Natural Resources Forum •• (2018) ••–•• DOI: 10.1111/1477-8947.12146

Community-based water supplies in Cikarang, Indonesia: are they sustainable?

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Abstract

Community-based water supply (CBWS) is an example of how a community manages common pool resources (CPR). This results in an alternative approach to solve water supply problems in developing countries by enhancing community participation in managing water supply. This research evaluates the sustainability of five CBWS projects in Cikarang, Indonesia by using Ostrom's design principles, with additional sustainability factors found in the Sustainable Development Goal (SDG) on drinking water and groundwater sustainability. Quinn et al. *(2007) criteria were used in the analysis, and the results show that the management of four CBWS institutions were absent and one CBWS institution was weak. With regards to the SDG's drinking water target, the CBWS institutions were unable to comply with safe water standards, and in terms of groundwater sustainability, efforts to monitor and sustain groundwater tables were absent. Results from this research suggest that more focus must be placed on water quality and groundwater sustainability for CBWS projects.*

Keywords: Community-based water supply; common pool resources; developing country; Cikarang; Indonesia.

1. Introduction

Groundwater withdrawal plays an important role in water supply. In 2010, the world's groundwater withdrawal reached 982 km^3 per year, supplying 26% of water needs for agricultural, domestic, and industrial usage (Margat and Van der Gun, 2013). In cities where piped water supply is limited, access to groundwater is the most common method to improve water availability for the population. For example, in Indonesia, 93% of groundwater withdrawal is supplied for domestic use (Margat and Van der Gun, 2013), and it is common for households to pump groundwater without a permit. This is because the right to access groundwater for daily needs is protected by the Indonesian Constitution and strengthened by laws as the first priority of water allocation (PP 121/2015 on use and allocation of water resources).

In terms of sustainability, unregulated groundwater pumping, similar to any unregulated harvesting of natural resources, such as pastoral, irrigation, forestry, and fisheries resources, could lead to the "tragedy of the commons" (Hardin, 1968). In this case, many users can access the same resources without the ability to exclude others. This results in rivalry. Such a practice, if allowed to continue, could lead to the degradation of resources. In the case of groundwater over-pumping, it could lead to diminished groundwater tables, higher pumping costs, land subsidence, water quality concerns and in coastal areas, seawater intrusion (Braadbaart and Braadbaart, 1997; Gleeson *et al.*, 2010; Margat and Van der Gun, 2013).

Some scholars disagree with the views of Hardin (1968) that the only way to manage the commons is through the implementation of property rights and management by government or private institutions. According to Agrawal (2003), three of the most thorough studies on this issue have been by Ostrom (1990), Wade (1994), and Baland and Platteau (1996). These authors have argued that the sustainable consumption of Common Pool Resources (CPR) can be achieved by more effective institution management, consisting of a group of CPR's users, abiding by common ownership and rules. Among the three studies, Ostrom's work is the most notable, winning the Nobel Prize for Economics in 2009. Accordingly, this research will focus on her work of the design principles for sustainable CPR institutions (Ostrom, 1990).

Ostrom (1990) proposed that eight design principles should exist to ensure the sustainability of a CPR institution: (1) clearly defined boundaries; (2) congruence

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Correction added on 19 March 2018, after first online publication: The name of the last author was corrected to "Lloyd HC Chua".

