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RESEARCH ARTICLE

LINKING WATER QUALITY TO DIARRHEAL INCIDENTS: A META-ANALYSIS FOR IMPROVED WATER RESOURCE MANAGEMENT

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ABSTRACT

Water quality typically determines diarrhea incidence rates, but findings vary widely across studies. This study want to synthesize those findings to find the relationship between water quality and diarrhea incidence. Method which utilized in this meta-analysis following PRISMA guidelines. The included study is observational studies (both case-control and cross-sectional studies) from databases including PubMed, ScienceDirect, Scopus, and Google Scholar. Only studies that report adjusted odds ratios (aOR) are included. Random-effects model was applied due to high heterogeneity. The results showed that water quality and diarrhea incidence are not significant (aOR = 0.63; 95% CI: 0.23–1.74; I^2 = 91.4%). Same results also found in subgroup analyses. This means that the relationship between water quality and diarrhea is not simple as it seems. Other factors such as sanitation, hygiene habits, and food contamination also influence diarrhea. Therefore, improving only on water quality to reduce diarrhea may not be sufficient. More integrated approach is needed to address diarrhea sustainably.

KEYWORDS

Diarrhea, Water Quality, Meta-Analysis, Public Health, Risk Factors

1. INTRODUCTION

Diarrhea is a disease that commonly affects children under five years (Ejiohuo et al., 2025; Uho et al., 2024). Diarrhea can be caused by various harmful microorganisms, including bacteria, viruses, and parasites (Aini, 2016; Folarin, 2013; Rahmawati et al., 2023). Thousands hundreds of young children die cause diarrhea (Geremew et al., 2024; Hubbard et al., 2025). Diarrhea also causes malnutrition, stunts children's growth, and makes them more susceptible to other infections (Khairunnisa et al., 2020; Leonard et al., 2021). In Indonesia, diarrhea still persistent in public health problem. Although the incidence of diarrhea has decreased, this trend does not necessarily reflect the true situation (Sabira, 2025). One environmental factor behind diarrhea is access to clean water. Clean drinking water not only hydrates the body but also prevents the spread of waterborne diseases (Chavez et al., 2020; Fibriana et al., 2021; Sarma et al., 2021). Global data report that access to clean water is still big challenge in the worlwide. Billions people have unmet needs of clean water and many still rely on water sources contaminated with feces (UNICEF, 2017). More than 2 billion people face water scarcity, and 1.7 billion are forced to use contaminated water. This situation increases the risk of exposure to harmful microorganisms that causing diarrheal.

Water quality is influenced by various aspects, including physical, chemical, biological, and radiological factors (Ministry of Health of the Republic of Indonesia, 2023). From these factors, microbiological factor serve as the most significant role in the transmission of diarrheal diseases as water can act as a carrier for pathogens cause gastrointestinal infections. However, water quality is not always as determining factor of diarrhea cause other factors can influence diarrhea too (Haryono et al., 2024; Irawan and Hastuty, 2022).

Many has shown that improving water, sanitation and hygiene (WASH) can reduce diarrheal disease in low- and middle-income countries (Levallois and Villanueva, 2019; Ross et al., 2023). If looking specifically at the role of water quality, the findings are not always align. Some studies found clear link between poor water quality and high risk of diarrhea. Meanwhile, another studies reveal that water quality may be not major determinant compared to factors like contaminated food, poor handwashing habits, or environmental exposures (Eshete et al., 2020).

Differences in the way previous studies conducted also make the results difficult to interpret. It is because every researcher has their own way to define and measure water quality, assess health impacts, and control other contributing factors. Indirect indicators like turbidity or coliform levels are often used but may not accurate to reflect presence of disease-causing pathogens. The complexity of fecal-oral transmission also make it's clear that water is only one part of the problem from other interrelated factors that play a role in the spread of diarrhea.

We need more comprehensive approach to better understand the relationship between water quality and diarrhea. Meta-analysis offer useful solution by integrating findings from multiple studies and make it easier to identify patterns and variations that can't see in separate studies systematically. Benefit for manage water resources is also can obtained from these findings. The benefit is achieving Sustainable Development Goals (SDGs), especially Goal 3 about good health and well-being and Goal 6 concern on clean water and sanitation (Lingkungan et al., 2022).

