

Livestock Pressure and River Water Quality in Jombang Regency, Indonesia Based on Monitoring Records and Livestock Statistics

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Research Article

Keywords: livestock pressure, river water quality, Jombang Regency, organic pollution, faecal contamination assessment

Posted Date: September 18th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10457219/v1>

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Additional Declarations: No competing interests reported.

Abstract

Purpose

Livestock production is important for rural livelihoods and food supply, but poorly managed manure, wastewater, and contaminated runoff may increase pressure on river systems. This study assessed whether river water-quality patterns in Jombang Regency, East Java, are consistent with livestock-related pollution pressure without using maps, buffer analysis, or spatial modelling.

Methods

River water-quality monitoring records from 2023 to 2025 were combined with administrative livestock statistics for 2024 and 2025. The dataset included 4,761 East Java monitoring records, of which 90 were from Jombang. Descriptive statistics and screening-benchmark exceedance frequencies were calculated for major water-quality parameters, and livestock pressure was interpreted at regency and subdistrict levels.

Results

Organic, nutrient, particulate, and microbial signals were repeatedly observed. Biochemical oxygen demand exceeded the screening benchmark in 58.9% of valid Jombang measurements, total phosphate in 47.8%, total suspended solids in 25.6%, and faecal coliform in 16.7%. Total coliform was measured less frequently but showed the highest exceedance frequency. Livestock statistics indicated substantial pressure from ruminants and poultry, particularly broilers, goats, cattle, layer chickens, sheep, and ducks.

Conclusions

The findings do not prove single-source causality because Jombang rivers are also affected by domestic wastewater, agriculture, drainage, and other human activities. However, the convergence between livestock intensity and organic, nutrient, and faecal indicators supports targeted non-spatial pollution control, including manure storage, wastewater containment, wet-season event sampling, and strengthened support for livestock-dense subdistricts.

1 Introduction

Livestock production is an important component of rural development in East Java because it supports household income, food security, employment, and farming-community resilience. However, poorly managed manure, litter, animal-washing water, and other livestock residues can place considerable pressure on freshwater systems. These wastes may contain biodegradable organic matter, suspended solids, nitrogen, phosphorus, faecal bacteria, pathogens, antibiotic residues, and antibiotic-resistance

genes. They may enter rivers through direct discharge, drainage channels, surface runoff, seepage, or manure application to agricultural land (Alegbeleye and Sant Ana, 2020; Li et al., 2022; Vaishnav et al., 2023).

The environmental significance of livestock waste can be understood using a source–pathway–receptor framework. The source includes animal housing, manure production and storage, washing areas, wastewater-treatment units, and untreated outlets, which may release nutrients, pathogens, pharmaceuticals, resistance genes, hormones, and trace metals (Burkholder et al., 2007; Wu et al., 2024). Cattle, pigs, and poultry are major contributors to livestock-derived nitrogen, phosphorus, and pathogen loads in river systems worldwide (Li et al., 2022).

The pathway refers to the routes by which pollutants reach water bodies, including rainfall runoff, storage leakage, drainage canals, subsurface flow, irrigation networks, household wastewater channels, and direct discharge. Pollutant transport is influenced by rainfall, runoff volume, manure-application practices, storage conditions, slope, vegetation, soil properties, and distance from water bodies (Smith et al., 2007; Joy et al., 2013; Hall et al., 2020). Runoff from manure-applied land may transport substantial faecal contamination, although storage, manure incorporation, vegetation, and delayed rainfall can reduce pollutant export (Meals and Braun, 2006). Thus, hydrological connectivity and waste management may be more important than livestock presence alone.

The receptor is the river, stream, lake, reservoir, or groundwater system receiving the pollutant load. Intensive livestock production has been associated with elevated nutrients, microbial contamination, and other indicators of water-quality deterioration (Cesoniene et al., 2019; Jones et al., 2019). Nevertheless, livestock numbers indicate only potential pressure and do not demonstrate how much waste reaches the river. Risks increase when manure production exceeds land-assimilation capacity, wastewater is inadequately treated, or drainage and rainfall efficiently connect livestock areas to receiving waters (Burkholder et al., 2007; Li et al., 2022). Livestock pressure should therefore be interpreted together with manure management, wastewater discharge, drainage configuration, rainfall-runoff processes, farm-to-river distance, and upstream–downstream water-quality evidence (Luna Juncal et al., 2023).

Earlier versions of this work emphasised GIS processing, river-buffer analysis, spatial modelling, hotspot identification, and priority zoning. Such methods are useful for locating pollution sources and identifying intervention areas, but they are not essential when the objective is to evaluate existing monitoring records and administrative statistics. The analytical design should be determined by the research question, data availability, monitoring frequency, spatial resolution, and intended interpretation (Yang and Moyer, 2020; Elfferich et al., 2024).

