LAUNDRY TRANSFORMATION INNITIATIVE

Indonesia Study Case

2026

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Executive Summary

This study investigates manual laundry practices in rural Indonesia using the DPSIR (Driver-Pressure-State-Impact-Responses) framework to assess how these activities interact at the system level. Data were gathered via household surveys, focus group discussions (FGDs), and key informant interviews, complemented by secondary sources and a literature review. Both quantitative and qualitative methods were employed to analyse the data, providing a description of the existing practices and environmental conditions.

The findings show the main drivers of manual laundry practices in the river and irrigation channel in Wrati Village, Pasuruan Regency, Indonesia, as economic constraints, inadequate clean water infrastructure, and convenience. Most residents do laundry daily using simple tools such as brushes, stones, and buckets. These activities put environmental pressure due to water and detergent use, with the most common detergents being single-sachet powders and liquids.

These activities generate 2.69 m^3/day of wastewater, which is discharged to water bodies through local drainage and/or directly into the river. The estimated pollutant load potential from laundry released to the environment without any treatment for the parameters surfactant, COD, BOD, and TSS is 444 kg/year, 9,072.4 kg/year, 12,475 kg/year, and 8,618.8 kg/year, respectively. Furthermore, the study area has no wastewater treatment, which exacerbates the impacts. Disposal of untreated laundry wastewater can alter water quality in recipient bodies. Pollutants such as surfactants, organic matter, and nutrients can change water characteristics. These alterations not only degrade water quality but also affect aquatic biota, sediment, and plants. Additionally, poor water quality can endanger people's health.

The proposed responses focus on prevention and mitigation mainly through technological solutions. Roof rainwater harvesting is suggested to address irregular water supply, while environmentally friendly soaps are recommended to reduce surfactant and phosphate risks associated with laundry. Simple wastewater treatment methods, like constructed wetlands and slow sand filters, are also advised before discharging wastewater into the environment. Behavioural interventions act as complementary strategies that strengthen prevention and mitigation responses, including education on hygiene practices, training, and restructuring the built environment. To ensure effective implementation, expert interviews identified key enabling factors, including stakeholder participation, context-specific adaptation, and engagement tools. They also highlighted significant barriers, such as socio-cultural influences, economic conditions, and willingness to change.

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1. Introduction

1.1 Background

One domestic activity that humans perform every day yet often overlook is laundry. In this study, laundry is defined as washing clothes. Laundry can be done using a washing machine or by hand. This practical choice depends on various factors such as personal preference, social status, and resource use (Retamal & Schandl, 2018). The study will specifically examine the manual laundry process. Laundry process involves multiple steps: soaking clothes in detergent, scrubbing to remove stains, rinsing, and drying. Additionally, fragrances are sometimes used at the final stage of the wash cycle (Ariel, n.d). Four factors determine cleaning performance in laundry, referred to as the Sinner circle: time, temperature, mechanical action, and chemistry (Bockmuhl, 2017). These aspects are closely related to the material consumption choices made by households.

The main resources used for doing laundry are water, detergent, and energy (Retamal & Schandl, 2018). The provision of clean and safe water is critical for humans as a basic need. The water needs to be physically accessible, acceptable, sufficient, affordable, and continuous. The minimum standard for water consumption for laundry is 40 L per person per day (WHO Regional Office for South-East Asia, n.d.). Research in Indonesia, particularly in peri-urban communities, estimates laundry water consumption at around 5–20 L/person/day, with a median of 10 L/person/day (Utami et al., 2023). Access to safe water coverage in rural areas in Indonesia was 14.4% in 2020. Low access to safe water can lead to various impacts, including water-related diseases such as diarrhoea, typhoid, dysentery and skin infections (Sutomo et al., 2021).

The use of detergent aims to remove dirt and pathogens from dirty clothes. Detergents consist of active agents, builders, fillers, additives, and perfumes. The key active components are surfactants like Sodium Lauryl Sulfate (SLS) and Linear Alkyl Sulfonate (LAS), which enhance cleaning efficiency, generate foam, and help eliminate grease (Nurdianti et al., 2024). There are two national standards for powder and liquid soap that regulate detergent composition, with a minimum surfactant concentration of 14% by mass and a minimum degradation rate of 60%. Additionally, the use of phosphate is still allowed for powder soap (BSN, 2017a; BSN, 2017b). The selection of detergent type and brand is based on consumers' knowledge levels, in-store displays, advertising, and preferences (Kamwendo & Maharaj, 2022). Research by Anitya (2018) indicated that in Indonesia, each household uses approximately 50 grams of detergent per day.

The process of washing clothes generates domestic wastewater. This wastewater is generally referred to as grey wastewater. It contains chemical constituents such as surfactants from detergents, leachates, oils, paints, and non-biodegradable fibres from clothes (Kulkarni & Jaspal, 2023). Viruses and bacteria have also been detected in soiled laundry and babies' nappies. Additionally, laundry wastewater can sometimes contain high concentrations of solids (such as TDS and TSS), oxygen demand (BOD and COD), and turbidity (Abney et al., 2021; Watiniasih et al., 2019).

Laundry wastewater characteristics are influenced not only by detergent brand and amount but also by textile type, fibre content, water availability, geographical location, and sociocultural behaviour (Khapra & Singh, 2024). Disposing of laundry wastewater to the environment without treatment can degrade the quality of water bodies, soil, and plants, and affect human health. The potential adverse effects on water quality include algal blooms, elevated toxicity levels, and further increases in microplastic concentrations from fabrics (Haribowo et al., 2024; Titah & Nasir, 2024).

Based on the explanation above, there is a need to explore laundry practices in depth, especially in rural areas in Indonesia. Most recent studies have focused on treating laundry wastewater from small- to medium-sized businesses in urban and semi-urban areas, as well as on alternative detergents (Haribowo et al., 2024; Titah & Nasir, 2024; Watiniasih et al., 2019; Sulfa et al., 2024; Sari & Setiawan, 2019). There remains a lack of understanding of laundry practices at the system level. The DPSIR (Driver-Pressure-State-Impact-Response) framework will serve as the foundation. It has been widely adopted for analysing issues related to human-environment interactions. Its strength lies in illustrating the relationships crucial for sustainable improvement and emphasising its function as a continuous feedback loop. This approach shifts focus from immediate environmental symptoms to the underlying socio-economic systems that cause them (Federigi et al., 2022; Singh et al., 2025).

1.2 Research objective

This research aims to analyse manual laundry practices in Indonesia by identifying water sources, quantifying water use, and documenting detergent use and wastewater generation to assess their environmental implications and potential opportunities for behavioural and technical interventions.

1.3 Research questions

Main research questions:

How do manual laundry practices affect water sources and the environment in the Indonesian case study?

Sub-research questions:

1. RQ1: What factors drive the community to practice manual laundry?
2. RQ2: How does manual laundry contribute to river pollution?
3. RQ3: What is the current state of river water quality in the Welang River?
4. RQ4: How does pressure from laundry activity affect environmental conditions and related health outcomes?
5. RQ5: What responses can be used to improve manual laundry practices?

2. Theoretical framework

Driver Pressure State Impact Responses (DPSIR) Framework

The DPSIR framework provides a systematic analysis of cause-and-effect relationships in environmental issues. There are five components (Federigi et al., 2022; Singh et al., 2025):

1) Driver: This aspect represents the social and economic aspects of human activities
2) Pressure: Human activities create pressure on the biological, physical, or chemical aspects of the environment.
3) State: The pressure influences the state of the system

4) Impact: Changes in environmental state lead to impacts, which are a multidimensional concept that includes human health, ecosystems, economic, and social aspects.
5) Responses: Actions that policymakers and society can take to address the problem across all aspects, including drivers, pressures, states, and impacts. Types of responses include prevention, mitigation, restoration, and adaptation (Kristiadi et al., 2022).

Below is the flowchart of the DPSIR Framework in the context of manual laundry.

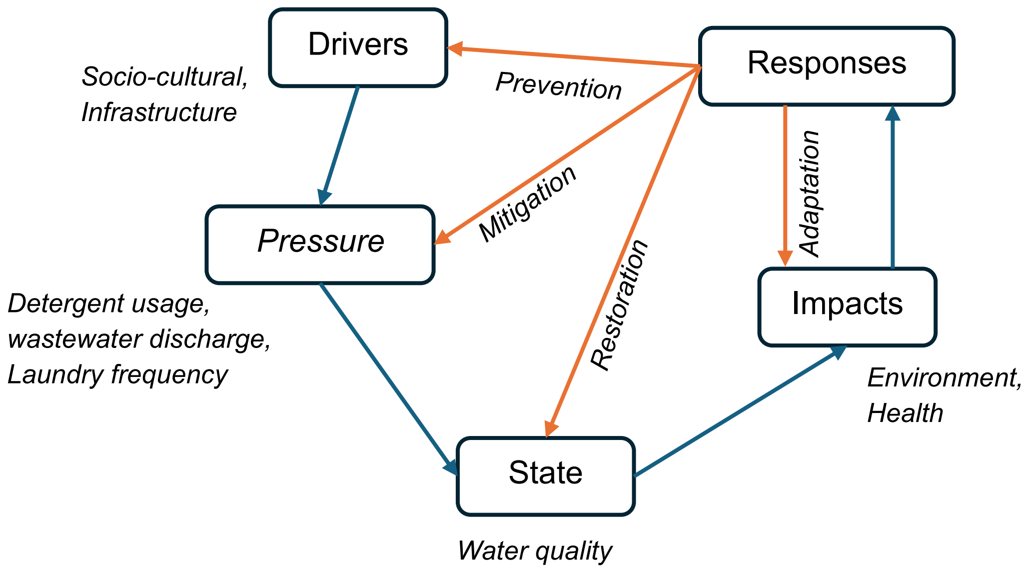


Figure 1 DPSIR Framework

To support the DPSIR analysis of this topic, environmental indicators have been selected from the literature on river pollution and adapted to the needs of this study, as explained below. In this study, the response type explored is prevention and mitigation, especially behavioural changes and technical aspects, to address the pressure. However, to ensure the response fits the context, the study must first address the local community's understanding, awareness, and willingness. Additionally, the barriers to the proposed responses will also be explored. The indicators used in this study are listed below.

DPSIR Elements	**Component**	***Indicator***
Identification of the driver of manual river laundry	Resident population	*Total inhabitant*
	Monthly income	*Indonesian Rupiah/month*
	Cultural Aspect	*Rituals*
	Access to water source	*Distance to water source (km) and type of water source*
	Access to electricity	*Types of electricity sources*
Identification of the pressures determined by manual river laundry	Locations of washing	*Riverbank vs house*

	Volume of water needed	*Litres/activity*
	Wastewater disposal pathways	*Open drainage vs direct disposal*
	Types and quantities of detergents used	*Gram/activity*
	Frequency and duration of laundry process	*Day/week Hours/activity*
	Pollutant load	*Gram/day*
	Volume of wastewater generated	*Litres/activity*
Evaluation of the state of river condition	Water quality	*Concentrations of surfactants, phosphates, BOD, COD, pH, TDS, TSS*
Evaluation of the river contamination impacts	Aquatic environment	*Eutrophication risk, aquatic organism abundance*
	Health impact	*Health symptoms*
Analysis of responses	Behavioural changes	*Awareness and willingness of residents*
	Technology intervention	*Low technology options*

3. Methodology

3.1 Study Area

Kejayan sub-district, Pasuruan Regency, is located in East Java Province, Indonesia. The sub-district encompasses 25 villages, with a total population of 70,299 people in 2025. Data collection will be conducted in Wrati Village. For the household survey, the area focused on 6 neighbourhoods: RT 3, RT 4, RT 6, RT 7, RT 9, and RT 10, with a total of about ± 239 households.

According to the land cover map, the study area is predominantly characterised by cropland used for paddy and corn cultivation, with a minor built-up area. The cropland within Wrati Village is part of the Selowengko Irrigation Area (D.I. Selowengko). Additionally, this area is part of the Welang River Watershed and is crossed by three tributaries of the main Welang River that flow through the village: Welang Lama River, Wrati River, and Curahweragan River.

