ISSN: 2621-4709 E-ISSN: 2621-2528
Journal of Applied Agricultural Science and Technology
Vol. 9 No. 2 (2025): 128-139

The Effect of Pesticide Residues on Environmental Quality in the Kromong II Watershed, Pacet District, Mojokerto Regency

Dimas Ganda Permana Putra [a,*], Zenita Afifah Fitriyani [b], Fahrur Rijal Ardiyanto [c], Yuni Rosita Dewi [d], Titik Khusumawati [e], Fariz Kustiawan Alfarisy [f], Mega Darmi Novita [a], Soesanto [a]

[a] Department of Agricultural, University Mayjen Sungkono, Mojokerto, Indonesia
[b] Department of Economic, University Mayjen Sungkono, Mojokerto, Indonesia
[c] Department of Education, University Mayjen Sungkono, Mojokerto, Indonesia
[d] Department of Sains, University of Surabaya, Surabaya, Indonesia
[e] Department of Law, University Mayjen Sungkono, Mojokerto, Indonesia
[f] Graduate School, State University of Surabaya, Surabaya, Indonesia

Abstract. *The river basin serves multiple ecological and socio-economic functions for the local community, particularly the Kromong II Watershed in Pacet District. A major issue in the upstream area of the watershed is the use of pesticides by local residents in agricultural land management. Excessive pesticide use leads to significant environmental residue accumulation. This study aimed to assess pesticide residue levels, evaluate the quality of irrigation water and soil fertility in rice fields, and map polluted locations using the ArcGIS 10.3 remote sensing application. The analysis was conducted at three designated research sites: Stations I, II, and III. Biochemical Oxygen Demand (BOD) was analyzed using the SNI 6989.72:2009 standard, while Chemical Oxygen Demand (COD) was measured following the SNI 6989.2029 method at the Mojokerto Regency Environmental Agency (DLH) Laboratory. Soil organic carbon (C-organic) was analyzed using the IKP-208 Organic Carbon Test, and total nitrogen (Total N) was determined through spectrophotometric analysis at the PT Graha Mutu Persada Laboratory. Metomil was analyzed using the Liquid Chromatography–Mass Spectrometry (LC-MS) method, while Profenofos was analyzed using Gas Chromatography–Mass Spectrometry (GC-MS). The study found that the highest levels of BOD and COD were recorded at Station III, with values of 11.4 mg/L and 28.6 mg/L, respectively. The highest total nitrogen (Total N) concentration was observed at Station I, measuring 0.14%, while the highest soil organic carbon (C-organic) content was found at Station III, at 7.87%. The LC-MS analysis of methomyl residues showed the highest concentration at Station III, with a value of 0.002 mg/L in irrigation water samples. Similarly, the GC-MS analysis of Profenofos residues indicated the highest concentration at Station II, measuring 8.25 ml/L. Based on these findings, it can be concluded that pesticide residue pollution, particularly from Profenofos, is most severe in the irrigation channel at Station II.*
Keywords: *methomyl; profenofos; residues; watershed.*

Type of the Paper: Regular Article.

1. Introduction

River basins are dynamic water systems that flow from upstream to downstream and have multiple functions essential to the livelihood, culture, and economy of surrounding communities. Anthropogenic activities that neglect ecological balance can lead to persistent pollution in these areas [1,2]. Pesticide contamination is among the most frequently observed sources of such

https://doi.org/10.55043/jaast.v9i2.348
Received September 21, 2024; Received in revised form April 27, 2025; Accepted May 20, 2025; Published May 25, 2025
* First corresponding author
Email: Dimasgandaunimas@gmail.com

pollution in river basins. This issue is closely associated with the practices of the local community, particularly upstream farmers who use pesticides to manage pest and disease infestations on agricultural land [3].

Common pesticide residues found in the environment include methomyl, profenofos, organochlorines, organophosphates, carbonates, triazines, and triazoles. Once released into the environment, these pesticides act as broad-spectrum toxicants and are non-selective in their effects, thereby posing a significant risk of environmental contamination [4,5]. Despite knowledge of safety protocols, over 90% of small-scale farmers do not use personal protective equipment (PPE) when applying pesticides. Additionally, 92% of farmers dispose of empty pesticide containers in the fields, contributing to the accumulation of non-biodegradable waste. Furthermore, 86% of farmers apply leftover pesticide residues to other crops [6]. Pesticide residues can adversely affect human health, commonly causing symptoms such as headaches, skin rashes, nausea, vomiting, and respiratory failure (Mecuria Teshome). Environmental pollution is evidenced by the degradation of water and soil quality, rendering them unable to perform their intended ecological functions. According to Government Regulation of the Republic of Indonesia Number 7 of 1973 concerning the Supervision of the Distribution, Storage and Use of Pesticides, Article 7 outlines provisions related to the construction of storage facilities, storage procedures, occupational safety and health, record-keeping of pesticide distribution, label standards, packaging, and residue management [7,8]. Government Regulation of the Republic of Indonesia Number 25 of 2000 addresses the division of authority between the central government and provincial governments as autonomous regions, emphasizing the implementation of policies at their respective regional levels. Environmental pollution mitigation should begin with the identification of pollution sources and the mapping of environmental pollution levels, as these steps can assist in the development of effective pollution control policies [9].