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Even though there is a massive research about water quality and diarrheal disease, but there's still a gap that connect public health outcomes with water resource management. The existing research only focus on one side, either looking at epidemiological links or technical side of water quality without explore the combining of these two in policy and practice. So, this study have an urgency to bridge these areas and offer recommendations for more integrated interventions.

Novelty that offers in this study is examining relationship between water quality and diarrhea through meta-analysis that goes beyond measuring epidemiological effects and links these findings to water resource management. Cause many prior studies have examined water quality or diarrhea separately. This study connect it with the importance of public health and environmental management as part of the same picture. It also combines results from different regions and study designs with adjusted odds ratios (aORs) to provide deep understanding of complexity this relationship. This study is not only valuable for academic but also serves as practical reference for developing sustainable water management policies. The research will assess the relationship between water quality and diarrheal incidence systematically through meta-analysis of observational studies. It have implications for improving water resource management and strengthening public health interventions more effective and sustainable.

2. Method

Meta-analysis approach is the method used with following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The process was divided into four main stages: searching for relevant studies, then filtering them, checking eligibility, and finally selecting those suitable for quantitative analysis.

First, articles are searched from several big databases including PubMed, ScienceDirect, Scopus, and Google Scholar using some of keywords and Boolean operators such as ("water quality" OR "drinking water") AND ("diarrhea" OR "diarrhoeal disease") with range between 2005 and 2025.

Next step is screening stage to remove duplicate articles. After screening we check the eligibility by reviewe the full text carefully with specific criteria. Articles with observational research (case-control or cross-sectional) about water quality and diarrhea, report adjusted odds ratios (aOR), and published in English will included. If they didn't have full text, didn't report aOR, used non-observational designs, or didn't focus on water quality or diarrhea will excluded.

Selected studies extracted using standard form like author, year, country, study design, sample size, population, type of water exposure, comparison group, outcomes, and aOR report with 95% confidence intervals. Diarrhea is defined as having loose or watery stools three or more times a day. Water quality referred to the physical, chemical, and microbiological characteristics of drinking water.

The quality of each study was assessed using a checklist from the Joanna Briggs Institute (JBI) (Moola et al., 2016, 2017). It allows researchers to assess goodness of the methods used, the potential for bias, and the relevance of study population being studied. Data then analyzed by Review Manager (RevMan 5.3). Pooled effect size is calculated using adjusted odds ratios (aOR) with 95% confidence intervals. The level of variation (heterogeneity) is measured by I^2, where values above 50% indicated moderate to high differences between studies.

Subgroup analysis is took by grouping studies based on their design (case-control vs. cross-sectional) to better understand these differences. Publication bias also checked visually using funnel plots. If the plot looked symmetrical pattern, it means the potential bias is low. All analyses take significance level at $p < 0.05$. The final results is presented by forest plots to illustrate the overall effect size and funnel plots to assess potential bias (Murti, 2020).

3. Result and Discussion

3.1 Results

Selection process of this study followed PRISMA guidelines. At the beginning, 634 articles were identified from various electronic databases. After removing duplicate records, 378 articles were left for further screening. Title and abstract screening excluded 257 articles due to irrelevance, non-observational design, non-English language, or lack of full text.

A total of 121 full-text articles were assessed for eligibility, of which 115 were excluded due to not reporting adjusted odds ratios, inappropriate analytical methods, or not focusing on water quality and diarrheal outcomes. Finally, six studies met the inclusion criteria and were included in the meta-analysis presented in figure 1.

