Vol. 27 No.2 (July 2026) 096-103
e-ISSN 2548-6101 p-ISSN 1411-318X

Jurnal Teknologi Lingkungan

Journal Homepage: ejournal.brin.go.id/JTL

COD and Phosphate Distribution Analysis from Domestic and Agricultural Activities Along Irrigation Channel in Metro City, Lampung, Indonesia

Analisis Distribusi COD dan Fosfat akibat Aktivitas Domestik dan Pertanian di Sepanjang Saluran Irigasi di Kota Metro, Lampung, Indonesia

NUR FAIZATURROHMAH[1], CHEISYHA ALFIRADINA[1], ANNISA FADHILAH[1], DAFFA ADLI NAUVAL PURNOMO[2], AHMAD DAUDSYAH IMAMI[1], DION AWFA[1], AND RIFKA NOOR AZIZAH[1*]

[1]Environmental Engineering Study Program, Faculty of Infrastructure and Regional Technology, Sumatra Institute of Technology, South Lampung, 35365, Indonesia.
[2]Landscape Architecture Study Program, Faculty of Infrastructure and Regional Technology, Sumatra Institute of Technology, South Lampung, 35365, Indonesia.
*Email: *rifka.azizah@tl.itera.ac.id

INFORMASI ARTIKEL

Histori artikel:
Diterima 26 Januari 2026
Disetujui 02 Juni 2026
Diterbitkan 31 Juli 2026

Kata kunci:
Chemical Oxygen Demand
Fosfat
Pemodelan Kualitas Air
Saluran Irigasi
Sumber Pencemar non-Titik
Sumber Pencemar Titik

ABSTRAK

Kualitas air irigasi memiliki peran penting dalam mendukung ketahanan pangan, keberlanjutan ekosistem, dan kesehatan masyarakat. Kecamatan Metro Pusat di Kota Metro, Lampung, sebagai wilayah yang bergantung pada sistem irigasi pertanian, rentan terhadap pencemaran dari sumber domestik dan non-domestik. Penelitian ini bertujuan menganalisis konsentrasi Chemical Oxygen Demand (COD) dan fosfat pada saluran irigasi serta memprediksi distribusi polutan di bagian hilir yang berasal dari aktivitas rumah tangga dan pertanian. Pengambilan sampel dilakukan pada empat titik Non-Point Source (NPS) dan tiga titik Point Source (PS). Hasil penelitian menunjukkan bahwa seluruh nilai COD melebihi baku mutu Kelas II berdasarkan Peraturan Pemerintah Nomor 22 Tahun 2021. Konsentrasi tertinggi ditemukan pada PS1 sebesar 285 mgL^{-1}, sedangkan konsentrasi fosfat tertinggi terdapat pada PS2 sebesar 4,34 mgL^{-1}, yang dipengaruhi oleh pembuangan deterjen dan limbah organik domestik. Dengan menggunakan metode neraca massa melalui pemodelan analitik, diprediksi adanya penurunan konsentrasi polutan di sepanjang aliran irigasi akibat proses sedimentasi dan degradasi alami. Konsentrasi COD menurun dari 104,93 mgL^{-1}pada segmen 1 (CR1) menjadi 89,63 mgL^{-1} pada segmen 2 (CR2) dan 50 mgL^{-1} pada segmen 3 (CR3). Konsentrasi ortofosfat menunjukkan pola serupa, yaitu penurunan dari 0,06512 mgL^{-1} (CR1) menjadi 0,06510 mgL^{-1} (CR2) dan 0,06481 mgL^{-1} (CR3). Oleh karena itu, pengendalian beban pencemaran, terutama di bagian hulu, sangat penting untuk menjaga keberlanjutan kualitas air. Hasil penelitian ini dapat menjadi rujukan bagi pemerintah daerah dalam merumuskan strategi pengelolaan sumber daya air yang berkelanjutan.

ARTICLE INFO

Article history:
Received 26 January 2026
Accepted 02 June 2026
Published 31 July 2026

Keywords:
Chemical Oxygen Demand
Irrigation Channel
Non-Point Source Pollution
Phosphate
Point Source
Water Quality Modelling

ABSTRACT

Irrigation water quality is of major importance for public health, environmental sustainability and food security. Located in the heavy agricultural irrigation systems, the Central Metro District in Lampung, Metro City, is vulnerable to contamination from domestic and external sources. The objective of this study is to determine the concentration of phosphate and COD (Chemical Oxygen Demand) in the district irrigation channel and to predict the spread of pollutants downstream due to residential and agricultural activities. The study was conducted at three Point Source (PS) and four Non-Point Source (NPS) sites. The results showed that all COD measurements exceeded the water quality limits of Class II based on Government Regulation No. 22 of 2021. The highest COD content (285 mgL-1) was recorded in PS1 and the highest phosphate concentration (4.34 mgL^{-1}) in PS2. Both were affected by the discharge of domestic organic waste from residential areas and detergents. The study used analytical modelling and a mass balance approach to estimate a slow decrease in pollutant concentrations downstream as a result of natural sedimentation and degradation processes. COD levels decreased from 104.93 mgL^{-1} in segment 1 or combined concentration NPS 1 (CR1) to 89.63 mgL^{-1} in segment 2 (CR2) and 50 mgL^{-1} in segment 3 (CR3). Orthophosphate concentrations exhibited a similar pattern, decreasing from 0.06512 mgL^{-1} (CR1) to 0.06510 mgL^{-1} (CR2) and 0.06481 mgL^{-1} (CR3). Therefore, lowering the total pollutant load in the irrigation system requires upstream pollution control. It is anticipated that the results of this study will assist local governments in developing sustainable plans for managing water resources.