The levels of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in upstream irrigation water serve as indicators of the presence of organic and chemical compounds that may affect the sustainability of agricultural activities [10,11]. Similarly, total nitrogen (Total N), organic carbon (C-organic), and soil pH are key parameters for assessing soil fertility in rice fields. Tertiary irrigation systems derived from primary river flows influence the hydrological characteristics of rivers, particularly in terms of material composition (such as dissolved nutrients, sediment, and organic matter) and flow dynamics (including water quality and quantity) [12]. Erosion and land-based pollutants are transported by surface runoff into river systems and surrounding soils, contributing to the accumulation of contaminants in the environment [13,14].

The accumulation of undegraded active pesticide compounds can lead to a decline in biodiversity within agroecosystems. The resulting deterioration in environmental quality significantly disrupts nutrient and energy cycles, ultimately impairing the functional capacity of the agroecosystem. Upstream farmers commonly use insecticides containing the active ingredients methomyl and profenofos to control pests and diseases [15,16].

In response to the issues outlined, this study aims to identify point sources of pesticide residue pollution and to map soil fertility conditions—focusing on C-Organic content, pH, and total nitrogen (Total N)—in areas frequently treated with pesticides [17]. Upstream water quality is assessed using Chemical Oxygen Demand (COD) and Biochemical oxygen demand (BOD) parameters, which are sampled to evaluate the water capacity for irrigation in rice fields within the Kromong II river basin. All data are processed to characterize the upstream conditions of the Kromong II watershed.

2. Material and Methods

2.1. Study area

This study was conducted in the Kromong II River Basin, Pacet District, Mojokerto Regency, from July to September 2024. Pacet District was selected for this study due to its location in the upstream watershed, which is characterized by significant agricultural activity. The research sample was obtained using purposive sampling, considering key points in the upstream, middle and downstream sections of the watershed. The method involved collecting three 1 kg soil samples from three locations suspected of excessive pesticide application, based on information gathered from interviews with local farmers. Irrigation water samples were collected from three locations suspected of excessive pesticide application, based on input from local farmers. Each sample weighed 1 liter and was taken from predetermined points in the study area [18]. After collection, the samples were transported to the laboratory for analysis. The research location is shown in Fig. 1.

2.2. Research Methods

This study employs a preliminary survey to identify the location of the spring headwaters and the agricultural land along the river [19,20]. The study utilized three research stations as sampling sites: Station I at the Sendi Village spring, Station II at the tertiary irrigation flow and rice fields in Sajen Village, and Station III at the irrigation flow and rice fields in Candiwatu Village. The sampling locations were tracked by measuring the coordinates and the distances between stations, and the data were processed using the ArcGis 10.3 remote sensing application.

Sampling of upstream spring water was conducted at a flow depth of 10 cm, with 1 liter of water collected. Upstream soil sediment was sampled from a depth of 15 cm below the surface, with each sample weighing 1 kg. At station II in Sajen Village, 1 liter of water was collected from a rice field ditch connected to the tertiary irrigation flow, and a 1 kg soil sample was taken from shallot farmland for pesticide residue analysis. Sampling at station III in Candiwatu Village was carried out by taking water in the rice field ditch leading to the tertiary irrigation flow with a weight of 1 liter and soil samples of pesticide residues were taken from shallot farmland with a weight of 1 kg.