The present study therefore applies a non-spatial, record-based assessment. River monitoring data are summarised using descriptive statistics, including the number of observations, minimum, maximum, mean or median, variability, and temporal patterns where available. Monitoring records can reveal water-quality conditions and anthropogenic pressures without spatial modelling, although sampling time and frequency may affect estimated trends, ranges, medians, and extreme values (Yang and Moyer, 2020; Liu

et al., 2023; Qi et al., 2022; Elfferich et al., 2024). Direct comparison of individual parameters with screening thresholds is also appropriate when the objective is to identify potential concerns rather than predict concentrations at unsampled locations (Cao et al., 2021).

The study also calculates exceedance frequency against selected screening benchmarks. This measure shows how often observations exceed an applicable threshold and may reveal recurring problems that are obscured by average values. Frequency- and probability-based approaches have been used to assess water-quality-standard breaches, although low-frequency monitoring may underestimate short-duration pollution events (Worrall et al., 2020; Qi et al., 2022; Elfferich et al., 2024). The benchmarks are used as interpretive reference values rather than as a definitive declaration of regulatory compliance, which may require prescribed locations, sampling schedules, analytical methods, averaging periods, and minimum sample numbers. Benchmark selection may also affect the interpretation of contamination and pollution sources (Roche et al., 2020).

Livestock pressure is assessed using official regency- and subdistrict-level statistics for cattle, dairy cattle, buffaloes, goats, sheep, pigs, and poultry. Such data provide an indicator of potential manure and wastewater generation and have been used in regional and catchment assessments of nutrient, organic, and microbial pressure (Li et al., 2022; Liu et al., 2023). Livestock effluent may contain high concentrations of organic matter, nutrients, and faecal microorganisms capable of affecting surface water and groundwater (Cao et al., 2021; Qi et al., 2023).

However, administrative livestock statistics are treated as pressure indicators rather than proof of causation. They do not identify farm locations, treatment efficiency, discharge timing, hydrological connectivity, or contributions from settlements, septic systems, crop farming, industry, and natural processes (Roche et al., 2020; Cao et al., 2021). The relationship between livestock activity and river pollution also depends on manure management, nutrient surpluses, soil accumulation, rainfall, runoff, and long-term catchment conditions (Kim et al., 2022; Liu et al., 2023). Consequently, regency and subdistrict comparisons are used to identify relative livestock pressure, not farm-level hotspots or direct causal relationships.

Jombang Regency provides a relevant case because it combines intensive livestock production with monitored river systems. This study uses repeated observations from the Brantas, Marmoyo, Rejoagung, Jarak, and Konto Suroboyo rivers during 2023–2025, together with official statistics on broilers, goats, beef cattle, layer chickens, sheep, dairy cattle, and ducks. The study aims to: (1) describe river water quality in Jombang Regency during 2023–2025; (2) summarise livestock pressure using administrative statistics; (3) interpret whether observed water-quality patterns are consistent with possible livestock-related pressure while acknowledging other sources; and (4) propose a non-spatial framework for monitoring, pollution control, and prevention.

2 Materials and methods

2.1 Study area and analytical scope

The study focused on Jombang Regency, East Java, Indonesia (see Fig. 1). The analysis was intentionally designed as a non-spatial assessment. It did not construct maps, calculate geographic buffers, perform spatial autocorrelation tests, or classify mapped priority zones. Rivers were treated as monitored environmental units, while livestock activity was treated as an administrative pressure indicator. This design allowed the analysis to remain closely linked to the available datasets while avoiding unsupported claims about the exact location and movement of pollutant sources.

2.2 Data sources

Three groups of data were used. First, river water-quality monitoring records for 2023, 2024, and 2025 were compiled. These records included sampling date, monitoring period, location code, river name, district or city, and measured parameters. The full East Java monitoring dataset contained 1,496 records in 2023, 1,608 records in 2024, and 1,657 records in 2025. From these records, 90 observations were identified for Jombang Regency, consisting of 35 records in 2023, 35 records in 2024, and 20 records in 2025. Second, livestock data were obtained from Jombang livestock statistics, including subdistrict-level populations for large livestock, small livestock, and poultry in 2024 and 2025. Third, provincial livestock statistics were used as supporting context for the role of livestock in East Java.

The main water-quality parameters analysed were pH, biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), dissolved oxygen (DO), nitrate, total phosphate, faecal coliform, total coliform, *Escherichia coli*, and ammonia where available. Because not all parameters were measured in every observation, the number of valid observations differed among parameters. This limitation was reported transparently rather than being corrected through imputation.

2.3 Data cleaning and preparation

The monitoring records were screened for missing values, non-numeric entries, and values stored as text. Numeric values containing quotation marks or text formatting were converted into comparable numeric values. Blank entries and entries marked with a dash were treated as missing. The Jombang subset was selected using the district or city field, and river names were retained as reported in the monitoring records. Livestock tables were checked against the official subdistrict-level statistics because these tables provided clearer totals and more stable categories than village-level working sheets.