1. INTRODUCTION

1.1 Background

Irrigation is a system designed to supply and distribute water to support agricultural and plantation activities. Irrigation channel also serves as water storage during the dry season and can accommodate excess rainfall (Lund et. al., 2023). To maintain irrigation water quality, strategies are needed to conserve and control irrigation water pollution. Conservation and control include maintaining the capacity of irrigation water to reduce pollutants (self-purification) before entering the channels (Pratiwi et al., 2023).

One irrigation channel in Lampung Province, Indonesia is in Metro City. To supply water for agriculture and plantations in Metro City, an irrigation network was built originating from the Way Sekampung Dam. However, human activities in the irrigation area can degrade irrigation water quality. For example, irrigation channels located in the city center, Central Metro District, Hadimulyo Timur and Hadimulyo Barat Villages are used as disposal sites for both fecal and household waste, which can contribute to the pollutants chemical oxygen demand (COD) and phosphate (Dinas Komunikasi Kota Metro, 2022).

The irrigation channel in Metro City has the potential to become tourism area and source of Class II domestic water if the irrigation water can be conserved and water quality is monitored and maintained (Entas et. al., 2017). As a first step in preserving and maintaining irrigation water quality in Metro City, a study was conducted on wastewater distribution in terms of COD and phosphate parameters resulting from domestic and agricultural activities.

Previous studies have investigated nutrient pollution in water bodies, particularly in river systems and surface water environments (Nugraha et.al.,2022; Hariyanto, 2018). However, most studies focus on river ecosystems, while limited attention has been given to irrigation channels influenced by both domestic and agricultural activities. Because point source and non-point source pollutants interact in irrigation systems, pollutant dynamics are more complicated, needing a more integrated analytical approach. Thus, this work uses a point source non-point source technique in combination with mass balance modelling to examine the spatial distribution of phosphate and Chemical Oxygen Demand (COD) along irrigation channels in Metro City. This method explores better understanding about distribution and spatial pollutants and the removal mechanism in irrigation systems.

1.2 Research Objectives

COD and phosphate concentration was monitored in every irrigation channel in Metro District to assess the change in water concentration from domestic source and agricultural source to downstream. This research also evaluated the rate of natural degradation of the contaminant in irrigation networks by comparing the concentration in every sampling location.

2. METHOD

2.1 Research Location and Period

Sampling was conducted on 19 July 2023 during the dry season; it was assumed that the effect of rainfall and surface runoff would be minor on the water quality. This allowed the irrigation channel to be assessed under relatively stable hydrological conditions. Samples were collected from both point-source (PS) and non-point-source (NPS) locations identified through GIS-based mapping, as presented in Figure 1. Because the sampling was conducted only once, the results represented water quality conditions at the time of sampling rather than seasonal variations.

2.2 Data, Tools, and Research Materials

Standard field equipment was used for sampling. Irrigation water samples were collected using a portable water sampler and stored in pre-cleaned plastic bottles. The samples were then transported to the laboratory in an insulated styrofoam container to minimize temperature fluctuations. Flow velocity was measured in situ using a current meter, whereas distances between sampling locations were determined with a measuring tape. Geographic coordinates together with site photographs were recorded using the GPS Map Camera application on an Android smartphone. The spatial distribution of COD and phosphate concentrations was processed and visualized using ArcGIS software.

2.3 Research Procedures

2.3.1 Research Data and Segmentation

In this study, the irrigation channel was divided into four segments. From each segment, one sample was taken from the water body to represent the influence of NPS, and another sample was taken from the drainage to represent the influence of PS. The segment division was based on water inflow from PS and the availability of sampling locations for NPS at segments 2, 3 and 4 to validate the model between test and simulation concentrations. Land use data were obtained from Thematic Geospatial Information (IGT) supported by satellite imagery and administrative maps. The data was further verified through field observations to ensure accuracy.

Table 1. Research data

No	Source	Data Category	Description
1	Thematic Geospatial Information	Tanah Airku	1:25.000.000
2	Google Earth Satellite Imagery	Google Earth	
3	Water Quality	Lab Test Water Quality and Government Regulation No. 22 of 2021	COD dan phospate

This research requires several data sets, as shown in Table 1. IGT data was used to obtain administrative maps and irrigation channel, supported by satellite imagery, to obtain land use information around the research segment in Central Metro District (Meng et al., 2023). IGT is a geospatial information that can illustrate one or several specific themes and referred to the Basic Geospatial Information.

