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NOT ALL WATER IS EQUAL: THE HIDDEN IMPACT OF DRINKING SOURCES ON MATERNAL HEMOGLOBIN

Rudi Saputra[1]✉, Grace Angelina[2], Syarifah Amira Najla[2], Dzulhannisa Tricindra[2], Rini Wahidatul Ulpah[2], Ahmad Ahsyar Hamri[2], Muhammad Khairul Nuryanto[3], Setyo Nugroho[4], Ratno Adrianto[5]

[1]Faculty of Public Health, Mulawarman University, Samarinda, Indonesia
[2]Medical Doctor Study Program, Faculty of Medicine, Mulawarman University, Samarinda, Indonesia
[3]Faculty of Medicine, Mulawarman University, Samarinda, Indonesia
[4]Regional Technical Implementation Unit of Palaran Health Center, Samarinda, Indonesia
[5]Faculty of Public Health, Mulawarman University, Samarinda, Indonesia

Abstrak

Kualitas air sangat penting bagi kesehatan maternal. Di Indonesia, konsumsi air yang tidak diolah atau berkualitas rendah dapat meningkatkan risiko anemia pada ibu hamil. Penelitian ini menelaah hubungan antara sumber air minum dengan kadar hemoglobin serta mengidentifikasi faktor-faktor yang memengaruhi pemilihan sumber air. Sebuah studi potong lintang terhadap 72 ibu hamil dilakukan di Puskesmas Palaran, Samarinda (Desember 2024–Januari 2025). Data mengenai sosiodemografi dan sumber air minum dikumpulkan melalui kuesioner, sedangkan kadar hemoglobin diperoleh dari catatan laboratorium. Karena distribusi data tidak normal ($p < 0,05$), uji Kruskal–Wallis dengan perbandingan post hoc digunakan. Determinan pemilihan sumber air dianalisis menggunakan regresi logistik multinomial. Sebagian besar responden (76,40%) mengonsumsi air galon isi ulang yang tidak direbus berhubungan dengan kadar hemoglobin yang secara signifikan lebih rendah dibandingkan air kemasan atau air PDAM ($p = 0,002$). Model logistik menunjukkan signifikansi ($\chi^2 = 75,233$, $df = 54$, $p = 0,030$; Nagelkerke $R^2 = 0,811$). Prediktor signifikan terhadap pemilihan sumber air mencakup jumlah kehamilan, riwayat keguguran atau kematian janin, riwayat persalinan, pendapatan rumah tangga, serta tingkat pendidikan ibu dan suami ($p < 0,05$). Konsumsi air galon isi ulang yang tidak direbus berkaitan dengan kadar hemoglobin yang lebih rendah dan risiko anemia yang lebih tinggi. Faktor reproduksi dan sosial ekonomi memengaruhi pemilihan sumber air. Edukasi mengenai penanganan air yang aman dan praktik perebusan air sangat penting untuk meningkatkan kesehatan hematologis ibu hamil.
Kata Kunci: Anemia, Hemoglobin, Ibu Hamil, Sumber Air Minum

Abstract

Water quality is vital for maternal health. In Indonesia, consuming untreated or low-quality water may increase anemia risk in pregnant women. This study examined the relationship between drinking water sources and hemoglobin levels and identified factors influencing water source selection. A cross-sectional study of 72 pregnant women was conducted at Palaran Health Center, Samarinda (Dec 2024–Jan 2025). Data on sociodemographics and drinking water sources were collected via questionnaire, while hemoglobin levels were obtained from laboratory records. Due to non-normal data distribution ($p < 0.05$), the Kruskal–Wallis test with post hoc comparisons was applied. Determinants of water source selection were analyzed using multinomial logistic regression. Most respondents (76.40%) consumed unboiled refilled gallon water, which was associated with significantly lower hemoglobin levels than bottled or PDAM water ($p = 0.002$). The logistic model was significant ($\chi^2 = 75.233$, $df = 54$, $p = 0.030$; Nagelkerke $R^2 = 0.811$). Significant predictors of water source choice included number of pregnancies, abortion or fetal death history, delivery history, household income, mother's and husband's education levels ($p < 0.05$). Unboiled refilled gallon water consumption is linked to lower hemoglobin levels and higher anemia risk. Reproductive and socioeconomic factors influence water source selection. Education on safe water handling and boiling practices is essential to improve maternal hematologic health.
Keywords: *Anemia, Drinking Water Sources, Hemoglobin, Pregnant Women*

