online May 28, 2026

Keywords:

Water Quality Index

Dynamic Weighting

Lake Sentani

Health Risk

Limnology

RWQI

Papua

ABSTRACT

Lake Sentani is the largest lake in Papua and an important raw water source facing pressure from residential expansion, agricultural runoff, domestic wastewater, and small-scale mining. This study developed and internally evaluated the Rational Water Quality Index (RWQI), integrating the Regulatory Violation Index (RVI), Toxicological Severity Score (TSS), and Limnochemical Similarity Coefficient (LSC). Data were collected from 45 sampling points across four limnological zones over three seasonal periods. The first-season dataset ($n = 45$) was used to develop the PCA-based LSC structure, while the subsequent two seasons ($n = 90$) assessed its temporal stability without recalibration. Overall performance was evaluated using classification accuracy, ROC/AUC, structural coherence, and consistency with trophic conditions. RWQI achieved 91.56% classification accuracy, $AUC = 0.980$, and $R^2 = 0.989$, outperforming SWQI, OWQI, and the Pollution Index. Spatial analysis identified the Harapan and Flafow River littoral zones as priority areas (RWQI 38.2–43.7, Poor), while the pelagic center maintained Good quality (RWQI 84.2). RWQI shows potential as an adaptive framework for tropical lake assessment, but independent external validation remains necessary before broader standardization.

Keywords: Water Quality Index; Dynamic Weighting; Lake Sentani; Health Risk; Limnology; RWQI; Papua

*Correspondence author.

E-mail: basuhpapua@gmail.com (Bambang Suhartawan)

doi: <https://doi.org/10.21771/jrtpi.2026.v17.no1.p175-183>

2503-5010/2087-0965© 2026 Jurnal Riset Teknologi Pencegahan Pencemaran Industri-BBSPJPPI (JRTPPI-BBSPJPPI).

This is an open access article under the CC BY-NC-SA license (<https://creativecommons.org/licenses/by-nc-sa/4.0/>).

Accreditation number: (Ristekdikti) 158/E/KPT/2026

INTRODUCTION

Lake Sentani, located in Jayapura Regency, Papua Province, is the largest lake in Papua, covering approximately 9,630 ha and serving as a class I raw water source for more than 300,000 residents (Nomosatryo et al., 2025). The lake also supports 17 endemic fish species, including the Sentani rainbowfish (*Chilatherina sentaniensis*), highlighting its ecological importance. However, water quality has progressively declined due to residential expansion, agriculture, domestic wastewater, and small-scale mining, increasing nutrient, sediment, heavy metal, and organic loads (Suhartawan, Alfons, et al., 2022; Suhartawan, Haurissa, et al., 2022). Similar eutrophication pressures have been reported in Lake Tondano (Onibala et al., 2025) and Lake Lut Tawar (Tamara et al., 2022). Water quality monitoring in Lake Sentani has largely relied on conventional methods, including the Pollution Index based on Ministerial Decree No. 115/2003, STORET, and static-weight Water Quality Index approaches. Previous applications include CCME-WQI in Yobeh Village (Suhartawan & Daawia, 2024), STORET (Suyatno et al., 2023), the Pollution Index for coastal community water needs (Suhartawan, Alfons, et al., 2022), British Columbia Water Quality Index/BC-WQI (Suhartawan, 2025), and spatial analysis of physical parameters associated with C mining activities (HSE et al., 2025).

However, static weighting schemes are generally insensitive to actual concentration variations (Uddin et al., 2021), limiting their suitability for heterogeneous tropical lakes (Johnston et al., 2024; Sutadian et al., 2016). Recent WQI studies therefore emphasize adaptive and data-driven weighting, including machine learning (Aldoury & Hammood, 2024; Ding et al., 2025; Uddin et al., 2022), and uncertainty estimation (Asadollah et al., 2021), while integrated frameworks combining regulatory violations, toxicological severity, and limnochemical correlations remain limited. RWQI addresses these limitations by integrating RVI, TSS, and LSC within a dynamic weighting framework. RVI captures regulatory deviation, TSS reflects toxicological significance, and LSC reduces redundancy among correlated parameters. Accordingly, this study formulates RWQI, integrates these three components, compares its performance with SWQI, OWQI, and IP, and maps the spatial distribution of Lake Sentani water quality

METHODS

Research Area and Design

The study was conducted at Lake Sentani, Jayapura Regency, Papua, in 2025 across the rainy, transitional, and dry

seasons. A total of 45 sampling points were selected using stratified systematic sampling across four limnological zones: Zone A, middle pelagic reference area (9 points); Zone B, sublittoral transition area around small islands (12 points); Zone C, littoral area near the main tributary estuary influenced by catchment runoff (15 points); and Zone D, epipelagic area near lakeside settlements affected by domestic waste (9 points).

