

Analysis of water fertility status based on the Trophic State Index (TSI) in the Air Hitam Urban Polder, Samarinda Ulu District, East Kalimantan

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ABSTRACT

Waters near urban centers are highly vulnerable to pollution, a condition likely occurring in the Air Hitam Polder in Samarinda, which receives inflow from urban drainage and is surrounded by intense human activity. This study aimed to determine the Polder's trophic status using the Carlson Trophic State Index (TSI) based on water transparency, total phosphate, and chlorophyll-a, analyzed spatially and temporally. It also assessed general water quality and examined the relationship between nutrients (phosphate, nitrate, ammonia) and chlorophyll-a. Measurements at five stations included transparency, chlorophyll-a, DO, EC, TDS, temperature, pH, and turbidity, with laboratory analyses for phosphate, nitrate, and ammonia. Sampling was conducted six times. Results show Station 3 had the highest TSI (75.25), likely due to its location near the main inlet carrying organic and inorganic materials. Temporally, the Polder was classified as hypereutrophic, with TSI values >60 at all stations. Phosphate had the strongest relationship with chlorophyll-a. Several parameters (DO, EC, TDS) met water quality standards, while others (phosphate, nitrate, ammonia, temperature, pH, transparency, turbidity) exceeded limits. Overall, current conditions are unsuitable for aquatic life, indicating the need for improved management to restore the ecological function of the Air Hitam Polder.

INTRODUCTION

The Air Hitam Polder is an artificial lake located near the city center, constructed in 2004 as a flood-control infrastructure for the Air Hitam area, with a total surface area of 60,500 m² (6.50 ha) (Hamdhani et al., 2023). In addition to its primary function as a flood-control system, the Air Hitam Polder also serves other roles similar to lentic water bodies, including ecological functions as habitat for aquatic organisms. The lake receives inflows from several urban drainage channels but lacks an outlet, making it vulnerable to the accumulation of untreated wastewater (raw wastewater) as well as pollutants originating from surrounding human activities. This condition has likely contributed to water quality degradation and may have led to increased fertility (eutrophication), which can negatively affect the ecological function and aquatic biota of the Air Hitam Polder.

In general, highly fertile water bodies are characterized by decreasing dissolved oxygen concentrations, reduced light penetration (lower transparency), and high phytoplankton abundance and

productivity (US EPA, 2012). According to Pratiwi (2013), nutrient inputs—particularly nitrogen and phosphorus—stimulate phytoplankton growth, which serves as a key indicator of increasing water fertility.

The trophic status of a water body can be assessed using several indices, including the Nygaard Index (Bellinger and Sigeo, 2010), the Trophic Index (TRIX) (Vollenweider et al., 1998), the Trophic Level Index (TLI) (Burns et al., 2005), the Delphi Method (DM) (Hortan 1965 in Parporov et al., 2010), the Tropical/Subtropical Reservoir Trophic State Index (TSItsr) (Cunha et al., 2013), and the Trophic State Index (Carlson, 1977). However, the most widely used method is the Carlson Trophic State Index (1977), which determines trophic status based on three influential parameters: water transparency (Secchi depth), total phosphate, and chlorophyll-a. This approach simplifies the assessment of water body conditions. These three parameters represent the physical, chemical, and biological aspects of water quality, respectively, and together they form a multidimensional measure by integrating interrelated variables. The resulting trophic status is categorized as oligotrophic (low fertility), mesotrophic (moderate fertility), eutrophic (high fertility), or hypereutrophic (very high fertility).

The objectives of this study were to determine the trophic status of the Air Hitam Polder using the Carlson Index—which requires three key parameters representing the physical (transparency), chemical (total phosphate), and biological (chlorophyll-a) characteristics of water quality—assessed spatially and temporally; to provide a general overview of water quality conditions in the Air Hitam Polder; and to examine the relationships between nutrient concentrations (phosphate, nitrate, and ammonia) and chlorophyll-a. Assessing and monitoring the trophic status is crucial as a basis for decision-making in managing and controlling eutrophication, as well as for maintaining the ecological integrity and functional sustainability of the lake. This study may serve as a reference for monitoring water fertility, nutrient levels, aquatic habitat suitability, and the continuation of ecological functions.