INTRODUCTION

Water is the essence of life, yet not all water is created equal. For pregnant women, a group particularly vulnerable to nutritional and environmental stressors, the quality of drinking water is more than just a matter of hydration, as it can shape both maternal and fetal health outcomes (Lestari & Indriani, 2022). Adequate and safe drinking water supports vital physiological processes, whereas contamination or mineral deficiency may silently undermine the body's ability to produce healthy blood cells (Baldi et al., 2020). Hemoglobin, an essential protein responsible for oxygen transport, plays a crucial role during pregnancy in sustaining both maternal well-being and fetal development. A deficiency in hemoglobin, known as anemia, is associated with serious complications such as intrauterine growth restriction, preterm birth, and an increased risk of maternal and neonatal mortality (Ashrafuzzaman et al., 2023).

In Indonesia, anemia remains a persistent public health challenge, particularly among pregnant women. The 2023 Indonesia Health Survey reported an anemia prevalence of 27.7% among expectant mothers, despite showing a 21.2% decrease compared with 2018 figures (Kemkes RI, 2024). The majority of cases are linked to iron deficiency; however, emerging evidence suggests that environmental factors, including drinking water quality, may also play a significant role. The type and source of drinking water, whether tap water, bottled water, or refilled gallon water, can influence hemoglobin levels through variations in mineral composition, iron content, and potential exposure to contaminants such as lead, cadmium, and nitrates (Baldi et al., 2020; Yu et al., 2021).

Heavy metals in drinking water can interfere with iron absorption in the gastrointestinal tract, thereby suppressing hemoglobin synthesis. Conversely, certain water sources with low iron or magnesium content may fail to support adequate erythropoiesis (Abbas et al., 2024; Davidson et al., 2022). Furthermore, waterborne infections, including giardiasis and dysentery, may exacerbate anemia risk by disrupting nutrient absorption (Baldi et al., 2020). Such multifaceted interactions highlight how water quality, often overlooked in discussions of maternal health, may have far-reaching biological consequences.

Preliminary observations at the Palaran Health Center in Samarinda revealed a substantial number of pregnant women with mild to moderate anemia, particularly among those consuming refilled gallon water that had not been boiled. These findings prompted further investigation into whether the choice of drinking water source influences hemoglobin concentration during pregnancy. Therefore, this study aims to examine the relationship between drinking water sources and hemoglobin levels among pregnant women in the Palaran Health Center area.

METHOD

This cross-sectional study was designed to investigate the association between drinking water sources and hemoglobin levels among pregnant women. Data were collected at a single point in time to evaluate the relationship between drinking water quality and maternal hemoglobin concentration. The study was conducted at Palaran Health Center,

Samarinda, Indonesia, from December 2024 to January 2025.

The study population comprised all pregnant women within the catchment area of Palaran Health Center in 2024. A purposive sampling technique was applied with predefined inclusion and exclusion criteria. Eligible participants included pregnant women who underwent hemoglobin examination during their first antenatal visit at Palaran Health Center in 2024, had resided in the study area for at least six months, consumed drinking water from wells, the public water supply (PDAM), bottled water, or refilled gallon water, and provided informed consent to participate. Exclusion criteria encompassed those with chronic conditions such as kidney or liver disease, hematologic disorders, or other systemic illnesses; regular consumption of multivitamins or iron supplements within the previous four months; a history of malaria, helminthic infection, autoimmune disease, or menstrual disorders; frequent consumption of iron-rich foods (e.g., liver or red meat); blood transfusion within the past four months; or a history of recurrent anemia prior to pregnancy.

The minimum required sample size was 72 respondents, determined using Lemeshow's formula for an unknown population, based on the reported prevalence of anemia among pregnant women at Lempake Health Center, Samarinda (24.7%) (Fathoni et al., 2023). The sample size calculation assumed a 95% confidence level (Z = 1.96) and a precision level (d) of 10%.

Data were collected using a structured, self-administered questionnaire distributed via Google Forms. Participation was voluntary and written informed consent was obtained from all participants before data collection. The independent variable was the source of drinking water, categorized as refilled gallon water (unboiled), refilled gallon water (boiled), PDAM water, or bottled water. The dependent variable was the hemoglobin level, obtained from laboratory results during antenatal examinations and expressed in grams per deciliter (g/dL).

Data were organized in Microsoft Excel and analyzed using IBM SPSS Statistics. Descriptive analyses were conducted to summarize participant characteristics, while inferential analyses were performed to test the research hypothesis. Data normality was assessed using the Kolmogorov–Smirnov test, as the sample size exceeded 50. For normally distributed data, differences in mean hemoglobin levels among drinking water source groups were analyzed using a One-Way ANOVA test. When data did not meet normality assumptions ($p < 0.05$), the Kruskal-Wallis test was used as a nonparametric alternative.