Table 1. Geographic Coordinates of Representative Sampling Points in Lake Sentani

N o.	Station	Zon e	Latitu de (LS)	Longitu de (BT)	Location Descriptio n
1	Central Pelagic	A	2°36'24 " S (- 2.6067)	140°33'3 6" East Longitud e (140,560 0)	Lake midpoint reference point; minimal anthropoge nic pressure
2	Sublittoral of P. Asei	B	2°35'41 " S (- 2.5947)	140°34'2 3" East Longitud e (140,573 0)	Waters around Asei Island, East Sentani District
3	Sublittoral of Ajau Island	B	2°36'18 " S (- 2.6050)	140°32'5 3" East Longitud e (140,548 0)	Waters around Ajau Island, Central Sentani District
4	Muara S. Harapan Littoral	C	2°35'17 " S (- 2.5880)	140°31'0 5" East Longitud e (140,518 0)	Harapan River Estuary, Sentani District
5	Littoral of the Flaflow Estuary	C	2°36'54 " S (- 2.6150)	140°30'1 8" East Longitud e (140,505 0)	Flaflow River Estuary, Waibu District
6	Littoral of the Borowa	C	2°37'30 " S (- 2.6250)	140°29'2 4" East Longitud e	Around Boroway Village, the western

	y River Estuary		(140,490 0)	boundary of the lake
7	Epipelagic Sentani City	D	2°33'58 " S (- 2.5661)	140°30'2 1" East Longitud e (140,505 7)
8	Epipelagic Pier	D	2°34'48 " S (- 2.5800)	140°30'3 6" East Longitud e (140,510 0)

Source: Estimated geographic position based on toponymic references and satellite imagery of Lake Sentani location, 2025

Table 1 presents eight representative stations across four limnological zones, around which 45 sampling points were distributed using stratified systematic sampling. Coordinates are reported in degrees-minutes-seconds with decimal equivalents.

Parameters Analyzed

The study analyzed physical parameters (temperature, pH, DO, turbidity, total suspended solids (TSSol), TDS, conductivity, and Secchi depth), chemical parameters (BOD₅, COD, TP, orthophosphate, TN, NO₃-N, NO₂-N, NH₃-N, chlorophyll-a, and total coliform), and toxicological parameters, including heavy metals and MBAS. In situ measurements used a YSI Pro DSS sonde, while ex situ analyses were conducted at the KAN-accredited Papua Province Regional Health Laboratory. Heavy metals were selected based on documented bioaccumulation and health risks in tropical aquatic ecosystems (Deep & Nasnodkar, 2023; Kebede & Geleta, 2023; Liu et al., 2022).

RWQI Construction

RWQI calculates the dynamic weight (w_i) for each parameter i as a composite function of the following three components. Regulatory Violation Index (RVI) measures the magnitude of the measured concentration violation (c_i^k) against the Class I water quality standard stipulated in Government Regulation No. 22 of 2021 (Government of the Republic of Indonesia, 2021), using a non-linear function. To accommodate parameters with different response directions, a directionality-adjusted concentration ratio (r_i) is first calculated as:

$$r_i = \begin{cases} \frac{c_i^k}{s_i}, & d_i = +1 \\ \frac{s_i}{c_i^k}, & d_i = -1 \end{cases}$$

where c_i^k is the measured concentration of parameter i at observation k , s_i is the corresponding regulatory threshold, and d_i is the directionality parameter. A value of $d_i = +1$ is assigned to parameters for which increasing concentration indicates deterioration, whereas $d_i = -1$ is assigned to parameters such as dissolved oxygen (DO), for which decreasing concentration indicates deterioration. The RVI is then calculated as $RVI_i = [\max(0, r_i - 1)]^{n_i}$ where $n_i = 1.5$ for non-DO parameters and ($n_i = 1.0$) for DO. Toxicological Severity Score (TSSi) was derived from the WHO Guidelines for Drinking-water Quality (World Health Organization, 2022). Scores of 0, 2, 4, 6, 8, and 10 represent negligible to critical toxicological severity, with higher values assigned to parameters associated with persistence, bioaccumulation, and greater human-health risk, particularly heavy metals such as Hg and Pb. Before integration into the weighting function, TSS was normalized to a 0–1 scale as $TSS_i^* = \frac{TSS_i}{10}$.