between appropriation and provision rules and local conditions; (3) collective-choice arrangements; (4) monitoring; (5) graduated sanctions; (6) conflict-resolution mechanisms; (7) minimal recognition of right to organize; and (8) nested enterprise (for CPR that belong to a larger system). Since these principles are applicable to CPR institutions across fields as diverse as pastoral, forestry, and fishery, the design principles have been reviewed by scholars with specific applications in mind. Some scholars criticized the principles themselves (Ostrom, 2008b), while others suggested modifications to the proposed design principles. Quinn *et al.* (2007) identified the difficulty of setting boundaries in pastoral applications, as suggested by the first principle. Based on experiences in forestry, pastoral, irrigation, and fishery, Cox *et al.* (2010) suggested that for principles 1, 2, and 4, each should be split into two sub principles. Principle 1 should delineate between user and resource boundaries, principle 2 should separate rules that manage resource allocation and those that ensure proportionality between cost and benefit, and principle 4 should distinguish between the availability and accountability of resource monitoring. Agrawal (2003) indicated that the design principles should include external factors such as markets, technology, states, and population pressures. However, these criticisms have been addressed by Ostrom (2008b), who understood that her design principles were not a 'one fits all' tool. She concluded that the principles' characteristics could be flexible depending on the condition of the CPR institution. Other scholars (Gutiérrez *et al.*, 2011; Kobayashi *et al.*, 2014; Pretty, 2003) have also observed that the success of CPR institutions can be attributed to the social capital in the community managing the CPR. However, it is clear that important elements, such as common rules, norms, and sanctions, which should exist for strong social capital (Pretty, 2003), are already internalized in Ostrom's design principles. With the flexibility of Ostrom's (1990) design principles, it is important to ensure that the factors determining the sustainability of CPR institutions be correctly defined in order for appropriate assessments to be made. The concern is based on the fact that since the release of the Environment and Development Report in 1987 by the World Commission on Environment and Development (Brundtland Commission, 1987), budget allocations for community participation projects increased (Ostrom, 2008a) by up to 600% between 1996 and 2003 (Mansuri and Rao, 2004). Despite this increase in funding, many projects were not successful, some due to technical reasons and/or ignorance of local issues (Mansuri and Rao, 2004; Starkl *et al.*, 2003). Therefore, we need to define the correct framework to assess the sustainability of CPR institutions.

In water management, community-based water supply (CBWS) projects, as an example of a CPR institution, were developed over the past two decades as a solution for developing countries' water problems (Starkl *et al.*, 2003). These community participation projects were seen as a good alternative in rural or peri-urban areas (Bakker, 2010; Isham and Kähkönen, 1999; Padawangi, 2010), as it was challenging for public water supplies to expand services while facing massive urbanisation, high population growth, and water quality degradation (Ujang and Buckley, 2002). Ostrom's design principles are well-suited for the water management sector, are relevant to current conditions, and are used as a tool to verify the sustainability of CBWS as shown in Leonard *et al.* (2015), Cox *et al.* (2010), Sarker *et al.* (2009), and Quinn *et al.* (2007). All of these studies utilized the eight design principles, albeit with some modifications.

Our study focuses on CBWS projects in peri-urban Cikarang, Indonesia, where groundwater is a vital resource. In this region, the main concerns are the issues of the physical environment of the CPR as discussed in Agrawal (2003), and on the access to safe water as a human right (UN, 2014). When a CBWS project works well, it benefits the community. However, when it fails, the effects are detrimental since the targeted community's water use problems are not addressed. Some who have access to shallow groundwater might privately pump groundwater, which could lead to the tragedy of the commons and spark environmental issues. Others who do not have better alternatives might source water from polluted sources, raising health concerns. Given that in 2015, 663 million people (UNICEF & WHO, 2015) were without proper access to safe water sources, this is indeed a significant issue. These communities need to be prioritized in the drinking water target of the Sustainable Development Goals (SDGs), which is to achieve universal and equitable access to safe and affordable drinking water for all by 2030 (UN, 2015). Therefore, a framework is needed to evaluate the sustainability of CBWS institutions that use groundwater as a water source. It should include an evaluation on the sustainability of CBWS institutions using Ostrom's design principles, the effort to sustainably use groundwater, and the ability to deliver safe and affordable water as expected by the SDG target. This framework will be beneficial for CBWS projects developed in locations where the problems of the tragedy of the commons and limited access to safe and affordable water occur simultaneously. It can be argued that our case study is fairly typical in many developing countries, and therefore will have a wide scope of application.

2. CBWS sustainability and Ostrom's institutional design principles

We use Ostrom's design principles (Ostrom, 1990) as a framework to evaluate the sustainability of CBWS institutions. Since our study is primarily focused on groundwater, we emphasize the application of the design principles in the context of groundwater as a CPR. Consequently, the variables of groundwater sustainability and the SDG's drinking water target are evaluated as part of Ostrom's design principles.