For variables showing statistically significant differences, post hoc analyses were performed to identify specific group comparisons contributing to the observed effects. This approach allowed for a detailed interpretation of pairwise differences in hemoglobin levels among different drinking water source groups. A multinomial logistic regression analysis was performed to determine the sociodemographic and reproductive factors associated with drinking water source selection. This study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine,

Mulawarman University, under approval number 169/KEPK-FK/IX/2025.

RESULT AND DISCUSSION

The majority of respondents were housewives (86.10%), with a mean age of 28.85±5.78 years, representing the reproductive age group. On average, respondents had experienced 2.53±1.40 pregnancies, with normal delivery being the most common mode of childbirth (52.80%), followed by cesarean section (19.40%). The mean number of abortions and fetal deaths was 0.24±0.54. The average body mass index (BMI) of respondents was 25.01±5.73 kg/m², indicating a tendency toward overweight status.

In terms of education, most respondents had completed senior high school (41.70%), while the majority of their husbands held a similar level of education (56.90%). Most husbands worked in the private sector (61.10%), with household incomes predominantly ranging between IDR 2,000,000 and 4,999,999 per month (63.90%). Regarding drinking water sources, 76.4% of pregnant women consumed unboiled refilled gallon water. The mean hemoglobin level among all respondents was 11.94±1.31 g/dL, which generally falls within the normal range (Table 1).

The Kolmogorov–Smirnov normality test showed that the data were not normally distributed ($p < 0.05$). Therefore, the Kruskal–Wallis test was applied to compare hemoglobin levels among different drinking water sources. The analysis revealed a statistically significant difference in maternal hemoglobin levels based on the source of drinking water ($p = 0.002$) (Table 2). Post hoc analysis indicated that pregnant women who consumed unboiled refilled gallon water had significantly lower hemoglobin levels compared to those who consumed bottled water. In contrast, no significant differences were observed among respondents who consumed boiled refilled water, bottled water, or PDAM water (Figure 1). These findings suggest that the consumption of unboiled refilled gallon water may increase the risk of anemia during pregnancy.

As shown in Table 3, several factors were significantly associated with drinking water source selection. These included the number of pregnancies ($\chi^2 = 11.743$, $p = 0.008$), number of abortions or fetal deaths ($\chi^2 = 9.433$, $p = 0.024$), and delivery history ($\chi^2 = 12.179$, $p = 0.007$). Socioeconomic factors such as household income ($\chi^2 = 22.880$, $p = 0.029$), mother's education level ($\chi^2 = 30.109$, $p = 0.003$), and husband's education level ($\chi^2 = 25.437$, $p = 0.013$) also showed significant associations with water source preference.

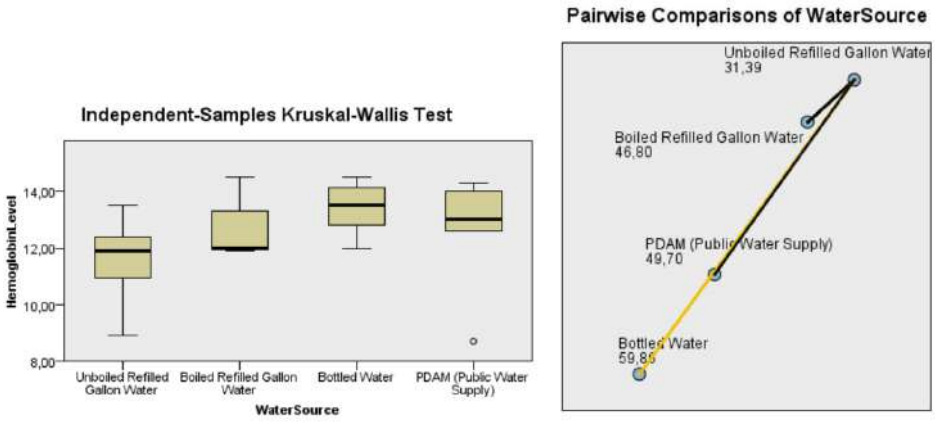
In contrast, mother's occupation ($\chi^2 = 3.368$, $p = 0.338$) and husband's occupation ($\chi^2 = 5.397$, $p = 0.494$) were not significant predictors in the model. These findings suggest that reproductive experience and educational attainment play a more substantial role in determining household decisions regarding drinking water sources than occupational factors. The overall model was statistically significant ($\chi^2 = 75.233$, $df = 54$, $p = 0.030$), with a Nagelkerke R^2 value of 0.811, indicating a strong explanatory power of the independent variables on water source choice.