Limnochemical Similarity Coefficient (LSC_i) is an adaptation of the Hydrogeochemical Similarity Coefficient for tropical lake ecosystems. The LSC was constructed from the PCA loading matrix of the first sampling season's exploration dataset. Parameters with high loadings on the same principal component were weighted downward to avoid overrepresentation (Bui et al., 2020; Onibala et al., 2025). Operationally, LSC_i was defined as $\frac{1}{(1+\bar{S}_i)}$, where $\bar{S}_i$ represents the mean absolute similarity of the PCA loading pattern of parameter i with the remaining parameters. Accordingly, parameters showing greater redundancy receive lower LSC values, whereas relatively independent parameters retain greater contributions to the weighting process. The RVI, TSS, and LSC components were subsequently integrated through the composite function $f_i = (1 + \alpha RVI_i) \left(1 + \beta \frac{TSS_i^*}{10}\right) LSC_i$, where the scaling constants α and β were both set at 1.0. The constant term of 1 ensures that parameters with no regulatory violation or negligible toxicological severity retain a non-zero preliminary contribution. The resulting parameter weights were normalized as $w_i = \frac{f_i}{\sum_{j=1}^m f_j}$, ensuring that $\sum_i w_i = 1$. The parameter-specific quality score q_i was defined as $q_i =$

$\frac{1}{(1+RWI_i)}$, whereby increasing regulatory violations progressively reduce the quality score. The final RWQI was calculated as:

$$RWQI = \sum_j (w_i \times q_i) \times 100$$

The final RWQI is expressed on a 0–100 scale and classified as Very Good (90 < RWQI ≤ 100), Good (70 ≤ RWQI ≤ 90), Fair (50 ≤ RWQI < 70), Poor (25 ≤ RWQI < 50), and Very Poor (0 ≤ RWQI < 25).

Table 2. Classification of Water Quality Status Based on RWQI Values

RWQI Range	Category	Water Use Eligibility
>90	Very good	Safe for all purposes; class I drinking water
70–90	Good	Can be used after standard processing
50–70	Fair	Requires further processing; restricted to agriculture
25–50	Poor	Not suitable without intensive processing
<25	Very poor	Severely contaminated; needs immediate rehabilitation

Source: Author Construction, 2025

RWQI was compared with SWQI, OWQI, and IP using Pearson correlation, five-class confusion matrix, ROC/AUC, MLR, and PCA (Noori et al., 2019; Sutadian et al., 2016). Analyses were performed in R 4.3 and Python 3.11 (Aldoury & Hammood, 2024; Ding et al., 2025), while spatial distribution was mapped in QGIS 3.x using Ordinary Kriging with an exponential variogram to generate seasonal and annual maps with land-use and pollutant-source overlays.

RESULT AND DISCUSSION

Water Quality Parameters of Lake Sentani

Measurements of 25 water quality parameters at 45 sampling points across four zones of Lake Sentani show significant spatial and temporal variation. Table 3 presents the average values of key parameters and a comparison with the quality standards of Government Regulation No. 22 of 2021 Class I.

Table 3. Results of Measurement of Water Quality Parameters of Lake Sentani at 8 Representative Sampling Points

N o.	Stati on	D O (m g/L)	TS Sol (m g/L)	TP (m g/L)	TN (m g/L)	NH ₃ -N (m g/L)	BO D ₅ (m g/L)	CO D (m g/L)
1	Cent ral Pelag ic	7.2	8.5	0.02 2	0.4 1	0.08	2.1	11.5
2	Subli ttoral of P. Asei	6.8	12.1	0.03 8	0.6 2	0.14	3.4	17.2
3	Subli ttoral of Ajau Islan d	6.5	15.3	0.04 7	0.7 4	0.19	4.1	21.8
4	Muar a S. Hara pan Litto ral	5.9	28.6	0.08 9	1.2 8	0.41	7.8	38.4
5	Litto ral of the Flafo w Estu ary	5.6	31.2	0.09 6	1.4 1	0.47	8.9	42.1
6	Litto ral of the Boro way River Estu ary	6.1	22.4	0.06 3	0.9 8	0.27	5.6	28.9
7	Epip elagi c Sent ani City	5.8	19.7	0.05 4	0.8 8	0.22	4.9	24.7
8	Epip elagi	5.5	24.1	0.07 1	1.0 7	0.31	6.3	33.1

c								
Pier								
– Class	≥6.	50	0.2	10	0.5	2.0	10	
I	0							
Qual								
ity								
Stan								
dard								

