RECHARGE

Resilience in a Changing Climate: Advancing Research on Groundwater for Equity

Policy Brief

November 2024

Groundwater Quality Risks in Indonesian Cities

Where are the riskiest locations for urban households in Indonesia that rely on self-supplied groundwater?

Cities with a greater proportion of households using wells compared to bores, and where population density is highest, have higher risk of faecal contamination of their water supply.

In 2020, an estimated 61% of households in Indonesian cities rely on self-supplied water for household use with 24% of households using groundwater as their main drinking water source (SUSENAS). Multiple studies across Indonesia have sampled water from these sources and found a range of contaminants in many of the sources sampled. The amount of contamination varies by location and over time. Faecal contamination is one of the most frequently found types of contamination and is the focus of this policy brief.

Providing piped water to these households is a large investment that will take many years, so this research aims to assist in setting priorities for where piped water should be provided first and to provide information to assist decision making on the types of investment that reduce health risk.

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Key Messages

- Self-supplied groundwater is the main drinking water source for 24% of people in urban areas of Indonesia. In a national survey, 21% of these households' water source had E coli levels >100 CFU/100mL (considered high risk).
- Wells are more than twice as likely to have high-risk water as boreholes. However, encouraging households to shift from wells to bores may undermine programs to provide and have people connect to improved piped water services.
- Groundwater under cities is a valuable, climate-resilient resource, but data important to managing groundwater is either missing or hard to access in most cities.
- Sanitary inspection of self-supply sources might be a useful interim way to encourage households to improve their water supply and reduce risks as well as raise awareness about risks.
- The benefit in terms of groundwater protection from "improving" on-site sanitation in dense urban areas is unproven and more research is needed.

Methodology

- Literature review identified the key factors that affect the transmission of pathogens from human excreta to groundwater sources in urban environments such as those in Indonesia.
- A range of publicly available data was used to create indicators for these key factors and generate a microbial risk index. This included types of water sources, population density, rainfall, and geology. Reliable Information on other factors was not found, most notably depth to groundwater, which is not well documented in Indonesia.
- SKAM-RT survey, a national water quality that sampled around 21,000 households across Indonesia, including 4,188 households located in cities (kota). Of those households in cities, 921 (22%) used groundwater as their main drinking water source. Data on a total of 622 of those urban households using groundwater was able to be used to calibrate the risk index.

The RECHARGE (Resilience in a Changing Climate: Advancing Research on Groundwater for Equity) project used an understanding of the sources and pathways by which pathogens enter groundwater supplies combined with existing data to create a "microbial risk index" for cities across Indonesia. This microbial risk index was created using the extensive nationally representative water quality (SKAM-RT) survey of 2020. The analysis of this and other data suggests further policy recommendations to assist in progress towards safe water for all households in urban Indonesia.

Policy Recommendation 1

Priority for piped water should be given to cities with higher proportions of households using wells as their drinking water source.

An analysis of the data collected in the SKAM-RT 2020 survey clearly shows that wells (shallow dug wells, typically 1 to 10m deep with protective plaster only in upper portion) exhibit higher levels of *E coli* contamination than bores (deeper drilled wells, typically 10 to 80m deep usually with proper protective casing). This difference exists even when other factors are adjusted for. Water from a well is more than twice as likely to have E coli >100 CFU/100 mL (high risk) compared to water from a borehole. This finding is consistent with the literature and can be put down the following reasons:

- Wells generally have more pathways that contamination can enter compared to bores.
- Wells typically access shallower, and hence more contaminated groundwater than bores.

This finding does not, however, suggest that households should be encouraged to replace wells with more expensive boreholes. Boreholes may still exhibit high levels of contamination as their construction reduces, but does not eliminate, the associated health risk, nor does it address other risks such as land subsidence. Additionally, if households were to invest in converting wells to boreholes as an interim measure, they may be less likely to connect to piped water from their PDAM (state-owned water company), which is the Government's preferred pathway to providing regulated, high-quality water services in urban areas.