Table 1. Sociodemographic and Clinical Characteristics of Pregnant Women

Characteristic	Frequency (n = 72)	Percentage (%)	Cumulative Percentage (%)
Age (years)	28.85±5.78		
Number of Pregnancies	2.53±1.40		
Number of Abortions and Fetal Deaths	0.24±0.54		
Delivery History			
Never Given Birth	20	27.80	27.80
Normal Delivery	38	52.80	80.60
Cesarean Section	14	19.40	100.00
BMI (kg/m^2)	25.01±5.73		
Mother's Occupation			
Housewife	62	86.10	86.10
Others	10	13.90	100.00
Husband's Occupation			
Civil Servant	7	9.70	9.70
Private Employee	44	61.10	70.80
Entrepreneur	21	29.20	100.00
Household Income (IDR)			
<500,000	1	1.40	1.40
500,000-999,999	2	2.80	4.20
1,000,000-1,999,999	8	11.10	15.30
2,000,000-4,999,999	46	63.90	79.20
5,000,000-20,000,000	15	20.80	100.00
Mother's Education Level			
Elementary School or Equivalent	8	11.10	11.10
Junior High School or Equivalent	15	20.80	31.90
Senior High School or Equivalent	30	41.70	73.60
Diploma	4	5.60	79.20
Bachelor's Degree	15	20.80	100.00
Husband's Education Level			
Elementary School or Equivalent	6	8.30	8.30
Junior High School or Equivalent	9	12.50	20.80
Senior High School or Equivalent	41	56.90	77.80
Diploma	4	5.60	83.30
Bachelor's Degree	12	16.70	100.00
Drinking Water Source			
Unboiled Refilled Gallon Water	55	76.40	76.40
Boiled Refilled Gallon Water	5	6.90	83.30
Bottled Water	7	9.70	93.10
PDAM (Public Water Supply)	5	6.90	100.00
Hemoglobin Level (g/dL)	11.94±1.31		

Table 2. Results of the Kruskal–Wallis Test Examining the Association Between Drinking Water Sources and Hemoglobin Levels Among Pregnant Women

Water Source	Mean Rank	p value
Unboiled Refilled Gallon Water	31.39	0.002
Boiled Refilled Gallon Water	46.80	
Bottled Water	59.86	
PDAM (Public Water Supply)	49.70	



Each node shows the sample average rank of WaterSource.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Unboiled Refilled Gallon Water-Boiled Refilled Gallon Water	-15,409	9,766	-1,578	,115	,688
Unboiled Refilled Gallon Water-PDAM (Public Water Supply)	-18,309	9,766	-1,875	,061	,365
Unboiled Refilled Gallon Water-Bottled Water	-28,466	8,390	-3,393	,001	,004
Boiled Refilled Gallon Water-PDAM (Public Water Supply)	-2,900	13,223	-,219	,826	1,000
Boiled Refilled Gallon Water-Bottled Water	-13,057	12,242	-1,067	,286	1,000
PDAM (Public Water Supply)-Bottled Water	10,157	12,242	,830	,407	1,000

Figure 1. Post Hoc Analysis Showing Differences in Hemoglobin Levels Across Drinking Water Sources

Table 3. Results of Multinomial Logistic Regression Analysis on Factors Influencing Drinking Water Source Selection Among Pregnant Women

Variable	Chi-square	df	p-value
Number of Pregnancies	11.743	3	.008
Number of Abortions and Fetal Deaths	9.433	3	.024
Delivery History	12.179	3	.007
Mother's Occupation	3.368	3	.338
Husband's Occupation	5.397	6	.494
Household Income	22.880	12	.029
Mother's Education Level	30.109	12	.003
Husband's Education Level	25.437	12	.013
Overall Model	75.233	54	.030
Nagelkerke R^2	.811		

This study revealed a significant association between drinking water sources and hemoglobin levels among pregnant women in the Palaran Health Center area. The majority of respondents (76.40%) consumed unboiled refilled gallon water and this group exhibited lower average hemoglobin levels compared to those consuming bottled or PDAM water. The Kolmogorov-Smirnov test indicated that the data were not normally distributed ($p < 0.05$), leading to the use of the Kruskal-Wallis test, which demonstrated a significant difference in hemoglobin levels among water source groups ($p = 0.002$). Post hoc analysis further confirmed that pregnant women who consumed unboiled refilled gallon water had significantly lower

hemoglobin concentrations compared to those who drank bottled water. These findings suggest that consuming unboiled refilled gallon water may increase the risk of anemia during pregnancy.