METHODOLOGY

This study involved water sampling from the Air Hitam Polder Lake at five different stations from 21 February to 28 March 2023. The research employed a survey method, water sampling, and laboratory analysis. The collected data consisted of several water quality parameters, with the primary parameters being transparency, total phosphate, chlorophyll-a, and ammonia.

Water sampling and measurements were conducted six times at one-week intervals at each station (Figure 1). At each station, a 500 mL composite water sample was collected in a measuring cylinder for in situ measurement of water quality parameters including pH, temperature, transparency, turbidity, chlorophyll-a, electrical conductivity (EC), total dissolved solids (TDS), and dissolved oxygen (DO). The water samples were then transferred into 650 mL bottles for transport to the laboratory for the analysis of phosphate, nitrate, and ammonia concentrations.

Phosphate analysis followed the procedures outlined in SNI 6989-31:2021 using a wavelength of 880 nm. Nitrate analysis followed SNI 6989-79:2011 using a wavelength of 543 nm. Ammonia analysis was conducted in accordance with SNI 06-6989.30-2005 using a wavelength of 640 nm.

CHL = Chlorophyll-a ($\mu\text{g/L}$)

TP = Total Phosphate ($\mu\text{g/L}$)

Table 1. Reference Standards for Trophic Status Classification

Trophic Status	Carlson TSI
Oligotrophic	$\text{TSI} \leq 40$
Mesotrophic	40 – 50
Eutrophic	50 – 60
Hypereutrophic	$\text{TSI} \geq 60$

Source: Carlson, 1977

Spatial analysis of trophic status dynamics was performed using GIS to generate TSI distribution maps for the study area, which were subsequently interpreted descriptively. Temporal analysis of trophic status dynamics was also conducted descriptively.

The relationships between nutrient concentrations (phosphate, nitrate, and ammonia) and chlorophyll-a concentrations were analyzed using simple linear regression in SPSS. Trend evaluation was used to determine the strength of correlations between independent and dependent variables, and the results were described descriptively.

$$Y = a + bx$$

Description:

Y = Dependent variable

a = Constant

x = Independent variable

b = Regression coefficient

RESULT AND DISCUSSION

Spatial Analysis of the Trophic State Index (TSI)

Based on the TSI calculations following Carlson (1977), the spatial trophic status of the Air Hitam Polder ranged from 71.28 to 75.25. The TSI calculation results are presented below:

Table 2. The spatial trophic status of the Air Hitam Polder

Location	TSI (CHL)	TSI (TP)	TSI (SD)	TSI Carlson
Station 1	65.89	73.25	77.72	72.29
Station 2	65.57	70.60	77.72	71.30
Station 3	70.63	77.41	77.72	75.25
Station 4	63.86	72.28	77.72	71.28
Station 5	70.03	74.88	77.72	74.21
Mean TSI				72.86