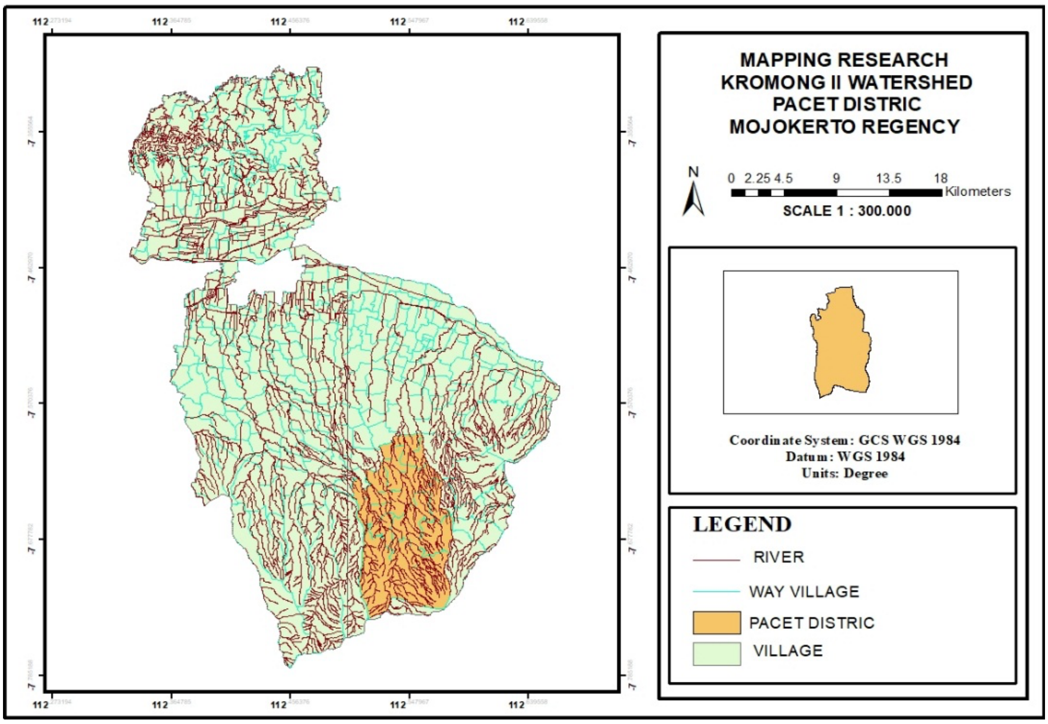

Fig. 1. Mapping Research

The first sampling procedure in the field involves preparing soil sample bottles with a capacity of 1 kg water sample bottles with a capacity of 1 liter, with three samples collected per data collection point. Name labels are prepared to assign numbers and collection locations. Soil and water sampling is conducted by collecting samples up to the specified weight limit as indicated by the scale. The sample bottles are labeled with names and numbers to identify and mark the samples, then placed in a cool box and transported to the laboratory. Soil analysis for N-Total and C-Organic content is conducted at the PT. Graha Mutu Persada Laboratory. Irrigation water analysis for BOD and COD content is performed at the Mojokerto Regency Environmental Service Laboratory. Analysis for Methomyl and Profenofos pesticide residue content is conducted at the Center for Plantation Seeding and Protection (BBP2TP), Surabaya.

2.3. Materials and Equipment

The collected water and soil samples were then analyzed in the laboratory to determine the parameters of TDS, pH, Temperature, BOD and COD, in accordance with water quality standards based on SNI 6989.72-2009 for BOD testing and SNI 6989.2-2019 for COD testing. An LC-MS test was conducted to determine the content of active methomyl residues [17]. GC-MS gas chromatography testing was carried out on the content of active prefenofos residues. Soil laboratory tests were conducted to determine the total N content, pH, temperature, and C-organic.

The research data were then processed using descriptive analysis, a technique to describe the collected data clearly and to distinguish each data set from the others.

3. Result and Discussion

3.1. Remote Sensing

The research results include ArcGIS mapping of the coordinate positions, as illustrated in Fig. 2. Fig. 2 shows the tracking path of the research, covering the distance from Station I to Station III, which spans 15.61 km and is indicated by an orange line. Location measurements were conducted using the Avenza Map application, which was overlaid with ArcMap 10.3, as shown in Fig. 2 [21,22]. The research location at Station I is characterized by forest and land cover with a waterfall spring used as the water sample source, along with soil sediment around the waterfall. Station II is located in Shallot field and river irrigation water. Station III is situated in rice fields cultivating rice, shallots, and sweet corn, and also includes river irrigation water flow [10].

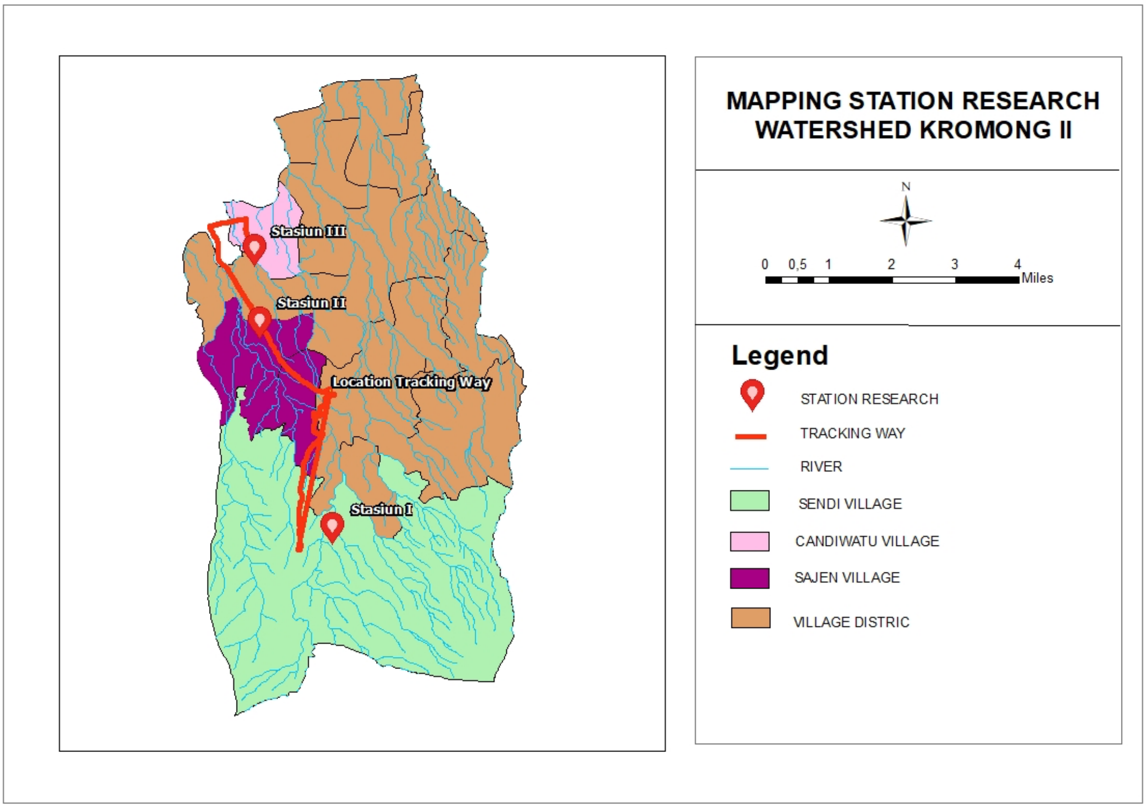

Fig. 2. Mapping Research Station Location

Table 1. Research Coordinate, Location, and Station

No	Coordinate	Location	Station
1	7°42'09.3"S 112°31'47.8"E	Sendi Village Spring	Station I
2	7°39'00.3"S 112°31'13.9"E	Land and irrigation areas of Sajen Village	Station II
3	7°38'02.6"S 112°31'11.2"E	Land and irrigation areas of Candiwatu Village	Station III