2.4 Analytical strategy

The analysis was conducted in four steps. First, the number of monitoring observations was summarised by year and river system. Second, annual descriptive statistics, including means, medians, and maximum values, were calculated for the main parameters. Third, a screening-benchmark approach was used to estimate the frequency of water-quality concern. For each parameter, exceedance frequency was calculated as the number of values above the benchmark divided by the number of valid

observations. For dissolved oxygen, values below the benchmark were counted as concerning because lower DO indicates reduced oxygen availability. Fourth, livestock pressure was described using total populations and the leading subdistricts for selected animal groups.

The screening benchmark was used only as an interpretive tool and not as a final legal compliance determination. A formal regulatory assessment would require confirmation of water-class designation, sampling design, quality-assurance records, and official analytical methods for each parameter. The purpose of the present assessment was to identify dominant pressure signals and management priorities, not to issue a legal compliance verdict.

2.5 Limitations of the non-spatial design

The removal of mapping affects the strength of inference. Without farm coordinates, upstream catchment delineation, or river-network modelling, the study cannot determine whether a specific livestock facility caused a specific downstream water-quality result. The interpretation therefore uses conservative language. It identifies plausible pressure relationships and management priorities but does not claim direct causality. This limitation is important because Jombang rivers also receive pressure from settlements, markets, small industries, agriculture, drainage networks, and other non-livestock sources. Table 1 shows the monitoring records in Jombang regency

Table 1 Monitoring records and dominant monitored rivers in Jombang Regency		
Year	Jombang records	Dominant monitored river systems
2023	35	Brantas, Rejoagung, Marmoyo, Konto Suroboyo, Jarak
2024	35	Brantas, Marmoyo, Konto Suroboyo, Rejoagung, Jarak
2025	20	Jarak, Marmoyo, Rejoagung, Brantas
<i>Note. Compiled from the 2023–2025 water-quality monitoring records.</i>		

3 Results

3.1 Monitoring coverage and river systems

The compiled East Java dataset contained 4,761 monitoring records for 2023–2025. Jombang Regency accounted for 90 records. The annual distribution was not fully balanced, with 35 records in 2023, 35 records in 2024, and 20 records in 2025. The records represented several river systems, particularly the Brantas, Marmoyo, Rejoagung, Jarak, and Konto Suroboyo rivers. This coverage was sufficient for a descriptive assessment of dominant water-quality signals, although it remained too limited for a strong causal model linking individual pollution sources to downstream conditions.

3.2 Annual water-quality patterns

The annual summaries indicated recurring organic, particulate, nutrient, and microbial pressure in the monitored rivers is showed in Table 2. Median BOD was 3.08 mg/L in 2023, 3.80 mg/L in 2024, and 2.90 mg/L in 2025. The 2024 median suggests stronger organic pressure than the other two years, and the highest individual BOD value, 14.9 mg/L, also occurred in 2024. COD values were generally lower relative to the screening benchmark, although the maximum COD reached 37.0 mg/L in 2024. TSS showed strong episodic variation, with maximum values of 837 mg/L in 2023 and 450 mg/L in 2024. This pattern suggests that sediment or suspended-material pulses occurred during particular sampling events rather than being uniformly high in all river observations.

Nitrate was not a dominant exceedance parameter in the Jombang subset. Across all years, nitrate values remained below the screening benchmark, with a maximum value of 9.45 mg/L. Total phosphate was more concerning. Median phosphate values were 0.207 mg/L in 2023, 0.220 mg/L in 2024, and 0.150 mg/L in 2025. These values indicate that phosphate remained close to or above the screening threshold in many observations. This signal is environmentally relevant because phosphorus may originate from manure, domestic wastewater, detergents, agricultural runoff, and food-related waste.

Microbial indicators also showed important signs of pressure. Faecal coliform values varied widely. Median values were low in 2023 and 2024 but increased to 515 MPN/100 mL in 2025. The highest faecal coliform value was 7,900 MPN/100 mL in 2023. Total coliform was measured less frequently, but the available data showed a high exceedance frequency. Because microbial indicators are directly connected to faecal contamination, they should receive greater attention in future monitoring, especially in river segments used for irrigation, washing, fisheries, or other community activities.