Existing piped water services in urban Indonesia often fail to provide safely managed water service, with 55% of the piped water samples having *E coli* > 0 compared to 61% for bores and 78% for wells. Therefore, there is a need to enhance both the water quality and reliability of piped services, and this aligns with Government policy.

Policy Recommendation 2

A risk ranking tool can assist in identifying cities where the greatest benefit could be achieved by providing pipe water.

The research started with an understanding of how pathogens enter groundwater supplies in urban areas of Indonesia as shown in Figure 1.

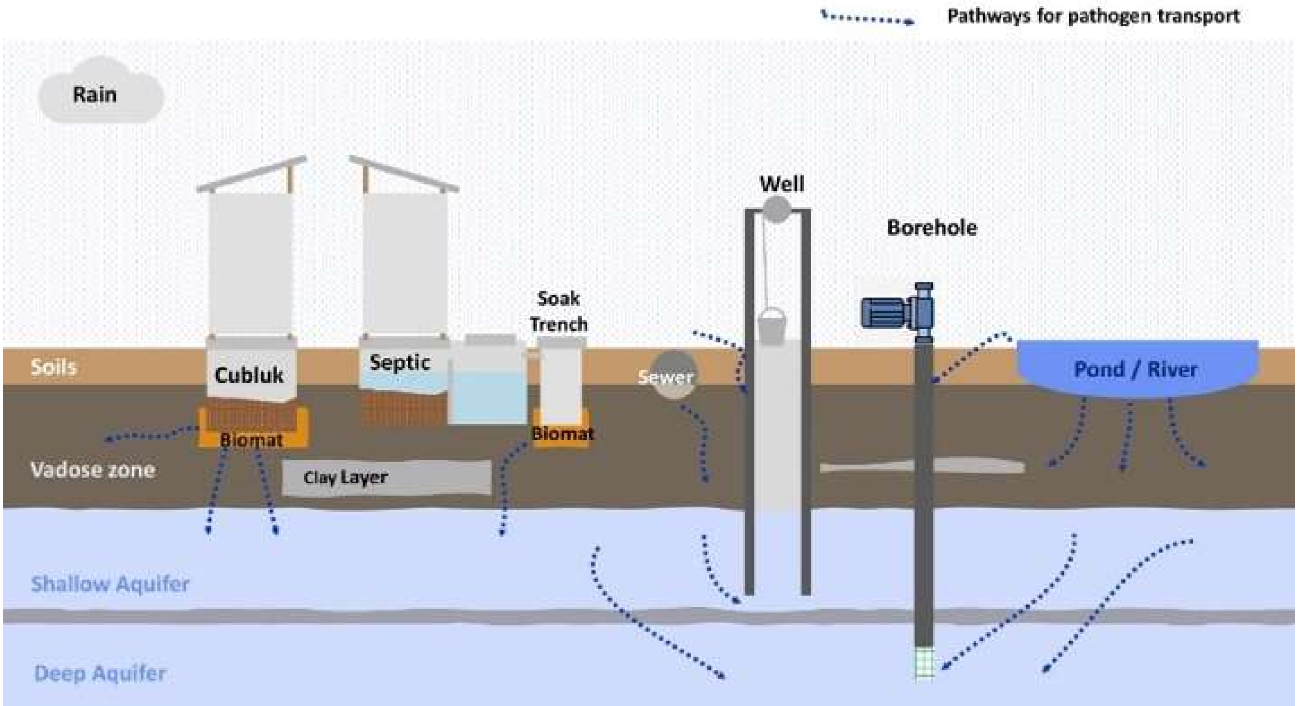

Figure 1 Conceptual Diagram

This understanding was used to identify factors expected to affect the likelihood of finding *E. coli* in groundwater sources. Data on these factors was sought and a microbial risk index calculated from the following factors:

- Type of water source.
- Population density.
- Geology (type of rocks/soils).
- Rainfall

This index does not include further additional factors that might also affect risk, notably depth to groundwater and the sanitary condition of the water sources, due to a lack of data, so does not explain all the variability in measured *E. coli* results. Rather, it is the best risk index that can be developed with current available data.