The determination of water quality parameters and soil fertility content was conducted at the location shown in Table 1, in the Station I area. Samples were collected at coordinates

7°42'09.3"S 112°31'47.8"E, at a waterfall with a large water discharge in Sendi Village, Pacet District. The determination of methomyl pesticide residue content, water quality, and soil fertility parameters was conducted in the Station II area. Samples were taken at coordinates 7°39'00.3"S, 112°31'13.9"E, from water irrigation in rice fields and two-month-old shallot fields in Sajen Village, Pacet District. The determination of profenofos pesticide residue content, water quality, and soil fertility content was performed in the Station III area. Samples were collected at coordinates 7°38'02.6"S, 112°31'11.2"E, from irrigation water in rice fields and one-month-old shallot fields in Candiwatu Village, Pacet District [23].

3.2. Water Quality Testing

The results shown in Fig. 3 illustrate the interrelated calculations of pH, BOD, and COD. A pH level above 6-7 indicates alkaline conditions in the upstream water. The BOD values, ranging between 8 – 11 based on the research findings, suggests that the water remains within normal limits. Similarly, COD values ranging between 20 – 30 mg/l indicate that water level quality in the upstream area is still within acceptable conditions [24,25]. Laboratory tests results according to the SNI 6989.72-2009 method for BOD and SNI 6989.2-2019 for COD of water quality are presented in Table 2.

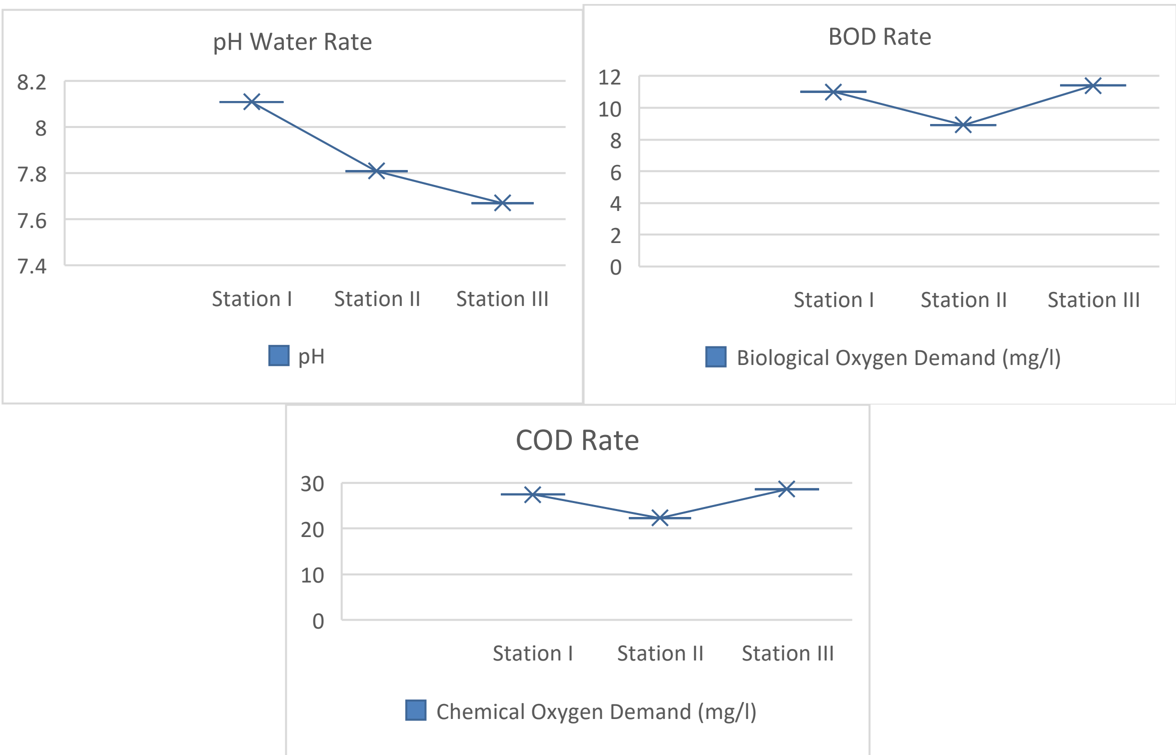

Fig. 3. pH, BOD, COD Rate

In the research data presented in Table 2, the pH comparison shows that values above 7.0 indicate alkaline conditions. Station I recorded a pH of 8.11; Station II recorded a pH of 7.81; and Station III recorded a pH of 7.67, with Station III being closest to neutral. The BOD (Biochemical Oxygen Demand) content, representing the amount of oxygen that can be broken down by microorganisms, was 11.0 mg/l, 8.93 mg/L at Station II, and 11.4 mg/L at Station III. The BOD analysis results indicate that Station II had the lowest BOD level among the three stations [16,26]. The BOD level at Station II is the lowest compared to other stations, possibly due to presence of highly toxicity components in the water samples, which may reduce the population of decomposing bacteria. A low BOD value indicates that most of the organic content is not degradable [27]. The COD (Chemical Oxygen Demand), which reflects the amount of chemical content dissolved in the water, was 27.4 mg/l, 22.3 mg/L at Station II, and 28.6 mg/L at Station III. The COD analysis results show that Station II had the lowest COD level among the three stations [5,24]. The temperature at Station I was 26.6°C, as it is located in the upstream spring area; Station II recorded a temperature of 31.7°C, and Station III recorded 32.7°C. [28]. The results of the study indicated that at Observation Station III, the BOD and COD levels were higher compared to the other stations, likely due to the dense population and the resulting high discharge inorganic compounds, which are susceptible to oxidation by oxidizing agents. According to the quality standards set in the Regulation of the Minister of Environment and Forestry No. 68 of 2016, the maximum allowable BOD concentration is 30 mg/L, and the maximum allowable COD concentration is 100 mg/L. Therefore, the BOD and COD levels at Station III remain below the regulatory thresholds [29].