Table 2
Selected water-quality summaries for Jombang Regency

Parameter	Valid observations	Median	Maximum	Exceedance frequency
BOD (mg/L)	90	3.355	14.9	58.9%
COD (mg/L)	90	14.65	37.0	7.8%
TSS (mg/L)	90	22.0	837.0	25.6%
DO (mg/L)	90	5.8	9.4	6.7% below benchmark
Nitrate as NO ₃ -N (mg/L)	90	0.57	9.45	0.0%
Total phosphate (mg/L)	90	0.20	2.12	47.8%
Faecal coliform (MPN/100 mL)	90	32.0	7,900	16.7%
Total coliform (MPN/100 mL)	11	8,400	42,900	72.7%
<i>Note. Exceedance frequency is a screening result calculated from available values and is not presented as a formal legal compliance decision.</i>				

Figure 2 summarise the frequency of water-quality benchmark exceedance for selected parameters in Jombang Regency. The results show that the most frequent concern was total coliform, with 72.7% of valid observations exceeding the screening benchmark. However, this result should be interpreted cautiously because total coliform was available for only 11 observations. Among parameters with complete observations, BOD showed the highest exceedance frequency, with 58.9% of the 90 valid measurements exceeding the benchmark. This indicates that biodegradable organic pollution was a dominant pressure in the monitored rivers. Total phosphate also showed a high exceedance frequency of 47.8%, suggesting that nutrient enrichment was an important concern. TSS exceeded the benchmark in 25.6% of observations, indicating episodic particulate or sediment-related inputs. Faecal coliform exceeded the benchmark in 16.7% of observations, supporting the presence of faecal contamination pathways. In contrast, COD and DO concerns were less frequent, while nitrate did not exceed the screening benchmark in any valid observation. Overall, the table and figure indicate that organic loading, phosphorus enrichment, suspended solids, and microbial contamination were the main water-quality issues in the monitored river systems of Jombang Regency.

3.3 Livestock population pressure in Jombang Regency

The administrative livestock statistics showed substantial livestock activity in Jombang Regency (Table 3). In 2024, the regency recorded 64,106 beef cattle, 8,346 dairy cattle, 99,035 goats, 60,665 sheep, 798,985-layer chickens, 16,115,633 broilers, and 822,115 ducks. In 2025, beef cattle declined to 47,041, dairy cattle declined to 7,634, goats increased to 102,478, sheep declined to 57,379, layer

chickens declined to 659,690, broilers remained high at 15,261,535, and ducks declined to 701,134. These figures show that poultry, especially broilers, dominated the livestock pressure profile by animal number, while goats and cattle remained important contributors to manure generation and local waste-handling demand.

Livestock pressure was unevenly distributed across subdistricts. In 2024, Plandaan had the highest beef cattle population, followed by Kabuh, Wonosalam, Bareng, and Ngusikan. Wonosalam dominated dairy cattle and goat populations. Bareng, Diwek, Mojowarno, Wonosalam, and Ngusikan were important broiler centres. For ducks, Plandaan and Kesamben were dominant. This uneven distribution is important for management because a uniform intervention across all subdistricts may be less efficient than a targeted programme for leading livestock centres.

Table 3
Livestock populations in Jombang Regency, 2024 and 2025

Animal group	2024 population	2025 population	Main 2024 concentration
Dairy cattle	8,346	7,634	Wonosalam, Mojoagung, Bareng
Beef cattle	64,106	47,041	Plandaan, Kabuh, Wonosalam, Bareng, Ngusikan
Goats	99,035	102,478	Wonosalam, Mojowarno, Bareng, Ngoro, Jogoroto
Sheep	60,665	57,379	Jogoroto, Mojowarno, Diwek, Ngoro, Bareng
Layer chickens	798,985	659,690	Ngoro, Diwek, Jogoroto, Jombang, Bareng
Broilers	16,115,633	15,261,535	Bareng, Diwek, Mojowarno, Wonosalam, Ngusikan
Ducks	822,115	701,134	Plandaan, Kesamben, Tembelang, Ngoro, Megaluh

Note. Processed from the Jombang livestock statistics by subdistrict.

3.4 Interpreting livestock pressure alongside water-quality indicators

The water-quality pattern is consistent with a mixed-source river system. BOD exceedance suggests biodegradable organic loading, phosphate exceedance suggests nutrient enrichment, and faecal or total coliform exceedance indicates faecal contamination. These signals can be associated with livestock waste, but they are not unique to livestock. Domestic wastewater, septic leakage, market waste, urban drainage, food processing, and agricultural runoff can produce similar indicators. The evidence should therefore be interpreted as a convergence of plausible pressures rather than proof that livestock is the only source.

Nevertheless, livestock remains a credible contributor because animal populations are large and the parameters showing concern are compatible with livestock-waste characteristics. Manure, litter, and livestock wastewater are typically rich in biodegradable organic matter, suspended solids, nutrients, and microorganisms. If manure storage is uncovered, if wastewater from animal washing flows into drains, or if manure is applied to land shortly before rainfall, pollutants can move rapidly into river systems. This risk is particularly relevant for broiler-intensive areas because high animal turnover can generate large volumes of litter and related residues over one production year.

The strongest conclusion from the combined evidence is not that livestock alone explains river degradation, but that livestock waste management must be included in the pollution-control strategy. Ignoring livestock would leave a major source category outside the intervention framework. Conversely, treating livestock as the sole cause would oversimplify the problem and could lead to unfair or ineffective policy. A balanced strategy should combine livestock controls with domestic wastewater management, drainage control, agricultural runoff reduction, and targeted microbial monitoring.

