



pH Characteristics of Bathwater and Skin Hydration Levels Among Residents of Muara Batang Empu Village, South Sumatra

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Keywords:

Skin Hydration;
Corneometer;
River water pH;

Abstract

River-dependent communities may experience impaired skin hydration because exposure to bathing water with unsuitable physicochemical characteristics can disrupt the epidermal barrier. This study examined the pH characteristics of Batang Empu River water, described residents' skin hydration levels, and evaluated the association between water pH and skin hydration. A cross-sectional study was conducted in Muara Batang Empu Village, South Sumatra, from December 2025 to January 2026. A total of 211 residents were recruited through consecutive non-random sampling. River-water pH was measured at four locations and four time points, while skin hydration was assessed and classified into five categories. Participant characteristics and hygiene-related behaviors were collected using questionnaires. Data were analyzed using the Kruskal–Wallis test and Pearson's chi-square test. Mean water pH values across the four locations ranged from 6.26 to 6.45. Among participants, 24.6% experienced severe dehydration, 19.0% had inadequate hydration, 20.4% had optimal hydration, and 18.0% each had good or excellent hydration. Water pH was significantly associated with skin hydration ($p = 0.02$), whereas age ($p = 0.54$) and sex ($p = 0.67$) were not significantly associated. River-water pH was associated with residents' skin hydration, highlighting the importance of improved water-quality monitoring and preventive skin-health education.

INTRODUCTION

The skin is the largest organ of the human body and functions as the primary barrier against environmental influences, including exposure to sunlight, pollution, microorganisms, and chemicals (Baker et al., 2023). Adequate skin hydration helps maintain skin softness, elasticity, and barrier function; conversely, inadequate hydration can cause dryness, scaling, itching, and irritation due to impaired barrier integrity (Fluhr et al., 2025). Skin hydration is influenced by internal factors, including age, sex, nutritional status, and fluid intake, as well as external factors such as environmental humidity, ultraviolet exposure, skincare product use, and bathing water quality (Załęcki et al., 2024).

Rural communities that rely on river water for bathing may be vulnerable to impaired skin hydration. River water contaminated with chemicals or having unsuitable pH levels may disrupt the skin barrier, increase transepidermal water loss (TEWL), and reduce water content in the stratum corneum (Camilion et al., 2022; Załęcki et al., 2024). Prolonged river bathing, frequent use of detergent-based soaps, and limited moisturizer application may further aggravate these conditions (Nanda et al., 2024; Yanto & Verawati, 2022).

According to the Ministry of Health of the Republic of Indonesia (1990), the quality standard for clean water requires a pH range of 6.5–9.0. Water with pH values outside this range may pose potential risks to human health (Hasrianti & Nurasia, 2017). Physiologically, normal skin pH ranges from 4.5 to 5.5, and repeated exposure to water with different pH levels may affect the activity of ceramide-producing enzymes and natural moisturizing factor (NMF),

thereby impairing skin barrier function and reducing skin hydration (Załęcki et al., 2024). This indicates a knowledge gap regarding the actual characteristics of river-water quality and its potential relationship with skin hydration among populations that depend directly on these water sources (Seol, 2024) .

Muara Batang Empu Village, Karang Jaya District, North Musi Rawas Regency, South Sumatra, is an area where many residents continue to use river water for bathing and other domestic activities (Statistik, 2024). This study aimed to describe the pH characteristics of Batang Empu River water and residents' skin hydration levels, as well as to analyze the relationship between water pH and skin hydration.

Evidence also indicates that bathing practices and cleansing products may influence skin condition. (Maahirah & Wijayadi, 2025) found that the pH of body soap used by medical students was associated with skin hydration levels, highlighting the importance of external pH exposure. (Nanda et al., 2024) reported associations between clean-water sources, water-use frequency, duration of exposure, and skin-related complaints. In a rural Indonesian setting, (Yanto & Verawati, 2022) also reported a relationship between river-bathing habits and dermatitis occurrence. However, these studies primarily examined soap pH, self-reported skin complaints, or clinically diagnosed dermatitis rather than directly assessing the association between measured river-water pH and objectively measured skin hydration.