2.1. Clearly defined boundaries

Ostrom emphasized that "Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself" (Ostrom, 1990: 90). This is a key principle that ensures that there is no conflict between neighbouring CPR institutions managing the same resources. Cox *et al.* (2010) further proposed the need to separate this principle into two sub principles: boundaries of the CPR and boundaries of the users. However, as evident in groundwater management (Sarker *et al.*, 2009), it is difficult to define the boundaries of the groundwater system, since the limits of groundwater sources are often difficult to accurately define. Indeed, research conducted by Niamir-Fuller (1998) in Sahelian Africa pastorals (also cited in Cox *et al.* (2010)) showed that the boundaries of successful CPR systems do not always need to be defined. Therefore, since the boundary of groundwater cannot be easily defined, the first principle will only consider the boundaries of the users.

2.2. Congruence between appropriation and provision of rules and local conditions

This principle refers to the "Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labour, material, and/or money" (Ostrom, 1990: 90). It describes the CPR institutions' need for the provision of rules that are congruent and address local conditions and values. Ostrom (2008a) also referred to this principle as proportional equivalence between benefits and costs, focusing on the need to maintain labour, material, and monetary inputs. In addition to the rules to maintain the robustness of the CPR institution, for CBWS institutions, this is also the principle that considers the SDG's drinking water target. The World Health Organization (WHO, 2011) provides standards for drinking water quality, which ultimately act as a reference for most countries when developing their own standards. These standards should be followed by water suppliers to ensure safe water delivery. In addition to safe drinking water, another concern of the SDG is tariff affordability. To some extent, tariff affordability is reflected by the user's ability to pay for water consumption, which is measured by a certain percentage of a household's income. The United Nations Development Programme (UNDP, 2006) states a standard of water affordability for all, by capping household expenses for water use to a maximum of 3% of the total family income. In practice, the maximum standard is between 2 and 4% (Smets, 2012). To support the SDG's drinking water target, the CBWS should also follow local tariff affordability standard.

2.3. Collective-choice arrangements

The third principle relates to the existence of users' involvement in adapting rules during the operation of the system. As stated by Ostrom (1990: 90) "Most individuals affected by the operational rules can participate in modifying the operational rules". This principle ensures that the rules, which might be made in the establishment of the CPR institution, are suitable under existing conditions. User involvement may vary depending on the condition of the institutions and local values. In practical situations, users' involvement in designing or modifying rules have been welcomed (van Ast *et al.*, 2014) but in other cases, the role of leaders has tended to dominate (Quinn *et al.*, 2007). It is clear that there is a need to ensure user participation when updating rules, whether the involvement is high or low.

2.4. Monitoring

Ostrom proposed that CPR institutions' monitoring should include monitoring user behaviour and a review to audit the condition of the CPRs. This is because "Monitors, who actively audit CPR conditions and appropriator behaviour, are accountable to the appropriators or are the appropriators" (Ostrom, 1990: 90). Both forms of monitoring should exist to sustain the CBWS institutions, either conducted by the users or other parties. For the case of groundwater resources, Margat and Van der Gun (2013) describe four elements of resource management that should be considered, the availability of sufficient and reliable area-specific information, the objectives of groundwater resources management, the right instruments to manage groundwater sustainability, and the effort to implement planning and decision-making processes. Due to the complexity of the works, most elements should be conducted by government institutions. However, experience across the world shows that groundwater management benefits from community involvement. Groundwater monitoring by communities in Lockyer Valley, Australia (Sarker *et al.*, 2009), in Neemkheda, India (Kulkarni *et al.*, 2004), and in Texas, United States (Gleeson *et al.*, 2010) are all examples of how effective this approach can be. In India, community involvement was considered to be the immediate solution to India's groundwater problems (Kulkarni *et al.*, 2004). Community involvement includes activities such as the monitoring of groundwater table and planning water allocation (Gleeson *et al.*, 2010, 2012). In Neemkheda, India (Kulkarni *et al.*, 2004), some farmers were willing to learn from scientists and conduct groundwater monitoring of shallow aquifer and planning water pumping based on the condition of the groundwater. Other community involvement is managing aquifer recharge by constructing rainwater harvesting systems or infiltration ponds (Dillon, 2005).

2.5. Graduated sanctions

The graduated sanction principle was designed to prevent users from breaking regulations. According to this principle, "Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both" (Ostrom, 1990: 90). Sanctions can be meted in proportionality to the level of offence (Cox *et al*., 2010). According to case studies, the actual sanctions applied varied (Ostrom, 1990), ranging from a warning to an exclusion from consuming resources. In this research, we identified the availability of sanctions and how well the sanctions were implemented.