4 Discussion

4.1 Organic pollution and oxygen stress

The frequent exceedance of BOD was one of the strongest signals in the Jombang dataset. BOD remains an essential indicator of biodegradable organic pollution because it represents the oxygen required by microorganisms to decompose organic matter in water. Where organic loading is high, microbial decomposition can intensify oxygen consumption and reduce dissolved oxygen, particularly in slow-flowing reaches, during low-flow periods, or under limited dilution. Recent water-quality research also emphasises that parameter selection should be linked to the dominant pressure being assessed; therefore, the combined interpretation of BOD and DO is more informative than treating either parameter in isolation (Moeinzadeh et al. 2024). In this study, DO-related concerns were less frequent than BOD exceedance, but this does not eliminate ecological risk because DO can vary rapidly with discharge, temperature, sunlight, reaeration, algal activity, respiration, and sampling time. A river may therefore show acceptable DO at the moment of sampling while still receiving substantial biodegradable inputs. This interpretation is consistent with recent river-monitoring studies that highlight the need for repeated observations and multi-parameter assessment when evaluating freshwater pollution under mixed anthropogenic pressure (Rajkumar et al. 2026; Thomas and Egbinola 2026).

From a livestock-management perspective, elevated BOD indicates the need to control organic inputs before they enter drainage networks and river channels. Livestock manure, wash water, feed residues, and poultry litter can contribute biodegradable organic matter, suspended solids, nutrients, and microorganisms when storage, runoff control, or wastewater containment is inadequate (Li et al. 2022; Vaishnav et al. 2023). Practical control measures should therefore include preventing the direct discharge of livestock wastewater, separating clean stormwater from contaminated operational water, covering or drying manure before reuse, composting litter, and installing simple settling or anaerobic

treatment units in areas with high animal density. These interventions do not require detailed spatial modelling as an initial prerequisite. However, they do require administrative targeting, field inspection, farmer assistance, wet-season checks, and before-and-after monitoring to verify whether organic pollution has been reduced.

4.2 Nutrient enrichment and the phosphate signal

Total phosphate exceeded the screening benchmark in nearly half of the valid observations, making phosphorus one of the most important nutrient signals in the Jombang monitoring records. Phosphorus is environmentally significant because it can stimulate algal growth, accelerate eutrophication, alter aquatic community structure, and intensify oxygen stress when it occurs together with biodegradable organic matter and warm water temperatures. Recent research evidence also shows that phosphate can differ significantly across seasons and should therefore be interpreted together with hydrological timing, land use, and other physicochemical parameters rather than as an isolated value (Atuhaire et al. 2026). In the present study, the phosphate signal should be interpreted cautiously because potential sources include livestock manure, domestic wastewater, detergents, fertilisers, food-related waste, and drainage from settlement or agricultural areas (Thomas and Egbinola 2026; Wang et al. 2023). Nevertheless, livestock remains a credible contributor because manure and poultry litter are recognised sources of phosphorus, particularly when they are stored outdoors, washed into drainage channels, or applied to land shortly before rainfall (Li et al. 2022; Vaishnav et al. 2023).

The contrast between nitrate and total phosphate is also important. Nitrate did not exceed the screening benchmark in the monitored Jombang records, whereas phosphate exceeded the benchmark frequently. This pattern suggests that nutrient pressure in the monitored rivers was not dominated by nitrate and that phosphorus-specific controls should not be overlooked. Such a result is plausible because nitrogen and phosphorus differ in their dominant sources, transformations, retention mechanisms, and transport pathways in catchment systems (Wang et al. 2023). Management responses should therefore move beyond a nitrogen-centred approach and include measures that reduce phosphorus release at source. Priority actions include improved manure storage, feed-efficiency improvement, dry litter management, prevention of runoff from manure piles, separation of clean stormwater from contaminated yard water, and careful timing of manure application in relation to rainfall. These measures are consistent with recent livestock-waste management literature, which emphasises containment, treatment, recovery, and reuse as practical pathways for reducing nutrient losses from animal production systems (Li et al. 2022; Vaishnav et al. 2023).

4.3 Microbial contamination as a public-health concern

Microbial contamination requires particular attention because it links river-water quality directly with public health, food safety, and community exposure. Faecal coliform and total coliform are useful screening indicators, although they are not source-specific and cannot distinguish human, livestock, poultry, wildlife, or mixed faecal inputs on their own. In rural and peri-urban river systems, these contamination pathways may include livestock manure, domestic sanitation leakage, animal markets,

slaughtering activities, stormwater runoff, and mixed drainage channels. Recent research evidence emphasises that water-quality deterioration should be interpreted as a public-health issue and monitored systematically because water bodies affected by human activity may become unsuitable for domestic, agricultural, or livelihood-related uses (Atuhaire et al. 2026). In the present study, the high total-coliform exceedance frequency was calculated from a small number of observations; therefore, it should not be overgeneralised. Nevertheless, the magnitude of the observed values is sufficient to justify more consistent microbial monitoring, especially at river locations receiving drainage from livestock-dense settlements and areas with mixed domestic and agricultural waste inputs (Li et al. 2022; Vaishnav et al. 2023).