Source: Primary Research Data, 2025

DO ranged from 5.5–7.2 mg/L; Stations 4, 5, 7, and 8 were below the Class I standard (≥ 6.0 mg/L), while the other stations met the threshold. Low DO was associated with organic matter decomposition (Madyawan et al., 2020). TP and NH₃-N were highest at Stations 4 and 5, reaching 0.089–0.096 mg/L and 0.41–0.47 mg/L, respectively, but remained below the Class I standards. This pattern is consistent with anthropogenic nutrient inputs previously reported for Lake Sentani (Nomosatryo et al., 2025; Suhartawan, Alfons, et al., 2022). TSSol at Stations 4–5 ranged from 28.6–31.2 mg/L, indicating sediment resuspension from the Cycloop watershed (Suhartawan, Alfons, et al., 2022). BOD₅ ranged from 2.1–8.9 mg/L across all representative stations, exceeding the Class I standard of 2.0 mg/L, with the highest values recorded at Stations 4 and 5, indicating substantial organic loading (Solissa et al., 2025).

Calculation and Distribution of RWQI Scores

Table 4 presents the results of the RWQI calculations and comparisons with other indices at eight representative sampling points. Figure 1 visualizes the comparison of the four indices.

Table 4. RWQI Scores and Comparison Between Indices at 8 Sampling Points

N	Statio	RW	SW	OW	I	TSI	RW
o.	n	QI	QI	QI	P	Carlson	QI
							Cate
							gory
1	Centr	84.2	79.	81.3	78	42.1	Good
	al		1		.4	(Oligotr	
	Pelagi					ophic)	
	c						
2	Sublit	72.5	66.	69.2	63	51.3	Good
	toral		4		.1	(Mesotr	
	of P.					ophic)	
	Asei						

3	Sublit	65.3	58.	61.4	54	57.8	Fair
	total		7		.9	(Mesotr	
	of					ophic)	
	Ajau						
	Island						
4	Muar	43.7	52.	49.8	57	68.4	Poor
	a S.		1		.3	(Eutrop	
	Harap					hic)	
	an						
	Littora						
	l						
5	Littor	38.2	47.	45.1	52	71.2	Poor
	al of		6		.8	(Eutrop	
	the					hic)	
	Flafo						
	w						
	Estuar						
	y						
6	Littor	55.8	54.	53.7	56	62.5	Fair
	al of		2		.1	(Mesotr	
	the					ophic-	
	Borow					Eutroph	
	ay					ic)	
	River						
	Estuar						
	y						
7	Epipe	59.4	61.	60.8	59	59.3	Fair
	lagic		3		.7	(Mesotr	
	Sentan					ophic)	
	i City						
8	Epipe	48.6	55.	53.2	58	65.1	Poor
	lagic		8		.2	(Eutrop	
	Pier					hic)	

Source: Primary Research Data, 2025

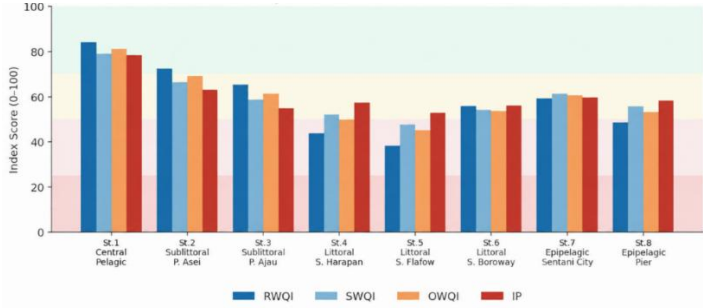


Figure 1. Comparison of RWQI, SWQI, OWQI, and IP Scores at 8 Representative Stations of Lake Sentani

The middle pelagic zone (Station 1) recorded the highest RWQI score (84.2, Good), while the Harapan and

Flafow River littoral zones (Stations 4–5) had the lowest scores (43.7 and 38.2, Poor). RWQI was strongly negatively correlated with Carlson TSI ($r = -0.934$, $p < 0.001$) based on the full observation-level dataset, indicating consistency with trophic status. Higher SWQI and OWQI scores at Stations 4–5 reflect the lower sensitivity of static weighting, whereas RWQI applies greater penalties as violation severity increases (Gharibi et al., 2012), consistent with reported limitations of fixed-weight WQI models in tropical waters (Aldoury & Hammood, 2024; Johnston et al., 2024).

Dynamic Weighting of RWQI: Seasonal Variation

Table 5 and Figure 2 present the normalized relative weights of six selected key parameters to illustrate seasonal changes in the RWQI weighting structure.