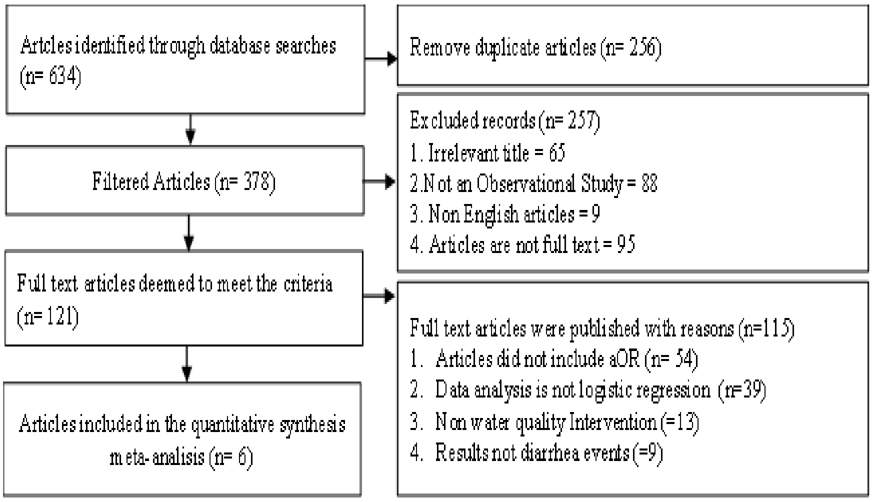

Figure 1: PRISMA flow chart

The six included studies were conducted across four countries: Indonesia, Ethiopia, Zimbabwe, and Nigeria. The study designs consisted of four case-control studies and two cross-sectional studies. Sample sizes ranged from 132 to 280 participants. All studies examined the association between water quality and diarrheal incidence using adjusted odds ratios (aOR), with varying effect estimates across settings.

Table 1: Characteristic of Study

Author	Country	Study Design	Sample Size	P (Population)	I (Intervention)	C (Comparison)	O (Outcome)	aOR (CI 95%)
(Saboksal et al. 2020)	Etiopia	Case control	198	People with diarrhea	Water quality	Not water quality	Diarrhea	1.22 (0.48-3.09)
(Rahmawati et al., 2023)	Indonesia	Case control	280	People with diarrhea	Water quality	Not water quality	Diarrhea	0.27 (0.15-0.49)

Table 1 (Cont): Characteristic of Study

(Maponga et al., 2013)	Zimbabwe	Case control	218	People with diarrhea	Water quality	Not water quality	Diarrhea	0.44 (0.24-0.82)
(Folarin et al, 2013)	Nigeria	Case control	132	People with diarrhea	Water quality	Not water quality	Diarrhea	0.13 (0.04-0.42)
(Yuniarto, 2005)	Indonesia	Cross-sectional	132	People with diarrhea	Water quality	Not water quality	Diarrhea	2.26 (2.02-2.51)
(Aini et al, 2016)	Indonesia	Cross-sectional	252	People with diarrhea	Water quality	Not water quality	Diarrhea	1.15 (0.45-2.96)

This research was conducted quantitatively and qualitatively, as can be seen in Table 2 and Table 3 below. The methodological quality of the included studies was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist. The results indicated that most studies fulfilled the majority of quality criteria, with total scores ranging from 23 to 24 for case-control studies and 16 for cross-sectional studies. Overall, the included studies were considered to have good methodological quality and acceptable validity (Moola et al., 2016, 2017).

Table 2: Quality Assessment of Case-control Study Design Articles on Risk Factors of Water Quality on Diarrhea Incidence

No	Question	**Publication (Author and Year)**			
		Soboksal et al. (2020)	Rahmawati et al. (2023)	Maponga et al. (2013)	Folarin et al. (2013)
1	Does the case-control study clearly answer the clinical problem?	2	2	2	2
2	Did the researchers use the correct method to answer the research question?	2	2	2	2
3	Are the cases selected in the right way?	2	2	2	2
4	Are the controls selected in the correct manner?	2	2	2	2
5	Is exposure measured accurately/correctly to prevent/minimize bias?	2	2	2	2
6	Beyond the exposure that has been studied, has the researcher taken into account the influence of all potential confounders in the study?	2	2	2	2
7	Did the researcher control for the influence of all potential confounders in the data analysis?	2	2	2	2
8	Is the magnitude of the exposure effect determined?	2	2	2	2
9	What is the precision of the exposure effect estimate?	1	2	2	2
10	Are the results reliable?	2	2	2	2
11	Are the results applicable to the target / local population?	2	2	2	2
12	Are the results of the study compatible with other available evidence?	2	2	2	2
	Total	23	24	24	24

Note: 2=Yes; 1=Can't tell; 0=No

The forest plot presented in Figure 2 illustrates the pooled association between water quality and diarrheal incidence. The overall analysis showed that water quality was not significantly associated with diarrhea (aOR = 0.63; 95% CI: 0.23–1.74). The confidence interval crossed 1, indicating that the association was not statistically significant.