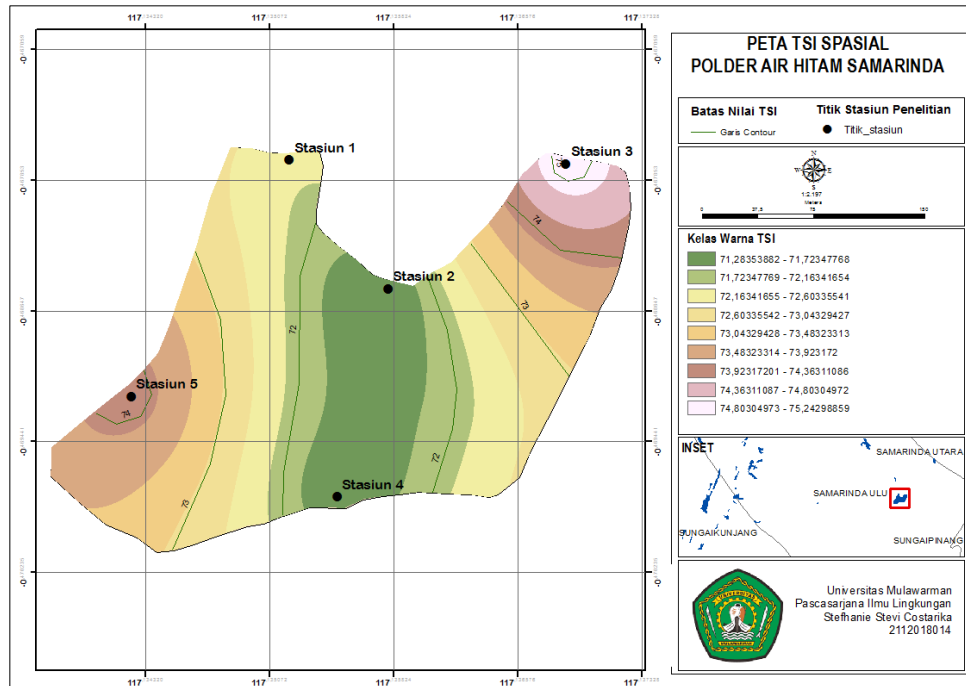


Figure 2. Spatial Distribution Map of the Trophic Status of the Air Hitam Polder

Station 3 recorded the highest TSI value. This elevated TSI is assumed to be influenced by higher phosphate and chlorophyll-a concentrations compared with the other stations. The primary factor contributing to the high TSI at Station 3 is its close proximity to the main inlet of the Air Hitam Polder. As the primary receiving area for organic and inorganic loads discharged from urban drainage, Station 3 experiences direct nutrient inputs, which increase chlorophyll-a concentrations. The absence of an outlet in the Polder likely promotes sediment accumulation near the inlet, further elevating nutrient levels.

Temporal Analysis of the Trophic State Index (TSI)

The following graph illustrates the weekly temporal variation of the trophic status of the Air Hitam Polder during the study period, based on TSI calculations (Carlson, 1977).

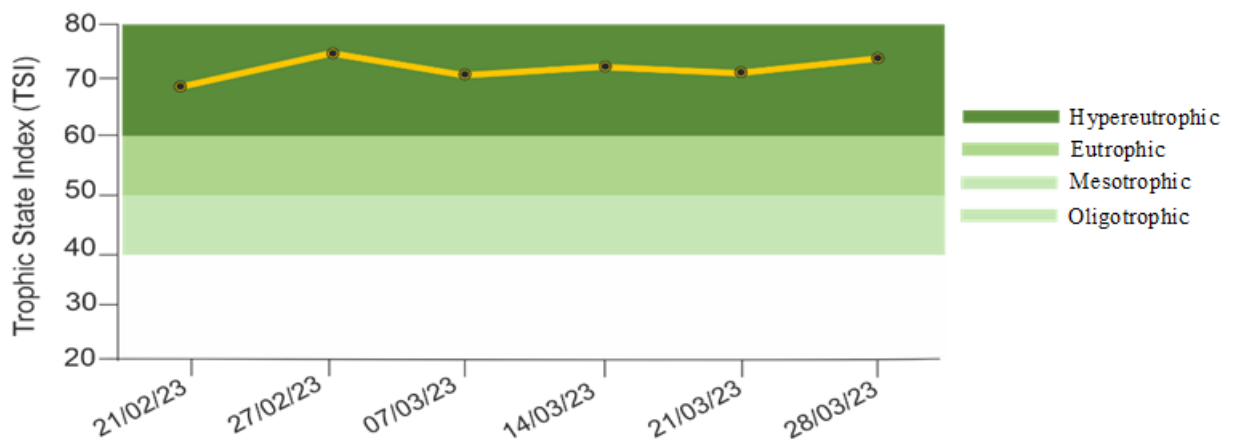


Figure 3. Temporal Trophic Status of the Air Hitam Polder

The weekly TSI values were as follows: Week 1 (69.19), Week 2 (74.98), Week 3 (71.52), Week 4 (73.38), Week 5 (71.87), and Week 6 (75.13). All weekly TSI values fall into the hypereutrophic category (TSI > 60), consistent with Carlson (1977).