Administrative map of Metro City was used as a base map to create a land use map around the irrigation channel segment of the Rawasari Bridge, East Hadimulyo, Metro City.

2.3.2 Determination of Sampling Points

Sampling points were obtained through analysis and observation to ensure accessibility. The point selection method was purposive sampling, based on the researcher's assessment on accessibility, time, and cost (Yusuf, 2016). The wastewater sources considered in this study included domestic wastewater generated from household activities such as bathing, washing, and sanitation, as well as agricultural runoff originating from the surrounding farmlands. The requirements for determining sampling points for water pollution control purposes are as follows:

1. In receiving water before mixing with wastewater.
2. In the wastewater drainage channel before entering the receiving waters.
3. In receiving waters after mixing with wastewater, but before mixing with or receiving with other liquid waste.

Table 2. Sampling points

Point	Coordinate		Site Description
	LS	LE	
NPS 1	-5.1107934	105.3041878	Area characterized by human activities, including a traditional market
PS 1	-5.1108609	105.3041948	
NPS 2	-5.1080303	105.3075479	Residential area with small-scale agricultural fields
PS 2	-5.1080330	105.3076475	
NPS 3	-5.1077811	105.3102063	Area consisting of agricultural land and residential settlements
PS 3	-5.1078283	105.3102405	
NPS 4	-5.1065573	105.3145575	Area consisting of agricultural and plantation land

Source: Field observation (2023)

The results of the analysis and observation included land use maps and flow into water bodies, such as drainage or waste pipes (Mujib, 2022). Sampling was conducted in the Central Metro District irrigation channel at 4 NPS points and 3 PS points (Table 2). The determination of sampling locations considered the distance from the upstream, waste entry points, and site accessibility (Nugraha et., al., 2022).

2.3.3 Sampling and Analysis

Water quality sampling was used to determine the concentration downstream of the irrigation. Sampling and analysis were conducted according to the procedures specified in SNI 6989.57:2008 (Badan Standardisasi Nasional, 2008) to obtain accurate and representative data on the conditions of the tested parameters.

The precise sampling locations were determined using GPS Map Camera application installed on an Android device. In addition, the channel flow velocity was measured using a current meter (Flowatch FL-03). The samples were transferred to 500 mL bottles and stored in a styrofoam box equipped with ice, before being taken to the laboratory.

The water samples were analyzed for COD and phosphate parameters according to SNI 6989:2021 (Badan Standardisasi Nasional, 2021) to ensure accuracy and repeatability of results. The COD concentration was analyzed using the titrimetric method. Phosphate concentration, expressed as orthophosphate or total phosphorus, was analyzed using the spectrophotometric ascorbic acid method. The results were compared with the irrigation water quality standards based on Government Regulation Number 22 of 2021.

2.3.4 Model Simulation and Validation

In this study, the irrigation flow studied began at NPS 1 (upstream of the irrigation system) and the wastewater entering the irrigation water body. This segmentation was based on the influx of water from PS and the availability of NPS sampling sites at points 2, 3, and 4 to validate the model between test and simulated concentrations (Hariyanto, 2018). The simulations in this study were divided into three scenarios for each COD and phosphate parameter, which would provide predicted results from both concentrations downstream of the irrigation system to classify the water class downstream of the irrigation system (Noor et. al., 2024). The model calculation in this study is based on several assumptions, including steady flow conditions, complete mixing of pollutants in the channel, no additional pollutant sources between sampling points, and first-order decay processes.

- Scenario 1

In the first scenario, the simulation incorporates the initial concentration at the non-point source upstream location (C_{NPS-1}) to estimate the simulated downstream concentration reduction (C NPSsim-1) using Equation 1 and Equation 2:

For COD:

$$L_2 = \left[C_{NPS-1} - \frac{B}{(K_5 + K_3)}\right] e^{-(K_5 + K_3)t} + \frac{B}{(K_5 + K_3)} \text{ .... (1)}$$

Where:

L_2 = Simulated COD concentration at the downstream location (mgL^{-1})

C_{NPS-1} = Initial COD concentration at the upstream non-point source (Scenario 1) (mgL^{-1})

$C_{NPSsim-(x)}$ = Simulated COD concentration at distance xx from the upstream (mgL^{-1})

B = COD loading rate entering the irrigation channel ($mgL^{-1}\cdot day$)

K_5 = COD decay coefficient due to biochemical oxidation (day^{-1})

K_3 = COD removal coefficient due to sedimentation and other loss processes (day^{-1})

t = Travel time of water flow (day)

e = Base of the natural logarithm

For phosphate:

$$\frac{dP_o}{d_t} = -\alpha_2.(\mu - \rho).ANPS - 1 - \frac{\sigma_2}{A_x} - f_{de} - f_{ad} - \sigma_4 \text{ .... (2)}$$