Table 5. Dynamic Weights of RWQI in Two Seasonal Periods

Seas on	DO	TSS ol	T P	T N	NH 3-N	BO D5	Tot al
Rain	0.18	0.21	0.20	0.14	0.16	0.11	1.00
Drou ght	.22	0.16	0.22	0.16	0.14	0.10	1.00

Source: Primary Research Data, 2025

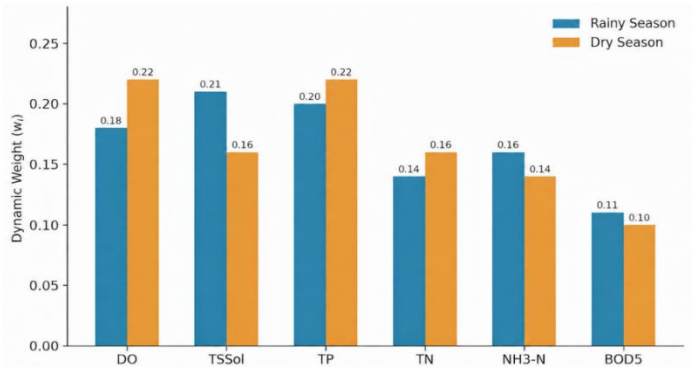


Figure 2. Normalized Relative Weights of Six Selected RWQI Parameters in Two Seasonal Periods

TSSol weights were higher in the rainy season (0.21), while DO and TP weights increased in the dry season (0.22 each), reflecting seasonal changes in runoff, dilution, and nutrient stress (Nomosatryo et al., 2025; Carlson, 1977; Onibala et al., 2025). The LSC was derived from the first-season dataset ($n = 45$) and retained for subsequent seasons ($n = 90$), providing temporal validation. Comparison of seasonal weight changes indicated that the main spatial classification pattern remained consistent.

Comparative Evaluation of Index Performance

Pearson correlation and MLR used the full dataset ($n = 135$), while classification accuracy and ROC/AUC were reported as aggregate validation metrics. PCA used the first-season dataset ($n = 45$) to derive the LSC structure, and the remaining observations ($n = 90$) were used to assess temporal stability without recalibrating the LSC. Ordinary Kriging was performed separately for each season using 45 spatial sampling locations.

Table 6 and Figure 3 present comparative performance metrics of the four water quality indices based on multi-criteria evaluation.

Table 6. Comparison of RWQI, SWQI, OWQI, and IP Performance

Evaluation Metrics	RWQI	SWQI	OWQI	IP
Classification Accuracy (%)	91.56	74.32	79.18	68.45
AUC ROC Curve	0.980	0.841	0.876	0.782
R ² (structural coherence)	0.989	0.892	0.921	0.847
Pearson Correlation (r) vs TSI	-0.934	-0.821	-0.859	-0.796
Spatial Heterogeneity Sensitivity	High	Low	Moderate	Low
Temporal Responsiveness	Adaptive	Static	Semi-adaptive	Static

Source: Primary Research Data, 2025

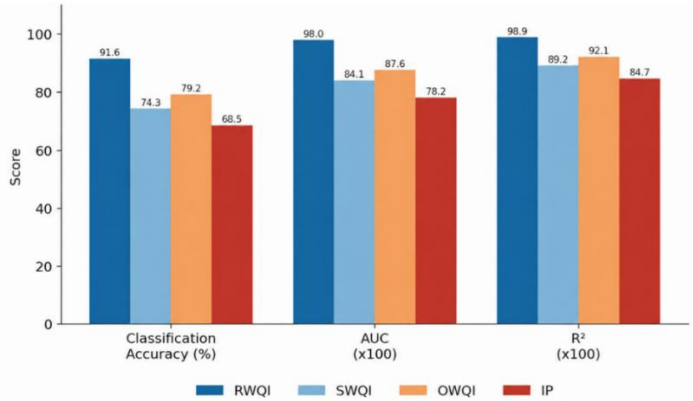


Figure 3. Comparative Performance Evaluation of RWQI, SWQI, OWQI, and IP

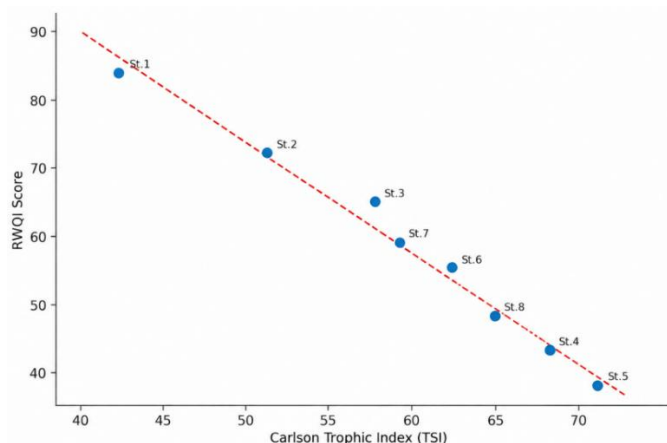


Figure 4. Illustrative Relationship between RWQI and Carlson Trophic Index (TSI) at Eight Representative Stations

