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Policy and regulatory context for self-supplied drinking water services in two cities in Indonesia: Priorities for managing risks

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A R T I C L E I N F O

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A B S T R A C T

Self-supply is the dominant drinking water service model for urban Indonesia. This paper examines its governance arrangements to identify risks due to the inexistence or implementation gaps of laws and regulations. The research applied a socio-ecological perspective to analyse interactions between water resources, governance, infrastructure and users and related-water security outcomes. We adopted a case study approach focused on two self-supply dominant urban areas by reviewing relevant regulations and conducting interviews with stakeholders.

The findings show that water security outcomes for self-supplied services were at risk. Overarching laws exist to support groundwater preservation. However, in practice over-extraction and contamination are common, resulting in environmental risks. Governance of groundwater use and associated permits demonstrate fragmented responsibilities and lack of a coordinated institutional framework to guarantee water safety and availability. Whilst construction standards define minimum distance of wells to pollution sources, non-compliance is common, pointing to technical risks. Users are formally responsible for storage, treatment and monitoring water quality but practice varies across households. The result is a range of potential social and health risks.

The study demonstrates a need for strengthened and coordinated implementation of the existing laws and regulations as well as increased acknowledgement of self-supply in policies in a concerted effort to ensure accessibility, safety and reliability of those services. We propose a modified governance framework to support further analytical and practical efforts to address risks to self-supplied services, towards improving safe and equitable water service delivery in Indonesia and elsewhere.

1. Introduction

Self-supply (Sutton and Butterworth, 2021) provides drinking water to a significant proportion of the population in the Asia-Pacific. In this service model, households invest in their own drinking water facilities. Over 700 million people depend on self-supply across rural and urban areas in this region (T. Foster et al., 2021). An estimated half of the global population use groundwater for domestic use

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mostly through self-supply (UNESCO, 2022). It provides a reliable, accessible and climate-resilient source of water that can be used to address gaps in service delivery (Howard et al., 2016; Velis et al., 2017). Approximately 33% of the population in Indonesia use self-supply, mainly originating from groundwater, as a primary drinking water source, with proportion of 28% and 37% in urban and rural areas, respectively (T. Foster et al., 2021).

Drinking water was deemed a human right by the United Nation General assembly more than a decade ago (UN General Assembly, 2010). The human rights entail three main roles for government: (i) to facilitate, (ii) to promote and/or (iii) to directly provide the right to drinking water. Yet it is increasingly apparent that potential roles for the government in supporting safe self-supplied drinking water are left unspecified (Grönwall and Danert, 2020). Operationalizing roles of government as duty-bearer within self-supply contexts requires appropriate and effective water governance (OECD, 2021). To our knowledge, specific research on the legal and policy framework and governance of self-supply is limited. Recent analysis often focuses on water supply in the national level (Araral and Wu, 2016; Beard and Mitlin, 2021) or in a watershed level (Hurlbert and Diaz, 2013). A sectoral focus also limits the scope of the analysis, often related to the agricultural sector or drinking water separately (Lee et al., 2021). Analysis of the latter sector also focuses mainly on the formal water sector, i.e., piped water (Kayser et al., 2015).

The lack of focus on this service model is concerning since groundwater resources are under threat from overexploitation and pollution, affecting quality and quantity of self-supplied service delivery (Margat and van der Gun, 2013; Molle et al., 2018) and groundwater depletion already poses an extreme threat to global water security (Gleeson et al., 2019). Furthermore, results from the water governance survey in the Asia-Pacific Region (OECD, 2021) show only 21% of the 48 surveyed Asia-Pacific countries allocate or monitor groundwater extractions, with none of those countries in South-East Asia. A coherent policy framework is needed to create an enabling environment for self-supply service model for safe and sustainable drinking water (Sutton and Butterworth, 2021).

This paper aims to analyse the policy and legal context for self-supplied water services in Indonesia, how this is operationalized through current institutional arrangements and practices, identify the resulting risk and opportunities, and the possible ways forward. The study applies and subsequently evolves Hoque et al. (2019) framework to Indonesia, a country of more than 278 million people. Under the constitution, the Indonesian Government has full responsibility over water resources for the greatest prosperity of the people shared across local, provincial, and national governments. However, there is a lack of evidence how this responsibility is implemented for self-supply.

This research is focused on two urban areas in Indonesia, Bekasi and Metro City. These cities provide a suitable context given their high use of self-supply (87% for Bekasi and 100% for Metro) (BPS Kota Bekasi, 2021; BPS Provinsi Lampung, 2019). The findings provide evidence and analysis to further guide the government in managing groundwater self-supply practice in Indonesia and provide a basis to conceptualize key dimensions of an institutional framework for governing and managing self-supplied service model in other country contexts.

2. Method

This study adopted a mixed method, case study approach to examine the institutional framework for groundwater-based urban self-supplied services in Indonesia. Case studies support analysis of a phenomenon within a specified context (Yin, 2009) and a mixed method approach supported both review of relevant legal and regulatory documents as well as in-depth interviews with local government officials (LGOs) and other actors involved in self-supplied services in two cities.