Table 3: Article quality assessment with cross-sectional study

No	Question	Publication (Author and Year)	
		Yuniarto et al. (2005)	Aini et al. (2016)
1	Are the criteria for inclusion in the sample clearly defined?	2	2
2	Are the research subjects and their settings described in detail?	2	2
3	Was exposure measured validly and reliably?	2	2
4	Are objective standards criteria used to measure the condition?	2	2
5	Are cofounding factors identified?	2	2
6	Were strategies to deal with confounding factors stated?	2	2
7	Were the outcomes measured validly and reliably?	2	2
8	Is the statistical analysis used appropriate?	2	2
	Total	16	16

Note: 2=Yes; 1=Can't tell; 0=No

Subgroup analysis revealed differing trends based on study design. In case-control studies, water quality showed a protective effect against diarrhea (aOR < 1), with an estimated effect of 0.38, whereas in cross-sectional studies, water quality was associated with an increased risk of diarrhea (aOR = 1.91). Evn so, neither of the subgroup results reached statistical significance.

Studies that included in analysis showed high heterogenity (I^2 = 91.4%). Due to significant differences between studies, so random-effects model is used to ensure the analysis remains relevant to diverse conditions. This variation is may be influenced by differences in study design, population, or methods..

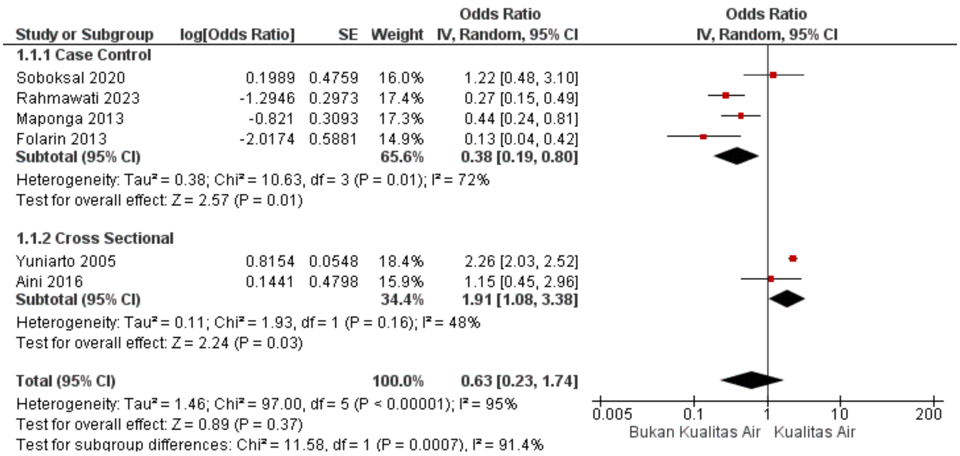

Figure 2: Forest Plot of Water Quality against Diarrhea Incidence

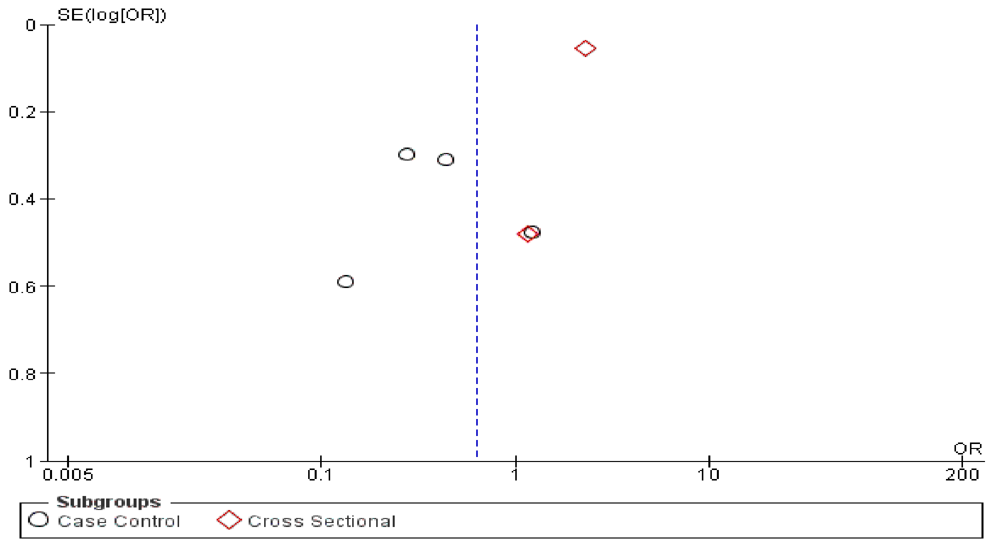

Figure 3: Funnel plot of Water quality against Diarrhea Incidence

The funnel plot in Figure 3 is look symmetrice which means that publication bias is minimal. It can be seenthat points in the both side are same totally. But, we need carefully to take an interpretation of this. Since

only six studies are included, the funnel plot may not be reliable to detect potential bias.

4. Discussion

This meta-analysis want to evaluate whether quality of eater is linked to diarrheal cases indifferent observational studies. Pooled results showed that there isn't a statistically significant relationship (aOR = 0.63; 95% CI: 0.23–1.74). And the studies varied quite a lot from each other (I^2 = 91.4%). It means that water quality and diarrhea is'nt something absolute because it depends on the context being studied

One reason for the inconclusive results may be differences in water quality measurement methods used in each study. The measurements may not fully represent the true risk and make the finding is mixed.

Diarrhea is not only spread through water, but can also be transmitted through the fecal-oral route by contaminated food, dirty hands, and environmental surfaces. One study found that factors like poor sanitation and hygiene may have a bigger role than water quality (Eshete et al., 2020).