RWQI showed the highest classification accuracy (91.56%) and AUC (0.980) compared with SWQI, OWQI, and IP, indicating strong discriminatory performance (Bui et al., 2020; Ding et al., 2025). Its R^2 of 0.989 also indicates strong internal consistency, although this does not constitute fully independent external validation. RWQI outperformed IP by 23.11% in classification accuracy and applied stronger penalties to cumulative violations through its non-linear weighting structure (Gharibi et al., 2012; Uddin et al., 2022), consistent with evidence supporting adaptive over fixed weighting schemes (Johnston et al., 2024). Further validation using independent biological, regulatory, or external datasets is still required.

Spatial Distribution of Water Quality and Priority Zones

Spatial analysis using Ordinary Kriging produced an RWQI distribution map with three clearly distinguishable priority zones (Figure 5):



Figure 5. Spatial Distribution Scheme of Water Quality Categories (RWQI) of Lake Sentani

Priority Zone I includes the Harapan and Flafow River estuaries (RWQI 38.2–43.7), while Priority Zone II covers the Sentani City and Pier epipelagic areas (RWQI 48.6–59.4), where wastewater management should be strengthened alongside existing filtration programs (Solissa et al., 2025; Suhartawan et al., 2023). The middle pelagic and Asei Island sublittoral areas form the Reference Zone (RWQI 72.5–84.2). RWQI increased with distance from tributary mouths ($r = 0.847$, $p < 0.001$), supporting the role of catchment runoff in Lake Sentani degradation (Nomosatryo et al., 2025; Jwaideh & Dalin, 2025; Mozafari et al., 2023).

Management Implications

RWQI can support Lake Sentani monitoring, spatial zoning, and threshold-based early warning, complementing existing water-treatment initiatives (Suhartawan et al., 2025). Application to other Papua lakes requires LSC recalibration to local limnochemical conditions, while RVI and TSS remain broadly applicable based on previous WQI applications in Papua (Suhartawan, Iriyanto, et al., 2022; Hamuna et al., 2018; Hamuna & Tanjung, 2021; Tanjung et al., 2022).

CONCLUSION

This study developed and internally evaluated the Rational Water Quality Index (RWQI), integrating RVI, TSS, and LSC within a dynamic weighting framework. RWQI achieved 91.56% classification accuracy and an AUC of 0.980, outperforming SWQI, OWQI, and the Pollution Index. It identified the Harapan and Flafow River littoral zones as priority areas (RWQI 38.2–43.7), while the middle pelagic zone maintained Good water quality (RWQI 84.2). However, the findings are limited by 45 sampling locations across three seasonal periods, the absence of independent external validation, the use of compiled toxicological scoring for TSS, and the first-season PCA basis of LSC. Application to other lakes therefore requires LSC recalibration and independent validation before broader standardization.

ACKNOWLEDGMENT

The author would like to thank the Environmental Engineering Study Program of Jayapura University of Science and Technology, the Papua Provincial Regional Health Laboratory, and all parties who have assisted in the implementation of field data collection at Lake Sentani.

References

- Aldoury, M. M. I., & Hammood, M. T. (2024). Assessment of many WQI models and development of new WQI model. *Water Supply*, 24(4), 1224–1242. <https://doi.org/10.2166/ws.2024.053>