As 34% households in Indonesia use groundwater as compared to rainwater, which is used by only 2% (Litbangkes RI, 2020), our analysis on self-supply focused on groundwater policy and regulation from central government (CG), provincial government (PG) and local government (LG). There are many different frameworks for understanding water governance (Hoque et al., 2019; Jiménez et al., 2020; Ménard, 2017; Mumssen et al., 2018). The most relevant of these for considering self-supply was the social-ecological system (SES) framework developed by Hoque et al. (2019), as this focuses on the human-nature interactions related to drinking water service delivery. Use of Hoques's framework, as an adapted version of Ostrom (2009) SES framework, enabled a holistic view on risks as described by Völker et al. (2017). It explores interactions among users, water resources, infrastructure and institutions that mediate these relationships. Those interactions reveal 'meso-institutions' performance in interpreting and operationalizing the policy framework of water services which is essential to identify the policy-implementation gap (Ménard et al., 2017) and implications for accessing safe and affordable water services.

Hoque et al. (2019) SES-based framework was therefore used to conceptualize current legal, policy and regulatory arrangements and to support systematic analysis of all relevant dimensions including: (1) water resources, including their quality, quantity and spatio-temporal distribution; (2) governance of groundwater use, specifically through groundwater permits; (3) infrastructure, encompassing water supply technologies to access the water resources; (4) users, including their practises in relation to treatment, storage and monitoring; (5) water security outcomes regarding water quantity, quality and affordability. Hoque's interdisciplinary perspective includes a risk perspective, which points to environmental risks related to groundwater resources, institutional risks related to governance, technical risks related to infrastructure, social and financial risks related to users and health and water security risks related to self-supply water security outcomes.

2.1. *Study location*

This study focused on two urban cities in Indonesia, Bekasi City (West Java Province) and Metro City (Lampung Province). Bekasi and Metro were selected as study locations as both cities have a high number of self-supply groundwater users (87% for Bekasi and 100% for Metro) (BPS Kota Bekasi, 2021; BPS Kota Bekasi, 2021) and a high proportion of households considered to fall within the poorest 40% of households nationally (B40) using self-supply was among the highest in Indonesia (92% for Bekasi and 100% for Metro of B40 population using self supply). Bekasi was chosen in particular because it is densely populated (13,841 people/km2) and is part of Greater Jakarta, the capital of Indonesia. Whereas Metro was chosen because of the particularly high proportion of households using dug wells (63%), including 10% who still uses unprotected dug well.

2.2. Data collection and analysis

Two main methods were employed, namely regulatory and policy review, and in-depth interviews.

There were 33 regulations and policies at the national level from the central government (CG), 18 regulations and policies at the regional level from the local government (LG) (11 for Bekasi and West Java Province; 7 for Metro and Lampung Province) and 3 national standard collected through Google search with Bahasa Indonesia keywords for inclusion comprising "water"; or "water supply"; or "water resources"; or "wastewater"; or "groundwater"; or "environment"; or "environmental risk"; or "sanitation"; or "urban planning'' as well as from key informants and tacit knowledge. Since self-supply is not yet regulated specifically, the keyword "self-supply" was not used. Each document was reviewed to extract points related to self-supplied groundwater, including specified mandates, roles and responsibilities of different levels of government, private sector actors (e.g., drillers, suppliers), households and rights of individuals (see Table S1 for complete legal review) seeking to identify gaps and associated risks, particularly compared with other service delivery models (e.g. piped systems, or community-based management systems).

The study included 29 stakeholder interviews to gain insight to the practical implementation of existing policies and regulation consisting of 6 and 7 LGOs from water-related institutions in Bekasi and Metro respectively, 1 refill water seller, 2 informal well diggers, 1 informal well driller and 6 households of each city. The in-depth interviews were conducted in Bahasa Indonesia and then transcribed and translated to English for analysis. Analysis was conducted deductively, reviewing interview transcripts for statements relating to implementation of relevant policies and regulations, and current household experiences managing self-supplied services. Some quotes have been included in the narrative, however with interviewees anonymised to protect privacy. This research has undergone and granted ethics approvals from Research Ethics Committee in University of Technology Sydney and Universitas Indonesia (29/UN2.F10.D11/PPM.February 00, 2020).

3. Results

In each section, we begin by describing the legal and regulatory landscape related to groundwater, followed by comparison with arrangements for other service models. We also describe general implementation in practice and gaps present in the current situation by systematically presenting analysis of responses in the order of LGO, household and service providers. We expressed explicitly where there was no relevant content from one or more of these informant groups.