Future monitoring should include *Escherichia coli* more consistently because it is a more specific indicator of recent faecal contamination than total coliform and is more directly relevant to health-risk interpretation. Where laboratory capacity permits, microbial source tracking should also be considered to distinguish human, cattle, poultry, and other animal contributions, particularly where management decisions require evidence on dominant faecal sources. This recommendation is important because livestock waste can carry not only faecal bacteria but also antibiotic residues, antibiotic-resistant bacteria, and antibiotic-resistance genes that may move through manure, runoff, drainage networks, and contaminated water bodies (Wang et al. 2024; Zalewska et al. 2021). Until such advanced methods are available, practical management should focus on reducing all faecal pathways into rivers. Priority measures include improved household sanitation, separation of animal wastewater from drains, covered manure storage, composting or drying of manure before reuse, safe disposal of slaughtering residues, wet-season inspection of runoff pathways, and community education for farmers and households. These actions are consistent with recent livestock-waste management literature, which emphasises containment, treatment, recovery, and safe reuse as key strategies for reducing microbial and nutrient pollution from animal production systems (Li et al. 2022; Vaishnav et al. 2023).

4.4 Why a non-spatial approach is still useful

The absence of maps does not reduce the practical relevance of the study. A non-spatial approach can still identify priority parameters, priority animal groups, priority subdistricts, and feasible management actions when the available evidence consists mainly of monitoring records and administrative statistics. This approach is particularly useful when decision-makers require rapid evidence base but do not yet have reliable farm coordinates, geocoded pollution-source inventories, or catchment-scale transport models. Recent water-quality literature shows that parameter choice, data completeness, and uncertainty strongly influence the interpretation of monitoring results; therefore, a transparent parameter-based assessment can be more defensible than a spatial product built from weak or incomplete source-location data (Moeinzadeh et al. 2024). In addition, studies of seasonal and land-use effects on river water quality demonstrate that spatial interpretation becomes stronger when monitoring design, temporal coverage, land-use information, and hydrological context are sufficiently integrated (Wang et al. 2023). For the present Jombang dataset, a cautious non-spatial interpretation is therefore

appropriate because it avoids implying a level of locational precision that the underlying livestock and water-quality records cannot fully support.

Nevertheless, non-spatial analysis has clear boundaries. It cannot determine upstream-downstream causality, estimate the distance between livestock facilities and river channels, identify drainage connectivity, or quantify pollutant movement through rainfall-runoff pathways. For this reason, the article does not present mapped priority zones or claim that specific farms caused specific downstream results. Instead, it proposes an administrative priority framework based on four practical criteria: subdistrict livestock intensity, repeated water-quality concern, dominant pollutant signal, and feasibility of intervention. This framework is consistent with multi-pollutant livestock-water research, which recommends interpreting livestock pressure together with other source categories rather than attributing river degradation to a single source without sufficient causal evidence (Li et al. 2022). The criteria can be applied immediately by local agencies for inspection planning, farmer assistance, and monitoring prioritisation, while more advanced spatial analysis can be developed later if reliable geocoded facilities, drainage pathways, and upstream-downstream monitoring data become available.

4.5 Policy and management implications

The findings support a tiered management strategy as summarized in Table 4. First, routine monitoring should continue at existing river locations, but microbial parameters should be measured more consistently. Second, livestock-dense subdistricts should receive preventive support, including training on manure storage, composting, wastewater separation, and dry-litter handling. Third, inspections should focus on visible discharge points, animal-washing areas, manure piles, and drainage outlets under both dry and wet conditions. Fourth, water-quality evaluation should distinguish dry-season baseline conditions from wet-season event conditions because rainfall can mobilise manure, sediment, and microbes rapidly. Fifth, interventions should be evaluated using before-and-after monitoring rather than infrastructure completion alone.

Table 4
Non-spatial intervention framework for Jombang Regency

Evidence signal	Likely management concern	Recommended response
BOD exceedance	Biodegradable organic loading from mixed wastewater sources	Control direct discharges, improve manure storage, introduce simple wastewater treatment, and monitor before and after intervention
Phosphate exceedance	Nutrient enrichment from manure, domestic wastewater, detergent, or fertiliser	Prevent manure runoff, improve litter management, regulate washing areas, and reduce nutrient release to drains
High TSS events	Sediment or particulate pulses during specific events	Inspect drainage channels, stabilise exposed soil near animal facilities, and monitor after rainfall
Faecal and total coliform signals	Faecal contamination from livestock, domestic sanitation, or mixed drainage	Increase E. coli monitoring, improve sanitation and animal-waste containment, and prioritise faecal pathway control
High broiler concentration	Large litter and waste turnover over one production year	Strengthen litter collection, composting, storage standards, and farmer assistance in broiler-intensive subdistricts
High ruminant concentration	Manure accumulation near housing, yards, or fields	Promote covered manure storage, composting, biogas where feasible, and runoff separation
<i>Note. The framework is designed for administrative decision-making and does not require maps or spatial zoning</i>		