These findings align with previous studies reporting that untreated drinking water poses a risk of bacterial and heavy metal contamination, both of which can inhibit iron absorption in the gastrointestinal tract and interfere with hemoglobin synthesis (Fahimah et al., 2024; Lin et al., 2022; Zhang et al., 2023). Tambunan, et al. (2024) similarly found that poor water quality, particularly from unboiled refilled gallon sources, was associated with lower hemoglobin levels among school-aged children in Palangka Raya. These results reinforce the importance of water quality in preventing anemia, not only in children but also in pregnant women. Abbas, et al. (2024) further demonstrated that exposure to heavy metals such as lead and cadmium in drinking water significantly reduced hemoglobin concentrations. Refilled water that is not properly treated often lacks adequate filtration or mineral enrichment processes, allowing contaminants to persist and increasing the risk of anemia in expectant mothers.

In contrast, properly processed drinking water such as bottled water typically contains essential minerals like iron and magnesium, which play important roles in erythropoiesis and maintaining hemoglobin levels (Ding et al., 2021). This supports the hypothesis that mineralized or purified water may contribute to better hematologic health among pregnant women. The present study also found that respondents who boiled refilled gallon water before consumption had relatively higher hemoglobin levels compared to those who did not. This finding is consistent with Kekes, et al. (2023), who emphasized that hygienic water handling behaviors, including boiling before consumption, are critical for preventing waterborne infections and nutrient malabsorption that can contribute to anemia.

Further analysis using multinomial logistic regression identified key factors influencing the choice of drinking water source. The overall model was significant ($\chi^2 = 75.233$, df = 54, $p = 0.030$) with a Nagelkerke R^2 of 0.811, indicating that sociodemographic and reproductive variables strongly explained variations in water source selection. Significant predictors included the number of pregnancies ($p = 0.008$), history of abortion or fetal death ($p = 0.024$), delivery history ($p = 0.007$), household income ($p = 0.029$), and the education level of the respondent and her husband ($p = 0.003$ and $p = 0.013$, respectively). These results highlight that women's reproductive experiences and socioeconomic conditions substantially shape household water consumption patterns.

Socioeconomic status, particularly education and income, plays a critical role in determining access to and preference for safer water sources. Pregnant women with higher education or income levels are more likely to understand the importance of water hygiene and to afford bottled or PDAM water. This observation is in line with Ningtyas & Asyifiradayati (2024), who found that education level is strongly correlated with health-related behaviors, including the use of safe drinking water. Education enhances health literacy and risk

perception, which directly influence preventive household practices.

Reproductive history also emerged as a determinant of drinking water source choice. Women with multiple pregnancies or a history of adverse pregnancy outcomes, such as abortion or fetal death tended to adopt safer behaviors, such as boiling refilled water or switching to PDAM or bottled sources. This behavioral adaptation may reflect increased health awareness after prior pregnancy complications, consistent with findings by Herzog-Petropaki, et al. (2022), who reported that past adverse experiences often motivate positive changes in maternal health behaviors. In contrast, occupational factors were not significantly associated with water source selection, suggesting that education and income exert stronger influence than employment type. This finding underscores that socioeconomic and experiential factors, rather than occupation alone, drive maternal decision-making regarding water safety.

Despite its valuable insights, this study has several limitations. The cross-sectional design precludes establishing causal relationships between drinking water sources and hemoglobin levels. Additionally, laboratory testing of water samples was not conducted, which limits the ability to directly identify contaminants or mineral deficiencies. The study was also confined to one health center area, potentially limiting the generalizability of the findings. Future studies should incorporate laboratory-based water quality analysis and longitudinal designs to better understand causal pathways between environmental factors and maternal anemia.

CONCLUSION

This study highlights that not all water sources offer equal health benefits for pregnant women. Those who consumed unboiled refilled gallon water were found to have lower hemoglobin levels than those who drank bottled or PDAM water, suggesting a higher vulnerability to anemia. Beyond water quality, maternal education, family income, and reproductive experiences also shaped the choice of drinking water source, reflecting how knowledge, resources, and lived experiences influence everyday health behaviors.

These findings emphasize the importance of safe water practices as an integral part of maternal health care. Promoting simple preventive actions, such as boiling water before consumption, choosing trusted water sources, and enhancing awareness about water hygiene can significantly reduce the risk of anemia and improve maternal well-being. Ensuring that every mother has access to safe and clean water is not only a matter of public health but also a foundation for healthier pregnancies and stronger future generations.

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