The increases observed during Weeks 2 and 6 are likely associated with rainfall events occurring one day prior to sampling. Runoff from rainfall may influence water quality conditions by transporting additional nutrient inputs from the surrounding urban drainage system into the Polder.

Relationship Between Chlorophyll-a and Phosphate, Nitrate, and Ammonia

Simple linear regression analysis was used to determine whether phosphate, nitrate, and ammonia significantly influence chlorophyll-a concentrations. The results are summarized below:

Table 3. Relationship between chlorophyll-a and phosphate, nitrate, and ammonia

<i>Nutrient</i>	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>R Square</i>
Intercept	37.9	8.8	4.3	0.000	0.019
Ammonia	18.4	25.2	0.7	0.471	
Intercept	21.5	11.5	1.9	0.072	0.132
Phosphate	172.8	83.7	2.1	0.048	
Intercept	55.8	11.6	4.8	0.000	0.048
Nitrate	-98.2	83.1	-1.2	0.247	

The correlation between ammonia and chlorophyll-a yielded an R^2 value of 0.019 (1.9%), indicating a very weak correlation, and the relationship was not statistically significant ($p = 0.471 > 0.05$). Syarifah et al. (2022) similarly reported that increasing ammonia concentrations tend to show a negative correlation with phytoplankton abundance (chlorophyll-a).

The correlation between phosphate and chlorophyll-a resulted in an R^2 of 0.132 (13.2%). Although the correlation remained weak (0.00–0.20), the relationship was statistically significant ($p = 0.048 < 0.05$), suggesting that increases in phosphate concentrations correspond to increases in chlorophyll-a in the Polder waters.

The correlation between nitrate and chlorophyll-a yielded an R^2 value of 0.048 (4.8%), also classified as a very weak correlation. The relationship was not statistically significant ($p = 0.247 > 0.05$).

Water Quality of the Air Hitam Polder

Across the five sampling stations in the Air Hitam Polder, pH values were relatively high, ranging from 9.12 to 9.54, indicating alkaline conditions. This is likely associated with the inflow of detergent-containing household wastewater entering the Polder through the urban drainage system.

The average water temperature ranged from 29.81 to 30.57°C. These values remain within the favorable range for plankton growth. According to Adani et al. (2013), plankton can grow and reproduce optimally at temperatures between 24–32°C. Thus, water temperature in the Air Hitam Polder still supports aquatic biota. Elevated temperature values may be influenced by several factors, including weather differences before and after sampling, sunlight intensity, and vegetation canopy cover near the sampling stations. Higher temperatures may also be linked to basin shallowing. According to Evy and Aida (2019), shallow waters tend to have higher temperatures because sunlight penetrates more easily.

Water transparency was recorded at approximately 0.29 m. Compared with the water clarity standard of 4 m stated in Government Regulation (PP) No. 22/2021, the transparency of the Air Hitam Polder is very low, indicating unfavorable conditions for aquatic life. Turbidity values ranged from 37.5 to 53.91 NTU,

with the highest values observed at Station 3. According to Kirk (2011), turbidity exceeding 60 NTU can reduce dissolved oxygen concentrations and limit light penetration, depending on the suspended materials present. The elevated turbidity at Station 3 is likely due to its proximity to the main inlet of the Polder. Based on PP No. 22/2021, the permissible turbidity threshold is <5 NTU; thus, turbidity levels in the Air Hitam Polder greatly exceed the allowable limit.