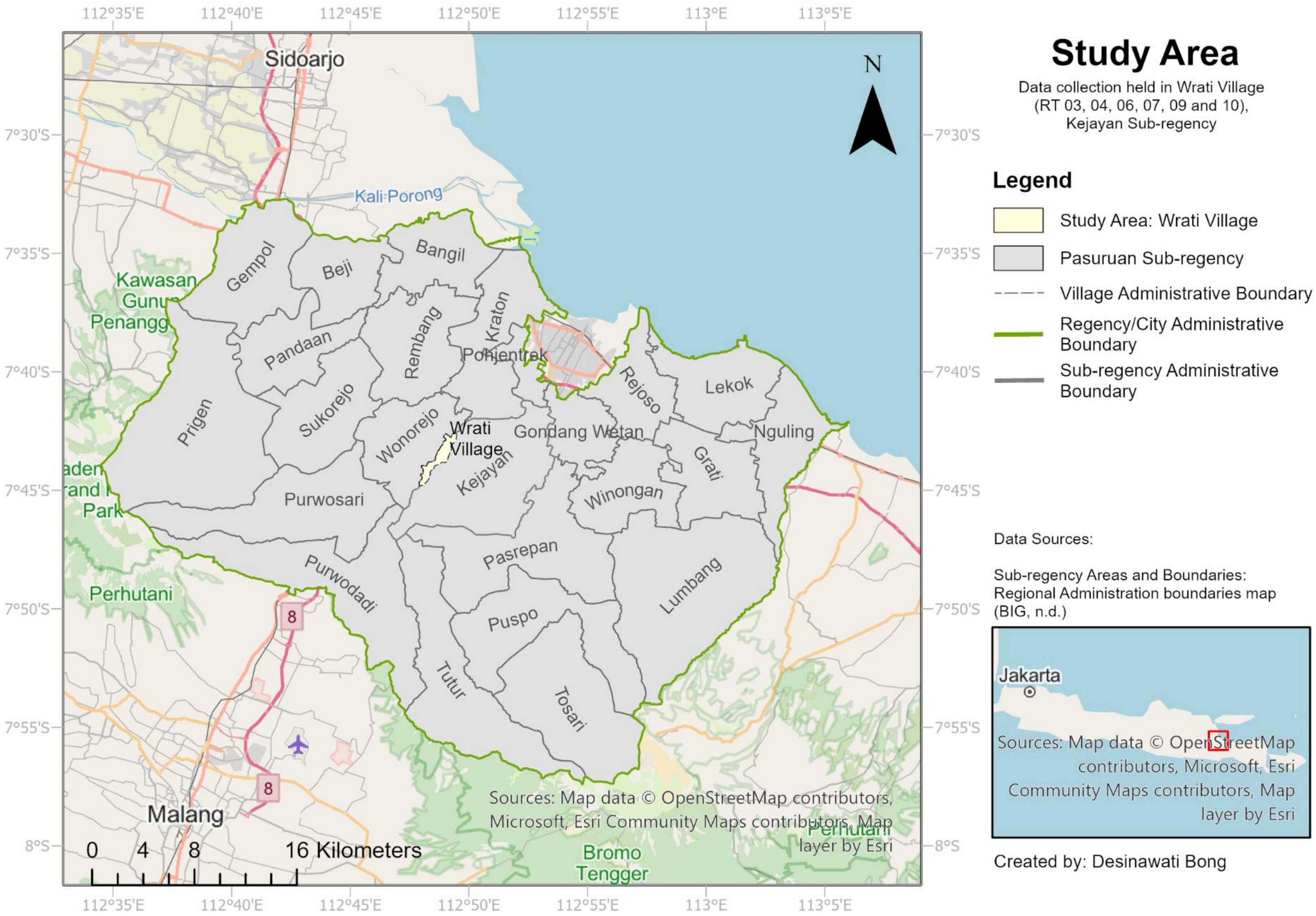


Figure 2 Study Area

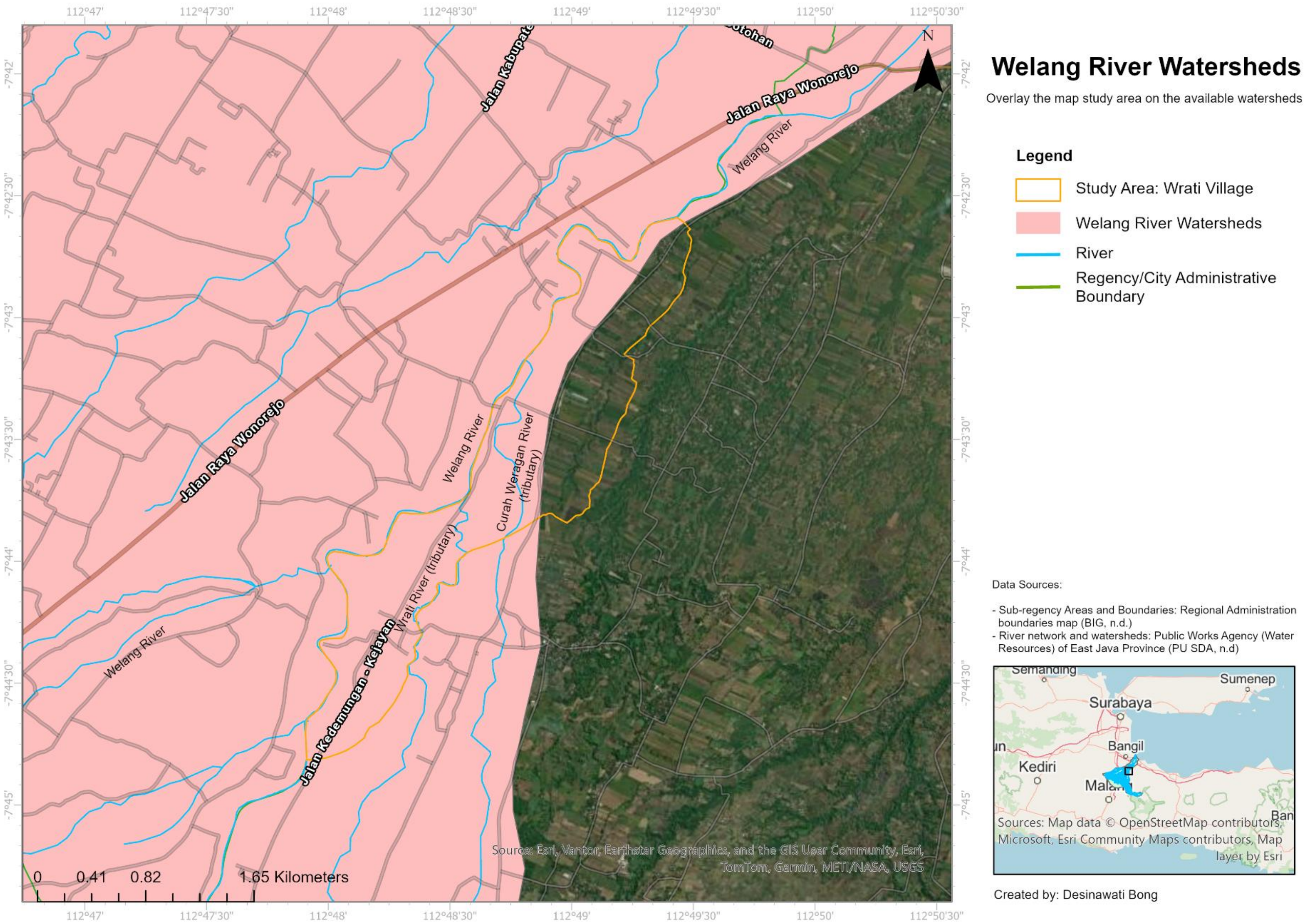


Figure 3 Welang River Watersheds

3.2 Data collection

Data collection consisted of five instruments:

1. **Household survey**
   Data collection through a household survey aimed to obtain information on environmental conditions in laundry practices (including water source quality through physical condition), detailed information on the laundry process, laundry as an entrepreneurial activity, and general information about households in the study area. The number of respondents was 31. The sampling process used direct outreach through door-to-door engagement, and participants were invited to take part in the study. During the process, the local partner and Village officers were involved to improve engagement and understanding, since most residents communicated in the local language. The survey was conducted on 17-19 June 2026, and each survey lasted 20-30 minutes, depending on the conversation. Before the survey, participants were asked to provide consent to participate and to have their photograph taken.
2. **Focus group discussion**
   The aim of the FGD was to gather qualitative data. The topic explored the laundry process and participants' perceptions, including their laundry behaviours such as current practices, priorities in daily chores, seasonal changes, and their ideas about the future of laundry. The FGD was conducted on 15 June 2026 in the Village Head's house, and there were 34 participants from across the neighbourhood, all of whom were women. The discussion was led by the local partner and two representatives of Gopa Metameta, including the writer. The process was conducted in a mix of local and Indonesian languages since the participants were more comfortable speaking in their local language. Before the FGD, participants were asked to provide consent to participate and to have their photograph taken. Details of FGD results are provided in Appendix A.
3. **Interview with Key Informants**
   The target respondents for the KII were experts in environmental, water quality, and seasonality. The aim was to identify the broader ground reality to complement the proposed response strategies. The interview format was semi-structured with 4 topics: seasonality and water quality; water availability and access; climate change and future trends; and implications for laundry solutions. The interviews were conducted with 3 key informants who work as university lecturers. Before the interview, participants were asked to provide consent, and the interview was recorded. Details of interview results are provided in Appendix A.
4. **Literature review**
   This research conducted a literature review on the impact of domestic laundry and on responses to improve this activity. Google Scholar and the Wageningen University and Research library search engine were used, with targeted keywords such as 'laundry wastewater characteristics', 'wastewater treatment', 'environmental impact', 'alternative laundry detergent', and '*river water quality'* to identify relevant peer-reviewed studies and grey literature. In addition, laundry wastewater and Welang River water quality data were obtained from secondary sources in the literature, as no direct water quality measurements were available.

5. **Field observation**
   The aim of the observation was to develop a comprehensive understanding of field conditions and use it to inform the interpretation of results from primary data collection. Type of data obtained (including photographs):
   - Washing locations
   - Discharge points
   - Water source locations
   - Conditions of settlements along river embankments

3.3 Data Analysis

1. **Household survey**
   Analysis of the household survey results was carried out using descriptive statistics with visualisation in tables and graphs. Each aspect of the survey was analysed differently depending on its purpose. Aspects of environmental conditions (e.g., water source type, seasonality, and water source quality) were analysed as percentages. Reasons for using multiple water sources were presented in the frequency distribution. For the laundry process, the analysis used percentages of time spent on laundry and on laundry steps, and the water bill for laundry was analysed using group frequency and distribution trend analyses. For detergent usage, a crosstabulation analysis was conducted, and for brand selection, mean and comparative descriptive analyses were used. To estimate the total water used for one laundry cycle, the median was used, as only one-third of respondents answered the question.
2. **Focus group discussion and key informant interview**
   The results from FGD and KII were analysed using thematic analysis. This process comprised six stages: data familiarisation, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and synthesising results. Each aspect of the questions was already grouped to answer a specific question. For response aspects, 6 themes were identified: stakeholder involvement, context-specific, economic factors, engagement tools, sociocultural, and infrastructure management.
3. **Literature review**
   The literature was analysed using narrative synthesis. The topic was explored: the impact of detergent composition on water quality, aquatic ecosystems, soil, plants, and water-related health risks. The intervention/strategy focused on addressing drivers (e.g., infrastructure, social and cultural) and on mitigation measures for material consumption and wastewater treatment. The results were visualised in a table. In addition, secondary water quality data were interpreted and contextualised to the study area.
4. **Observation**
   Data from observations were analysed using descriptive methods to strengthen on the ground information.

In addition, estimation of laundry wastewater generation and pollutant load potential (PLP) from laundry activities used the approach adapted to the laundry context by Pangestu et al (2017). The calculation was based on several key variables, including population size, emission factors, urban equivalent ratio, and pollution load transfer coefficient. For surfactant load, a mass balance approach was used. To estimate how much detergent is released into the water body, the pollution load was calculated based on household-level daily detergent use. The formulas were:

$$Laundry\ wastewater\ generation = Total\ HH\ x\ P\ x\ WC\ x\ \%\ LW$$

Equation 1

$$PLP = P\ x\ EF_{LW}\ x \propto x\ U_{ER}\ x\ \%\ of\ laundry\ component$$

Equation 2

$$Surfactant\ load = \ \%_{avg}\ surfactant\ x\ Total\ HH$$

Equation 3

Where:
P = population (persons)
EF_{LW} = Emission factor for laundry wastewater
$\propto$ = load transfer coefficient
U_{ER}= urban equivalent ratio
$Total\ HH$ = total households in study area
% LW = percentage of laundry wastewater (50-80% of total wastewater)
WC = water consumption (L/person/day)
$\%_{avg}$ = average percentage of surfactant in detergent

Detailed calculations are provided in Appendix B.

4. Results

4.1 Driver of Manual Laundry

5.1.1 Infrastructure

Most residents in Wrati Village had two sources of clean water: primarily private household connections and the river (Figure 4). Generally, water from private household connections was used for cooking, house cleaning, bathing, and drinking (it must be boiled first). The river water was used for laundry and bathing. Water from private household connections came from a communal water treatment plant (which uses groundwater) managed by village officers.

The river that runs through the study area is a tributary of the Welang River (main river), namely the Wrati River. It is important to recognize the distinction between residents' perceptions and the actual facts. Upon verification with official government data, it is confirmed that the water source passing through neighbourhoods 3, 4, 7, 9, and 10 is not a river but an irrigation channel. This irrigation channel is situated within the irrigation area known as D.I. Selowengko.

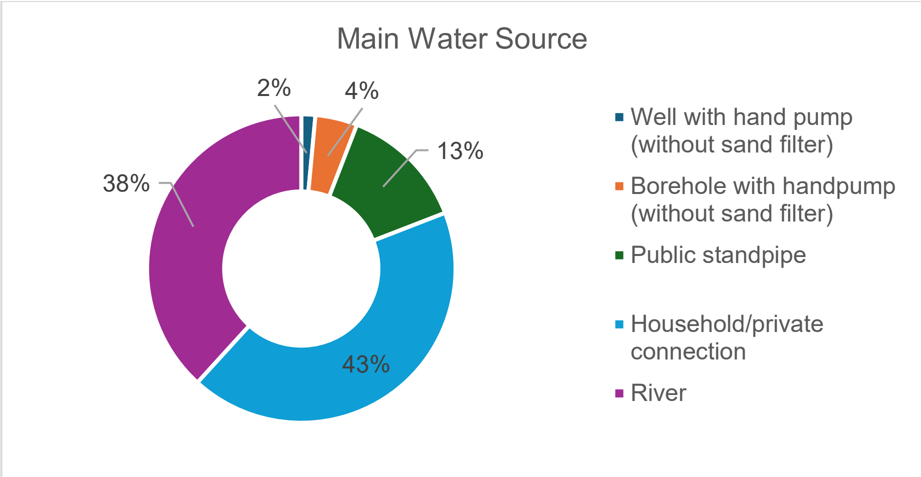


Figure 4 Main Water Source in Study Area

Regarding laundry, most respondents reported using river water and they did laundry at the water source. However, during the rainy season or planting season, they did laundry at home. This was because they perceived the water as more turbid and the water level as rising, which prevented them from doing laundry there. There were 6 laundry locations in the area, and each neighbourhood had its own spot.