2.6. Conflict-resolution mechanisms

These mechanisms are either formal or informal institutions that allow users to resolve disputes within the organization. They allow "Appropriators and their officials (to) have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials" (Ostrom, 1990: 90). Such mechanisms may include moderation by group leaders, appeals to a courts system, or arbitration at group meetings. Without such tools, organizations can quickly become ineffective due to infighting. Examples from Northern New Mexico and Orissa, India showed that these mechanisms are needed to ensure the success of the institutions (Cox *et al*., 2010). The goal for this study is to identify if such a mechanism exists in the CBWS institutions.

2.7. Minimal recognition of right to organize

The next primary principle for a long enduring CPR institution is the right to organize. This principle requires that the institutions manage themselves and that "The rights of appropriators to devise their own institutions are not challenged by external government authorities" (Ostrom, 1990: 90). This authority will result in institutions that are better able to conduct sustainable consumption of resources in the long term without refusal from government institutions, as applies in communities managing water supply (Adams and Zulu, 2015; Sarker *et al*., 2009). In this research, we identify whether this right exists in the CBWS institutions.

2.8. Nested enterprise (for CPRs that belong to a larger system)

The last principle should be applied to CPR institutions that belong to a larger system, as it entails the "Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises" (Ostrom, 1990: 90). It is a mechanism through which resource management is organized in multiple layers of management. In a water resource application, such as irrigation and water supply, the institutions commonly use resources from a larger system. Hence, the management of water resources needs to be coordinated with the higher level institutions (Sarker *et al*., 2009). The mechanism is identified in this research to ensure the existence of the principle to maintain the sustainability of groundwater resources.

3. Methods

3.1. Study area

In Indonesia, CBWS projects have been promoted by the national government since early 2000. These projects enhance access to improved water sources (Ministry of Public Works of Indonesia, 2011), support the achievement of the drinking water target of the Millennium Development Goals (MDGs), and enable the accomplishment of the first target of Goal 6 of the SDGs, which is to provide universal and equitable access to safe and affordable drinking water for all by 2030 (UN, 2015). The CBWS projects appear in many national and local government programmes to provide water supply to communities. PAMSIMAS, a community-based water and sanitation service programme, is the most common. A large number of projects from this programme are jointly funded with loans from international donors as well as national and local government funding — and sometimes include funds from communities. The projects are often focused on rural areas or urban slums, with the aim to build water supplies that use groundwater, and can include sanitation facilities. After the development of the CBWS institutions, some villagers will be appointed to operate the CBWS institutions.

As with any other community-driven projects, CBWS projects experience both successes and failures. A 2014 government report (CPMU Pamsimas, 2014) showed that almost 30% of the projects (from among 1,990 villages) did not work as expected. They were either partly functioning (23%) or not working at all (7%). While numerous factors were responsible for project failures, an evaluation of CBWS projects in Central Java (Isham and Kähkönen, 1999) showed that the problems occurred in either the planning or operational stages. In the operational stage, most of the issues were due to the inability of the committees to effectively manage institutions and control service performance.

During 2011–2013, the Ministry of Health established a community water supply and sanitation project (Egis International, 2011) as part of a larger programme to improve the condition of Citarum River, known as the Integrated Citarum Water Resources Management and Investment Programme (ICWRMIP). The project aimed to improve community water access by changing from the previous practice of fetching water directly from the West Tarum Canal to connecting the water supply to homes by building 11 CBWS systems for eight *desa* (villages) on the canal's

Figure 1. Water tank in Pasirsari, Cikarang.

riverbank in the Cikarang area. The CBWS systems worked by pumping groundwater 80–100 m below the surface, from a cross border aquifer, the Karawang–Bekasi aquifer, which is managed by the Energy and Mineral Resources Agency (EMRA) of the West Java provincial government. The water was collected in a 32 m^3 water tank tower (Figure 1) and distributed by gravity without treatment to homes via a pipe distribution system.