5 Conclusions

This study shows that the relationship between livestock activity and river water quality in Jombang Regency can be assessed without maps, spatial modelling, or priority zoning maps. The three-year monitoring dataset showed recurring concerns for BOD, total phosphate, TSS, and microbial indicators. Across 90 Jombang observations from 2023 to 2025, BOD exceeded the screening benchmark in 58.9% of valid values, total phosphate in 47.8%, TSS in 25.6%, and faecal coliform in 16.7%. Total coliform was available for only 11 observations but showed a high exceedance frequency. These results indicate that organic loading, nutrient enrichment, particulate pulses, and faecal contamination are the main concerns in the monitored rivers.

The livestock statistics confirm that Jombang has substantial animal-production pressure. Broiler populations exceeded 16.1 million in 2024 and remained above 15.2 million in 2025. The regency also recorded large populations of beef cattle, goats, sheep, layer chickens, dairy cattle, and ducks. The scale of these populations makes livestock-waste management an essential component of river-pollution control. At the same time, the results should not be interpreted as evidence that livestock is the sole

source of degradation. Jombang rivers are affected by mixed pressures, including domestic wastewater, drainage, agriculture, and other human activities.

The practical implication is that pollution control should be targeted but does not need to begin with maps. Local agencies can prioritise livestock-dense subdistricts, parameters with repeated exceedance, and visible faecal or organic-waste pathways. Recommended actions include improved manure storage, wastewater containment, separation of clean and contaminated runoff, consistent microbial monitoring, wet-season event sampling, and before-and-after evaluation of interventions. This non-spatial framework provides a realistic basis for immediate action while leaving room for more advanced spatial analysis when reliable geocoded facility data become available.

Declarations

Author Contribution

W.I.K.contributed to data compilation, analysis, and manuscript drafting. A.S.contributed to livestock-data interpretation and manuscript review. M.P.K. contributed to conceptual development, supervision, and manuscript review.

Acknowledgement

We are grateful to the Environmental Agency of East Java Province Indonesia and the Indonesian East Java Livestock Service Agency for facilitating this research

Data Availability

The data analysed in this study are available from the corresponding author upon reasonable request, subject to permission from the relevant data-owning institutions.