3.1. Water resources conservation

Management of water resources is regulated within the National Water Law no.17/2019 including water source protection, quantity conservation, quality management and pollution control. This is then detailed specifically for groundwater in other regulations such as in West Java Regulation no.1/2017 where individuals and businesses are prohibited to carry out activities that pollute groundwater. The LG Regulation of Lampung no.5/2019 stipulates that the holder of an extraction and exploitation permit of groundwater and all parties related to groundwater utilization are obliged to carry out groundwater conservation, which includes the prevention of groundwater pollution although no specific groundwater quality standard exists. Environmental risk was mentioned in Law No.32/2009 on protection and management of the environment where each business or activity that potentially has significant environmental impact is required to conduct an environmental risk analysis detailed in a recent national regulation, Government Regulation No.5/2021.

Conservation of groundwater quantity is well regulated in Law Number 37/2014. For example, there is specific recommended infrastructure aimed for groundwater conservation such as infiltration wells as part of the requirement of building permits. Compared to groundwater quantity, groundwater quality is not strictly regulated. There are only preventive measures such as a national standard or *Standar Nasional Indonesia* (SNI) 2398:2017 concerning safe distance between septic tanks and drinking water wells. There are also no groundwater quality regulations, compared to surface water quality regulations, such as Government Regulation no.22/2021, which are very strict and renewed regularly.

The interviews demonstrated that LGOs in Bekasi and Metro have implemented some actions to conserve groundwater, for example, conducting unannounced inspections to industries along the river basin and planning to increase the service coverage of piped water. However, one of the LGOs in Metro stated that the follow up actions are still lacking:

> *" …. . We calculated the water quality status in this past month and it's mostly beyond the limit. Water demand and water availability are also not balanced. So does the land. The carrying capacity of the land has been exceeded. But there isn't any policy to follow up those conditions."* (LGO Metro).

The interviews did not discuss the extent of groundwater conservation actions undertaken by households and private sector actor. However, most participants did not know of any regulation regarding groundwater, which implies low awareness regarding groundwater conservation.

Lack of conservation implementation has resulted in increased risk of groundwater contamination and depletion reported by the stakeholders. Most interviewees reported that the depth of groundwater abstraction increased in the last two decades. An LGO suggested that:

> *" …. from now on we are consuming water, but we must also seek conservation measures so that our future generations, who will live in Metro, will (also) not experience difficulties. It could be that we are enjoying groundwater now but in 10 years, our children and grandchildren, who just want to drink water, just want to take a shower, buy X (packaged water brand) because the clean water is no longer available. The water quality is declining"* (LGO Metro).

This finding was also reported in a Groundwater Potential Study led by the Environmental Management Agency Bekasi (2014) where one of four sampling points had a vulnerable - critical groundwater condition based on simulation of groundwater subsidence. Due to the groundwater depletion, some households need to lower their water pump and the well digger reported the need to dig deeper to get water.

> *"Yes [lowering water pump], around three times. Yes, the [pump] machine is lowered. My husband can do it"* (Female-Bekasi).

> *"The well depth previously was 12 m, now it needs more than 20 m [depth]"* (Well digger – Bekasi).

Interviews revealed that stakeholders both in Bekasi and Metro were aware of the high risk of microbial contamination in groundwater, perceiving that they cannot use it for drinking water as it may impact health in the long term. Some attributed groundwater quality problems not to anthropogenic but only to natural causes. According to one LGO:

> *"Even sometimes the [groundwater in] 60 m [depth] is yellow and smelly, for example in North Bekasi, because there is housing which was previously swamp land and has clay soil"* (LGO Bekasi).

3.2. Governance through groundwater use and permits

Water resources in Indonesia are managed in an integrated manner involving the government from the central to the regional levels. Herein, groundwater governance will focus on groundwater permits mandated to CG and/or LG (Water Law no 17/2019) indicating their equal authority so CG may regulate groundwater or give authority to LG. Prior to the enactment of the Water Law, groundwater and surface water use was under the authority of the Ministry of Energy and Mineral Resources (MEMR) and the Ministry of Public Work and Housing (MPWH), respectively. In the new law, both types of water resources are managed by the latter. However, the Draft of Government Regulation as the derivative of the Water Law has not yet been completed so groundwater licensing authority is still under MEMR (Government Regulation no.121/2015) until the draft is formalized. In the MEMR Regulation no.2/2017, groundwater is managed at the basin level in an integrated manner with surface water. The majority of groundwater basins are within provincial boundaries, but some are cross-province and countries.

Groundwater permits have various provisions depending on its use. Article 45 of Water Law states that a permit is not needed for daily use when it does not disturb the natural condition of the water source, and it is not intended for large group use requiring a large quantity defined as groundwater extracted from boreholes with a diameter of more than 5 cm or more than 25 m^3/month/household. Drilling and digging wells require permits in some conditions. In Bekasi, a digging permit is required for groundwater use for business and non-business other than daily needs and public irrigation and/or for wells less than 40 m (Article 32 West Java Government Regulation No.1/2017 on Groundwater). Meanwhile, Lampung Government Regulation no.5/2019 article 15b and 15d does not detail the depth requiring permits.