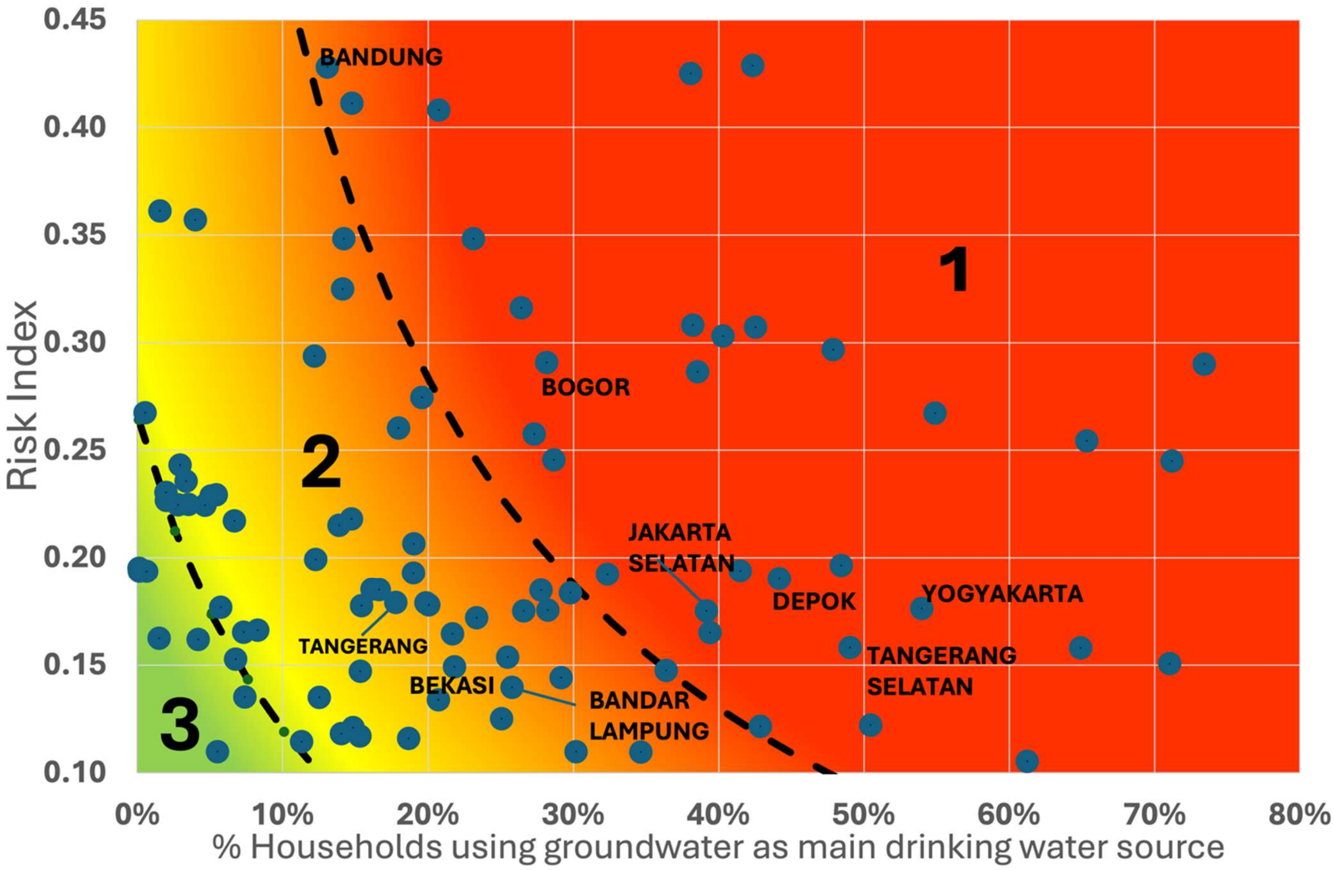

Figure 2 Risk Diagram

A plot of this index against the proportion of households in a city that use groundwater as their drinking water source is shown in Figure 2. Cities in the top right of the diagram have both a high proportion of their population using groundwater for drinking and are more likely to have higher *E coli* in the groundwater. We have marked the graph in three zones, 1 being highest priority, 2 medium priority and 3 the lowest priority. The colouring indicates that due to uncertainty in the modelling, there is not a hard boundary between zones. Cities with large populations that are in the highest priority zone include Depok, Jakarta Selatan, and Yogyakarta. More detail on the assessment method is provided in a separate "Technical Note".