Total Dissolved Solids (TDS) ranged from 176.66 to 292.16 mg/L, still below the standard threshold of 1,000 mg/L in PP No. 22/2021. Electrical Conductivity (EC) ranged from 350.66 to 358.5 $\mu\text{S}/\text{cm}$, showing relatively stable values across stations. These values fall within the normal conductivity range for freshwater systems (50–1500 $\mu\text{S}/\text{cm}$; US EPA, 2012). Dissolved oxygen concentrations ranged from 11.04 to 12.08 mg/L. These high levels are likely associated with microalgal activity. Another contributing factor is the sampling time, which was conducted in the late afternoon (approximately 4 PM), shortly after the daily peak of dissolved oxygen concentration (Hamdhani et al., 2023).

Total phosphorus concentrations ranged from 100.33 to 160.83 $\mu\text{g}/\text{L}$, with the highest values recorded at Station 3. According to PP No. 22/2021, the water quality standard for phosphorus supporting aquatic biota is 30 $\mu\text{g}/\text{L}$. The high phosphorus concentration at Station 3 is likely influenced by its proximity to the main inlet that receives discharge from Samarinda's densely populated drainage system along A.W. Syahrane Street. Several smaller inlets contribute irregular flows, typically only after rainfall (Hamdhani et al., 2023).

Nitrate ($\text{NO}_3\text{-N}$) concentrations ranged from 0.117 to 0.133 mg/L. Effendi (2003) noted that nitrate levels in aquatic systems are influenced by agricultural discharge (fertilizers), fisheries activities, and industrial effluents. Based on PP No. 22/2021, the nitrate threshold is 0.75 mg/L. Thus, nitrate concentrations in the Air Hitam Polder are relatively high considering its urban watershed, and increases may result from household wastewater and stormwater runoff due to the Polder's location within a densely populated settlement.

Ammonia concentrations ranged from 0.229 to 0.415 mg/L. Although PP No. 22/2021 does not specify ammonia standards for lakes, PP No. 82/2001 (Class II) sets the maximum allowable ammonia concentration for fish at <0.02 mg/L. Asmawi (1983) stated that ammonia concentration suitable for fish survival is <1 mg/L, and levels exceeding 1.5 mg/L indicate pollution and can be toxic to aquatic organisms. Widiatmoko (2013) similarly noted that high ammonia levels may indicate contamination. Therefore, although ammonia values remain below the acute toxicity threshold, they exceed the Class II water quality standard for aquatic life.

Chlorophyll-a concentrations ranged from 29.66 to 59.16 $\mu\text{g}/\text{L}$, with the highest value at Station 3 and the lowest at Station 2. The elevated chlorophyll-a concentration at Station 3 corresponds with the high phosphorus concentration observed at the same station. According to Linus et al. (2016), chlorophyll-a concentration is strongly influenced by phosphorus availability and water transparency, as these factors directly affect photosynthesis and phytoplankton biomass production.

CONCLUSION

The Air Hitam Polder in Samarinda is experiencing significant water quality degradation driven by inputs from urban drainage and surrounding human activities. Based on the Carlson Trophic State Index, the Polder is consistently classified as **hypereutrophic**, both spatially and temporally. Station 3 exhibited the highest trophic level due to its proximity to the main inlet, which delivers high loads of organic and inorganic materials. Among the nutrients analyzed, **phosphate showed the strongest influence on chlorophyll-a**, indicating that phosphorus is the primary driver of algal growth in this system.

Although some water quality parameters (DO, EC, TDS) met established standards, several key parameters—such as phosphate, nitrate, ammonia, temperature, pH, transparency, and turbidity—exceeded allowable limits. These conditions collectively indicate that the Polder’s current ecological state is inadequate to support healthy aquatic life.

Effective management interventions are therefore urgently needed to reduce nutrient inputs, improve water clarity, and restore the ecological functioning of the Air Hitam Polder.