Groundwater permits for other water service models are more stringent than those for self-supply. The Water Law (Article 45) requires permits to use water resources for business purposes. In Government Regulation no.121/2015, the packaged water sector requires water business and quota permits simultaneously. In addition, the holder of a water business license also has an obligation to maintain the function of water resources and control the water pollution. If the source of water comes from groundwater, the permit holder is also required to construct monitoring and infiltration wells.

Piped water service providers who utilize groundwater require a permit (Government Regulation no.121/2015). They generally prepare a water safety plan to assess the risks which are audited by the Financial and Development Supervisory Agency (*Badan Pengawas Keuangan dan Pembangunan* or BPKP) to assess the performance of the service provider. Compared with other water resources, such as surface water, permits for groundwater are less regulated and enforced, thus households and micro and small business with self-supply therefore generally have relatively unlimited access to groundwater with minor consequences.

For piped water services, the service providers need to pay for the groundwater resource used with pricing detailed in provincial regulation. Compared to the cost of piped drinking water, the absence of a visible cost component to pay for the resource used in self-supply, and absence of permit show scarce government control over self-supply.

Our key informants revealed limited knowledge of relevant laws and regulations concerning groundwater permits. An LGO from Bekasi noted that they did not know whether households needed permission to dig wells. Another LGO from Bekasi noted that a permit is only needed for a depth more than 100 m. In Metro, some LGOs noted that there were no permit requirements for dug wells or boreholes at household level. Overall, Government mostly perceived their permit system to be applicable to private sector actors rather than households.

In general, there seems to be agreement that households are not required to hold permits to access groundwater on land that they own, which increases institutional risk because CG and LG who are mandated to regulate water sources are unlikely to be able to control groundwater use. One of the LGOs raised their concern about that issue:

"In the 1945 Constitution, the earth, water and the natural resources contained therein are the property of the state. So, the water in the ground, the land on which we buy or we own it, the land underneath belongs to the state. However, the weakness is that our land can be owned by individuals. Finally, the mindset is, whatever is on the land down to the bottom, up to the top is also owned by individuals …. Maybe we need agrarian reform or provide knowledge and awareness that we do have land above the earth's surface, but the earth, water and the wealth contained therein are owned by the state. So, the state has the right to regulate, regulate how we use water" (LGO Metro).

LGOs were concerned about excessive use of groundwater and that businesses did not adhere to the required permits, especially informal, micro and small business that are often outside the monitoring scope which is often limited to larger industries, such as was noted by LGOs in Bekasi. Additionally, one Metro LGO also noted:

"… but what worries me a little is that the private sector also uses water sources for their business activities by taking groundwater without any supervision … now people are free to set up laundry, car wash, motorbikes wash that use a lot of water, hotels, but there is no supervision over the use of groundwater" (LGO Metro).

In order to uphold the permit requirement for small businesses, it is considered that everyone has a role to play in overseeing the implementation of regulations according to their respective roles, including civil service investigator or the police. An LGO in Metro mentioned:

"Regarding who needs to oversee [the regulations] … everyone also has a role and has the authority … The resident, maybe they can report it. Our friends in the media can report it. Our friends in NGO can do many things. The [role of] government is also clear, there is the law enforcer. Maybe the environmental affair is not a sexy [topic]. Even in the police institution, there is a Special Criminal [division], which must also take care of spatial planning, the environment, all sectors. All institutions also have a significant role in implementing the rule" (LGO Metro).

Some Bekasi LGOs and a representative from Metro water utility agreed that more control was required concerning household groundwater use, one noting well constructions often not meeting standards of construction and minimum lateral distance to on-site sanitation system, which risks adversely impacting groundwater quality. A Metro LGO stated that building owners should take responsibility for abstraction through building permits:

"I'm sad, how come the regulations for households are not regulated. So, one of the intervention efforts is from building permits as well as familiarization and internalization of responsibility in using water and conserving the water to the building owners" (LGO Metro).

However, some households think that safeguarding of groundwater does not necessarily need government regulation. One household in Metro relates groundwater availability to spiritual practice:

"Insya Allah (God willing), it's not (groundwater does not run out even though there are many boreholes), as long as people are still praying to God" (Male-Metro).

All well drillers and diggers agreed that the drilling and digging permit is not needed for household purposes. However, some well drillers had expected more support from the government, such as providing training or supervision regarding construction standards and tools, to ensure the construction standard are met and sustained.

3.3. Infrastructure

Infrastructure of water systems in Indonesia is well regulated in regulations and standards covering technical specifications and competency standards for the operator. Various technical options for self-supply service model are mentioned in Government Regulation no.122/2015 and MPWH Regulation no.27/2016 on Implementation of Drinking Water Supply System, broadly explaining the abstraction system of groundwater. Specific construction standards and guidelines for protected wells as well as boreholes are detailed in other documents such as SNI 03-2916-1992 and community based and/or rural water supply guidelines (Kementerian PUPR, 2016) for protected well constructions. These documents include material and construction specification of well floor and wall, abstraction equipment and drainage. The distance between wells and potential sources of contamination is also regulated in SNI 2398:2017 to respect groundwater depth and safe distance from pollution sources. Workers in the drinking water sector must be certified based on MPWH Regulation no.15/2018.