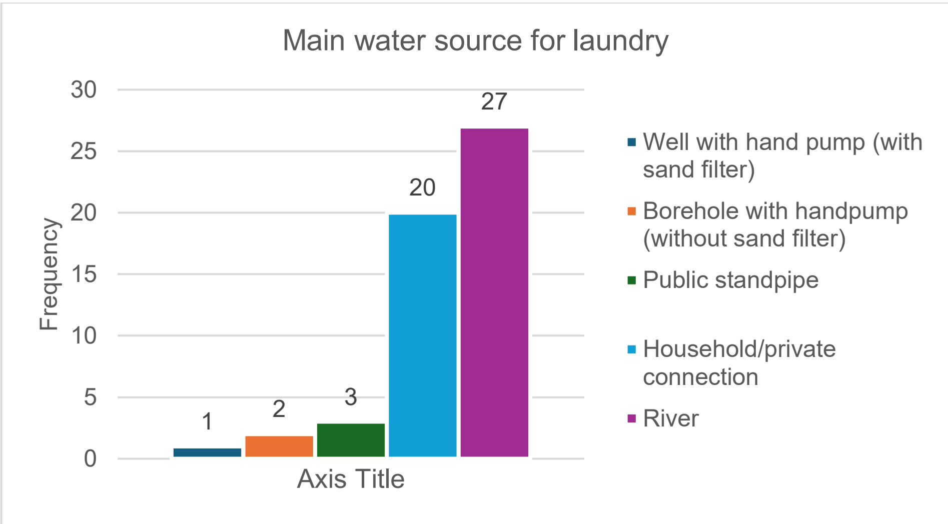


Figure 5 Main Water Source for Laundry in Study Area

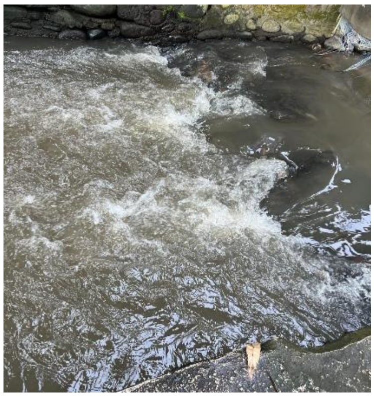

Neighbourhood 6 (Spot 1)


Neighbourhood 6 (Spot 2)


Neighbourhood 7 (Spot 1)

Neighbourhood 7 (Spot 1)

Neighbourhood 7 (Spot 1)



Neighbourhoods 3 and 4

Figure 6 Laundry Locations in Study Area

Most respondents spent under 30 minutes travelling to the water source for laundry, with some taking about 5 minutes on foot since the laundry spots were in their backyard or in front of their house. However, if they used water from their household connection, travel was unnecessary.

Figure 7 Access Road to water source (River)

Water Source Quality in the study area (Physical Condition)

As for water source quality in physical condition, most respondents perceived the water at household connections as clear, as shown in Figure 8. For river water quality, they also perceived it as clear, except during the rainy and planting seasons, when it was turbid. However, during observation, the river water colour was brown, and trash was found. In addition, residents in neighbourhood 6 mentioned that during the planting season, the water sometimes smelled like fertiliser. This aligned with the observation results, which showed that the area surrounding the water source consists of paddy and corn fields.

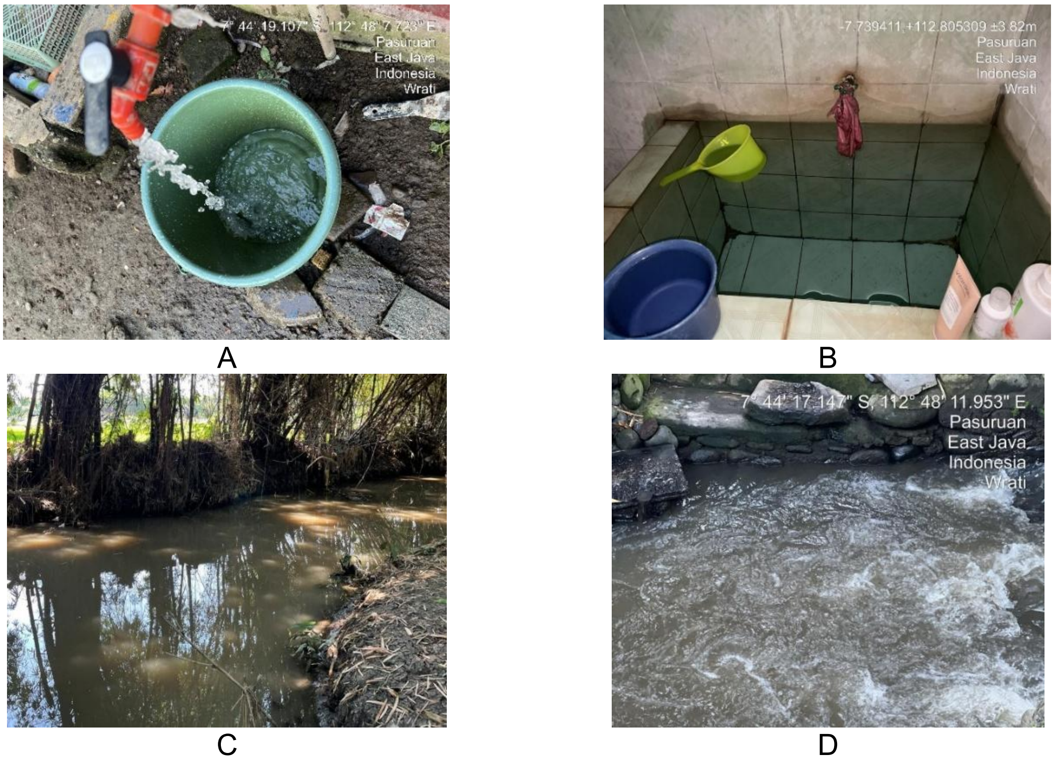


Figure 8 A & B: Water quality from the household connection (physical condition); C & D: Water quality in the river and irrigation channel (physical condition)

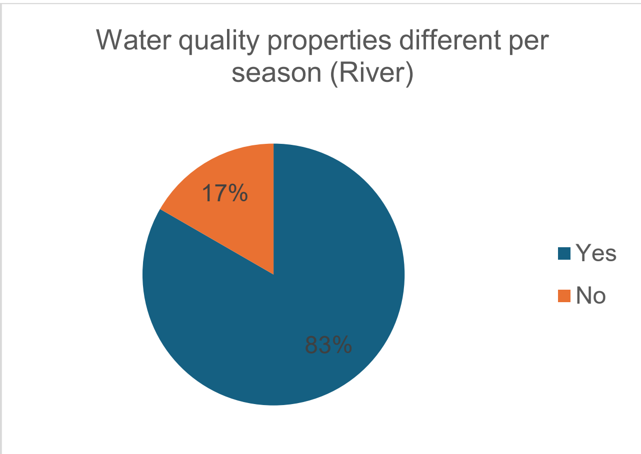


Figure 9 Respondents' Perception of the Seasonality Effect on River Water Quality

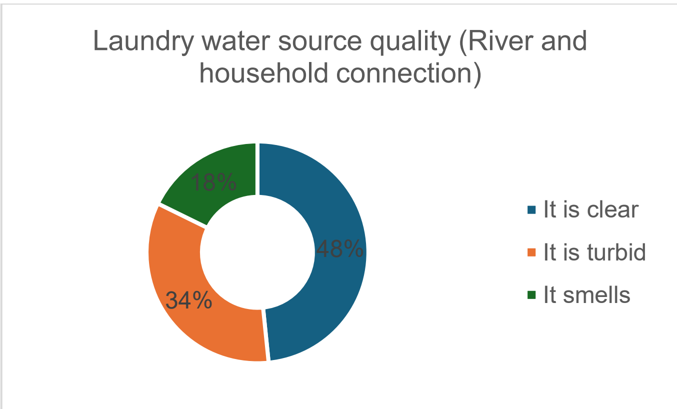


Figure 10 Respondents' Perception of Laundry Water Source Quality

5.1.2 Social Culture

Looking at the social and cultural aspects of why they had multiple water sources for laundry, especially doing laundry in the river/irrigation channel, it showed that cost-saving was the major factor behind their decision, as in Figure 11. Cost savings were linked to monthly income; the survey showed that most respondents earn <2,000,000 IDR (equivalent to 100 EUR), as in Figure 12. In Pasuruan Regency, the minimum wage in 2026 was 5,187,681 IDR.

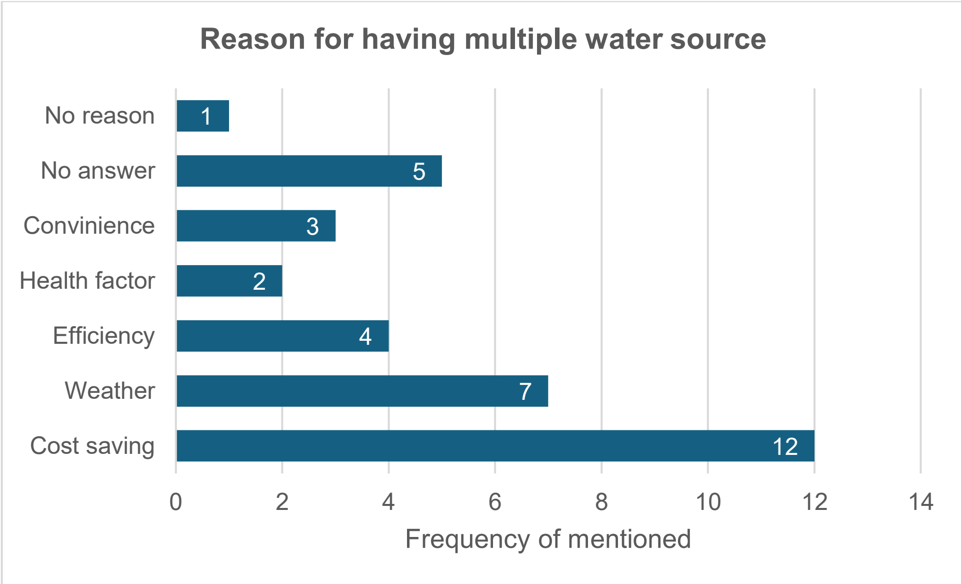


Figure 11 Reason for Having Multiple Water Sources for Laundry

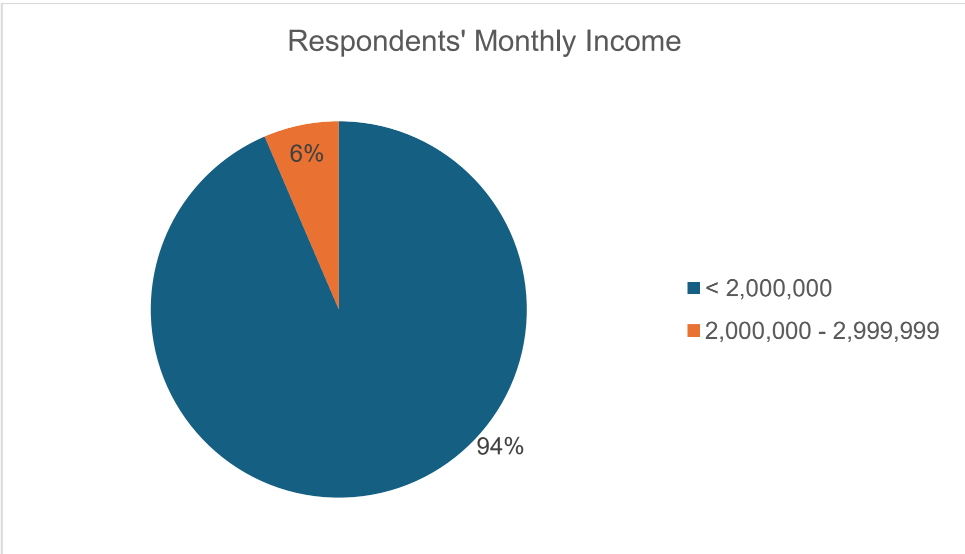


Figure 12 Respondents' Monthly Income in the Study Area

The total amount of money spent on domestic water bills per household is shown in Figure 13. It shows that the average monthly payment is about 33,000 IDR, with a range of 10,000 to 80,000 IDR. As for laundry specifically, we obtained only 4 samples, indicating that water bills ranged from 5,000 IDR to 35,000 IDR per household/month. The water price in the study area was 2,000 IDR per cubic metre.

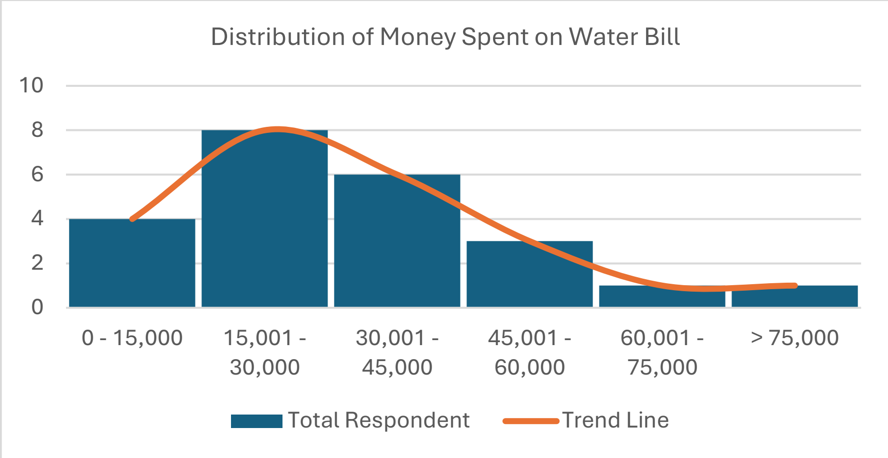


Figure 13 Distribution of Money Spent on Water Bill

Another reason related to their social background was convenience. They responded that they usually do laundry after finishing work on the cropland. In addition, FGD results indicated that some participants liked doing laundry in the river because it allowed them to interact with each other. However, this reason didn't emerge in the individual survey. Moreover, an intriguing exchange occurred as participants deliberated on the rules and rituals associated with the laundry process. They stated that, in terms of religious practices, doing laundry at the river aligns with their beliefs but isn't associated with any particular ritual they observe.