- Asadollah, S. B. H. S., Sharafati, A., Motta, D., & Yaseen, Z. M. (2021). River water quality index prediction and uncertainty analysis: A comparative study of machine learning models. *Journal of Environmental Chemical Engineering*, 9(1), 104599. <https://doi.org/10.1016/j.jece.2020.104599>
- Bui, D. T., Khosravi, K., Tiefenbacher, J., Nguyen, H., & Kazakis, N. (2020). Improving prediction of water quality indices using novel hybrid machine-learning algorithms. *Science of the Total Environment*, 721, 137612. <https://doi.org/10.1016/j.scitotenv.2020.137612>
- Carlson, R. E. (1977). A trophic state index for lakes. *Limnology and Oceanography*, 22(2), 361–369. <https://doi.org/10.4319/lo.1977.22.2.0361>
- Deep, S. S., & Nasnodkar, M. R. (2023). Metal speciation in sediments and bioaccumulation in edible bivalves to assess metal toxicity in a sand mining impacted tropical (Aghanashini) estuary, southern India. *Marine Pollution Bulletin*, 194, 115455. <https://doi.org/10.1016/j.marpolbul.2023.115455>
- Ding, F., Hao, S., Zhang, W., Jiang, M., Chen, L., Yuan, H., Wang, N., Li, W., & Xie, X. (2025). Using multiple machine learning algorithms to optimize the water quality index model and their applicability. *Ecological Indicators*, 172. <https://doi.org/10.1016/j.ecolind.2025.113299>
- Gharibi, H., Mahvi, A. H., Nabizadeh, R., Arabalibeik, H., Yunesian, M., & Sowlat, M. H. (2012). A novel approach in water quality assessment based on fuzzy logic. *Journal of Environmental Management*, 112, 87–95. <https://doi.org/10.1016/j.jenvman.2012.07.007>
- Government of the Republic of Indonesia. (2021). Government Regulation of the Republic of Indonesia Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. State Secretariat of the Republic of Indonesia.
- Hamuna, B., & Tanjung, R. H. R. (2021). Heavy Metal Content and Spatial Distribution to Determine the Water Pollution Index in Depapre Waters, Papua, Indonesia. *Current Applied Science and Technology*, 21(1), 1–11. <https://li01.tci-thaijo.org/index.php/cast/article/view/245057>
- Hamuna, B., Tanjung, R. H. R., Suwito, S., Maury, H. K., & Alianto, A. (2018). Study of seawater quality and pollution index based on physicochemical parameters in the waters of Depapre District, Jayapura. *Journal of Environmental Sciences*, 16(1), 35–43. <https://doi.org/10.14710/jil.16.1.35-43>
- HSE, S. B., Nainggolan, H., & Suhartawan, B. (2025). Spatial analysis of water quality status of Lake Sentani based on temperature, pH, DO, TDS parameters due to C mining activities in Ifar Besar Village, Sentani District, Jayapura Regency. *Journal of Innovative and Creativity* (JOECY), 5(2). <https://doi.org/10.31004/joecy.v5i2.1946>
- Johnston, N., Rolfe, J., & Flint, N. (2024). A systematic review of agricultural use water quality indices. *Environmental and Sustainability Indicators*, 23, 100417. <https://doi.org/10.1016/j.indic.2024.100417>
- Jwaideh, M. A. A., & Dalin, C. (2025). The multi-dimensional environmental impact of global crop commodities. *Nature Sustainability*, 8, 396–410. <https://doi.org/10.1038/s41893-025-01528-6>
- Kebede, M. T., & Geleta, L. (2023). Consumer health risk assessment from some heavy metal bioaccumulation in common carp (*Cyprinus carpio*) from Lake Koka, Ethiopia. *Heliyon*, 9(3), e14560. <https://doi.org/10.1016/j.heliyon.2023.e14560>
- Liu, X., Zhang, J., Huang, X., Zhang, L., Yang, C., Li, E., & Wang, Z. (2022). Heavy metal distribution and bioaccumulation combined with ecological and human health risk evaluation in a typical urban plateau lake, southwest China. *Frontiers in Environmental Science*, 10, 814678. <https://doi.org/10.3389/fenvs.2022.814678>
- Madyawan, D., Hendrawan, I. G., & Suteja, Y. (2020). Dissolved oxygen (DO) modeling in Benoa Bay waters. *Journal of Marine and Aquatic Sciences*, 6(2), 270–280. <https://doi.org/10.24843/jmas.2020.v06.i02.p15>
- Mozafari, Z., Noori, R., Siadatmousavi, S. M., Afzalimehr, H., & Azizpour, J. (2023). Satellite-based monitoring of eutrophication in the earth's largest transboundary lake. *GeoHealth*, 7(5), e2022GH000770. <https://doi.org/10.1029/2022GH000770>
- Nomosatryo, S., Lipus, D., Bartholomäus, A., Henny, C., Ridwansyah, I., Sujarta, P., Yang, S., Wagner, D., & Kallmeyer, J. (2025). The role of anthropogenic influences on a tropical lake ecosystem and its surrounding catchment: A case study of Lake Sentani. *FEMS Microbiology Ecology*, 101(1), fae162. <https://doi.org/10.1093/femsec/fae162>
- Noori, R., Berndtsson, R., Hosseinzadeh, M., Adamowski, J. F., & Abyaneh, M. R. (2019). A critical review on the application of the National Sanitation Foundation Water Quality Index. *Environmental Pollution*, 244, 575–587. <https://doi.org/10.1016/j.envpol.2018.10.076>
- Onibala, M., Thambas, A. H., & Riogilang, H. (2025). Water quality analysis in Lake Tondano using temporal evaluation, WQI, CCME-WQI, and PCA. *Jurnal Sosial Dan Teknologi (SOSTECH)*, 5(5), 1597–1618. <https://doi.org/10.59188/jurnalsostech.v5i5.32095>
- Solissa, E. V., Suhartawan, B., & Alfons, A. B. (2025). Water treatment of Lake Sentani through a multi-media filtration approach (case study of Hobong Village, Sentani District). *Journal of Innovative and Creativity*