Where:

$\frac{dP_o}{d_t}$ = Rate of change of orthophosphate concentration over time (mgL^{-1}day^{-1})
ρ = Orthophosphate concentration in the irrigation channel (mgL^{-1})
α_2 = Phosphate uptake coefficient by aquatic organisms (day^{-1})
μ = Phosphate uptake rate (day^{-1})
ϱϱ = Phosphate release rate (day^{-1})
ANPS−1 = non-point source contributing area in Scenario 1 (m^2)
σ_2 = Phosphate settling flux (mg day^{-1})
f_{de} = Phosphate loss due to denitrification or biological degradation (mgL^{-1}day^{-1})
f_{ad} = Phosphate adsorption rate to sediments (mgL^{-1}day^{-1})
σ_4 = External phosphate loss coefficient (mgL^{-1}day^{-1})

When a point source is identified along the flow path, a combined concentration (CR) is calculated using Equation 3:

$$C_R = \frac{\sum C_i Q_i}{\sum Q_i} \quad (3)$$

Where:
CR = Combined concentration after mixing point and non-point sources (mgL^{-1})
Ci = Pollutant concentration from source ii (mgL^{-1})
Qi = Discharge from source ii (m^{3}s^{-1})

- Scenario 2

In the second scenario, after the combined concentration (CR) is obtained, concentration reduction is evaluated not from the initial upstream value (C_{NPS-1})), but from the progressively decreasing CR at successive distances, denoted as $C_{NPSsim-(x):}$

For COD, Equation 4 was used:

$$L_2 = \left[C\ NPS_{sim-(x)} - \frac{B}{(K_5 + K_3)}\right] e^{-(K_5 + K_3)t} + \frac{B}{(K_5 + K_3)} \quad (4)$$

For phosphate, Equation 5 was applied:

$$\frac{dP_o}{d_t} = -\alpha_2.(\mu - \rho).C\ Ax - \frac{\sigma_2}{A_x} - f_{de} - f_{ad} - \sigma_4 \quad (5)$$

A new combined concentration (CR) is computed whenever a fresh point source enters the irrigation channel. In the direction of the downstream end of the canal, this procedure is repeated one after the other.

- Scenario 3

In Scenario 3, to ascertain the percentage error between calculated concentrations and observed (measured) concentrations at monitoring locations NPS-2, NPS-3, and NPS-4, the model is validated through computational analysis. Equation 6 is used to determine the Root Mean Square Percent Error (RMSPE), which is used for error evaluation.

$$\text{RMSPE} = \sqrt{\frac{1}{n}\left[\sum_{n=1}^{n}\left(\frac{C_{obs} - C_{sim}}{C_{sim}}\right)^2 x\ 100\%\right]} \quad (6)$$

Where:
RMSPE = Root Mean Square Percentage Error (%)
n = Number of observation points
Cobs = Observed (measured) concentration at monitoring point ii (mgL^{-1})
Csim = Simulated concentration at monitoring point ii (mgL^{-1})

Analytical models and mass balance equations were used in modelling simulations to forecast the distribution of COD and phosphate in the irrigation channel. Based on changes in NPS and PS concentrations, three simulated scenarios were created, and the outcomes were shown as concentration reduction graphs and dispersion maps. The Root Mean Square Error (RMSE) approach was used to compare the simulation findings with field test data at points NPS 2, NPS 3, and NPS 4 to validate the model.

3. RESULTS AND DISCUSSION

3.1 Land Use Around the Central Metro Irrigation

The amount and type of pollutant which entered the irrigation was influenced by combination for each land used in the riverbanks. In Figure 1, it is observed that NPS are spread along the irrigation channel while PS mostly comes from discharge channel. The analyzed irrigation channel is about 1.4 km in length and slows water from about 34.07 ha of catchment area.

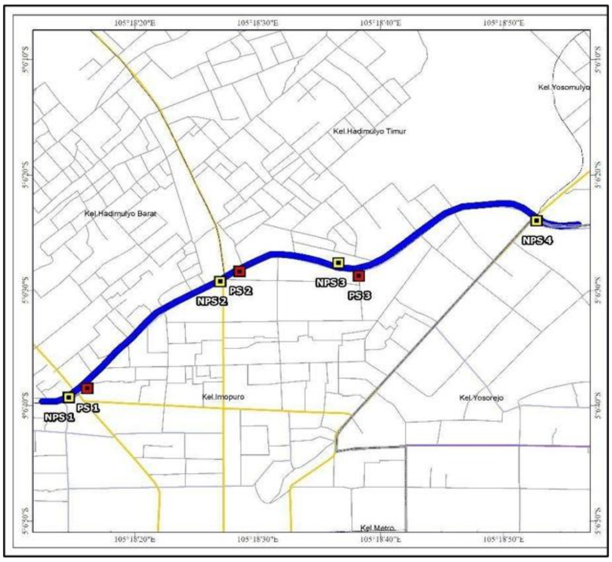


Figure 1. Research location and sampling points

As seen in Figure 2, the land use distribution in its catchment area of the riverbank was dominated by residential at about 45% (15.41 ha). Then there are agricultural land (19%, 6.49 ha) and sports grounds (21%, 6.97 ha). Other land uses are ponds (3%, 1.09 ha) and highways (12%, 4.11 ha). The high percentage of residential areas showed that wastewater from households was the most significant influent. It often contains easily degraded organic material and nutrients from household activities.