Self-supply is covered in construction-related regulations in a similar way to other water service models. Both piped water systems and non-piped water systems which includes self-supply are both equally described in the MPWH Regulation no.27/2016 with an appendix each for non-piped water and piped water systems. Technical supervision for the construction of water supply system (piped and non-piped water) is the responsibility of Minister, Governor and/or *Bupati*/Mayor. This is also mentioned in MPWH Regulation no.18/2012.

LGOs interviewed during this research acknowledged that infrastructure in households do not comply with guidelines and regulations. To move forward, both Bekasi and Metro were trying to implement well SNI for newly constructed houses through the building permit (*Izin Mendirikan Bangunan* or IMB).

Not all households nor the private sector were aware of the rules concerning the distance between the septic tank and the well. However, the households mostly knew that the well should be far from a septic tank without knowing the exact distance or the regulation.

"I do not know [the regulation]. I just thought, there must be leaching, right? So, it needs to be far, but I don't know how many meters is needed in the regulation. What I know is that you must construct a well far away [from the septic tank] because there will be leaching [from the septic tank]" (Female – Metro).

One well digger in Bekasi with more than 10 years of experience was not aware of the regulation concerning the regulated 10 m distance between well and septic tank. They mentioned that since they were neither certified nor have formal training or monitoring, it is difficult to be informed of these regulations. Those who are aware are usually informed from school or on-the-job learning and had strategies to minimize contamination even though the distance between well and septic tank was less than regulated. That one well digger mentioned the strategy would include casting the well, using two different pipe sizes, and deepening the well or using a borehole system, which was understood to keep contamination from shallow septic tanks to a minimum:

"If the house owner asked to dig a well and it's [the location of water source] near the septic tank, actually it's not allowed. I usually suggest using two casing pipes,4 and 8 inches, or cast the left and right side of well to prevent the leaking" (Well digger-Bekasi).

3.4. Treatment, storage and monitoring by users

Several laws and regulations exist to address self-supply treatment, storage and monitoring. Drinking water operators, including households who are operating their self-supplied water, are mandated by the Regulation of the Ministry of Health (MoH) no.492/2010 to ensure safe drinking water in terms of physical, chemical, microbiological, and radioactive requirements.

Water, sanitation and hygiene behaviours of the community and households are detailed in the MoH Regulation no.3/2014 regarding Community-Based Total Sanitation (*Sanitasi Total Berbasis Masyarakat* or STBM). One of the 5 pillars of STBM is drinking water and food management where communities supported by public health agencies and sanitarians must cultivate adequate treatment for basic drinking water as well as provide and maintain a health water treatment facility with assistance and monitoring from the local government with further details on household methods of treating and storing clean drinking water.

Treatment and storage of other water service models are more strongly regulated than self-supply. For example, water treatment and storage regulation in water treatment plants for piped drinking water are regulated because they involve elaborate and complex systems. Standard Operational Procedures of these facilities are established by system operators as mandated in MPWH Regulation no.4/2020. At the user level, treatment and storage of drinking water is equally regulated as the STBM regulation (MoH Regulation no.3/2014) for this aspect did not differentiate the regulation by service model types.

The mandate for internal and external monitoring of water supply system is regulated in the MoH regulation no.736/2010. Internal (from the service provider) and external (from Health Agency) piped water quality monitoring (WQM) parameters include residual chlorine besides other parameters (microbial, physical, and chemical) which are also tested in non-piped water system (includes self-supply). Piped WQM should be conducted minimum once a month for one sample in every 5000–10,000 users for most parameters, depending on the number of users, water quality parameter, and monitoring model (internal or external). The piped water monitoring is conducted in every production and distribution unit for internal monitoring, and the farthest point of distribution unit for external monitoring. Meanwhile, the internal and external monitoring for non-piped water systems (including self-supply) should be done at a minimum of once every month or six months in each water facility, depending on the parameter. The stipulated frequency and parameters also apply to for refill water depots.

Interviews revealed widespread implementation of drinking water management practices described in STBM. Public healthcare centre staff including sanitarians and midwives reported conducting sanitary inspections and advocating to community members methods to obtain safe drinking water either from self-supply or from refill water.

"Currently, water testing is being carried out at the household level .... in 6 sub-districts namely Jatiraden, Bekasi Jaya, Jatirahayu, Jatisari, Jatisampurna, Pengasinan, which is funded by the Ministry of Health" (LGO Bekasi).

STBM implementation in drinking water management at the household level was reported to be fairly high by one of LGOs in Metro:

"..In its [STBM] pillars, there is the provision of safe and healthy food in pillar 3, and in safe and healthy food there is quality drinking water. We've reached more than 80 [percents] ... [we] educate on how to minimize the possible risk of pollution. Then the treatment earlier, for example, sedimentation or boiling, and it includes the education on how if the family uses refill water. We recommend boiling first to ensure safety, health, for themselves and their family" (LGO Metro).