The results differed slightly depending on the type of study. Case-control studies show that better water quality offered protection, while cross-sectional studies showed a higher risk. However, both of them are insignificant statistically. May be it comes from methodological limitations such as recall bias in case-control or cross-sectional studies which cannot confirm a cause-and-effect relationship.

High heterogeneity value (I^2 = 91.4%) showed that the analyzed studies are highly diverse in terms of location, population characteristics, measurement methods, and environmental conditions. It emphasizes that local context significantly influence understanding of the relationship between water quality and health. This means that a single aggregated result may not fully reflect the real situation.

These findings claim that improvement on water quality alone is not enough to reduce diarrhea cases. Need more efforts continued implementation such as providing clean water, improving sanitation, promoting hygiene habits, and maintaining food safety.

All of these is known as WASH (Water, Sanitation, and Hygiene) that will effective if implemented together than separately (Levallois and Villanueva, 2019; Ross et al., 2023). This also relates to get Sustainable Development Goals (SDGs) at Goal 3 (Good Health and Well-Being) and Goal 6 (Clean Water and Sanitation). If policies focus only on provide clean water without keep good sanitation and hygiene, their impact on disease reduction will be minimal.

Several limitations that acknowledged are the number of studies that used small (n = 6). Another one is the high heterogeneity value, making the combined results less accurate. Observational studies make causality not clear. Differences in measurement of water quality and the presence of other factors that influence the results.

Future research should be used standard measurement of water quality, involve larger diverse samples, and employ longitudinal or experimental design. Lastly, it is important to think include environmental, behavioral, and socioeconomic factors together to obtain more understanding of diarrhea transmission.

5. Conclusion

The findings showed water quality isn't linked to diarrheal cases significantly (aOR = 0.63; 95% CI: 0.23–1.74). Heterogeneity also have a high value (I^2 = 91.4%). These findings suggest that water quality isn't the main driver of diarrheal disease.

Other factors like sanitation, hygiene habits, contaminated food, and environmental exposure may have a bigger role. It means that improvement on water quality might not have strong impact unless it's combined with other public health efforts.

From water management perspective, this points need to be integrated with another approach. Efforts to improve water quality should go hand in hand with better sanitation, hygiene practices, and environmental health.

These efforts are more likely reduce diarrheal disease effectively. Going forward, more research still needed with more consistent methods. So, we can get clearer evidence and support evidence-based policies.

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