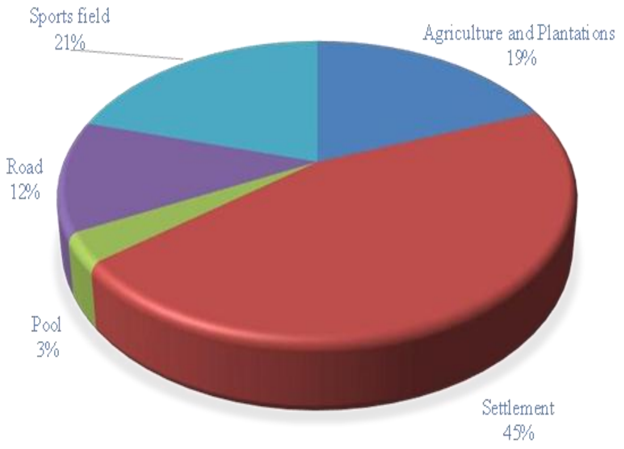


Figure 2. Land use distribution

Diffused pollutant loading through surface runoff is further exacerbated by the comparatively high percentage of sports fields and agricultural land, especially fertilizers and organic matter related to fertilizer application and soil erosion. On the other hand, despite making up a lesser fraction of the catchment, roads and ponds may nevertheless serve as secondary sources of pollution due to sediment resuspension and rainwater runoff.

Due to direct wastewater discharge and inadequate treatment facilities, prior research has demonstrated that irrigation canals draining residential-dominated catchments frequently have elevated COD concentrations, frequently surpassing 100 mgL^{-1} (Wardhana, 2000). Consequently, the spatial heterogeneity of water quality measurement along the irrigation channel, especially the elevated amounts of organic pollutants found in upstream and highly inhabited areas, can be explained mechanically by the observed land use pattern. Sedimentation processes, natural biological degradation, and dilution from extra water inflow are probably responsible for the drop in point source (PS) concentration along the irrigation channel.

3.2 Irrigation Water Quality in Metro City

With values of 105 mgL^{-1} at NPS 1 and 285 mgL^{-1} at NPS 2, Figure 3 demonstrates that the COD of irrigation water quality did not fulfil Class II water quality standards (Government Regulation Number 22 of 2021). Similarly, drainage water at PS 1 and PS 2 had COD values of 285 mgL^{-1} and 214 mgL^{-1}, respectively. The input of untreated organic-rich wastewater from conventional markets is mechanically responsible for the rise in COD concentration from NPS 1 to NPS 2. High quantities of proteins and lipids in waste from fish and poultry trading operations greatly raise the oxygen requirement during microbial decomposition. Baja (2012) observed a 2- to 3-fold rise in COD downstream of market drainage outflows, which is consistent with the quantitative finding that the COD concentration at NPS 2 was almost 2.7 times greater than that at NPS 1. Both biological oxidation processes—in which microorganisms break down organic matter—and dilution effects—which arise from increased water inputs down the channel—have an impact on the decrease in COD content.

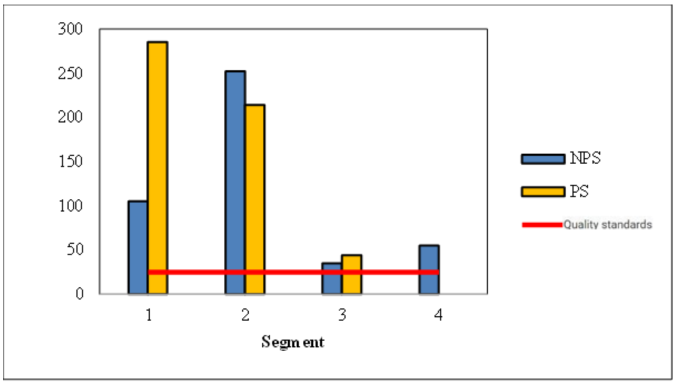


Figure 3. COD concentration against Class II Quality Standards in Metro City Irrigation Channel

In contrast, NPS 3, PS 3, and NPS 4 are primarily agricultural regions with a minor amount of residential land usage. At NPS 3, the COD content was 35 mgL^{-1}; at NPS 4, it was 55 mgL^{-1}. The input of pollutants from PS 3, which had a concentration of 44 mgL^{-1}, was responsible for the rise in concentration at NPS 4. Despite being lower than residential zones, COD concentrations in agricultural areas were still higher than Class II water quality guidelines, suggesting ongoing organic pollution.