4.2 Pressure from Laundry Activity

4.2.1 Laundry frequency and material (water, detergent, and tools) usage

Laundry frequency and steps

Most respondents reported doing laundry every day, and one-third did it twice a day (morning and afternoon). The reason for this choice was to avoid laundry from becoming an overwhelming chore later. Only two households did laundry every two to three days. All respondents did laundry in under 4 hours/week, ranging from 30 minutes to 1 hour per laundry session.

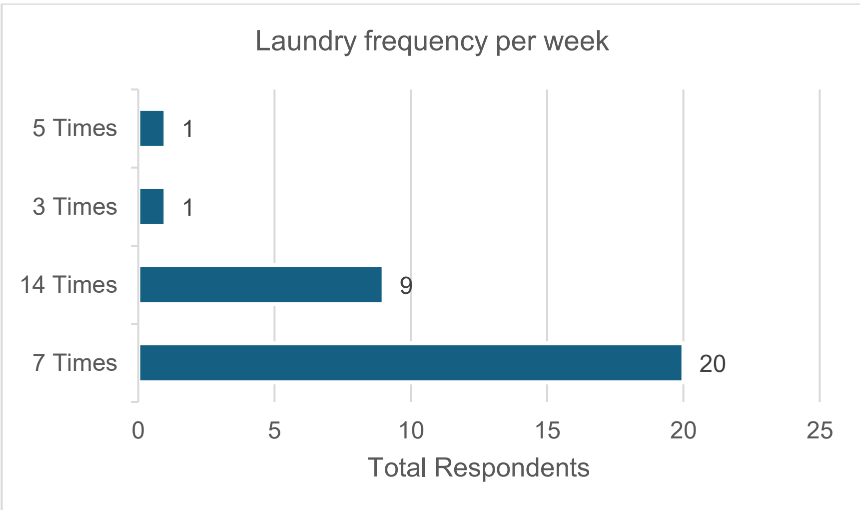


Figure 14 Laundry Frequency

To look in detail at the laundry process at the household level, as follows:

1. Sorting: This process is about separating clothes that have different colours/fabrics. In the study area, only a few households sorted, and the types of clothes were usually white clothes, school uniforms, dirty clothes (after working in the crop fields), and prayer dresses.
2. Soaking: Almost half of the respondents soaked their clothes, and the time they used varies from 5 minutes to 2 hours.
3. Cleaning: This process involves the removal of stains from clothing through the utilisation of tools such as brushes and detergents. All respondents reported that they did not use a scrub board and relied solely on the bathroom floor; if they did, they used the river, and if they did, they used the stone built there.
4. Rinsing: This process aims to wash away leftover soap suds and can be done multiple times, depending on the respondent's preference. Before drying, some respondents mentioned using fabric softener (as a special treatment) on specific types of clothing, such as school uniforms and a prayer dress, to add extra fragrance.
5. Drying: Most of the respondents reported that they dried the clothes under the sun using clotheslines that were made from bamboo or wire. Only 2 respondents mentioned ironing the clothes after they were dry. The drying area was usually placed in front of their house/next to the side of the house.

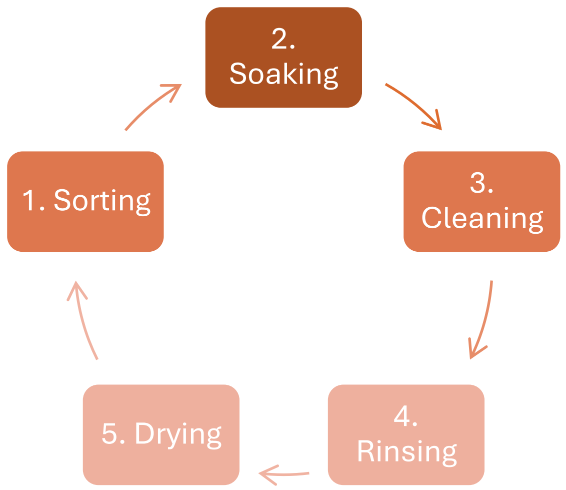


Figure 15 Laundry Process

Water consumption

Based on the survey results, only 12 respondents provided an overview of their water usage per laundry cycle if they did laundry at home. Those who did laundry at the river couldn't provide details because the river's water was constantly flowing. The number of buckets used per household per laundry cycle ranged from 1 to 10, with a median of 3. The volume of each bucket ranged from 15 to 30 litres, with a median of 17 litres. Total water consumption per cycle was approximately 47 litres per household, or 14 litres per person per laundry cycle.

Table 1 Estimation of Total Water Consumption per Laundry Time

	Total Buckets	Bucket volume (Litre)	Total water consumption (Litre)	Total persons in one household	Total water consumption per person (L)
Average	4	19	69	3	26
Median	3	17	47	4	14

Source: Own calculation, 2026

The overview of their water usage for laundry conducted at home is as follows:

1. 1 bucket of 16 L for the cleaning step with detergent
2. 1 bucket of 16 L for the first rinse
3. 1 bucket of 16 L for the second rinse.

Therefore, each household uses 48 litres of water per laundry cycle.

**Note: This is an example of 1 household*

Detergent consumption

Regarding detergent utilisation, all respondents utilised various brands, predominantly powder and liquid detergents. The field comprised 16 detergent brands. All detergents had a total surfactant content ranging from 4% to 20%. Certain brands incorporated antibacterial agents, perfumes, capsule perfumes, and softening agents. Detergent types and their composition in the study area can be seen in Figure 17.

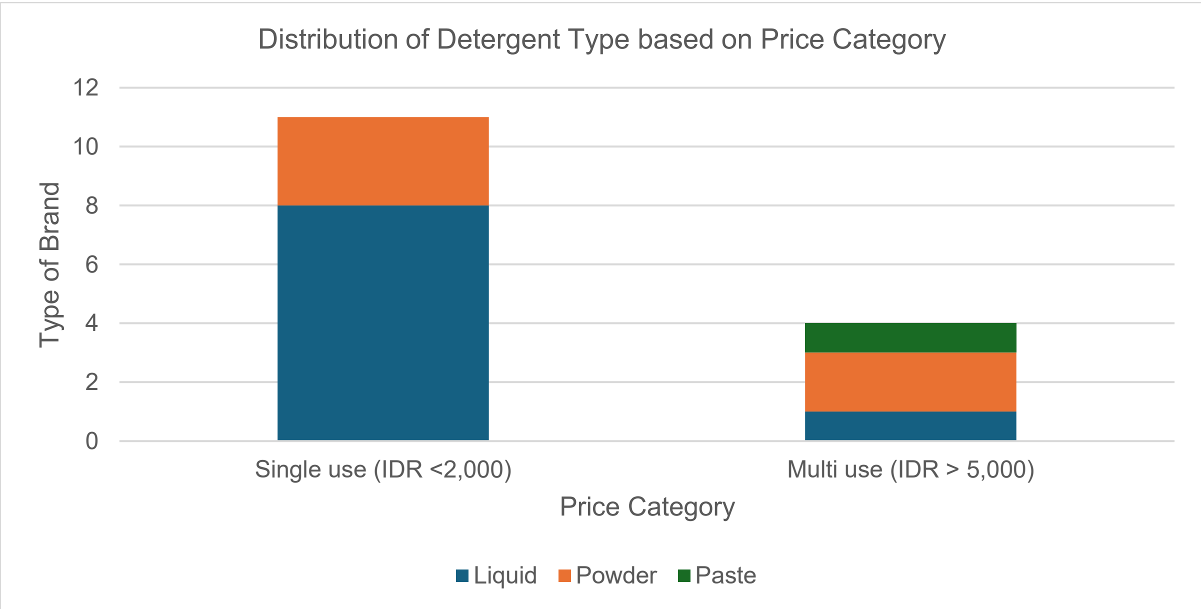


Figure 16 Distribution of Detergent Type based on Price Category

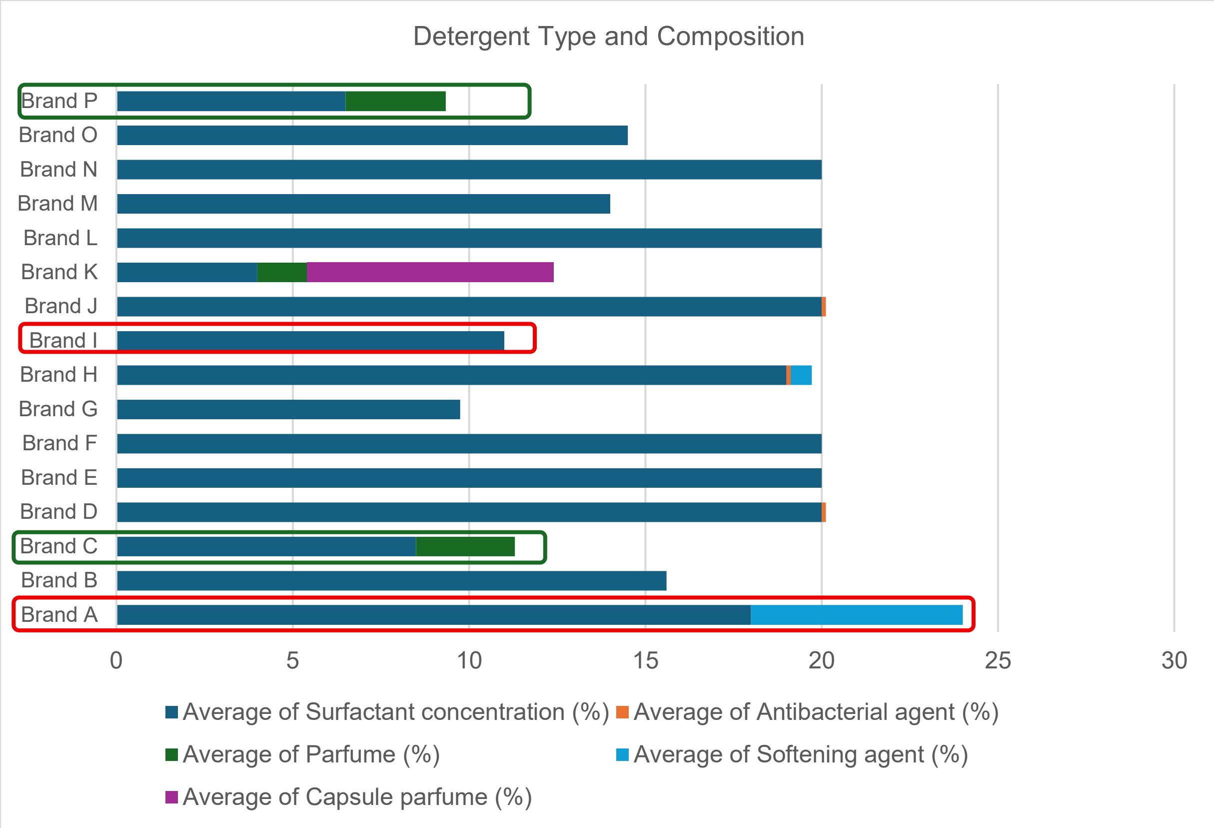


Figure 17 Detergent Type and Average Composition (red box indicates anionic surfactant and green box indicates cationic surfactant)

4.2.2 Wastewater generation (pollutant load and characteristics)

The volume of wastewater from river laundry activity could not be determined because the water was discharged directly back into the river. For home laundry, based on Equation 1, total wastewater volume in the study area (with an estimated total of 239 households) was 8.03 m^3/day (or 8.4 L/person/day).

Pollution load potential

Based on available detergent data, the average surfactant mass in a single-use detergent was 5.1 grams. It was assumed that all households did laundry every day.

Total surfactant load per day	= total households x surfactant mass in detergent
	= 239 household x 5.1 grams
	= ± 1,216 gram/day = ± 444 kg/year

It is estimated that ± 444 kg/year (equivalent to 1.27 gram/day/person) of surfactant was released into the environment via water bodies or soil due to inadequate drainage infrastructure in the study area.

For other pollutants such as BOD, COD, and TSS, the results are presented in Table 2.

Table 2 Potential Pollutant Load from Laundry Activity in Study Area

Pollutant type	Laundry PPL (kg/year)	Total PPL (kg/day)	Total PPL (gr/person/day)
BOD	5234.1	14.34	15
COD	7196.9	19.72	20.63
TSS	4972.4	13.62	14.25

Source: own calculations (Author, 2026)

Since no primary data were available on the characteristics of laundry wastewater in the study area, this value was derived from secondary data on similar domestic laundry activities in Jakarta, Indonesia. In general, laundry wastewater exhibited high concentrations of BOD, COD, and TSS. For other parameters listed in the water quality standard, such as oil and grease, pH, ammonia, and MBAS, the values complied with the standard. Note that Indonesia has no specific national standard for domestic laundry wastewater; the standard used below is based on general domestic wastewater (a combination of black and grey wastewater). Table 3 shows the general characteristics.