Table 2. Water Quality

No	Station	pH	BOD (mg/l)	COD (mg/l)	Temperature (^{0} C)
1	Station I	8.11	11.0 mg/l	27.4 mg/l	26.6^0 C
2	Station II	7.81	8.93 mg/l	22.3 mg/l	31.7^0 C
3	Station III	7.67	11.4 mg/l	28.6 mg/l	32.7^0 C

3.3. Soil Quality Testing

The results shown in Fig. 4 illustrate that N-Total, pH, and C-Organic values influence one another. pH levels below 6-7 can be said to be acidic in the upstream area's soil. The N-Total content ranged from 1,448 mg/kg to 2,101 mg/kg, while C-organic content ranged from 55,600 mg/kg to 78,700 mg/kg [30,31]. The research findings indicate that N-Total levels remain within normal limits. This suggests that the normal levels of N-Total and C-organic are not affected by pesticide residue pollution, which serves as a benchmark for soil quality based on laboratory tests results from PT Graha Mutu Persada using the IKP-48 method, in accordance with the Decree of the Minister of State for the Environment Number 28 of 2003 [31]. The study also shows that Organic C levels are within normal ranges in the soil area of the research location.

Table 3. Soil Testing

No	Station	N-Total (mg/kg)	pH	C Organic (mg/kg)	Temperature (^{0} C)
1	Station I	1.448 mg/kg	6.0	55.600 mg/kg	23.0^0 C
2	Station II	2.101 mg/kg	5.5	69.300 mg/kg	31.7^0 C
3	Station III	1.486 mg/kg	5.5	78.700 mg/kg	32.0^0 C