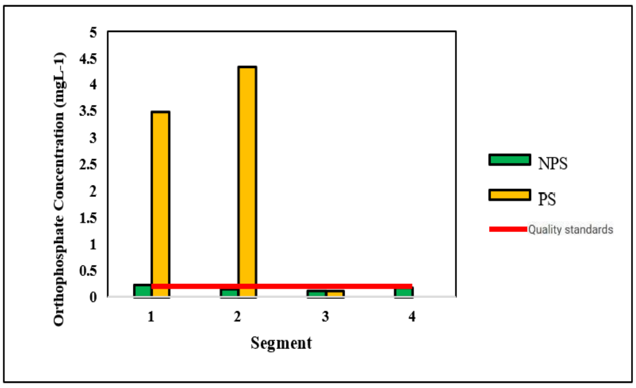


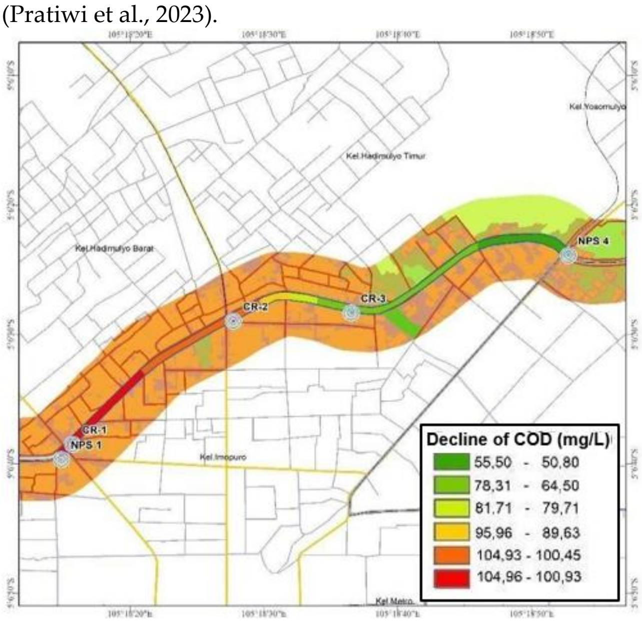
Figure 4. Orthophosphate concentration against Class II Quality Standards in Metro City Irrigation Channel

Also shown in Figure 4 for the four segments of the irrigation channel with point sources (PS) and non-point sources (NPS) are water quality standards for orthophosphate concentrations. In the aquatic environment, orthophosphate is mostly found in the form of orthophosphate, polyphosphate and organic phosphate compounds (Kalkhajeh et al., 2019). As illustrated in Figure 4, the concentrations of the orthophosphate at the non-point sources were maintained at relatively low and stable levels across the whole study area, with a range of approximately 0.09 to 0.22 mg L-1, and all values near or below the water quality standard. Stronger concentrations were observed at the point sources in Segments 1 and 2, with 3.49 mg L^{-1} (PS-1) and 4.34 mg L^{-1} (PS-2), respectively. These concentrations were an order of magnitude greater than the water quality standard, suggesting localised phosphorus inputs into the irrigation channel (Withers et al., 2014). The higher concentrations at PS-1 and PS-2 are associated with residential areas and commercial activities such as a traditional market, where phosphorus-rich wastewater from domestic activities especially detergent discharge and other organic pollutants, is directly discharged into the drainage system (Withers et al., 2014). In contrast, orthophosphate concentrations at PS-3 and corresponding NPS in Segments 3 and 4 were low (about 0.12 mg L^{-1} and 0.18 mg L^{-1}, respectively) indicating that these zones had relatively low anthropogenic phosphorus inputs and were less affected by domestic and commercial wastewater discharges.

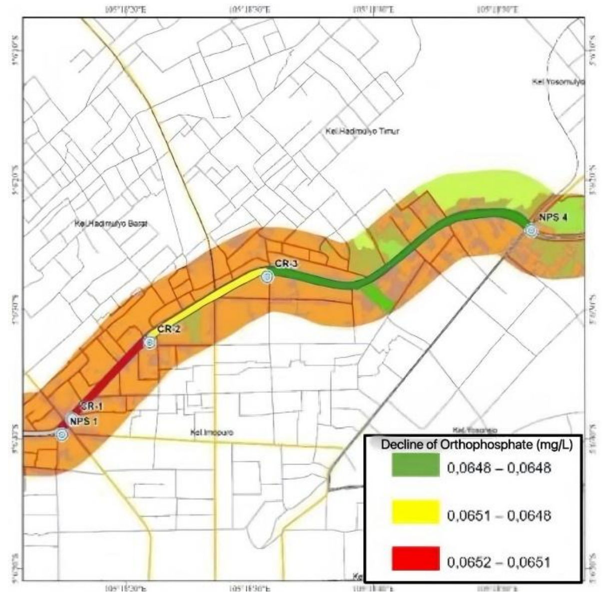
Low flow velocity in irrigation channels hinders microbial decomposition of organic matter and restricts reaeration, which allows COD to persist over longer distances (Siti, 2018). The simultaneous rise of both parameters seen in this study can be explained by prior research showing a positive association between COD and phosphate concentrations in agricultural streams due to fertilizer runoff and organic matter mineralization processes (Addiscott & Thomas, 2000).