A CBWS system costing more than IDR 300 million (more than US$23,000[1]) per unit was jointly funded. Eighty per cent of the funding came from national government and Asian Development Bank (ADB) loans, and the rest from community participation in the form of cash and in-kind (e.g. providing labour during the construction phase). The development of the system was assisted and monitored by the Municipal Health Agency (MHA), which together with appointed consultants and village officers, published public announcements, assisted communities in planning their contribution, and determined the location of the system. The area where the CBWS systems were located was not serviced by the local government-owned water supply corporation (PDAM/*Perusahaan Daerah Air Minum*), except in Pasirsari. Before the existence of the CBWS, families living near the canal usually fetched water from the canal for washing and bathing. Other households relied on individual groundwater pumping from an unconfined aquifer. The aquifer yield was seasonal and limited in some places due to the geological characteristics of the area, which included less permeable material (Dirks *et al*., 1989; Naryanto, 2011).

Thus, prior to the implementation of CBWS institutions, two problems existed. First, fetching water from a river could place a burden on community health. Second, as groundwater supply in unconfined aquifers was limited in a number of places, it sparked the tragedy of the commons, because every household located close to the aquifer drew water from wells with electric pumps. Therefore, the existence of CBWS institutions could help address problems related to the tragedy of the commons, and at the same time shift households from using unclean water. However, without sustainable consumption, CBWS groundwater extraction could also lead to another tragedy of the commons, or one between CBWS systems and other companies that withdraw groundwater from the same aquifer. This concern arose due to the fact that groundwater consumption in the Karawang–Bekasi aquifer had caused an existing contaminated zone to be expanded (ESDM JABAR, 2012) and land subsidence (Chaussard *et al*., 2013).

3.2. Institutional arrangement

During the preparation of the systems, the MHA, together with the village leaders, appointed personnel, usually village officials, to form a committee to manage its corresponding CBWS institution. The committee plays the role of regulator of the CBWS institution, and consists of at least three members: a leader, a technician, and a treasurer. Their main task is to manage the operation and maintenance of the systems. The committee is also responsible for determining water tariffs and for managing finances, such as collecting consumption fees from users (households that consume water from the CBWS distribution system) and distributing funds for operational use, including the committee’s monthly salary. Even though the committee is appointed by the MHA and village leaders, there is no obligation for the committee to provide a formal report to the village or the municipal government. However, since most committee members are village officials, informal communication with village leaders and MHA officers is often maintained. Even though CBWS institutions may be built under a single programme, management is left to the individual committee. Therefore, water tariffs and salary rates for the committee can differ between CBWS institutions. Three CBWS institutions pay their committees with a fixed monthly wage (ranging from US$23–US$38 per person per month), one CBWS institution pays its committee at a rate of 23 cents per user, while another CBWS

[1] In this article, US$1 equals IDR 13,000. IDR refers to the Indonesian currency (Indonesian Rupiah).

institution distributes 30% of its monthly income to the committee.

3.3. Data collection

Purposive sampling was used in which CBWS institutions built under ICWRMIP were targeted. Information about the CBWS institutions was gathered from key informant interviews. This method was chosen because the committee leader, as the key informant, had all the information for the CBWS institutions since their establishment.

Under the ICWRMIP, seven CBWS institutions were built in four villages in 2011 and 2012, and four CBWS institutions were built in another four villages in 2013. One CBWS institution was sampled from each of the four villages in the first batch, resulting in four CBWS samples. Later, an additional CBWS institution was included, resulting in a total of five CBWS institutions sampled: CBWS Cibatu, CBWS Jayamukti, CBWS Pasirtanjung 1, CBWS Pasirtanjung 2, and CBWS Pasirsari. The location of each CBWS is shown in Figure 2. In addition, interviews with local government officers, two from the MHA and one from the Water Resources Agency, were also conducted to obtain information on ICWRMIP projects. The CBWS institutions were chosen based on the leader's response and availability for interview. Assistance was obtained from an MHA official who had been assisting the development of CBWS institutions. In-depth interviews were conducted from 22 October 2015 to 6 November 2015.

Information about water quality was obtained by taking one sample from a point in the distribution system in each CBWS, as required by the *Permenkes 736/2010* (regulations for supply for less than 5,000 people). The regulation also mandates samples to be taken every month for an institution's performance assessment. However, in this research, water quality sampling is only needed to obtain information on water quality. Therefore, samples were only collected on two occasions: 11 November 2015 (the dry season) and 1 February 2016 (the rainy season). The samples were taken to a local government laboratory for analysis and the results were compared against government drinking water standards.