This issue is particularly relevant in Muara Batang Empu Village, Karang Jaya District, North Musi Rawas Regency, South Sumatra, where river water remains an important source for bathing and other household activities (Statistik, 2024). Residents may experience repeated exposure to river water while also being affected by occupational sunlight exposure, frequent bathing, soap use, limited moisturizer and sunscreen application, and variations in daily water intake. River-water quality may also fluctuate due to rainfall patterns, organic matter decomposition, domestic activities, and agricultural or household waste. These interacting conditions create a specific environmental-health context that cannot be fully represented by findings from urban populations or controlled skincare studies.

Despite increasing research on skin-barrier physiology, a research gap remains regarding the relationship between bathing-water pH and skin hydration in river-dependent rural communities. Previous studies have rarely combined direct measurements of river-water pH at multiple community bathing locations with objective corneometer-based assessments of skin hydration at the individual level. Evidence from young adults, clinical populations, or commercial cleansing-product users cannot be directly generalized to residents who routinely bathe using untreated surface water. Addressing this gap is important because early impairment of skin hydration may occur before visible dermatological symptoms, such as dryness, pruritus, irritation, or dermatitis, become apparent.

The novelty of this study lies in its environmental–dermatological approach, which integrates direct pH measurements of multiple bathing-water sources with objective assessments of residents' skin hydration levels. The analysis also considers relevant individual characteristics and behaviors, including age, sex, occupation, bathing frequency, skincare and sunscreen use, and daily water consumption. This approach provides locally specific evidence regarding whether variations in river-water pH are associated with differences in skin hydration under actual community exposure conditions. Although the cross-sectional design does not establish causal relationships, the study provides an empirical basis for future longitudinal

research incorporating seasonal water-quality monitoring, microbiological parameters, heavy-metal analysis, and transepidermal water loss measurements.

Accordingly, this study aimed to characterize the pH of bathing water used in Muara Batang Empu Village, describe residents' skin-hydration levels, and examine the relationship between these two variables. Scientifically, this research contributes to expanding skin-hydration studies into rural, river-dependent populations that remain underrepresented in environmental dermatology. Practically, the findings may support residents, healthcare professionals, and local authorities in developing water-quality monitoring programs, skin-health education, safer bathing practices, and preventive skincare interventions. More broadly, the study may contribute to evidence-based environmental-health strategies for communities whose daily hygiene practices remain closely dependent on natural water sources (Salsabila & Wardhana, 2024).

METHOD

This study employed a comparative analytical design with a cross-sectional approach conducted in Batang Empu Village, Karang Jaya District, North Musi Rawas Regency, South Sumatra, from December 2025 to January 2026.

The study population consisted of residents of Batang Empu Village who met the inclusion criteria, namely willingness to participate and provide informed consent. The exclusion criteria included residents with skin disorders such as ichthyosis and psoriasis. The sample size was calculated using a limited population proportion formula with a 95% confidence level ($Z = 1.96$), an estimated proportion of 0.5, and a 5% margin of error, resulting in a minimum sample size of 203 participants from a population of 429 individuals. Participants were recruited using consecutive non-random sampling.

River-water pH was measured at four locations along the Batang Empu River, with each location separated by 500 m, using a calibrated portable digital pH meter with standard buffer solutions. Skin hydration levels were assessed using a corneometer based on electrical capacitance measurements at three anatomical sites: the dorsal hand, forearm, and calf. Each site was measured three times, and the mean value was calculated. Skin hydration was categorized based on corneometer values as follows: ≤ 33 AU (severe dehydration), 34–37 AU (low hydration), 38–42 AU (optimal hydration), 43–52 AU (good hydration), and ≥ 53 AU (excellent hydration).

Additional data were collected through questionnaires covering age, sex, occupation, body soap use, moisturizer use, sunscreen use, bathing frequency, and daily water consumption. Data were analyzed using the Kruskal–Wallis test for non-normally distributed numerical variables and Pearson's chi-square test for categorical variables. This study received ethical approval under approval number 717/KEPK/FK UNTAR/XII/2025.

RESULTS AND DISCUSSION

After screening based on inclusion and exclusion criteria, 211 research subjects were obtained. The average age of the subjects was 47.45 ± 13.86 years. Most of the subjects were female (90.05%), working as housewives (46.0%) or farmers (43.3%). Almost all subjects did not use *skincare* (84.8%) or sunscreen (97.2%). The average frequency of bathing was 17.13

times per week and water consumption was 9.07 glasses per day. The complete characteristics of the research subjects are presented in **Table 1**.