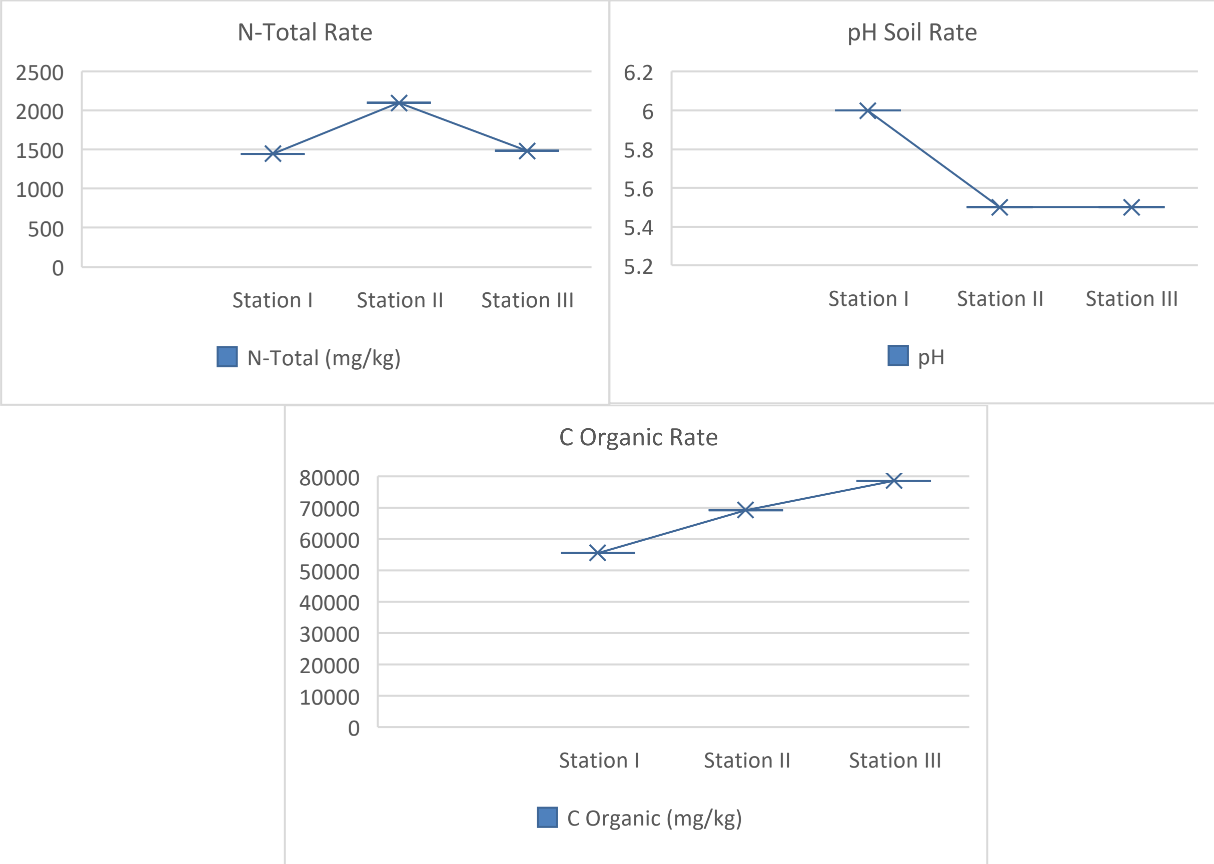

Fig. 4. N-Total, pH, and C Organic Rate

In the study of soil quality testing shown in Table 3, the N-Total parameter, which functions as a nutrient for plant vegetative growth, was 1.448 mg/kg at Station I, 2.101 mg/kg at Station II, and 1.486 mg/kg at Station III. These results indicate that the highest N-Total content was found at Station II. The pH values were all below 7.0, classifying the soil as acidic: Station I had a pH of 6.0, while Stations II and III both had a pH of 5.5. The organic C content, which plays a role in carbon binding in the soil, was 55.600 mg/kg at Station I, 69.300 mg/kg at Station II, and 78.700 mg/kg at Station III. The recorded temperatures were 23.00°C at Station I, 31.70°C at Station II, and 32.00°C at Station III [17,32].

3.4. Pesticides Residues

The research selected methomyl and profenofos at test parameters because upstream farmers widely use pesticides with the trademarks Danke (Metomil) and Curacorn (Profenofos). As shown in Table 4, testing was not conducted at Station I due to the absence of agricultural land, as the area consists entirely of bamboo forest. At station II, the analysis showed the results for profenofos showed concentrations of 4.30 mg/kg in soil samples (LOQ: 0.01) and 8.25 mg/L in water samples (LOQ: 0.01). At Station III, the methomyl analysis showed concentrations of 0.007 mg/kg in soil samples (LOQ: 0.01) and 0.002 mg/L in water samples (LOQ: 0.01). These calculation parameters indicate the intensive use of pesticides on agricultural land in Pacet District, Mojokerto Regency. The results of the crematography analysis were obtained from the machine testing. The testing was conducted using the chromatogram method, with the result calculated by multiplying the chromatogram value by the volume of the solvent and dividing it by the sample weight. The solvent volume was 15 ml, and the soil sample weight was 5 grams. The analysis results are presented through the LC-MS and GC-MS methods [7,27].

Table 4. Residues Result

No	Sample	Parameters	Test Methods	Result	LOQ	Unit	Station
1	Soil	-	-	-	-	-	Station I
	Water	-	-	-	-	-	
2	Soil	Profenofos	IKP.P-18 (GC-MS)	4.30	0.01	mg/kg	Station II
	Water	Profenofos	IKP.P-18 (GC-MS)	8.25	0.01	mg/l	
3	Soil	Methomyl	IKP.P-18 (UPLC-MS)	0.007	0.01	mg/kg	Station III
	Water	Methomyl	IKP.P-18 (UPLC-MS)	0.002	0.01	mg/l	

Recommendations to reduce the use of chemical pesticides include the use of biopesticides derived from fungi, bacteria, nematodes, and other environmentally friendly biological control agents. Biopesticides should be applied at the beginning of the planting period to support the life cycle of biological control agents and during the phase when pest levels are still within the economic threshold, rather than after pests and diseases infestation has occurred [34]. Sustainable agricultural land management strategies may include crop rotation, the use of organic fertilizers, application of biopesticides, and use of appropriate irrigation water sources [35]. The use of biopesticides also supports sustainable development, specifically Sustainable Development Goals (SDGs) No. 15, which focuses on the conservation, restoration, and sustainable use of terrestrial ecosystems through practices such as sustainable land management and reduction of land degradation [36,37].

4. Conclusions

The results of the study on environmental vulnerability in the Kromong II River Basin showed that the highest BOD and COD values were recorded at Station IIIat 11.4 mg/L and 28.6 mg/L, respectively. The highest total N content was observed at Station I, at 0.14 mg/kg, while the highest organic C content was found at Station III, at 7.87 mg/kg. LC-MS analysis at Station III detected a Metomil residue of 0.002 mg/L in the irrigation water flow, and GC-MS analysis at Station II revealed a profenofos residue of 8.25 mg/L in the irrigation water flow. The highest pollution point was identified at coordinates 7°38'02.6"S 112°31'11.2"E. Based on these laboratory results, the condition of the land and upstream water is classified as polluted.

Abbreviations

Not applicable

Data availability statement

Data will be shared upon request by the readers

CRediT authorship contribution statement

Dimas Ganda Permana Putra: Conceptualization, Methodology, and Formal analysis. **Zenita Afifah Fitriyani, Yuni Rosita Dewi, Titik Khusumawati, Fariz Kustiawan Alfarisy:** Visualization, writing – original draft and editing. **Mega Darmi Novita, Soesanto:** Investigation, Project administration, Resources.

Declaration of Competing Interest

The authors of the manuscript declare no conflict of interest or competing interest

Acknowledgements

Acknowledgements are addressed to Penelitian Dosen Pemula 2024 Direktorat Akademik Pendidikan Vokasi Kementrian Pendidikan, Kebudayaan, Riset dan Teknologi Republik Indonesia.

References

[1] Ait-Mouheb N, Mange A, Froment G, Lequette K, Bru-Adan V, Maihol J claude, et al. Effect of untreated or reclaimed wastewater drip-irrigation for lettuces and leeks on yield, soil and fecal indicators. Resour Environ Sustain 2022;8. https://doi.org/10.1016/j.resenv.2022.100053.