It would be possible to use this approach to identify which specific areas within a city have higher risk than other areas. This would require higher resolution data likely available at local level, including proportions of households using wells at a "*kelurahan*" or "*desa*" level.

Policy Recommendation 3

The current systems to monitor and record data on groundwater should be improved.

It is clear from the literature that the depth to groundwater is a critical factor protecting groundwater from contamination. The depth required to remove *E coli* to below detection level depends on the nature of the ground material, but in most conditions in Indonesia 10m would be adequate. Exceptions would be where fractured rock or very coarse material exists. However, we were not able to find reliable information on groundwater depths (especially shallow aquifers) generally across Indonesia.

Currently several government agencies monitor aspects of groundwater, including Ministry of Health, who have undertaken surveys including the SKAM-RT program that covers drinking water quality, and the Geological Agency within the Ministry of Energy and Mineral Resources Groundwater. Under the Geological Agency several centres have roles involving groundwater, with the Groundwater Conservation Centre being tasked with monitoring groundwater levels. This centre has real time monitoring of 220 bores and wells across west Java focused on deep groundwater monitoring. Additionally, there are local initiatives such as that undertaken by the Jakarta Special Regional Environmental Service. Bringing these initiatives together and expanding them to achieve a more comprehensive monitoring system covering depths and quality would have wider benefits than just improving this risk assessment, as groundwater is an important climate-resilient source of water for many Indonesian cities, provided it is managed sustainably.

Policy Recommendation 4

Sanitary inspections of wells and boreholes could be used to help reduce risk.

Transmission of pathogens into groundwater from nearby sanitation systems is not the only contamination pathway. Wells and boreholes rely on good construction and maintenance of barriers (borehole casing, plinth, and drainage around well head etc.) to ensure surface contamination does not enter the well or bore water. Literature supports the view that contamination entering a well or bore from the surface can be significant. The SKAM-RT survey included a set of questions about each household's bore or well where "yes" answers indicated a fault or a potential source of pollution. The Technical Note provides detail on the questions asked and which ones were most associated with high *E coli.*

By adding the number of "yes" answers we obtained a "sanitary score" for the water source. Only questions that a household could act upon were included in this score (so, the proximity of neighbour's sanitation system was left out).

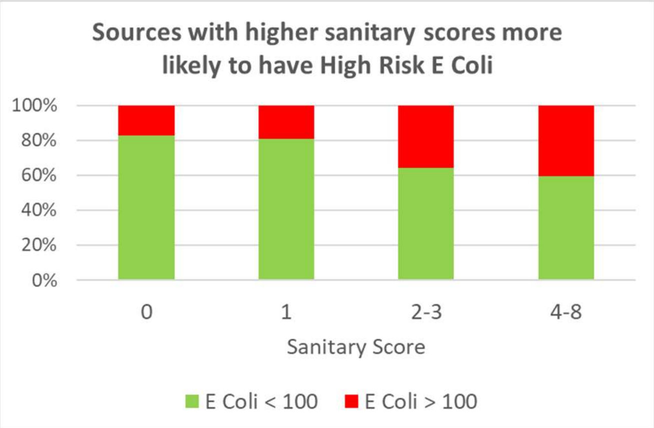

Figure 3 Sanitary Score & Proportion High Risk E coli

Statistical analysis shows that, after removing confounding factors, a household with three detected faults is 1.6 times more likely to have *E. coli* > 100 CFU/100mL (high risk) than a household well with no faults.