Table 3 Laundry wastewater characteristics

Parameter	Unit	Water Quality Standard*	Value
Physical parameter			
Temperature	°C	-	27.8 ± 2.7 (28.5)
Conductivity	µs/cm	-	1,382 ± 991 (1,256)
TSS	mg/L	50	**102.7 ± 101.3 (62)**
TDS	mg/L	-	228.3 ± 167.3 (144.2)
Oil and grease	mg/L	10	9.6 ± 8.5 (5)
Chemical Parameter			
pH	mg/L	6-9	6.3 ± 1.3 (6.7)
Ammonia (NH_3)	mg/L	20	6.3 ± 6.8 (4.25)
Total nitrogen	mg/L	-	195.7 ± 60.9 (217)
Total phosphorus	mg/L	-	2.3 ± 1.9 (1.38)
Phosphate	mg/L	-	8.4 ± 4.4 (8.09)
COD	mg/L	100	**419.3 ± 81.1 (440)**
BOD	mg/L	50	**155**
DO	mg/L	-	4.6 ± 3.7 (6.64)
MBAS	mg/L	10	0.1 ± 0.1 (0.02)
Metals			
Iron (Fe)	mg/L	-	0.7 ± 0.4 (0.31)
Sodium (Na)	mg/L	-	5.9 ± 6.7 (2.37)
Potassium (K)	mg/L	-	14 ± 8.9 (9.08)
Chopper (Cu)	mg/L	-	0.03 ± 0.03 (0.01)
Zinc (Zn)	mg/L	-	0.2 ± 0.2 (0.14)
Magnesium (Mg)	mg/L	-	5.8 ± 3.3 (5.24)
Aluminium (Al)	mg/L	-	0.5 ± 0.2 (0.48)
Lead (Pb)	mg/L	-	0.02
Nickel (Ni)	mg/L	-	0.01
Non-metals			
Chloride (Cl)	mg/L	-	190.5 ± 209.3 (115)
Silica (Si)	mg/L	-	5.5 ± 2.9 (3.94)

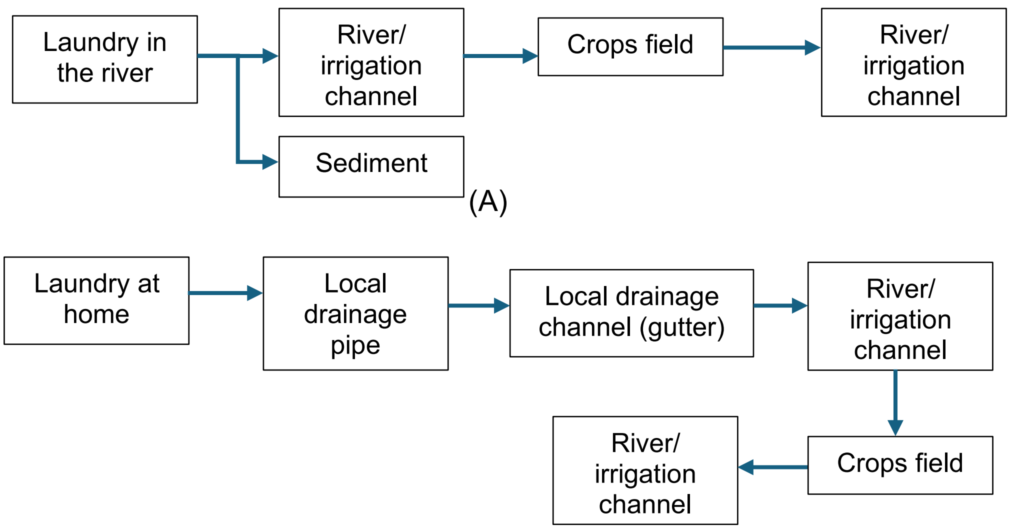
Source: Hafiza et al., 2019 (bold indicates the concentration exceeded the standard)

**WQS based on Regulation of the Minister of Environment/Environmental Control Agency Number 11 of 2025: Wastewater Quality Standards and Wastewater Treatment Technology Standards for Domestic Wastewater*

Wastewater disposal pathway

There were two pathways of pollutant release to the environment: 1) direct release into the water bodies (river or irrigation channel) and 2) indirect release from households into the local drainage pipe, then flowing into the gutter, and finally reaching the river or irrigation channel. Field conditions of the drainage system in the area are shown in Figure 19. The drainage infrastructure in the study area consisted of a wastewater pipe and an open gutter. According to an interview with the village officer, wastewater from their house was discharged via a pipe and then flowed into the gutter/drainage area at the location. Water from this gutter system flowed into the closest water bodies (a tributary river or irrigation channel).

During the dry season, the drainage channel was usually dry, and it filled with rainwater only during the rainy season. In a housing area near an irrigation channel, we found that an individual pipe from a house discharged directly into the channel. Additionally, no wastewater treatment was available. Blackwater from their toilet was treated in an individual septic tank, and the fate of the overflow water from the treatment remains unclear; the officer was also unsure.



(B)

Figure 18 Two types of wastewater disposal pathways in the study area

A B

C

Figure 19 Drainage Infrastructure in Study Area (A: Wastewater pipe from the house; B: Gutter in front of the house; and C: Wastewater pipe discharges directly to the channel)

Details of manual laundry location practice in the study area are shown in Figure 20.

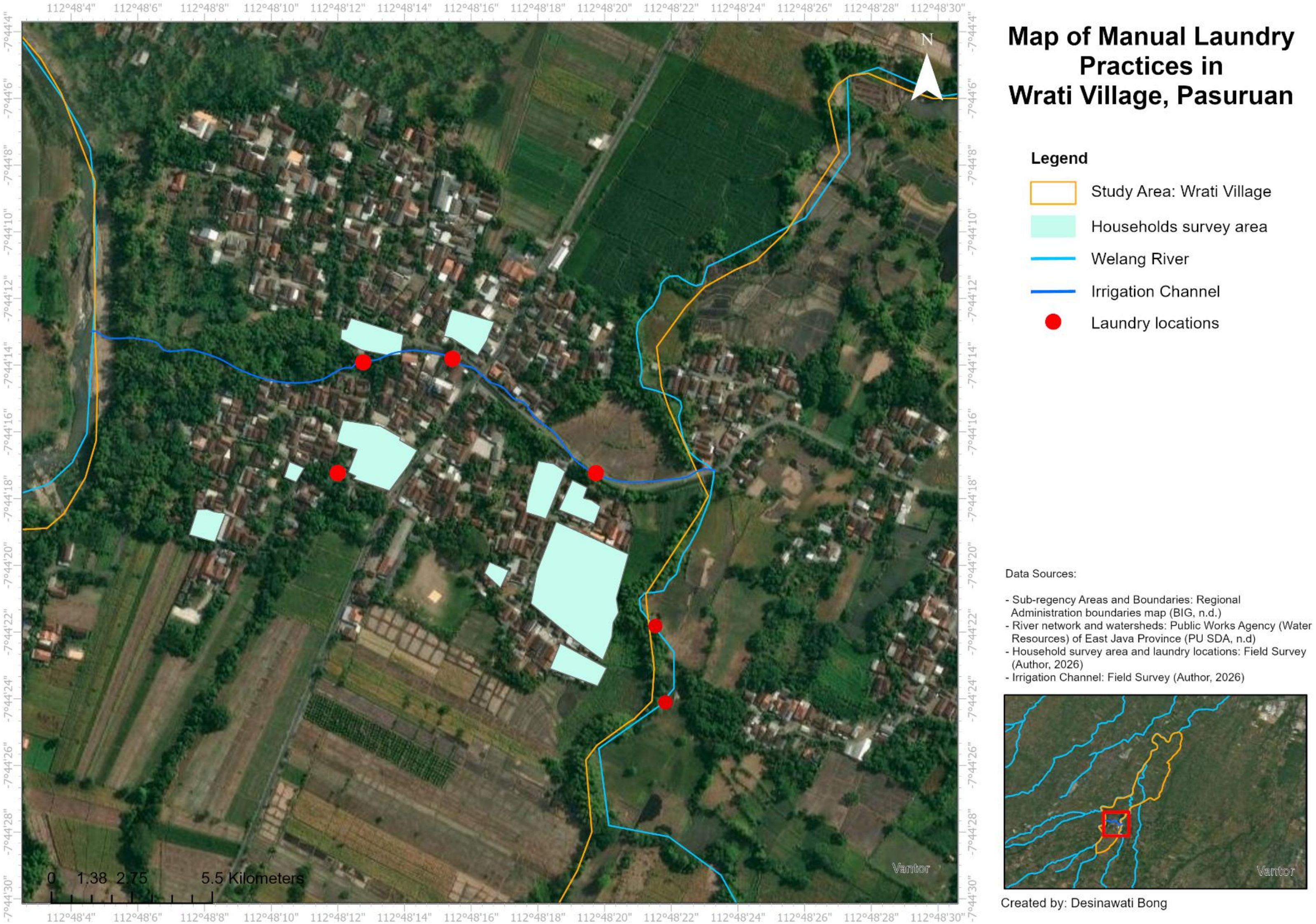


Figure 20 Location of Manual Laundry Practices in Study Area

4.3 State of Water Quality

The clean water source used for laundry in the study area is part of the Welang River Watershed. This river is also used for Selowengko irrigation area. River water quality in the upstream area of the laundry activity is shown in Table 4. For BOD, COD, and ammonia, concentrations at all locations except point L3 exceed the quality standards set by Government Regulation No. 22 of 2021 for Class II Surface Water Used for irrigation and clean water sources. Other parameters such as TDS, pH, DO, lead, and total coliform still comply with the required standards.

Table 4 Water Quality in Welang River Watersheds (Upstream Side of Laundry Activity)

Parameter	Unit	WQS	L1 (rice field A)	L2 (rice field B)	L3 (Dry field A)	L4 (Dry field B)	L5 (Settlement A)	L6 (Settlement B)
TDS	mg/L	1,000	158.5	135	194	164.5	159.5	187.5
pH	-	6-9	7.96	7.86	7.6	7.16	7.59	7.69
DO	mg/L	Min. 4	7.88	7.24	7.19	7.48	7.19	7.2
BOD	mg/L	3	**5.23**	**5.04**	**4.24**	**4.7**	**5.58**	**4.86**
COD	mg/L	25	**28.31**	**28.94**	24.14	**41.12**	**29.71**	**25.51**
Lead (Pb)	mg/L	0.03	0	0	0	0	0	0
Cadmium (Cd)	mg/L	0.01	<0.0018	<0.0018	<0.0018	<0.0018	<0.0018	<0.0018
Ammonia (NO_3)	mg/L	0.2	**5.99**	**3.72**	**3.61**	**16.83**	**5.31**	**3.22**
Total coliform	100 MPN/mL	5,000	1,700	2,600	2,300	2,850	1,900	3,150

Source: Nita et al., 2025

In the downstream sections of the laundry location, all parameters complied with the national standard except for DO. The impact of laundry activity could not be quantified because the existing water quality data were far from the study area.

Table 5 Water Quality in Welang River (Downstream side of Laundry Activity)

Parameter	Unit	WQS	Area 1
TSS	mg/L	50	18
Color	Pt-Co	50	0.54
pH	-	6-9	7.48
Dissolved Oxygen (DO)	mg/L	Min. 4	**3.78**
Total nitrogen	mg/L	15	3.68
Total phosphates as P	mg/L	0.2	<0.02
Hydrogen Sulphide (H_2S)	mg/L	0.002	<0.002
Arsenic (As)	mg/L	0.05	<0.001
Cadmium (Cd)	mg/L	0.01	<0.0001
Mercury (Hg)	mg/L	0.02	<0.0004
Lead (Pb)	mg/L	0.03	<0.001
Total detergent	mg/L	0.2	<0.16

Source: Ramadhani et al., 2025

4.4 Impact of Laundry Activity on Environment and Health

The impacts of laundry activities were primarily caused by the use of detergents and the wastewater they generate, which was discharged directly into the environment without treatment. The surfactant content in detergents has a broad impact on ecosystems, including water quality, fish, soil, and plants. Potential impacts include the formation of a foam layer that can reduce oxygen penetration into the water, increase toxicity, and decrease bioremediation rates. In fish, it can cause a decline in organ function. Meanwhile, in soil and plants, it has the potential to reduce soil conductivity and chlorophyll. Other pollutants, such as COD, nutrients, pathogens, and heavy metals, have various impacts, including eutrophication and health effects such as gastrointestinal diseases and even nervous system damage. Details of the impact are shown in Table 6.

Table 6 Impact of Untreated Laundry Wastewater on the environment and health aspects

Pollutant Category	Parameter	Impact category	Mechanism	Sources
Surfactant	LAS	Water quality	A production layer of foam on the surface, which can reduce oxygen penetration.	Mousavi & Khodadoost, 2019
		Sediment	Sorption to suspended solids that can influence bioavailability.	Belanger et al., 2002
		Aquatic biota	Exposure to fish may be adversely affected by liver damage and reduced oxygen consumption efficiency; these effects can trigger physiological stress, respiratory impairment, and behavioural changes, such as decreased swimming activity.	Rejeki et al., 2008
		Aquatic biota	At certain concentrations in water, LAS can cause a decline in invertebrate populations and emergence.	Belanger et al., 2002
		Aquatic biota	Potentially reduces algal biodiversity at high LAS concentrations in the water.	Belanger et al., 2002
		Aquatic plants	Low concentrations of detergent can temporarily stimulate plant growth. Higher concentrations reduce chlorophyll content, causing browning, inhibit growth, and reduce biomass.	Mousavi & Khodadoost, 2019
		Soil	Removing humus from the soil, reducing hydraulic conductivity, and increasing soil salinity and alkalinity, particularly in sandy and alluvial soils.	Hardie et al., 2021
		Health	Skin irritation due to contact between stratum corneum and surfactants, acids, and bases.	Landeck et al., 2020
Organic mater	COD	Water quality	Causes dissolved oxygen (DO) depletion that leads to shifting to anaerobic conditions (e.g. H_2S and CH_4 formation)	Ratnaningsih et al., 2019
Nutrient	Phosphate	Water quality	Triggers eutrophication and extreme growth of algae	Mousavi & Khodadoost, 2019
	Nitrate	Health	Birth defects, colorectal cancer and thyroid conditions caused (if there is oral consumption)	Wulandari et al., 2024
Pathogen	Faecal coliform and E. coli	Health	Diarrhoea is a symptom of gastrointestinal diseases	Lin et al., 2022

Pollutant Category	Parameter	Impact category	Mechanism	Sources
Heavy metals	As, Hg, Pb	Health	Damage to the central nervous system, skin disease	Wulandari et al., 2024

Additionally, regarding health impact, 13% of respondents reported experiencing skin problems (e.g., irritation, rashes) during or after doing laundry. Most health issues they experienced were joint and bone pain. This was likely caused by the posture during laundry (bending/squatting).