[2] Zhang Y, Li Y, Huang G, Ma Y, Zhou Y. Optimizing sustainable development in arid river basins: A multi-objective approach to balancing water, energy, economy, carbon and ecology nexus. Environ Sci Ecotechnology 2025;23. https://doi.org/10.1016/j.ese.2024.100481.

[3] Shahid M, Singh UB. The ecological hazards of profenofos revealed by soil beneficial-bacteria, plant seedlings, and plasmid nicking assays: A short-term toxicity investigation. Plant Stress 2024;14. https://doi.org/10.1016/j.stress.2024.100577.

[4] Ramos RO, Albuquerque MVC, da Silva SF, Lyra WS, Araújo MCU, de Sousa JT, et al. Pathways, by-products, reaction intermediates, and kinetics study of degradation of profenofos via photo-assisted peroxidation. Desalin Water Treat 2022;276:237–49. https://doi.org/10.5004/dwt.2022.28902.

[5] Ndiribe CC. The nature fit concept of waste reduction: Prospects for engineering a clean future. Resour Environ Sustain 2023;14. https://doi.org/10.1016/j.resenv.2023.100127.

[6] Trap J, Blanchart E. Intensifying the soil ecological functions for sustainable agriculture: Acting with stakeholders. Curr Res Environ Sustain 2023;5:100225. https://doi.org/10.1016/j.crsust.2023.100225.

[7] Peraturan Pemerintah. Peraturan Pemerintah No . 7 Tahun 1973 Tentang: Pengawasan Atas Peredaran, Penyimpanan Dan Penggunaan Pestisida. Jakarta 1973;1960:2. https://peraturan.bpk.go.id/Details/68075/pp-no-7-tahun-1973

[8] Soto-Barajas MC, Archundia D, Martínez OGR, López E, Almazan J, Prado B. Current and future perspectives on biopesticides analysis in soil. J Nat Pestic Res 2025;12. https://doi.org/10.1016/j.napere.2025.100120.

[9] Yuan Z, Pang Y, Gao J, Liu X, Sheng H, Zhuang Y. Improving quantification of rainfall

runoff pollutant loads with consideration of path curb and field ridge. Resour Environ Sustain 2021;6. https://doi.org/10.1016/j.resenv.2021.100042.
[10] Ferrans L, Jani Y, Hogland W. Chemical extraction of trace elements from dredged sediments into a circular economy perspective: Case study on Malmfjärden Bay, south-eastern Sweden. Resour Environ Sustain 2021;6. https://doi.org/10.1016/j.resenv.2021.100039.
[11] Gil-Rodas N, Guevara-Mora M, Rivas G, Dávila G, García D, Contreras-Perdomo A, et al. A comparative study of several types of indices for river quality assessment. Water Qual Res J 2023;58:169–83. https://doi.org/10.2166/wqrj.2023.029.
[12] Niu S, Jiang Y, Liu H, Wang R, Cheng B, Cheng Y. Occurrence of dissolved organic matter in storm-drain inlet sediments and its implication for urban stormwater infrastructure sustainability. Resour Environ Sustain 2024;16. https://doi.org/10.1016/j.resenv.2024.100158.
[13] Aryani D, Wahyuningsih S. Pollution of Pesticide Residues in Rivers : Review. Aquasains 2021;10:979. https://doi.org/10.23960/aqs.v10i1.p979-994.
[14] Amr SSA, Abujazar MSS, Alazaiza MYD, Albahnasawi A, Bashir MJK, Nassani DE. The potential use of natural coagulants for microalgae harvesting: a review. Water Qual Res J 2023;58. https://doi.org/10.2166/wqrj.2022.026.
[15] Li M, Peng J, Lu Z, Zhu P. Research progress on carbon sources and sinks of farmland ecosystems. Resour Environ Sustain 2023;11. https://doi.org/10.1016/j.resenv.2022.100099.
[16] Ortega-Hernandez JM, Qiu D, Pla-García J, Yuanxun Z, Martinez-Frias J, Long X, et al. Key factors in developing controlled closed ecosystems for lunar missions. Resour Environ Sustain 2024;16. https://doi.org/10.1016/j.resenv.2024.100160.
[17] Mirella da Silva L, Mena IF, Sáez C, Motheo AJ, Rodrigo MA. Remediation of soils contaminated with methomyl using electrochemically produced gaseous oxidants. Chemosphere 2024;362. https://doi.org/10.1016/j.chemosphere.2024.142653.
[18] Syafrudin, Sarminingsih A, Juliani H, Budihardjo MA, Puspita AS, Mirhan SAA. Water Quality Monitoring System for Temperature, pH, Turbidity, DO, BOD, and COD Parameters Based on Internet of Things in the Garang Watershed. Ecol Eng Environ Technol 2024;25:1–16. https://doi.org/10.12912/27197050/174412.
[19] Jiang Y, Huang Z, Li L, Dong Q. Local–global dual attention network (LGANet) for population estimation using remote sensing imagery. Resour Environ Sustain 2023;14. https://doi.org/10.1016/j.resenv.2023.100136.
[20] Hijazi DA, BiBi A, Al-Ghouti MA. Sustainable waste utilization: Geopolymeric fly ash waste as an effective phenol adsorbent for environmental remediation. Resour Environ Sustain 2024;15. https://doi.org/10.1016/j.resenv.2023.100142.
[21] Pal B, Samanta S, Pal DK. using remote sensing and GIS techniques 2012. https://www.ijaet.org/media/0004/37I6-IJAET0612635.pdf
[22] Shaikh M, Birajdar F. Analysis of Watershed Characteristics Using Remote Sensing and GIS Techniques. International Journal of Innovative Research in Science, Engineering and Technology 2015;4:1971–6. https://doi.org/10.15680/IJIRSET.2015.0404023.
[23] Faizel H, Balkhi SAA, Vijayanandan A. Variability in excitation–emission spectra among wastewater treatment units and applications of fluorescence-based water quality monitoring. Water Qual Res J 2024;59:159–69. https://doi.org/10.2166/wqrj.2024.003.
[24] Werkneh AA, Gebru SB. Development of ecological sanitation approaches for integrated recovery of biogas, nutrients and clean water from domestic wastewater. Resour Environ Sustain 2023;11. https://doi.org/10.1016/j.resenv.2022.100095.
[25] Fletcher J, Willby N, Oliver DM, Quilliam RS. Resource recovery and freshwater ecosystem restoration — Prospecting for phytoremediation potential in wild macrophyte stands. Resour Environ Sustain 2022;7. https://doi.org/10.1016/j.resenv.2022.100050.
[26] Yasmin F, Sakib TU, Emon SZ, Bari L, Sultana GNN. The physicochemical and