Table 1. Characteristics of the research subjects (n = 211)

Features	n (%)	Rerata ± SD
Age (years)		47.45 ± 13.86
Gender		
Male	21 (9,95%)	
Women	190 (90,05%)	
Jobs		
Farmer	91 (43,3%)	
IRT	97 (46,0%)	
Others	22 (10,7%)	
Skincare Uses		
No	179 (84,8%)	
Ya	32 (15,2%)	
Sunscreen Uses		
No	205 (97,2%)	
Ya	6 (2,8%)	
Frequency of Showers (times/week)		17,13
Water Consumption (glasses/day)		9,07

Description: IRT = housewife; The data is presented as n (%) or average.

River Water pH

The average pH of river water at the four consecutive measurement points was 6.33; 6,26; 6,45; and 6.36 (Table 2). All pH values are below the quality standard (Ministry of Health of the Republic of Indonesia, 1990), so it can be categorized as not meeting clean water standards (Ministry of Health of the Republic of Indonesia, 1990); (Hasrianti & Nurasia, 2017).

Table 2. Results of pH measurement of Batang Empu River water

Location	pH based on sampling time				Rerata
	07.30	11.30	15.30	19.30	
Kampung 1	6,2	6,85	6,4	5,9	6,33
Kampung 2	6,15	6,8	6,3	5,8	6,26
Kampung 3	6,3	6,95	6,55	6	6,45
Kampung 4	6,2	6,9	6,45	5,9	6,36

The average pH of the water of the Batang Empu River at the four measurement points ranged from 6.26-6.45, all of which were below the quality standard (Ministry of Health of the Republic of Indonesia, 1990). This low pH condition indicates a tendency to acidify the river water (Sarijuwita & Tan, 2023) . A decrease in the pH of river water can be caused by several factors: the community's domestic activities (washing with detergent and disposing of waste into the river), industrial waste with sulfuric acid content, as well as natural biological processes such as the decomposition of organic matter that produces organic acids (Ramadanti & Setyowati, 2022). Climate change and an increase in atmospheric carbon dioxide that produces

carbonic acid also contribute to the acidification of surface water (Vikriansyah et al., 2024). These findings are in line with reports of water quality in several rivers in Indonesia that show substandard pH, especially in areas exposed to household and agricultural waste (Faradillah & Pujiastuti, 2022) .

Skin Hydration Levels By Gender

The proportion of severe dehydration is higher in women (20.9%) than in men (3.8%). In contrast, excellent hydration was found more in women (17.1%) than men (0.9%). The *Pearson chi-square* test found no meaningful association between sex and skin hydration levels ($p = 0.67$) (Table 3).

Table 3. Skin hydration levels based on gender

Up Hydras	Male n (%)	Women n (%)	Total n (%)	P value
Severe Dehydration	8 (3,8%)	44 (20,9%)	52 (24,6%)	0,67
Lack of hydration	4 (1,9%)	36 (17,1%)	40 (19,0%)	
Optimal Hydration	4 (1,9%)	39 (18,5%)	43 (20,4%)	
Good Hydration	3 (1,4%)	35 (16,6%)	38 (18,0%)	
Excellent Hydration	2 (0,9%)	36 (17,1%)	38 (18,0%)	

**Pearson chi-square test; The p value of > 0.05 is meaningless.*

The study did not find a meaningful relationship between sex and skin hydration levels. These findings differ from (Luebbarding et al., 2013) which found that men tend to have lower stratum corneal hydration than women. This difference is likely due to external confounding factors that are difficult to control in observational research designs (Mashadi & Moniaga, 2024) , such as the intensity of ultraviolet exposure, soap usage patterns, and fluid intake, given that most subjects work as farmers or housewives with relatively similar UV exposure (Patrick et al., 2022) .

Skin Hydration Levels Based on Age

The median age of subjects with severe dehydration was 48.5 years (IQR = 24 years), while the median age in the very well hydration group was the highest, which was 50.5 years (IQR = 19 years). The *Kruskal-Wallis* test found no meaningful association between age and skin hydration levels ($p = 0.54$) (Table 4).