- (JOECY), 5(2).
<https://doi.org/10.31004/joecy.v5i2.1945>
- Suhartawan, B. (2025). Application of the British Columbia Water Quality Index (BC-WQI) method to determine the water quality status of Lake Sentani in Jayapura. *Riwayat: Educational Journal of History and Humanities*, 8(1).
<https://doi.org/10.24815/jr.v8i1.44412>
- Suhartawan, B., & Daawia, D. (2024). Application of the CCME-WQI method to analyze lake water quality on the coast of Yobeh Village, Sentani District, Jayapura Regency. *Dinamis: Journal of Civil Engineering, University of Science and Technology Jayapura*, 21(2), 78–84. <https://doi.org/10.58839/jd.v21i2.1438>
- Suhartawan, B., Alfons, A. B., & Daawia, D. (2022). Water quality status based on pollution index to meet the needs of sanitary hygienic water for communities around Lake Sentani in Jayapura Regency. *Journal Research of Social Science, Economics, and Management*, 2(3), 273–290.
<https://doi.org/10.59141/jrssem.v2i03.263>
- Suhartawan, B., Alfons, A. B., Rumawak, S. A., & Balabuana, G. B. (2023). Fulfillment of community needs for clean water in Hobong Village, Sentani District, Jayapura Regency. *Jurnal Abdimas Dinamis*, 4(1), 14–19. <https://doi.org/10.58839/jad.v4i1.1168>
- Suhartawan, B., Alfons, A. B., Tanwir, T., Anggraeni, D., Tjolleng Taba, H. H. I., Nuriah, Y., & Daawia, D. (2025). Community empowerment to meet clean water needs in Ifale Village, Sentani District, Jayapura Regency. *Jurnal Medika*, 4(4).
<https://doi.org/10.31004/13n41k92>
- Suhartawan, B., Haurissa, J., & Rumawak, S. A. (2022). Lake Sentani water quality index based on NSF-WQI as raw water for drinking water for Lake Sentani coastal communities, Jayapura Regency. *Jurnal Syntax Admiration*, 3(9), 1189–1204.
<https://doi.org/10.46799/jsa.v3i9.481>
- Suhartawan, B., Iriyanto, S. M., Suyatno, & Daawia. (2022). Analysis of well water quality index in Yamta Village, Arso District, Keerom Regency, Papua Province. *Syntax Literate Journal*, 7(12).
<https://doi.org/10.36418/syntax-literate.v7i12.11626>
- Sutadian, A. D., Muttil, N., Yilmaz, A. G., & Perera, B. J. C. (2016). Development of river water quality indices – A review. *Environmental Monitoring and Assessment*, 188, 58.
<https://doi.org/10.1007/s10661-015-5050-0>
- Suyatno, Suhartawan, B., Iriyanto, S. M., & Daawia. (2023). Application of STORET method to determine Lake Sentani water quality status in Papua Province. *Indonesian Journal of Social Technology*, 4(9).
<https://doi.org/10.59141/jist.v5i3.942>
- Tamara, R., Barus, T. A., & Wahyuningsih, H. (2022). Water quality analysis of Lake Lut Tawar, Central Aceh Regency, Aceh. *Jurnal Serambi Engineering*, 7(4).
<https://doi.org/10.32672/jse.v7i4.4972>
- Tanjung, R. H. R., Yonas, M. N., Suwito, Maury, H. K., Sarungu, Y., & Hamuna, B. (2022). Analysis of surface water quality of four rivers in Jayapura Regency, Indonesia: CCME-WQI approach. *Journal of Ecological Engineering*, 23(1), 73–82.
<https://doi.org/10.12911/22998993/143998>
- Uddin, M. G., Nash, S., & Olbert, A. I. (2021). A review of water quality index models and their use for assessing surface water quality. *Ecological Indicators*, 122, 107218.
<https://doi.org/10.1016/j.ecolind.2020.107218>
- Uddin, M. G., Nash, S., Diganta, M. T. M., Rahman, A., & Olbert, A. I. (2022). Robust machine learning algorithms for predicting coastal water quality index. *Journal of Environmental Management*, 321, 115923.
<https://doi.org/10.1016/j.jenvman.2022.115923>
- World Health Organization. (2022). Guidelines for drinking-water quality (4th ed., incorporating the 1st and 2nd addenda). World Health Organization.