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Figures

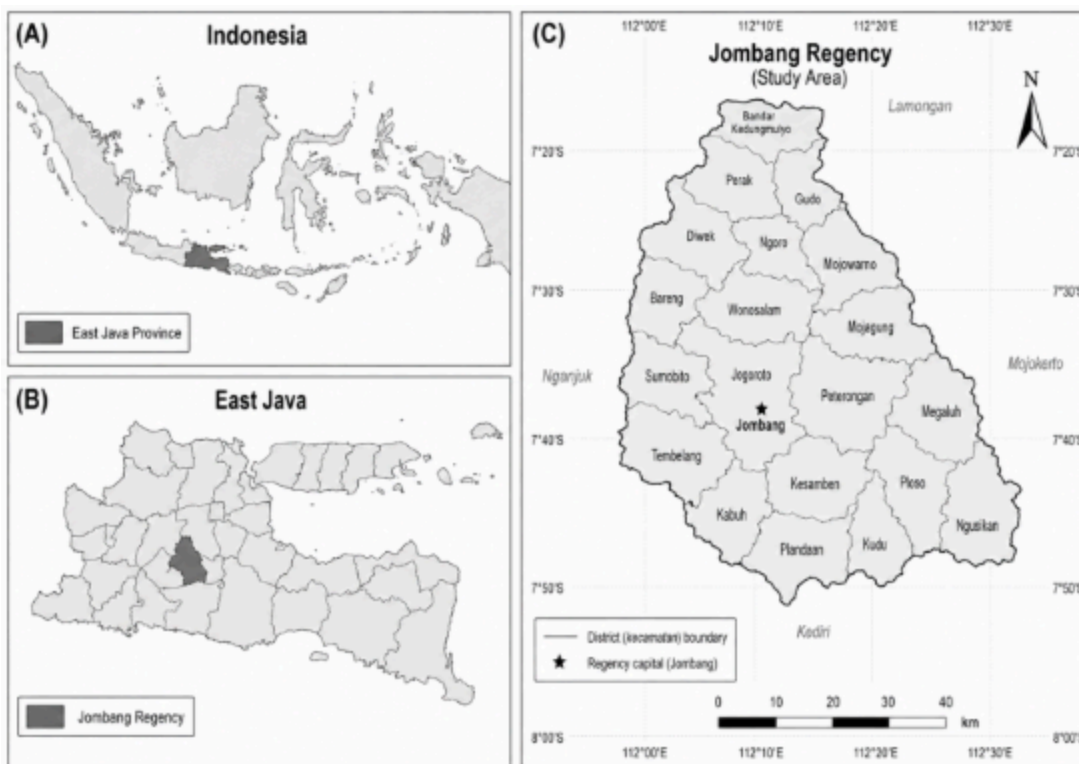
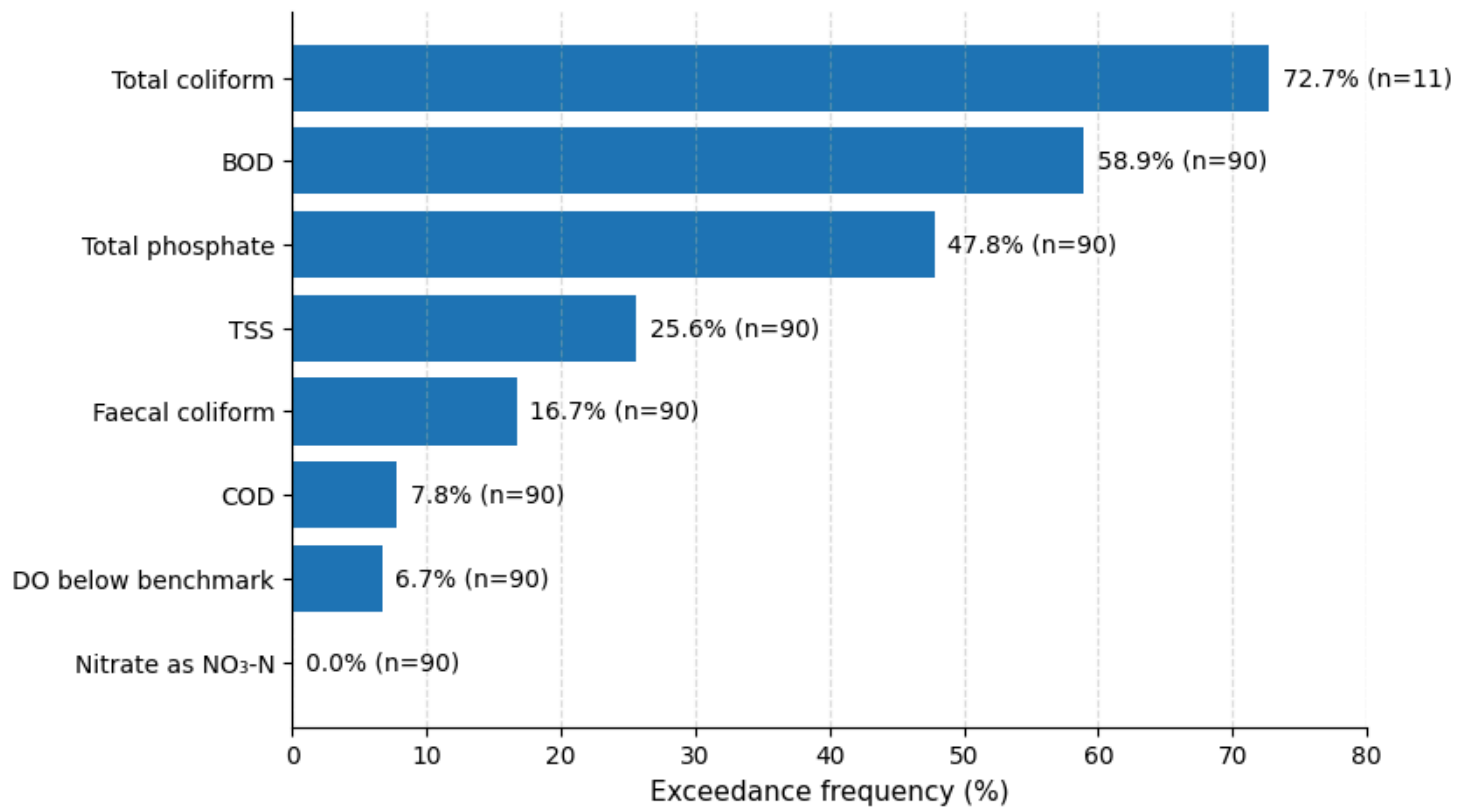


Figure 1

Location of Jombang Regency, East Java, Indonesia. (A) Location of East Java Province within Indonesia; (B) location of Jombang Regency within East Java Province; and (C) administrative districts of Jombang Regency, including the regency capital, neighboring regencies, geographic coordinates, north direction, and scale.



Note: DO represents observations below the screening benchmark. Total coliform frequency is based on only 11 valid observations.

Figure 2

Frequency of water-quality benchmark exceedance for selected river water-quality parameters in Jombang Regency. DO represents observations below the screening benchmark. Total coliform should be interpreted cautiously because it was based on only 11 valid observations, whereas the other parameters were based on 90 valid observations.