In terms of monitoring water quality, generally, households only monitor visual and olfactory parameters of their groundwater in terms of colour, taste or odour while most of households interviewed were not aware of the risk of other pollutants.

"Safe water is water that is clear, odourless and usually fresh and has good taste" (Female – Bekasi).

In contrast, refill water depots have their water quality analyzed at a quite expensive price estimated at IDR 900 thousand (62 USD) per sample for all required parameters. The public health agency in Metro checks the water safety of the refill water depots twice a year but the results are never returned to depots, as informed by an interview with a refill owner.

3.5. Water security and water service delivery outcomes

The law stipulates that the government assures people's right to a supply of water that is of sufficient quantity, of good quality, continuous, sustainable and affordable. This is operationalized in the Government Regulation no.122/2015 and MPWH Regulation no.29/2018 that provincial governments must provide a minimum of 60 L of clean water/person/day fulfilling visual and olfactory requirements for clean water as their minimum standard service. In terms of water quality, drinking water must fulfil the criteria regulated by the MoH (no.492/2010 and no.736/2010) for various parameters. Affordability of self-supplied services is not regulated. Rather a cost estimate for dug well construction is published by the MPWH, with a protected well with a depth of 9 m estimated to cost around 20 million IDR (1385 USD) (Kementerian PUPR, 2016).

In contrast to self-supply, piped water services are regulated at the national level through Government Regulation no.122/2015 on drinking water systems. It includes how providers must guarantee certainty of quantity, quality, continuity of supply and how customers are notified in the event of water supply interruption and how a complaints facility is ensured. The Regulation of MPWH on national development policy and strategy of drinking water supply system (*Kebijakan dan Strategi Nasional Pengembangan Sistem Penyediaan Air Minum* or KSNP-SPAM) is used as guidance for regulating, implementing and developing sustained drinking water supply systems for the central and regional governments, business communities, private and society. None of these service standards are specifically for self-supply.

Piped water services also have regulated tariffs to ensure that households have access to affordable services in contrast to self-supply. On the other hand, the cost of self-supply, especially related to construction and equipment are unregulated with no formal mechanisms to ensure services remain affordable for households. One of the well diggers mentioned that there is also a special price for middle-low or neighbour compared to the middle-high household (middle to upper class).

Although self-supplied water quality is less likely to be monitored, interviews revealed that household participants considered water from boreholes was considered to have better quality than piped water. One household in Metro reported:

> *"Everyone here has PDAM installed, but the water is bad … first, is a bit cloudy. Second, the smell of chlorine …. So, people don't want to use PDAM water, because PDAM is inferior to well water. Well water is better" (Female-Metro)*.

Water availability, quality, and affordability are main reasons for the use of self-supplied services and non-use of public piped services in line with the implementation of a drinking water supply system (Government Regulation no.122/2015). Interrupted services and monthly fees for public water supply contrasted with ease of groundwater access and positively-perceived groundwater quality. These differences are key reasons why households prefer groundwater self-supply over public water supply. LGOs mentioned the importance of improving public water supplies so that people can rely on them. From the interviews, the piped water supply company in Bekasi and Metro confirmed these public perspectives as their challenge, especially in areas without a drinking water piped network nearby. Meanwhile, expanding the pipe network is a demanding process for LGOs.

> *"There is an assumption that groundwater is better, but for dense areas it is actually not recommended. We socialized there [in the dense area], it was difficult because we were afraid that people would be offended regarding the water they used. However, if we socialized in areas where the pipe network has existed, we are confident. If the area is still far (from the pipeline network), we are not confident. It's because we're afraid they'll wait for the pipe network to be facilitated quickly … …. This [expanding piped network] is related to regional government priorities. Water is a basic need, but the process is not easy. There's a lot of bureaucracy, rules, etc"* (LGO Bekasi).

Although a preferred approach by households, it is unclear to what extent self-supply can provide water that is free from contamination and available when needed, as required by the Sustainable Development Goals because they are not regulated explicitly and rarely monitored.

4. Discussion

The findings of this study are aligned to other studies that point out inadequate legal and regulatory frameworks for groundwater in most countries with limited implementation (FAO, 2016) and lack of policy, regulation and monitoring of self-supplied water services (Grönwall and Danert, 2020; Sutton and Butterworth, 2021). This increases multi-faceted risks to the delivery of safe water to households, and is an issue requiring attention given the ubiquitous nature of this service model (T. Foster et al., 2021). The discussion below focuses on these risks, contextualising them within wider literature and practice, and with a view to highlighting those areas most in need of attention moving forward.

4.1. Environmental risks - groundwater resources

In Asia and the Pacific, environmental risks of groundwater resources have been identified, such as deteriorations and fluctuations of groundwater quality (Enitan-Folami et al., 2019) considerable groundwater withdrawal, deterioration of water quality due to saline intrusion (UNESCO, 2022) and water shortages in dry season (Carrard et al., 2019). In this study, households were deepening wells and increasing pump power as a coping mechanism, which might exacerbate vulnerable groundwater conditions and increase long-term environmental risk.