Table 4. Skin hydration levels by age

Up Hydras	Median Age (years)	IQR	P value
Severe Dehydration	48,5	24	0,54
Lack of hydration	48,0	18	
Optimal Hydration	45,0	18	
Good Hydration	49,0	20	
Excellent Hydration	50,5	19	

**Kruskal-Wallis test; The p value of > 0.05 is meaningless.*

These findings differ from (Ding et al., 2024) who reported improved skin hydration in older age groups. These differences are likely due to variations in environmental and lifestyle factors between study populations that are difficult to control in cross-sectional designs

The Relationship Between River Water pH and Skin Hydration Levels

Analysis using *Pearson chi-square* found a statistically significant relationship between the pH level of river water and skin hydration levels ($p = 0.02$). Severe dehydration was most commonly found in Village 2 (pH 6.26) as many as 21 (10%) subjects, followed by Village 3 (pH 6.45) as many as 20 (9.5%) subjects. Excellent hydration was most commonly found in Village 1 (pH 6.33) and Village 2 with 15 and 17 subjects respectively. The distribution of data can be seen in Table 5.

Table 5. The relationship between the pH level of river water and the hydration level of the skin

Location (pH)	Severe Dehydration	Lack of hydration	Optimal Hydration	Good Hydration	Excellent Hydration	P value
Kampung 1 (6,33)	11 (5,2%)	10 (4,8%)	9 (4,3%)	18 (8,6%)	15 (7,1%)	0,02*
Kampung 2 (6,26)	21 (10%)	17 (8,1%)	23 (11%)	15 (7,1%)	17 (8,1%)	
Kampung 3 (6,45)	20 (9,5%)	13 (6,2%)	11 (5,2%)	5 (2,4%)	3 (1,4%)	
Kampung 4 (6,36)	0	0	0	1 (0,5%)	1 (0,5%)	

**Pearson Chi-square test; The p value of > 0.05 is meaningless.*

A significant relationship was found between the pH of river water and skin hydration levels ($p = 0.02$). Physiologically, the normal skin pH ranges from 4.5–5.5. The pH of the river water in this study (6.26–6.45), although lower than the neutral pH, was still higher than the optimal pH of the skin. Repeated exposure to water whose pH is higher than the pH of the skin can affect the activity of the enzymes *β -glucocerebrosidase* and *acid sphingomyelinase* — the enzymes that produce *ceramides* — that work optimally at the acidic pH. Disruption of the activity of these enzymes decreases the production of intercellular lipids, increases TEWL, and reduces NMF synthesis from filaggrin, resulting in decreased skin hydration levels (Załęcki et al., 2024). These findings are consistent with a study (Maahirah & Wijayadi, 2025) on medical students in Jakarta that showed that the use of alkaline pH (>8) body soap correlates with lower skin hydration. Although the mechanisms are different, these two findings confirm the importance of water exposure pH in maintaining the integrity of the skin barrier.

The study has several limitations: a *cross-sectional* design that does not allow causality inference, temporally and spatially limited measurement of river pH, non-measurement of other water quality parameters (heavy metals, microbes), and the absence of multivariate analysis to adequately control confounding factors. A pH measurement that is limited to one day is also a limitation, considering that river pH fluctuates depending on the season and anthropogenic activity.

CONCLUSION

This study found that the pH values of Batang Empu River water across the four measurement locations ranged from 6.26 to 6.45. Among the 211 residents assessed, skin hydration levels varied from severe dehydration to excellent hydration. River-water pH was significantly associated with skin hydration levels ($p = 0.02$), whereas age ($p = 0.54$) and sex

($p = 0.67$) were not significantly associated with skin hydration. These findings suggest that bathing-water characteristics may be related to skin hydration among residents who routinely use river water. However, because this study employed a cross-sectional design, measured water pH over a limited observation period, and involved uneven participant distribution across locations, the findings should not be interpreted as demonstrating a causal relationship.

Future studies should employ longitudinal or repeated-measures designs with balanced sampling across bathing locations and conduct water-quality assessments across different seasons and times of day. Additional parameters, including water temperature, hardness, detergent residues, microorganisms, heavy metals, and organic pollutants, should be evaluated alongside skin-surface pH, transepidermal water loss (TEWL), and corneometer-based hydration measurements. Multivariable analyses are also recommended to control for potential confounding factors, including bathing frequency and duration, soap use, moisturizer and sunscreen use, occupation, ultraviolet exposure, fluid intake, age, and sex. Such research would provide stronger evidence for developing community education programs, routine river-water monitoring, and preventive skin-care interventions for populations that depend on untreated river water.

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