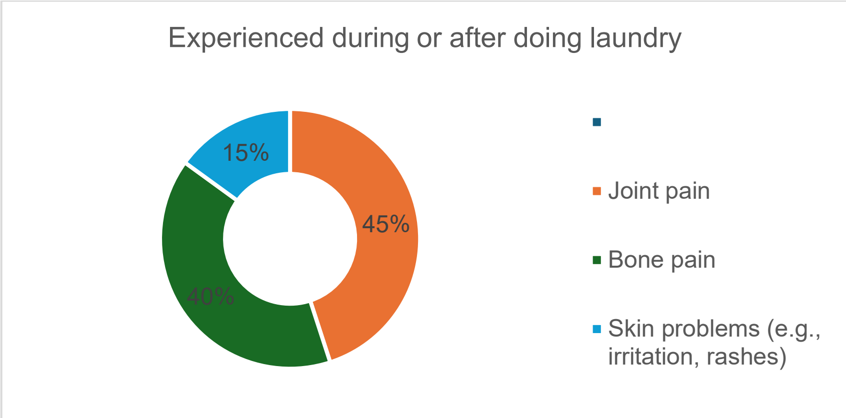


Figure 21 Health Impact during or after doing laundry

4.5 Responses to Improve Laundry Practices

To address the identified challenges, a series of strategic responses has been formulated and categorised into two main approaches: prevention and mitigation. The proposed technical responses focus on the communal scale. In this context, the communal scale refers to a facility that serves multiple households. Prevention responses aimed to address the drivers of doing laundry in the river, whereas mitigation measures aimed to minimise the pressures associated with these activities. Table 7 outlines these response actions in detail, including aim, action details, expected benefits, and potential challenges.

Table 7 Prevention and Mitigation Strategies in Technical Aspect

Responses Category	Response action	Aim	Expected benefits	Potential challenges	Source
Prevention	**Roof Rainwater Harvesting** A method for collecting rainwater that falls on a house's roof and storing it in water tanks. The system consists of the catchment area to collect rainfall, a water delivery system from the catchment to the storage, a storage system, and a system to distribute to the end user.	Addressing intermittent water supply and reducing dependence on the river	• Water bill costs can be reduced. • Having an extra water supply that is reliable, since it is possible to store water during the rainy season and use it during dry season/harvest season	• Reliance on adequate storage capacity • Initial cost for investment • Potential disruption to the current water supply	Juliana et al., 2017;
Mitigation	**Using an alternative soap that is more environmentally friendly** Some fruits, e.g., coconut leaf waste, quillaja, starfruit, Sapindus rarak DC) contain saponins (natural surfactants) and can be used as an SLS replacement in detergent compositions.	To reduce the environmental risk of detergent consumption that contains surfactants and phosphates	• Biosurfactants exhibit greater biodegradability, lower toxicity, and better environmental compatibility. • Potential reduction of phosphate and surfactant entering the environment	• The availability of the product in study area • Additional cost to buy detergent for community • Community perception of cleanliness and satisfaction with detergent performance	Sari & Setiawan, 2019; Masyithah et al., 2024; Oleszek & Hamed, 2010
Mitigation	**Constructed wetland** Process: The water treatment system includes a bed layered with gravel, sand, and wetland plants on top. The system can	To reduce the environmental risk of wastewater discharge that has high COD, TSS, surfactant, and phosphate	• No electrical energy is required • Low operating cost • Can be built and repaired with locally available materials • Application level can start from the household to the city level	• Requires larger land areas • The process is Climate change sensitive, including extreme weather and climatic hazards, which could	Hassan et al., 2021; Agaton & Giulia, 2024

Responses Category	Response action	Aim	Expected benefits	Potential challenges	Source
	remove organic load, suspended solids, and moderate pathogens. Substrate type, macrophytes used, and hydraulic load are key factors in determining treatment effectiveness. Effluent: the treated water can be used for non-potable reuse in agriculture		• Management level varies from household to public.	undermine the unit's sustainability.	
Mitigation	**Slow Sand Filtration** Process: This system consists of beds of sand or granular material (e.g. river sand, silica, gravel, ceramic) that allow water to flow by gravity. Pollutant removal occurs through physical and biological processes. The top layer, called schmutzdecke, plays a role in bacteriological purification. Factors that determine treatment effectiveness: Hydraulic loading rate and feeding mode	To reduce the environmental risk of wastewater discharge that has high COD, TSS, surfactant, and phosphate	• Easy to operate, simple, and low-cost.	• Operational challenges such as cleaning the media at a certain frequency and backwashing procedure. • Scaling up may be difficult.	Verma et al., 2017; Agrawal et al., 2021; Freitas et al., 2023

In addition to technical interventions, behavioural interventions were recommended to address the socio-cultural driver of river laundry. Three approaches were identified: education, training, and restructuring (Michie et al., 2011). Examples of each approach can be seen in Table 8.

Table 8 Behavioural Intervention

Approaches	Examples	Expected benefits	Sources
Education about hygiene practices	Community-based educational campaigns using town hall meetings, peer educators, and visual aids to disseminate the messages	Allowing community members to co-create solutions and feel ownership over behavioural shifts Foster social accountability and collective action	Jacob, 2026
Training	Capacity-building program targeting local stakeholders. Training includes theoretical knowledge and practical skills	Community may take proactive roles in maintaining technical interventions.	Jacob, 2026
Restructuring the built environment	Provide a communal laundry station.	Because this infrastructure is available, people can modify their behaviour by using the technology repeatedly. Communities can experience the changes and perceive the benefits in a short period.	Michie et al., 2011

4.5.1 Experts' interview results

The interview results were split into two groups: 1) enabling factors and 2) barriers to such a changing system component. For enabling factors, three sub-groups were considered important from experts' perspective: stakeholders' involvement, context-specific factors, and engagement tools. For barriers, there were five sub-groups, namely education level, willingness to change, economic status, socio-cultural factors, and time constraints. Results are shown in Table 9.

Table 9 Enabling Factors and Barriers of Intervention Implementation according to Experts

Group	Sub-group	Quotes
Enabling factor	Stakeholders' involvement	*"In some programs, sometimes people who are not involved in the decision-making" – KI1* *"Lack of coordination from top government to village officer" – KI3*
	Context-specific	"*It is important to take all geographical and sociocultural beliefs*" *– KI1* "*At least there are 3 factors that should be incorporated in the planning process: topography, sociocultural, political situation." – KI3*
	Engagement tools	*"…demonstrating this with visuals of water samples and laboratory tests and communicating clearly and using language they can easily understand, and also explaining the benefits they can gain" – KI2* *"Maybe more articles in the newspaper about how important the issue is" – KI1*

Group	Sub-group	Quotes
	Management committee	*"Besides hardware (infrastructure), one of the most important factors is software. It means mentoring and empowerment of infrastructure management, as well as the communities." - KI3*
Barriers	Education level	*"…because the community didn't understand, everything was returned to the facilitator's decision" – KI2* *"But for those who have had these habits for a long time and haven't caused any problems, they consider them normal" – KI2*
	Willingness to change	*"They consider these activities to interfere with their main jobs" – KI2* *"Willingness and acceptance; it is important for people recognising it as important" – KI1*
	Economic status	*"This willingness to pay remains quite low because their income is low and not increasing" – KI1*
	Socio-cultural factors	*"In such programs, social aspects are often not captured" – KI2*
	Time-bound	*"…these are very slow processes" – KI1* *"Based on experience, I think 2 years is the minimum to make sure that the program is running smoothly" – KI3*

5. Discussion

5.1 Drivers and Pressure

The drivers that cause these communities to wash into the river are divided into two factors: infrastructure and socio-economic factors. Regarding infrastructure, the main available water source (house connection) does not meet one crucial aspect: continuity. Water flow occurs only at specific times, eliminating its reliability for household use. The existence of other water sources, in this case rivers, fills the gap in continuity. In peri-urban and rural areas in Indonesia, it is common to use multiple sources for different purposes (Utami et al., 2024). Further investigation shows that this intermittency can be affected by various factors, including technical, financial, institutional, and environmental constraints, such as drought (DuChanois et al., 2019).

Another factor that emerged in the field is the lack of ability to pay clean water bills. These women, most of whom work as farm labourers, face financial constraints that require them to prioritise spending. Their income is below the minimum wage in Pasuruan Regency, and their irregular income, which depends on the harvesting season, adds another burden. As Rahayu et al. (2019) note, the capacity to pay for water determines water consumption patterns. Households with lower incomes tend to be marginalised and to consume less water.

Furthermore, river laundry practices exist not only for functional needs but also for social incentives. Respondents describe being happy to do household chores and to gather with other neighbours. Similarly, two experts interviewed noted that people in rural areas in Indonesia tend to engage in communal activities. Anderson et al. (2019) state that rivers offer spaces that mediate social exchange, which can contribute to well-being, community cohesion and everyday social life.

Another notable finding is that seasonality significantly influences their choice of laundry location. They explained that they typically do laundry at home because, during the rainy season, rising water levels and deteriorating water quality hinder this activity. This means the water supply system must be available across seasons and have stable quality that supports domestic activities.

Those findings mean the community have some knowledge and understands the environmental conditions. However, since it's part of their daily routine, it leads to a normalisation of suboptimal water quality. Psychological distance causes people to compare their situation to worse conditions elsewhere, which can hinder critical evaluation (Lázaro-Salazar et al., 2025). Additionally, this denial of dirty water reflects cognitive dissonance, helping avoid the discomfort of using unhygienic water. Interestingly, this dissonance is challenged when people use items of higher symbolic value, like prayer robes or uniforms, or choose to wash clothes at home with cleaner water sources. This shows a fragmented understanding. People are aware of differences in water quality, but they suppress this awareness during routine activities to protect their psychological comfort.

The environmental pressure of doing manual laundry in the river comes from material consumption in this case: water and detergent use. In the context of water consumption, it is difficult to measure, since they do their laundry directly in the river. In the in-home study case, the median was 14 Litres per person per day. This finding aligns with a previous study by Utami et al. (2024), which shows that the average water consumption in peri-urban areas in Indonesia is 6-17 litres per person per day.

Single-use detergents are notably popular among households, compared with large packs. Their rationale for this preference includes their economic circumstances and convenience. Since they do their laundry at the river, where carrying a single-use detergent is more feasible. As Cullen et al. (2026) noted, single-use sachets for home and personal care are widespread in Indonesia. This is partly due to limited income. A study in Addis Ababa showed that the price and availability factors have a strong relationship in buying decisions, while brand awareness has a moderate relationship (Gebrewahid, 2021). Using single-use sachets has pros and cons. In the context of preventing detergent overuse, they are more manageable, whereas using a large pack can be difficult for the household to measure their use. Waste management of detergent sachets remains important to prevent them from entering water bodies.

Most detergent brands used by the community comply with the national standard for surfactant concentration, which requires a minimum of 14% by mass, except for 2 brands. Other components in the detergent cannot be assessed, as providing composition details is not mandatory except for the active agent (surfactant). This suggests that laundry results may be ineffective in removing pathogens or microbes from dirty clothing due to the use of substandard detergents. As Abney et al. (2021) stated, the reduction in pathogen release and/or inactivation is influenced by detergent selection, other additives (bleach), water temperature, and drying time.

The use of phosphates in detergents in Indonesia is still common and allowed. In powder soap/detergent, the maximum concentration of phosphate is 5% of the fraction mass (BSN, 2017a). However, the existing powder soap in the study area contains no information provided on the package about this. A previous study by Setiawati and Ariani (2021) reported that the average phosphate concentration in powdered detergent in Indonesia ranged from

0.18% to 5.45% w/w. In other countries, such as EU countries, the maximum is 0.5 grams per wash (European Parliament and Council, 2012).

Wastewater volume generation from laundry activities in the study area is 8.03 L/person/laundry cycle. This finding slightly differs from previous studies, which reported volumes ranging from 10 to 33.6 litres/capita/day in low-income countries. Factors such as washing techniques, laundry load sizes, fabric types, and usage habits likely contribute to variation in greywater production (Shaikh & Ahammed, 2024; Vakil et al., 2014). Determining wastewater generation volume is a critical step in designing the treatment process.

The estimated pollutant load for the parameters surfactant, COD, BOD, and TSS released from laundry activity are 444 kg/year, 5,234.1 kg/year, 7,196.9 kg/year, and 4,972.4 kg/year, respectively. The pollutant load from washing activities indicates how much pollution a water body receives. This is crucial for managing water quality. If pollutants are constantly discharged, water bodies may surpass their capacity to handle them. Over time, sustained pollution can impair the river's self-purification capacity.