The Indonesian MPWH's planned mandate for groundwater would allow focusing on managing groundwater permits and sustainability both in terms of quantity and quality. An established institutional and academic capacity building is required to ensure the people involved have capability to overcome the complexity of groundwater management (Jadeja et al., 2018) because mismanagement of groundwater resources is often due to a lack of hydrogeological capacity (UNESCO, 2022).

4.2. Technical risk - self-supply infrastructure

Inadequate infrastructure is a significant aspect impacting water quality, posing a technical risk for self-supply users (Sutton and Butterworth, 2021) and this study confirmed varied construction practices in the Indonesian context. Service providers, including suppliers and vendors of pumps and household water treatment systems, well diggers and pump technicians can be trained and certified for borehole construction and groundwater conservation, a solution that was expressed by some interviewees. Trained and certified service providers can be further regulated through licencing and drilling permit, as implemented in Tanzania (Sutton and Butterworth, 2021). The institutional agency in charge could also be mandated to establish, review, and socialize well construction standards. Government oversight and enforcement of technical standards can also be done through drilling records that are sent back to the government as a follow up, as practiced in Queensland, Australia (Queensland Government, 2020). With this structure in place, it may support the implementation of standards and regulations which were lacking based on our findings, especially related to permit requirements and minimum distance between well and septic tank.

4.3. Social and financial risks - users

Self-supply as a self-managed service model inevitably poses social risks. Contamination during treatment and storage is partly due to low awareness of households (Moropeng et al., 2021), also a significant social risk. Although raw water sources from groundwater may have high risk of microbial contamination, proper household treatment may reduce health risk (Bain et al., 2020; Ghaudenson et al., 2021) which would ensure compliance with the various Indonesian regulations. The majority of self-supplying households treat their water by boiling (Priadi et al., 2022; Sodha et al., 2011) as also reported from our interviews. Beyond socialization and education, ensuring safe household water treatment and storage should also include behavioural changes which requires more elaborate intervention (Kelly and Barker, 2016). The Indonesian government through the MoH has committed to improving education of household water treatment through the establishment of a roadmap on water quality monitoring 2020–2030. However, the achievement target, which is currently based on the percentage of *puskesmas* that provide education (Kementerian PUPR, 2019), can be leveraged further to consider the percentage of people who are educated or even change their behaviour.

There are also financial risks for users associated with self-supply. Households with self-supply often complement their drinking water source with both bottled and refill water, as confirmed in the interviews, which has economic consequences (Nastiti et al., 2017), increasing financial risk. Poor households rely the most on both bottled and refill water and become the most affected to the economic consequences, which emphasizes the need for government to reducing this inequality (Kooy and Walter, 2019).

4.4. Health and water security risks – water security outcomes

Several categories of self-supply infrastructure, including unprotected wells and boreholes, have been shown to have higher faecal contamination than piped water (Genter et al., 2021). These risks also increase in the wet season (Cassivi et al., 2021). Overall changes in water quantity and quality was reported by households. The overall conditions of groundwater resources, overuse, inadequate infrastructure and mixed user practices significantly increase the health risks to users of self-supplied services (Sutton and Butterworth, 2021).

Water security can also be achieved through appropriate monitoring tools. A study from Charles et al. (2020) emphasized that new monitoring tools are needed to shift the current practices that only focus on 'safety' into 'security' that ensure the safe services are sustained. For this new perspective, water quality monitoring needs to be frequent and integrated with sanitation inspection to gain knowledge of risks and water safety planning to manage the risks (Charles et al. 2020).

4.5. Institutional risk - governance

The Indonesian National Water Law stipulates that water resources are controlled by the state for the prosperity of the people. However, this study demonstrated that groundwater is regarded as a private resource with no sense of shared resources and no need for conservation and formal governance (FAO, 2016). Fischer et al. (2020) identified unintentional consequences of reallocating management responsibility for rural water services away from government agencies towards individuals and households in rural Bangladesh. Privately invested and unregulated water systems lead to risks of untested water quality and unmonitored water supply which was also demonstrated by our findings. Apart from the ownership rights, water governance in Indonesia is also fragmented where management of surface water and groundwater is spread among various directorates and ministries also observed by Mulyana & Prasojo (2020) and Ardhianie et al. (2022).

To overcome barriers toward a more centralized governance, there needs to be a clear formal government mandate for the self-supply service model through national and sub-national policies and regulations (Carrard et al., 2019) which, at the moment, does not exist in Indonesia. Institutional functions in the public domain related to groundwater management, especially to regulate extractions between competing users and prioritizing domestic water use as human right, is highly important (FAO, 2016).