3.3 Prediction of Wastewater Distribution

The COD distribution in the irrigation channel of Central Metro District was assessed with hydrodynamic models and the water quality models. Simulation results (Figure 5) showed that section 1 (CR1), located near the traditional market and classified as the household polluted source, has the highest COD concentration at 104.93 mgL^{-1}. Afterwards, the value dropped to 55.50 mgL^{-1} (14,6%) in segment 3 (CR3) and 89,63 mgL^{-1} (47,1%) in segment 2 (CR2). The reduction is the result of combination of hydrodynamic dilution, microbe degradation and organic material sedimentation along the channel. Similar reduction of COD rate (40–55% in the channel reach 1–2 km) had been shown in an irrigation system with the same hydraulic condition (Pratiwi et al., 2023).



(A)



(B)

Figure 5. Distribution map of pollutant distribution (A) COD & (B) Orthophosphate

Predicted distribution of phosphate was similarly patterned. The highest concentration of phosphate was 0.0652 mgL^{-1} (CR1) near household pollution sources. The concentration decreased to 0.06510 mgL^{-1} for segment 2 (CR2) and 0.0647 mgL^{-1} for segment 3 (CR3). Although the reduction of an absolute concentration of phosphate was relatively small, the observed trend indicates that biogeochemical processes played a greater role than dilution in controlling phosphate concentrations. Adsorption in sediment and cation sedimentation like calcium and iron vanished all the phosphate, primarily in slow irrigation channel. Previous study shows that effectivity of phosphate reduction in the system ranging from 0.5–2% per kilometer (Wardhana, 2000) which was consistent with the number of this research projected.

The model was validated by comparing the simulated and observed concentrations by means of RMSPE, which is reported as percentage (%). The COD model had an RMSPE of 79.5% compared with the orthophosphate model at 56%. RMSPE values of less than 20% close to 0% generally indicate a high degree of consistency between simulated and observed concentrations and indicates the model output is like field circumstances. The obtained RMSPE values for both COD and orthophosphate are fairly high, indicating that the model has not yet captured enough of the complexity of the water quality processes happening in the irrigation channel.

The drawback in predicting concentration model primarily may cause uncertainty in parameter kinetic which is used in model analytic, specifically unknown minimum and maximum range whether from leaching, transformation, or removal. Moreover, mass equilibrium approach linked with the limited inherent like condition assumption of steady state and mixed uniform that can reduce model accuracy when utilized for irrigation channel with pollutant inlet that heterogeny and the variably hydrodynamic condition that state by Ren et al., (2021).

4. CONCLUSION

The land used around Central District of Metro Irrigation Channel is dominated by residential (15.41 ha) and agricultural (6.49 ha) sectors, which have a great impact on the quality of irrigation water. COD readings ranged from 35 to 285 mgL-1 and were always above the Class II threshold of 25 mgL-1. Orthophosphate concentrations were generally low along the channel, but much higher than the source. corresponding to localized inputs from business and residential activities. The residential and commercial areas that are densely populated have higher polluted concentration in the upstream sections.

The model simulations could capture the basic spatial trends of the distribution of orthophosphate and COD along the irrigation channel. Model validation utilizing RMSPE results were 56% for orthophosphate and 79.5% for COD. The result shows low accurate prediction. Even though RMSPE at about 20% is generally acceptable, that model must be interpreted as a wide regional pattern, not a specific concentration. The relatively higher inaccuracy was due to onetime sampling, uncertainty in parameter kinetic range, and simplified model assumption in analytical mass balance included the homogenized dilution in steady state condition. Future studies need to consider multi-temporal data and better parameter calibration to increase model performance.

DAFTAR PUSTAKA

Addiscott, T. M., & Thomas, D. (2000). Tillage, mineralization and leaching: Phosphate. *Soil and Tillage Research, 53*(3–4), 255–273. https://doi.org/10.1016/S0167-1987(99)00110-5

Badan Standardisasi Nasional. (2008). *SNI 6989.57:2008 Air dan air limbah—Bagian 57: Metoda pengambilan contoh air permukaan*.

Badan Standardisasi Nasional. (2015). *SNI 8066:2015 Tata cara pengukuran debit aliran sungai dan saluran terbuka menggunakan alat ukur arus dan pelampung*.

Badan Standardisasi Nasional. (2021). *SNI 6989.31:2021 Air dan air limbah—Bagian 31: Cara uji kadar ortofosfat dan total fosfor menggunakan spektrofotometer dengan reduksi asam askorbat*.

Baja, S. (2012). *Perencanaan tata guna lahan dalam pengembangan wilayah: Pendekatan spasial & aplikasinya* (Edisi 1). Yogyakarta, Indonesia: CV Andi Offset.