3.4. Analysis

This study adopted an evidence-based qualitative analysis as described in Salkind (2010). In her work, Ostrom (1990) used empirical evidence from each case to

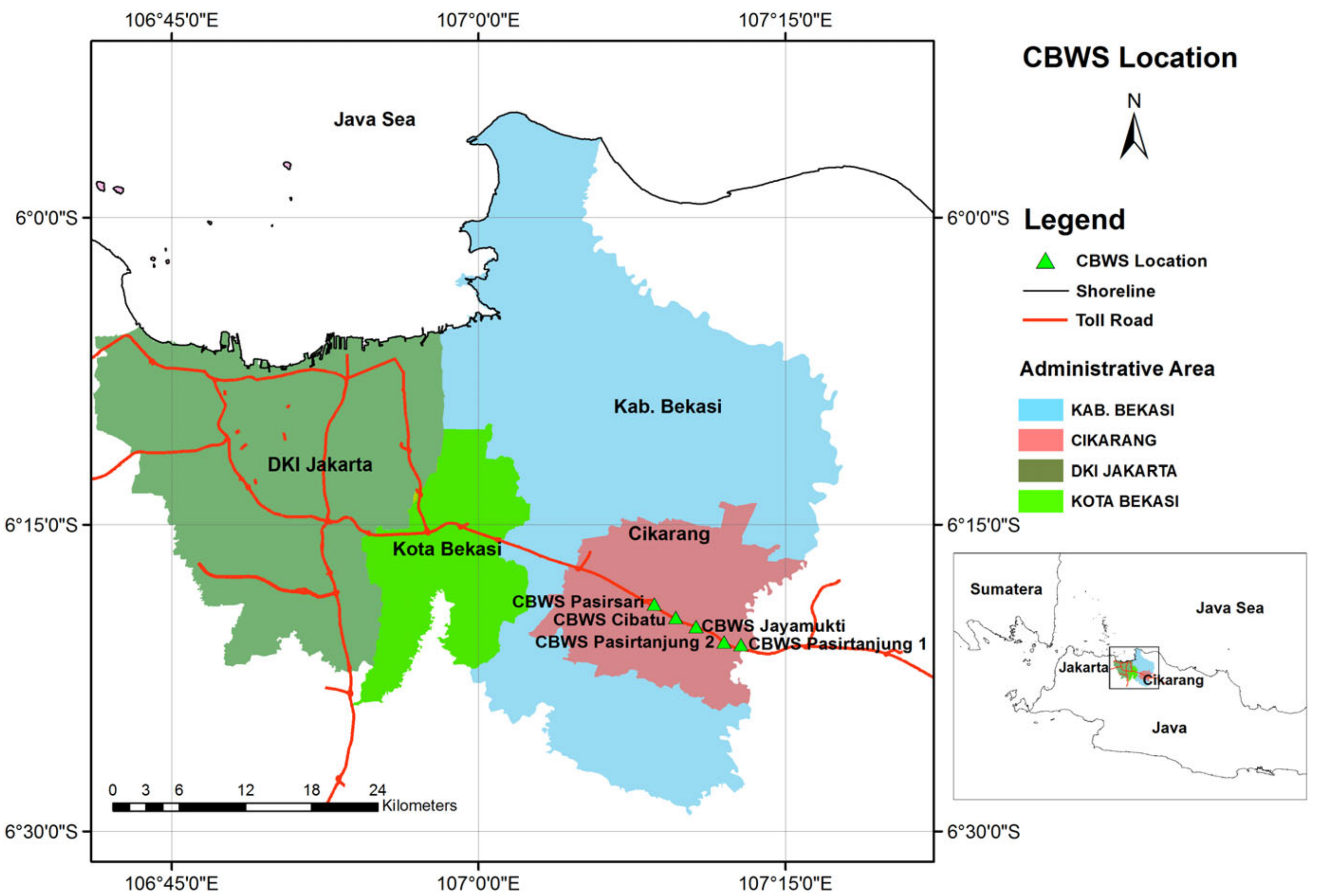

Figure 2. Location of sampled CBWS institutions.