microbiological quality assessment of Maddhapara hard rock-mine discharged water in Dinajpur, Bangladesh. Resour Environ Sustain 2022;8. https://doi.org/10.1016/j.resenv.2022.100061.
[27] Santoso AD. Keragaan Nilai DO, BOD dan COD di Danau Bekas Tambang Batubara Studi Kasus pada Danau Sangatta North PT. KPC di Kalimatan Timur. J Teknol Lingkung 2018;19:89. https://doi.org/10.29122/jtl.v19i1.2511. https://www.researchgate.net/publication/323146081_Keragaan_Nilai_DO_BOD_dan_COD_di_Danau_Bekas_Tambang_Batubara_Studi_Kasus_pada_Danau_Sangatta_North_PT_KPC_di_Kalimatan_Timur
[28] Zammi M, Rahmawati A, Nirwana RR. Analisis Dampak Limbah Buangan Limbah Pabrik Batik di Sungai Simbangkulon Kab. Pekalongan. Walisongo J Chem 2018;1:1. https://doi.org/10.21580/wjc.v2i1.2667.
[29] Menteri Lingkungan Hidup Dan Kehutanan Republik Indonesia. No.68 Tahun 2016 PL: Baku Mutu Air Limbah Domestik. Peraturan Menteri Lingkung Hidup Dan Kehutan Republik Indones 2016:1–13. https://ppkl.menlhk.go.id/website/filebox/5/170314114854P.68%20BAKU%20MUTU%20LIMBAH%20DOMESTIK.pdf
[30] Sari SM, Kumolontang WJN, Warouw VRC. Analisis kadar hara nitrogen total pada tanah sawah di tapadaka kecamatan dumoga tenggara kabupaten bolaang mongondow. Soil Environ 2021;21:29–33. https://doi.org/10.35791/se.21.3.2021.38762 https://ejournal.unsrat.ac.id/v3/index.php/soilenvironmental/article/view/38762
[31] Departemen Pertanian. Pedoman Teknis Pengkajian Pemanfaatan Air Limbah Dari Industri Minyak Sawit Pada Tanah Di Perkebunan Kelapa Sawit 2009;1:86–8. https://toolsfortransformation.net/wp-content/uploads/2017/05/28-tahun-2003-Pedoman-pemanfaatan-air-limbah.pdf
[32] He Z, Wang H, Liu W, Sun J, Huang J, Han J, et al. A novel self-enhanced electrochemiluminescent aptamer sensor based on ternary nanocomposite PEI/RuSi-MWCNTs for the detection of profenofos residues in vegetables. Heliyon 2024;10. https://doi.org/10.1016/j.heliyon.2024.e25167.
[33] Meng S, Chen X, Song C, Fan L, Qiu L, Zheng Y, et al. Effect of Chronic Exposure to Pesticide Methomyl on Antioxidant Defense System in Testis of Tilapia (Oreochromis niloticus) and Its Recovery Pattern. Applied Sciences 2021;11:3332. https://doi.org/10.3390/app11083332
[34] Puspita L, Hidayah N, Indrawan AR, Carolina HS. Analysis of Science Process Skills : The Impact of Project-Based Learning Assisted by Mind Mapping on Biology Subjects. Biosfer : Jurnal Tadris Biologi 2024;15:179–91. https://dx.doi.org/10.24042/biosfer.v15i2.25564.
[35] KN AR, Khastini RO, Hardianti F. Freshwater Trophic State of Sindang Heula Dam in Terms of Chlorophyl Content. Biosf J Tadris Biol 2022;13:83–92. https://doi.org/10.24042/biosfer.v13i1.10472.
[36] Endale Y, Samuel ZA, Kebede S, Bayu AB. Blended natural and synthetic coagulants for the COD and BOD removal from surface water; optimization by response surface methodology: The case of Gibe river. Heliyon 2024;10. https://doi.org/10.1016/j.heliyon.2024.e37961.
[37] Kinnunen J, Rossi PM, Herrmann I, Ronkanen AK, Heiderscheidt E. Factors affecting effluent quality in on-site wastewater treatment systems in the cold climates of Finland and Sweden. J Clean Prod 2023;404:136756. https://doi.org/10.1016/j.jclepro.2023.136756.