Dinas Komunikasi Kota Metro. (2022, July 6). *Informasi Pemerintah Kota Metro*. Retrieved January 10, 2023, from http://info.metrokota.go.id

Effendi, H. (2003). *Telaah kualitas air: Bagi pengelolaan sumber daya alam dan lingkungan perairan*. Yogyakarta, Indonesia: Kanisius.

Entas, D., Kurniawati, R., Harwindito, B., & Karlina, K. (2017). *Culinary tourism development model in Metro Lampung City*. *Journal of Business on Hospitality and Tourism,* 2(1), 185–195. https://doi.org/10.22334/jbhost.v2i1.54

Fatikhasari, A. I. (2020). *Peran Dinas Lingkungan Hidup dalam penyelesaian kasus pencemaran saluran irigasi di Kabupaten Bantul* (Unpublished paper).

Hariyanto. (2018). *Analisis penerapan sistem irigasi untuk peningkatan hasil pertanian di Kecamatan Cepu, Kabupaten Blora* (Undergraduate thesis).

Irianto, I. K. (2017). *Kualitas air Sungai Badung dalam menunjang pengembangan pariwisata air ditinjau dari sifat fisik perairan* (Master's thesis).

Kalkhajeh, Y. K., Amiri, B. J., Huang, B., Khalyani, A. H., Hu, W., Gao, H., & Thompson, M. L. (2019). Methods for sample collection, storage, and analysis of freshwater phosphorus. Water, 11(9), 1889. https://doi.org/10.3390/w11091889

Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia. (2021). *Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor 5 Tahun 2021 tentang tata cara penerbitan persetujuan teknis dan surat kelayakan operasional di bidang pengendalian pencemaran lingkungan*.

Lund, A. A. R., Gates, T. K., & Scalia, J. IV. (2023). Characterization and control of irrigation canal seepage losses: A review and perspective focused on field data. *Agricultural Water Management*, *289*, 108516. https://doi.org/10.1016/j.agwat.2023.108516

Maghfiroh, L. (2016). *Penentuan daya tampung beban pencemaran Sungai Kalimas Surabaya (Segmen Taman Prestasi–Jembatan Petekan) dengan pemodelan QUAL2Kw* (bachelor's thesis).

Meng, X.-N., Xu, S.-C., Hao, M.-G., et al. (2023). Can digital-real integration promote industrial green transformation: Fresh evidence from China's industrial sector. *Journal of Cleaner Production, 426*, 139116. https://doi.org/10.1016/j.jclepro.2023.139116

Mujib MA, Ikhsan FA, Apriyanto B, Astutik S, Khasanah AN. Evaluasi Daya Tampung Beban Pencemaran Air Sungai Menggunakan Pendekatan Metode Neraca Massa. Jurnal Kesehatan Lingkungan Indonesia [Online]. 2022 Jun;21(2):152-161. https://doi.org/10.14710/jkli.21.2.152-161.

Noor, S. S. M., Saad, N. A., Akhir, M. F. M., & Rahim, M. S. A. (2024). QUAL2K water quality model: A comprehensive review of its applications and limitations. *Environmental Modelling & Software, 181*, 106284. https://doi.org/10.1016/j.envsoft.2024.106284

Nugraha, W. D., Hadi, S. P., Sasongko, S. B., Anisa, A. N., & Budihardjo, M. A. (2022). The use of QUAL2Kw to analyze the concentration of pH, nitrate, phosphate, and fecal coliform on water quality: A case study of the Klampok River, Semarang Regency. *Jurnal Presipitasi: Media Komunikasi dan Pengembangan Teknik Lingkungan,* *19*(2), 208–221. https://doi.org/10.14710/presipitasi.v19i2.208-221

Pemerintah Republik Indonesia. (2021). *Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021 tentang penyelenggaraan perlindungan dan pengelolaan lingkungan hidup*. Jakarta, Indonesia: Sekretariat Negara.

Pratama, D. (2021). *Pengaruh tata guna lahan terhadap daya tampung beban pencemaran air sungai (Studi kasus: Sungai Way Jelai)*. Bandar Lampung, Indonesia: Institut Teknologi Sumatera.

Pratiwi, D., Sumiarsa, D., Oktavia, D., & Sunardi, S. (2023). Water quality influences self-purification in the

Cihawuk and Majalaya segments upstream of the Citarum River, West Java, Indonesia. *Water, 15*(16), 2998. https://doi.org/10.3390/w15162998

Ren, L., Ding, K., Hu, Z., Wang, H., et al. (2021). Processes and mechanisms of phosphorus mobility among sediment, water, and cyanobacteria under hydrodynamic conditions. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-021-16255-6

Withers, P. J. A., Neal, C., Jarvie, H. P., & Doody, D. G. (2014). Agriculture and eutrophication: Where do we go from here? Sustainability, 6(9), 5853–5875. https://doi.org/10.3390/su6095853