determine the strength of each principle and the robustness of the institutions. Other studies (Cox *et al*., 2010; Quinn *et al*., 2007) used empirical evidence to determine the strength of each principle and used categorization to determine the robustness of the institutions. In this research, empirical evidence based on interviews with committee leaders will first be used to determine the strength of Ostrom's design principles. To begin, we evaluate the strength of each principle in a CBWS institution, and classify it as either strong, weak, or absent, based on the strength of the principle. We use Quinn *et al*.'s (2007) formula to determine the strength of CBWS institutions. According to Quinn *et al*. (2007), the management of CBWS institutions is categorized as strong only if all principles are strong, weak if up to three principles are weak or absent (the rest being strong), or absent if neither of these two conditions are met.

4. Results and discussion

The strength of the design principles for each CBWS institution is shown in Table 1. The management of four out of the five CBWS institutions is categorized as absent, except for CBWS Pasirtanjung 2. The similarity in results reveals the homogeneity of CBWS management, despite individual committees having the autonomy to manage their corresponding CBWS institution. This is possible since the CBWS institutions were developed as part of the same project and according to the proximity between each of the CBWS institutions. Community-based water supply (CBWS) Pasirtanjung 2 is categorized in weak condition because it was weak in two principles and absent in one. All other CBWS institutions are categorized as having absent management because they possessed three weak principles with one absent, with the exception of CBWS Jayamukti, which had 2 weak principles and two absent.

The results in Table 1 suggest a low level of sustainable CBWS institutions. All these institutions are able to meet water demand; however, there are concerns with being able to meet the SDG's drinking water target and groundwater sustainability, which is the focus of this research. Evidently, the performance of all CBWS institutions in the water quality sub principle is weak, especially that of CBWS Jayamukti. This does not support their function as water supply providers tasked with the distribution of safe water to users. Another concern is the absence of monitoring of CPR conditions and nested enterprise that could threaten groundwater sustainability. Therefore, under current management, the CBWS institutions cannot sustainably support their water supply system in order to meet the SDGs.

This study shows that Ostrom's conventional design principles may wrongly result in a strong CPR institution when used to evaluate a CBWS project, if SDG water targets and groundwater sustainability requirements are not considered. This indicates that these two variables are important considerations in ensuring the sustainability of the institutions and groundwater resources.

4.1. Clearly defined boundaries

Among CBWS institutions, user boundaries were clearly defined. Since the establishment of the CBWS, the institutions had clearly defined all boundaries based on *rukun tetangga* (RT)/ neighbourhood groups as the smallest residential cluster (Table 2). After the operation of the water supply systems, some CBWS institutions expanded their coverage. The expansion meant that CBWS Pasirtanjung 1 and Pasirtanjung 2 supplied the same RT; however, there was no overlap between their coverages. Community-based water supply (CBWS) Pasirtanjung 1 also expanded its coverage to another *desa* in the same *kecamatan* (sub district), which was geographically separated by a toll road by an underground piping system beneath the road. In 2015, the number of users of each CBWS varied between 55 and 318 households (Table 2). The user's arrangement showed that the existence of the first principle is strong for all CBWS.

4.2. Congruence between appropriation and provision rules and local conditions

Before discussing the ability of CBWS institutions to provide water supply according to the SDG's drinking water

Table 1. The strength of design principles for each CBWS institution

	Design principles	Cibatu	Jayamukti	Pasirtanjung 1	Pasirtanjung 2	Pasirsari
1	Clearly defined boundaries	Strong	Strong	Strong	Strong	Strong
2	Congruence between appropriation and provision rules and local conditions	Weak	Absent	Weak	Weak	Weak
3	Collective-choice arrangements	Strong	Strong	Strong	Strong	Strong
4	Monitoring	Weak	Weak	Weak	Weak	Weak
5	Graduated sanctions	Weak	Weak	Weak	Strong	Weak
6	Conflict-resolution mechanisms	Strong	Strong	Strong	Strong	Strong
7	Minimal recognition of right to organize	Strong	Strong	Strong	Strong	Strong
8	Nested enterprise	Absent	Absent	Absent	Absent	Absent
	Overall	Absent	Absent	Absent	Weak	Absent