Besides priorities between competing users of groundwater, technical options in densely populated areas are necessary. If sanitation containment and groundwater sources are both needed in a small space and densely populated area, which was a common practice found during the interviews, appropriate planning, construction, and monitoring methods of the two facilities need to be established, or even prioritize installation of mains sewerage (S. Foster et al., 2020). As another alternative, government should decide on areas with the highest risks of groundwater contamination and depletion to ascertain priority areas for expanding piped water service provision.

4.6. A framework to support future analysis and action

Based on our findings, we propose a modified socio-ecological framework based on Hoque et al. (2019) for groundwater-based self-supply management (Fig. 1). We propose that Water Resources, Infrastructure and Users as the three main aspects of self-supply management with a strong governance embedded in the three aspects, centred around the water security outcomes using a risk-based approach. To render the invisible groundwater visible (UNESCO, 2022), a more present and deliberate self-supply groundwater-based governance is needed as defined by FAO (2016).

The governance process may start with a comprehensive groundwater systems assessment and then followed by a single self-supply policy document (UNESCO, 2022) by the key agency/working group adopting a risk-based approach. It includes an effective institutional and legal framework of the three key aspects, effective knowledge management systems, raised awareness as well as policies, incentive structures and concrete plans (UNESCO, 2022). The improvement of transparency, participation, and coordination of broader stakeholders, such as NGO and private sector, are required during the governance process to implement good governance (Biggs et al., 2013; Gerlak et al., 2018).

5. Conclusion

Self-supply of drinking water relying on groundwater has been the approach for many households in Indonesia. Our regulatory and policy review along with our in-depth interviews demonstrated that self-supply is currently under-regulated, with no clear roles and responsibilities for the government, users nor service providers. Water quantity is mostly regulated for businesses while permit requirements for self-supply at the household level are almost inexistent and most stakeholders expressed that households are not required to hold permits to access groundwater on land that they own. Infrastructure design standards do exist although there is limited enforcement of these standards. These findings imply increasing risks in the following ways: 1) environmental risks: declining groundwater quality and decreasing groundwater quantity; 2) technical risks: non-standard infrastructure construction which triggers potential for contamination; 3) social and financial risks: low awareness of proper household treatment and storage and additional cost for complementary water sources; 4) health and water security risk: inability to access safe drinking and domestic water supply; and 5) institutional risks: Ownership of groundwater as a private resource and fragmented governance.

With increasing observed risks on self-supply water service delivery, the current self-managed system must be transformed into an effective governance of the three main aspects of self-supply, which are (1) water resources, (2) users, and (3) infrastructure, shifting the perception that households have the absolute right to use groundwater, while still ensuring human rights. All actors involved must have responsibilities related to sustainability and risk reduction on top of their rights. Strengthening governance systems and policies that respond to the risks associated with self-supply will be critical to achieve water security and the human right to water in Indonesia.

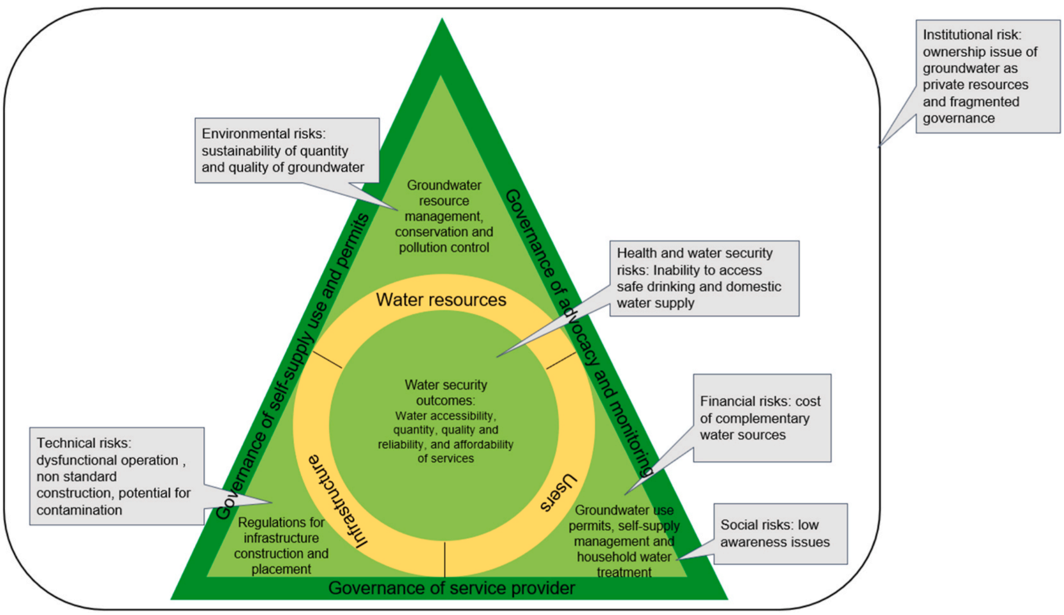

Fig. 1. A modified socio-ecological framework based on Hoque et al. (2019) for groundwater-based self-supply management.

Author contribution

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Declaration of competing interest

Editor-in-chief of Environmental Development,

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). She is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envdev.2023.100940.

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