The pathways by which surfactants and phosphates enter the environment are mainly influenced by existing sanitation infrastructure. At the research site, the lack of domestic wastewater treatment meant pollutants are discharged directly into unlined drainage channels, seeping into the ground or spreading via runoff into water bodies. The long-term impacts of this situation may include declining water quality and threats to local public health. Additionally, the use of irrigation water channels warns authorities to take action, as Mousavi & Khodadoost (2019) stated that the accumulation of LAS in agricultural produce might threaten its quality and safety.

These findings show that everyday laundry, a seemingly simple activity, can impact the environment due to the use of detergent soap that contains pollutants like surfactants, organic materials, and phosphates. If laundry wastewater is released into the environment without adequate long-term treatment, it can lead to environmental degradation. It emphasises the importance of proper wastewater management in rural areas.

5.2 State and Impact

Secondary data on the water quality of the Welang River indicate that water quality varies with the surrounding land use. BOD, COD, and ammonia concentrations generally exceed regulatory standards. BOD and COD concentrations indicate domestic wastewater discharge, while high ammonia concentrations may be attributable to fertiliser residues from agricultural land (Ratnaningsih et al., 2019). These findings are consistent with respondents' experience that the water is usually more turbid and smells like fertiliser, especially during the planting season. Based on land-use conditions in the study area, the area is dominated by agricultural and residential land.

Additionally, the sub-district itself does not yet have a centralised domestic wastewater treatment system, allowing multiple sources to enter the river ecosystem. River water quality in the downstream area of Wrati Village shows decreased DO levels and doesn’t comply with the standard. Lower DO concentration in the river indicates there is a high concentration of organic matter (Ratnaningsih et al., 2019). This suggests that river water quality is influenced by other anthropogenic activities, such as crop fields, settlements, and small businesses along the river network.

Although detergent concentration remains within the standard, this does not necessarily imply the absence of impacts from laundry wastewater. The laundry effluent contains surfactants and organic substances that may contribute to water-quality degradation. However, the LAS content in water and sediment resulting from direct river laundry activities is influenced by a combination of degradation, hydrodynamic dispersion, and dilution (Gordon et al., 2009). Therefore, the effect of laundry activity needs to be assessed with comprehensive indicators and by accounting for other possible pollution sources in the catchment.

Seasonality cannot be fully assessed due to data limitations. However, there is an indication that it happens in the study area. FGD and survey results stated that water quality in the rainy season is more turbid than in the dry season. Turbidity in the river is affected by TSS levels. This condition is likely associated with increased runoff carrying soil from upstream and nearby cropland (Istomi et al., 2025). Seasonality significantly influences river water quality because hydrological conditions vary throughout the year. During periods of heavy rainfall, increased river discharge affects pollutant transport, dilution, and sedimentation, causing water quality to fluctuate over time (Xu et al., 2019). Consequently, evaluating how laundry activities impact water quality demands a deeper analysis, considering the complexity of these hydrological dynamics.

The study indicates that disposing of untreated laundry wastewater can alter water quality in recipient bodies. Components in laundry soap, including surfactants, organic matter, and nutrients, can change water characteristics. These alterations not only degrade water quality but also affect aquatic biota, including plants. Additionally, poor water quality can pose health risks to people.

Most studies reviewed in this research consistently highlight the negative effects of laundry wastewater on aquatic environments, such as decreased oxygen levels, eutrophication, and ecological disturbances. Nonetheless, research by Misra et al. (2010) demonstrates beneficial effects of using laundry greywater for tomato gardens, showing improvements in biomass and leaf area. This benefit is attributed to nutrients like phosphorus, iron, zinc, and sodium that plants absorb. Additionally, other positive outcomes include the uptake of sodium and iron pollutants by the soil. However, high surfactant concentrations can cause adverse effects. Furthermore, Chaici et al. (2015) found that nonionic surfactants can act as soil wetting agents, enhancing water infiltration, soil water retention, corn yields, and irrigation efficiency. Despite these benefits, concerns persist about the accumulation of sodium, metals, and surfactant residues, which could pose environmental and health risks over time.

Women have reported skin issues like irritation and rashes. Detergents can alter skin pH and harm the acid mantle of the stratum corneum. The level of irritation varies with factors such as surfactant type; for instance, surfactants with C10-C14 chains are usually harsher. Additionally, individual skin conditions, such as atopic dermatitis and compromised skin barrier function, influence the extent of irritation (Landeck et al., 2020). Water quality also affects other health risks, particularly in communities relying on river water. Poor water quality can cause gastrointestinal diseases like diarrhoea through oral intake. These issues may also arise from activities such as bathing. Long-term, large-scale exposure can lead to additional health problems.

These findings suggest that water quality in the study area's watersheds has already declined. Although the specific impact of laundry activities cannot be measured precisely, signs suggest that human activities may reduce water quality. The Welang watersheds are a vital water source in East Java, supporting clean water supply, irrigation, and industrial activities. Laundry not only degrades the environment but also poses health risks to these women through unhygienic conditions.

5.3 Responses (opportunities and challenges)

Field findings indicate that limited infrastructure, particularly the continuity of the clean water supply, is a key driver of doing laundry in water bodies. To address this issue, rainwater harvesting technology has been proposed as an alternative water source to reduce river pollution from laundry. This technology has been widely implemented in areas with clean water scarcity because it is relatively easy to operate (Juliana et al., 2017; García-Ávila et al., 2023). The system scale can range from the household level to larger catchment areas. Factors such as storage and catchment systems are essential for ensuring smooth operation and preventing further water contamination (García-Ávila et al., 2023).

In line with Expert 3's perspective, using multiple water sources is a common strategy in Indonesia. However, introducing the technology to the community remains crucial. A study by Mukaromah (2020) shows that in Semarang, where multiple water sources are available, some residents view RWH as a supplementary option. Therefore, it's crucial to ensure the system to be installed is suitable for the area, as it can influence how people perceive the technology. Additionally, installing new systems may incur extra costs, which could already be a burden for the community. Input from Expert 3 also emphasises the importance of conducting a comprehensive assessment of existing infrastructure before installing a new one. This assessment should not be limited to the technical aspects of infrastructure but should also encompass the governance of local clean water providers.

Managing the use of conventional detergents is crucial, with bio-detergents offering a less toxic alternative (Sari & Setiawan, 2019; Masyithah et al., 2024; Oleszek & Hamed, 2010). No studies in Indonesia have explored the biodetergent market's availability and potential. Research by Simangunsong & Nuvriasari (2026) indicates that green features, brand trust, and environmental awareness influence purchase intention, but awareness alone doesn't drive purchases. Furthermore, Rumangkit et al. (2025) found that environmental knowledge doesn't significantly affect willingness to pay more, as consumers prioritise brand trust, especially under financial constraints. Given income levels, willingness to pay more can be a financial burden, making brand assurance vital for market success. To promote this behavioural shift, a large-scale public awareness campaign is essential.

Laundry wastewater treatment is also a crucial intervention to consider. Disposal of wastewater without prior treatment will inevitably degrade the quality of the receiving water body. The proposed intervention for treating rural domestic wastewater includes constructed wetlands (CW) and slow sand filters (SSFs). A study by Vásquez et al. (2024) shows that CW using *E. crassipes* reduces COD (92.37 ± 4.24%) and phosphate (99.06 ± 0.56%). In addition, LAS removal up to 98% was achieved using *Phrafmites australis* with artificial grey wastewater (Thomas et al., 2017). For SSFs, removal efficiency is up to 89% for TSS, 79% for turbidity and ±93% for surfactant parameters (Fitriani et al., 2023; Chaabane et al., 2022).

The effectiveness of CW processing is determined by hydraulic residence time (HRT), hydraulic loading rate (HLR), and feeding type (Wu et al, 2015). Meanwhile, for SSF units, effectiveness is determined by hydraulic residence time (HRT) and media filter size (Abdiyev et al., 2023). Which for HRT and HLR are related to laundry frequency. Given this, there may be a need for additional units such as equalisation, pre-sedimentation, and a larger area for effective and efficient treatment.

Raising public awareness from the outset of the technology intervention is crucial, as people now regard their activities as normal and as having no negative impact on themselves or the environment. Successful behavioural transformation to stop river laundry requires strong integration between interventions (Table 8) and enabling factors in the field. Education and training approaches, for example, cannot be implemented top-down. In-depth interviews confirmed criticism of previous programs that often neglected community involvement in decision-making and lacked coordination from the central government down to the village level (KI1; KI2; KI3, 2026). Therefore, early community involvement is crucial. This aligns with studies by Nelson et al. (2021) and Daniel et al. (2023), which show that active community involvement from the planning stage can foster a sense of ownership, raise awareness, and stimulate lasting behavioural change.

Furthermore, expert informants provided practical guidance on effective engagement methods. Public education should not be theoretical but rather utilise tangible visual aids that are easy to understand (KI2), supported by broader information dissemination in the mass media (KI1). In this context, the active involvement of women's groups is key, given their central role in domestic activities such as laundry. On the other hand, restructuring of built environment, for example through the provision of community public laundry facilities (Michie et al., 2011), will not be sustainable without capacity building. An expert informant (KI3) emphasised the importance of establishing, mentoring, and empowering local management committees to maintain the infrastructure.

Communal facilities offer benefits like avoiding high capital and operating costs, ensuring proper management, and creating jobs. The South African LaundRecycle project showed ecological, economic, and social benefits, such as conserving freshwater through RWH and greywater reuse, and providing income and jobs for locals (Bühler et al., 2024). However, drawbacks exist, such as the risk of underutilisation, as surveys show people prefer doing laundry at home for mobility. This aligns with Daniel et al. (2023), who found that household water systems in Indonesia perform better than communal ones.

While this study primarily addresses technical and behavioural aspects, the findings show that economic constraints are one of the biggest drivers. The long-term viability of these interventions remains deeply intertwined with local economic capacities. The lack of a tailored financial scheme within this analysis could raise questions, as financial factors are essential for infrastructure sustainability. Additionally, strong governance, stakeholder coordination, and robust regulatory frameworks are needed (John & Ajibade, 2024).

Ultimately, a single solution cannot resolve all current issues. Instead, a combination of short, medium, and long-term strategies is necessary. As Novotný et al. (2018) stated, the dynamic in this process is complicated by the fact that the success of interventions is influenced by educational background, economic capacity, and local cultural structures. By aligning technical solutions and social approaches, this strategy has the potential to achieve transformative and sustainable change.

5.4 Limitations

The data collection in this study encountered several limitations. Firstly, the large-scale Focus Group Discussion (FGD) might have limited some participants' willingness to share their views openly. Secondly, language barriers were present in the discussion; some participants felt uneasy discussing in Indonesian. Although efforts were made to tailor message delivery effectively, translation by local partners may have diminished the depth or altered the original meaning of participants' statements.

The household survey used a random sample of only 31 household heads (KK), which limited how well the results could be generalised to the larger population. Language barriers also persisted during the survey, and some questions remained hard for participants to understand despite being adapted to the local context. These issues could introduce bias and distort the accuracy of the responses.

Meanwhile, in the in-depth interview method, time and resource constraints limited the number of respondents that could be reached. Furthermore, manual laundry is not yet a priority issue in Indonesia, so direct information on this topic is very limited. Therefore, aspects of domestic wastewater (greywater) treatment and drinking water supply were used as proxies in several discussion topics.

Limitations were observed in the use of secondary data, which mainly focused on macro-sanitation or drinking water supply as proxies to tackle the issue. Differences in geographic scope, climate, social factors, and infrastructure readiness across regions were often overlooked, as the emphasis was on adapting to Indonesia's general context. Consequently, more detailed research and review of these aspects are necessary in the future.

Finally, in the data analysis, there is an absence of secondary and primary data on raw water quality and wastewater effluent. Future research should focus on detailed water quality assessments at the study sites, covering physical, chemical, and biological parameters. This is crucial for developing more effective future strategies and interventions. Additionally, the indicators used to measure water and detergent consumption need improvement. Currently, the study depends on respondents' recall, which introduces the risk of errors and inaccuracies.

6. Recommendation and Conclusion

6.1 Recommendation

Further research:

1. Conduct water quality assessments for water sources (household connections and river), wastewater, and receiving water bodies across the seasons to get comprehensive data, so that, while assessing the pressure from laundry, the impacts and creating the strategy, responses can be more appropriate.
2. Increase the sample size of the total population to ensure more representative and generalizable data. Furthermore, research instruments should be adjusted to minimise retrospective recall burden and ensure construct validity across all variables. This is crucial to ensure all variables are measured correctly, allowing for more detailed and in-depth statistical analysis between variables.

3. Expand this scope by examining financial schemes, infrastructure management models, and policy frameworks required to operationalise these interventions effectively.

Future Project:

1. Expand the intervention into laundry wastewater management.
2. Test local materials as an alternative bio-detergent; this can be one of the future business models that help women and also reduce the environmental impact.
3. Development of an integrative module for the utilisation of tools for long-term use.
4. Raising awareness among the community about the impact of unhygienic practices using different campaign tools.

6.2 Conclusion

Laundry practices in Wrati Village, Pasuruan Regency, often take place in the river due to limited access to continuous clean water infrastructure. Economic limitations and traditional habits sustain this practice, which exerts environmental pressure through high water and detergent use. Currently, water quality at the research site is below applicable standard levels. This decline results not only from river laundry but also from surrounding land use and the absence of proper domestic wastewater treatment facilities.

Without management efforts, environmental impacts can cause serious ecosystem damage, including lower water quality from surfactant pollutants, organic matter, phosphates, nutrients, and heavy metals. Beyond degrading water quality, these pollutants may endanger aquatic life if their levels exceed lethal thresholds. Additionally, these negative effects might spread to sediment, soil, and plants through uptake mechanisms that surpass tolerance levels. Health-related water issues also pose risks to the community, such as skin irritation and gastrointestinal problems.