REFERENCES

- Adani, N. G., M. R. Muskanonfola dan I. B. Hendrarto. 2013. Kesuburan Perairan Ditinjau dari Kandungan Klorofil-a Fitoplankton: Studi Kasus di Sungai Wedung Demak. *Diponegoro Journal of Maquares*, 2 (4), 38 -45
- Asmawi. S. 1983. *Pemeliharaan Ikan Dalam Keramba*. Gramedia. Jakarta
- Bellinger EG, and Sigeo DC. 2010. *Freshwater Algae: Identification and Use as Bioindicators*. Chichester (GB): Wiley-Blackwell
- Burns, N., J. McIntosh, & P. Scholes. 2005. Strategies for Managing the Lakes of the Rotorua District, New Zealand. *Lake and Reservoir Management* 21(1):61-72
- Carlson, R. E. (1977). A trophic state index for lakes. *Limnology and Oceanography*, XXII(2), 361-369
- Cunha, D. G. F., do Carmo Calijuri, M., & Lamparelli, M. C. (2013). A trophic state index for tropical/subtropical reservoirs (TSI_{sr}). *Ecological Engineering*, 60, 126-134
- Effendi, H. 2003. *Telaah Kualitas Air Bagi Pengelola Sumberdaya dan Lingkungan Perairan*. Institut Pertanian Bogor. Bogor. 257 hal.
- Evy Afriyani Sidabutara, Aida Sartimbula, M. H. (2019). Suhu, Distribusi Dan, Salinitas Terlarut, Oksigen Di, Kedalaman Teluk, Perairan Kabupaten, Prigi Trenggalek, Kabupaten Timur, Jawa Teluk, Perairan Sepanjang, Trenggalek. 3(1), 46–52.
- Hamdhani, H., Sharaha, M., Fadhillah, F.N., Gregorius, V.N. (2023). Aplikasi Perhitungan Tingkat Kesuburan Perairan dengan Metode Carlson pada Perairan Urban Danau Polder Air Hitam di Kota Samarinda. Universitas Mulawarman, Samarinda.
- Kirk J. 2011. *Light and Photosynthesis in Aquatic Ecosystems*. New York. Cambridge University Press.
- Linus, Y., Salwiyah, dan Irawati, N. (2016). Status kesuburan perairan berdasarkan kandungan klorofil-a di Perairan Bungkutoko Kota Kendari. *Manajemen Sumber Daya Perairan*, II(1), 101-111.
- Parparov, A, G. Gal, D. Hamilton, P. Kasprzak P, & A. Ostapenia. 2010. Water quality assessment, trophic classification and water resource management. *Journal of. Water Resources and Protection*. 2: 907-915.
- Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021. “Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup.” Sekretariat Negara Republik Indonesia: 483. <http://www.jdih.setjen.kemendagri.go.id/>.
- Pratiwi, N.TM., Hariyadi, S., Ayu, I.P., Iswantari, A., dan Amalia, S.J. 2013. Komposisi fitoplankton dan status kesuburan perairan Danau Lido, Bogor-Jawa Barat melalui beberapa pendekatan. *Fakultas Perikanan dan Ilmu Kelautan*. Institut Pertanian Bogor.
- Syarifah, W., Zainuri, M., Indriyawati, N, 2022. The Relationship Between Ammonia Levels and the Abundance of Phytoplankton in the morning and evening in Ujung Piring Bangkalan Astuary. *Faculty*

of Agriculture. Universitas Trunojoyo Madura.

US EPA. (2012). Monitoring and Assessing Water Quality | US EPA – EPA Archives. Retrieved November 28, 2022, from <https://archive.epa.gov/water/archive/web/html/index-18.html>.

Vollenweider, R., A. F, Giovanardi. G, Montanari and A, Rinaldi. 1998. Characterization of The Trophic Conditions of Marine Coastal Waters with Special Reference to the NW Adriatic Sea: Proposal for a trophic scale, turbidity and generalized water quality index. *Journal Environmetric*, 9 (1):329-357.

Widiatmoko, W. (2013). *Pemantauan Kualitas Air Secara Fisika dan Kimia di Perairan Teluk Hurun*. Balai Besar Pengembangan Budidaya Laut (BBPBL) Lampung. Politeknik Negeri Lampung. Bandar Lampung.