The association between water source sanitary inspection scores and *E. coli* is clear for wells but not so clear for bores, possibly because it is more difficult for an external inspection to see faults in the barriers of a bore.

For both bores and wells, the questions most associated with high *E coli* are those asking about the presence of standing water and/or poor condition of ring around the well.

One of the questions asks if a sanitation system is less than 15m from the bore or well. The answer to this question had no significant association with high *E coli*, which fits with academic literature that says horizontal separation distances are not an effective way to manage risks of contamination. The model predicts the risk of high *E coli* approximately doubles for every 10,000 people/km^2 increase in population density. It is however difficult to use this to set a "safe" population density or "safe" distance between houses. It is also likely that at lower population densities other sources of contamination such as domestic livestock become more common and act against the benefit of lower population density.

The World Health Organisation has recently updated their guidance on inspections of water sources and these cover self-supply situations and may be useful in future inspections. Work has also been done on an inspection tool for household sanitation systems (not water source) and this is sitting with the Ministry of Health. The issue of how much the quality of a sanitation system impacts water quality is discussed next.

Policy Recommendation 5

Improving household sanitation by upgrading cubluks to septics needs more evidence that there are benefits to groundwater quality.

Since sanitation systems are a source of contamination, understanding how to reduce this contribution is important. Sanitation systems in use include single household systems, centralized systems and decentralized systems. Any of these systems may contribute to groundwater contamination, along with houses with no sanitation system and grey water that is often discharged to street drains. It is beyond the scope of this work to be able to identify which of these sources is most important, and it will no doubt vary from city to city.

Single household systems are the most common and the SKAM-RT survey categorized these as either "cubluks" or "septics". The terms "cubluk" and "septic" are loosely applied in Indonesia. Generally, a cubluk is understood to be a single tank in the ground with a porous floor and/or sides for receiving black water. A septic tank is understood as a sealed tank with a pipe to a separate leach field or infiltration pit. In practice, many such systems in Indonesia do not include the leach field or well-designed infiltration pit, with liquid overflow going directly to drains or being dispersed directly into the ground. Some stakeholders hold the view that a properly constructed septic tank will provide greater treatment of sewage and so provide greater protection of groundwater than a cubluk.

The SKAM-RT and SUSENAS surveys include questions on a household's sanitation, so some analysis of this information was done to see if there is any association with the type of sanitation reported by a household and the *E coli* count in groundwater sources. We were not able to find any significant associations between the type of sanitation and *E coli* regardless of sanitation system type.

Determining the benefits of upgrading cubluks to septics would require research investment. Such research should be a priority given the investments being made in upgrading cubluks to septic tanks.

Similarly, understanding the benefits to groundwater quality of other possible sanitation upgrades, including treatment of gray water or adoption of decentralized or centralized systems requires studies specific to each city to account for local conditions such as hydrogeology.

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Suggested Citation

Hansen P; Priadi C; Willetts J; Foster T; Irawan D; Hanadayani R; Pratama M; (2024) Groundwater Quality Risks in Indonesian Cities: Policy brief, Published by University of Technology Sydney, Institute for Sustainable Futures and Universitas Indonesia

Further reading

- The SKAM-RT survey is reported on in "Household Drinking Water Quality Study in Indonesia 2020" Public Health Efforts Research Centre, Research and Development Agency, Ministry of Health of the Republic of Indonesia.
- WHO sanitary inspections Water Sanitation and Health (www.who.int)
- Onsite Sanitation Systems and Contamination of Groundwater: A Systematic Review of the Evidence for Risk using the Source-Pathway-Receptor Model; Mbae et al, submitted for publication 2024
- Self-supplied drinking water in low- and middle-income countries in the Asia-Pacific; Foster et al, NPJ Clean Water 2021
- Sipasti website managed by Groundwater Conservation Agency of ESDM: https://sipasti.co.id/monitoring/map/all/Realtime

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This document is an output from research funded by Department of Foreign Affairs and Trade (DFAT). The views and opinions expressed in this document are those of the authors and do not necessarily reflect the views of DFAT or the Australian Government.

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