The response strategy emphasises prevention and mitigation by providing infrastructure and social interventions. This combined approach aims to change community behaviour, stop river laundry, and reduce human impact on the environment. Additionally, reinforcing key enabling factors is vital for the system's sustainability and for reducing potential barriers during the transition.

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Appendix

Appendix A: Interview and FGD results

Key informant 1

Topic	Answer
Driver of doing manual laundry in the river	First, there is no sufficient infrastructure in that area to support domestic activities. That's why they are seeking alternative solutions suited to their situation. Additionally, people enjoy gathering in public spaces. Additionally, some people in other countries like India (based on her experience) are unaware that other parts of the world have more hygienic practices and different cultures.
Pressure of laundry	The challenges from detergent composition in WWTPs are phosphorus and surfactants. They can cause eutrophication and alter the water quality.
Enabling factors of successful intervention	Raising awareness through engaging and attractive advertising tools. Highlight the negative consequences of unhygienic behaviour, targeting individuals from school-age children to the elderly. Furthermore, having a suitable financial scheme is crucial to sustain the system. Additionally, local willingness and acceptance are essential, as they are part of the system.
Challenges implementing intervention	The first concern is continuity after the pilot project ends. The project only ran during the initial phase and then stalled due to the lack of involvement from local stakeholders in infrastructure management. Infrastructure management is crucial because, in addition to ensuring operations and maintenance, the financial system also plays a crucial role. This highlights the importance of involving stakeholders at different levels and backgrounds to support the project, such as local government and educational institutions. Additionally, different knowledge backgrounds add a new challenge because people don't even know their practices are unhygienic and harm the environment.

Key informant 2

Topic	Answer
Program implementation in Indonesia	Indonesia's current program implementation mostly follows a top-down approach, mainly for infrastructure under the authority of the Ministry of Public Works and Public Housing. This method often neglects social aspects, causing infrastructure to become just monuments after completion. Community involvement in program execution is hindered by longer timelines, often due to limited community knowledge. Additionally, budget allocations in Indonesia tend to be focused on specific timeframes and targets, which also affects the process.

Topic	Answer
Enabling factors of successful intervention	Technology selection, with regard to its operation and maintenance, should be easy and can be fully handled by locals. It includes the cost as well. In addition to that, raising awareness and giving the community knowledge about the problem must use simple explanations that match their current knowledge level; otherwise, it will be difficult for them to understand. Mentioning the benefits that they will receive also important. Make sure the aspect of social interaction is still in place, especially if it is part of their life. Using a unique and engaging approach is also suggested; for example, demonstrate and show the fact that using wastewater treatment can change the water quality from turbid to clear. With more tangible output, they can understand it better and realise that their behaviour is unhygienic and needs improvement.
Challenges implementing intervention	Limited community knowledge complicates decision-making, leaving the facilitator to make the decisions. This leads to operational difficulties for community operators. Furthermore, because they generally have primary jobs, managing infrastructure becomes an additional burden. Furthermore, willingness to pay remains low due to the lack of additional benefits from the new infrastructure. In technical terms, especially in rural areas that have agricultural areas. The agricultural runoff management needs to be improved since it can also worsen the water quality.
Seasonality and climate change affect the water source availability and quality and its mitigation in the Indonesian context	Every area in Indonesia has different issues related to that. In Java, since groundwater extraction is already high, the impact may be more severe than on other islands like Sumatra. In West Indonesia, they have already experienced water scarcity due to the climate and geographic context. In Kalimantan, the issue is more about water quality due to peatlands. Furthermore, due to the adverse effects of climate change on water resources, Indonesia's infrastructure primarily relies on traditional designs that are not equipped to handle these changing conditions. Additionally, in Indonesia, this topic has emerged only at the national level and hasn't reached local regions, while the country remains dominated by rural areas. Programmes related to this are limited to the national level, which has the capacity and resources, whereas regional areas have fewer resources. In Indonesia, one of the biggest problems is water quality, with domestic wastewater as the major contributor. This is because of a lack of infrastructure, even though the policy is in place. Additionally, seasonality affects the treatment process: in the dry season, it is more challenging due to organic pollutants. Whereas in the rainy season, high flow and volume make the concentration lower.

Key informant 3

Topic	Answer
Provision of drinking water system in rural area Indonesia	In rural areas, when no regional-owned enterprises provide a water system, the local government (village level) is responsible, or the community self-supplies through a traditional well. In the past, there was a program called *Pamsimas* (communal clean water supply). The program was funded by donors, national funding, or a combination of national and local funding. Usually, the village used its village fund, or the community had to pay a fee to access the water source. In that case, with budget limitations, it was impossible to build the whole system from source to household connection. Areas with unique topography or limited, scarce water sources need a higher budget to build the system. In that regard, it was quite rare to find an area with a drinking water system that fully covers the entire village. Especially when there was no extra funding or grant to expand the system.
Success factors of sustainable WASH provision in Indonesia	1. Committee They are responsible for managing the system's operation and maintenance. Their performance directly impacts the system's long-term functionality. They need support and guidance to perform effectively, especially since people in rural areas often lack detailed knowledge of these systems. Therefore, ongoing training and guidance are crucial. Additionally, they must demonstrate integrity to ensure proper management of financial matters. The legal status of water committees remains essential, but each type of legal entity has both advantages and disadvantages. For instance, committees with a legal entity, such as village-owned enterprises, can access bank loans to expand their systems. However, conflicts of interest among stakeholders can sometimes arise. Conversely, independent committees often face challenges in securing loans or grants to upgrade their systems, and they require support and connections with local NGOs or other stakeholders. 2. Good financial performance Besides the committee, another crucial factor is the system's financial performance. To improve and expand the system long-term, good financial results are necessary. Users must pay for water consistently, as these payments support maintenance and operational costs. Additionally, regular payments can increase a sense of belonging to the existing service, since users also receive the benefits directly.
Factors to consider when expanding the system or building a new one.	1. The current system's performance should be thoroughly examined, including both infrastructure and management aspects. Since these aspects are interconnected, a single solution is unlikely to suffice; instead, more comprehensive actions are needed. 2. Human complexity is particularly notable in rural Indonesian communities where limited knowledge exists. Long-term guidance and awareness campaigns are essential to encourage behavioural change.

Topic	Answer
	3. In Indonesia, given the complexity of the local context, including topography, land-use management, and culture, it is important to consider all aspects during the development phase. Including locals in the planning process and decision-making remains crucial, since they will run the system for the long term. 4. System type: communal or individual.

Focus Group Discussion

Location: Wrati Village, Kejayan sub-district, Pasuruan Regency, East Java

Participants: 34 women

Result:

A. Laundry activities

1. All participants are responsible for doing the laundry in their household, and most of them do it every day. Some participants do it twice a day (in the morning and afternoon).
2. They mentioned that doing laundry in the river only takes 30 minutes, with the longest taking 1 hour, depending on how much clothing they have. Doing laundry at home takes longer than doing it in the river.
3. Three people mentioned that sometimes their children help them with doing laundry. They mentioned that their husband is not helping them with chores.
4. Laundry steps include collecting clothes at home, then bringing them to the river, adding detergent, brushing the clothes, rinsing and drying. However, they also mentioned that they sometimes rinse the clothes again at home and use fabric softener as a final step**. (Laundry process)**
5. They prefer and like to do laundry in the river because they can socialise and interact with other people. **(Positive experiences)**
6. What they like about washing clothes is seeing their clothes clean and also being able to release emotions. When we asked what they don't like about doing laundry, they said it's when they don't have money.
7. During the rainy season, they mentioned that doing laundry is more difficult than in the dry season **(challenges).**
8. In the past, before detergents became popular, people used bar soap. Nowadays, they use liquid or powder soap. Their detergent purchase depends on their income. If they have money, they will buy a big one rather than a single-use one. They buy the detergent in a small shop in the neighbourhood. **(past vs present)**
9. One of the participants mentioned that the older generation used soapberry nuts (*Sapindus rarak* or *Sapindus Saponaria*) as laundry soap. First, they ground the fruit and mixed it with water, which produced a lather. **(past vs present)**

10. There is a special treatment for clothes like school uniforms or white clothes; they wash them at home because it will be cleaner. They wash them separately and add fabric softener. **(Special treatment)**
11. There is no ritual or specific time for doing laundry. Regarding religious practices, they believe that doing laundry at the river already aligns with their beliefs. **(Rules and rituals)**
12. The challenges they faced while doing laundry were that sometimes they found a snake passing by them, but it did not bite them. Also, it's very common to find freshwater crab (*Gecarcinucoidea*). When this crab bites, the response is usually just a shock, with no pain, because it is small. Furthermore, no treatment is necessary **(challenges)**.
13. Some of the participants mentioned they wish their children would buy a washing machine to make laundry easier. However, some people also said that they don't have the knowledge to use it. The majority of participants prefer free access to water. **(Ideal future)**
14. There is a laundry service (like hired help) in this area. The system is based on the weight of clothes per kilogram. The price per kilogram is 5000 with ironing and 3000 per kilogram only for washing. Some of them used the service during big events like weddings. However, it's very rare. Some people mentioned they want to use this service, but they want to save money. In contrast, some people said they prefer to do it themselves because cleanliness standards vary among people.

B. Water source

1. The majority of women do their laundry in the river located in their backyard/neighbourhood. It takes only 5-10 minutes to walk. The reason is that laundry time can be shorter due to the river's continuous flow. Some of them also mentioned that they want to save money because if they do it at home, they have to pay for water bills. Some of them pointed out that they have a lot of things to pay for, such as water and electricity.
2. They mentioned that before the individual house connection was installed (through a village grant program), they used to have their own well and didn't have to pay for the water bills. They use water from the HH connection for drinking (boil it first) and cooking.
3. During the rainy season, the river experienced a rising water level and also became more turbid, as mud comes from the crop fields. In the past, the rainy season usually started in December and lasted until May. However, these days they cannot predict the rainy season as they did in the past. They perceived the water colour as brown. Sometimes, the water is also smelly. The local partner mentioned that there is sometimes waste from livestock disposed of in the river. **(Seasonality)**.

Appendix B: Calculation of wastewater generation and total potential pollutant load

1. Wastewater volume (equation 1)

Total households in the study area: 239 HH

Average people per household: 4 persons

Water consumption: 14 L/day/person (primary data)

$\text{Laundry wastewater generation} = \text{Total HH x P x WC x \% LW}$

= 239 x 4 person x 14 L/day/person x 60%

= 8.03 m^3/day

The estimated wastewater generation from the study area is 8.03 m^3/day.

2. Estimation of total potential pollutant load (equations 2 and 3)

$$PLP = P \ x \ EF_{LW} \ x \propto x \ U_{ER} \ x \ \% \ of \ laundry \ component$$

Equation 4

$$Surfactant \ load = \ \%_{avg} \ surfactant \ x \ Total \ HH$$

Equation 5

Where:
P = population (persons)
EF_{LW} = Emission factor for laundry wastewater
$\propto$ = load transfer coefficient
U_{ER}= urban equivalent ratio
$Total \ HH$ = total households in study area
% LW = percentage of laundry wastewater (50-80% of total wastewater)
WC = water consumption (L/person/day)
$\%_{avg}$ = average percentage of surfactant in detergent

Surfactant load from study area:

The assumption was made that all households did laundry every day.

%average surfactant based on primary data = 5.1 grams

$\text{Surfactant load} = \ \%_{\text{avg}} \text{ surfactant x Total HH}$

= 5.1 grams/day x 239 HH

= 1215.9 gram/day = ± 444 kg/year (1.27 gram/day/person)

Potential pollutant load for BOD, COD, and TSS:

The following assumptions were made:

- The distance from the house to the water source ranged from 0- 100 m (based on observations). So, the load transfer coefficient used was 1 (Pangestu et al., 2017).

- The study area was categorised as a rural area, so the urban equivalent ratio was 0.625 (Pangestu et al., 2017).
- The percentage of laundry wastewater in total domestic grey wastewater was 60% (the range was 50-70% according to Utami et al. (2024).
- Emission factor for domestic wastewater BOD, COD, and TSS was 0.04 kg/person/day, 0.055 kg/person/day, and 0.038 kg/person/day, respectively (Pangestu et al., 2017).

PPL BOD

$\mathrm{PLP} = \mathrm{P \; x \; EF}_{\mathrm{LW}} \mathrm{\; x} \propto \mathrm{x \; U}_{\mathrm{ER}} \mathrm{\; x \; \% \; of \; laundry \; component}$

= 239 HH x 4-person x 0.04 kg/person/day x 1 x 0.625 x 60%

= 14.34 kg/day = 5234.1 kg/year

= 15 grams/person/day

PPL COD

$\mathrm{PLP} = \mathrm{P \; x \; EF}_{\mathrm{LW}} \mathrm{\; x} \propto \mathrm{x \; U}_{\mathrm{ER}} \mathrm{\; x \; \% \; of \; laundry \; component}$

= 239 HH x 4-person x 0.055 kg/person/day x 1 x 0.625 x 60%

= 19.72 kg/day = 7196.9 kg/year

= 20.63 grams/person/day

PPL TSS

$\mathrm{PLP} = \mathrm{P \; x \; EF}_{\mathrm{LW}} \mathrm{\; x} \propto \mathrm{x \; U}_{\mathrm{ER}} \mathrm{\; x \; \% \; of \; laundry \; component}$

= 239 HH x 4-person x 0.038 kg/person/day x 1 x 0.625 x 60%

= 13.62 kg/day = 4972.4 kg/year

= 14.25 grams/person/day