Table 2. CBWS coverage, number of connections, and water consumption 2015

CBWS	Coverage	Location	Number of household connections	Average monthly consumption per CBWS (m^3)	Average monthly consumption per household (m^3)
Cibatu	2 RT	Desa Cibatu Kecamatan Cikarang Selatan	301	6,024	21.18
Jayamukti	1 RT	Desa Jayamukti Kecamatan Cikarang Pusat	138	2,735	19.82
Pasirtanjung 1	2 RT	Desa Pasirtanjung Kecamatan Cikarang Pusat	222	3,639	12.19
	1 RT	Desa Pasirranji Kecamatan Cikarang Pusat	96		
Pasirtanjung 2	4 RT	Desa Pasirtanjung Kecamatan Cikarang Pusat	310	7,736	25.38
Pasirsari	2 RT	Desa Pasirsari Kecamatan Cikarang Selatan	55	1,469	26.81
Total			1,122		
Average				4,320	21

Source: CBWS committees and authors' elaborations.

target, there is an issue regarding the arrangement of labour and materials as part of this principle (Ostrom, 2008a). All CBWS committees experienced issues in system maintenance, such as leaking pipes and broken pumps. Some of these problems have been occurring since the establishment of the system, for example, pipes may have been leaking due to poor workmanship and problems with broken pumps occurring because of a lack of maintenance. For simple problems, the committees could hire local labour, but for more complex problems they lacked sufficient funds to engage specialists to maintain the system. Therefore, the committees raised concerns about a lack of training, as expressed by a CBWS Cibatu leader during an interview (CBWS Cibatu, 23 October 2015). Apparently, these problems are not new, and could have been anticipated beforehand. The World Bank report (Isham and Kähkönen, 1999) identified problems in the construction, operation, and management of CBWS in Central Java, Indonesia. The report proposed some policies for improvement that could be used for future projects, claiming "project funders and staff need to place a high priority on the training and monitoring of water committees". Similar issues have also occurred in other countries, including Bolivia (Newman *et al*., 2002), as well as sub-Sahara (Harvey and Reed, 2007). In these instances, technical problems arose during the operation of the water supply system, and a lack of training to operate and maintain the systems has been reported.

Institutions employing CBWS do not have the necessary experience that those in the irrigation sector in Indonesia have. The irrigation sector has a long history of community management (namely Subak, Mitra Cai, and Dharma Tirta), followed by support from government-managed water user groups such as P3A (*Perkumpulan Petani Pemakai Air*). Following the success of the irrigation sector, some of their approaches can be used as a benchmark for CBWS. Research on the irrigation sector (Ricks, 2016) shows that government officials' communication (commonly from the municipality level) with farmers significantly improves the performance of water user institutions. Currently in CBWS, government involvement is limited after the operational stage. The experience of the irrigation sector indicates that there is an argument for municipality involvement to bring about improvement to CBWS performances, and that these improvements should continue past the initial stage (Ricks, 2016).

4.2.1. Safe drinking water quality

The first target of the SDG on water and sanitation (UN, 2015) is expected to be met by 2030. In Indonesia, CBWS as part of the water supply system is also expected to deliver safe and affordable drinking water. In terms of potability, Indonesia's Ministry of Health (MOH) regulation on drinking water standards, the *Permenkes* 492/2010, mandates all water supply providers to comply with physical, chemical, and microbiological standards in their water supply. In addition, *Permenkes 736/2010* sets mandatory procedures related to the monitoring of water quality. Since the decentralization era, government regulation 16/2005 on water supply system development states that a water service provision is the responsibility of municipal governments. This means that monitoring water quality is also under municipal government jurisdiction, but that the implementation might differ between municipalities.

Since the beginning of the ICWRMIP project, water quality monitoring for CBWS water samples had only been conducted once during establishment, as was required, and had been found to meet government specifications. Subsequently, neither the committees nor the MHA conducted further lab testing to monitor CBWS water quality, not even in Jayamukti where users were aware of salinity issues (CBWS Jayamukti, 22 October 2015). This is contrary to regulation (*Permenkes 736/2010*), which mandates water quality monitoring to be conducted frequently each year.

The laboratory results of the water samples collected in this study showed that with the exception of CBWS Pasirtanjung 1 (colour was close to the limit), all of the samples collected during the rainy season in February 2016 were coloured. All of the CBWS water samples were contaminated by coliform bacteria, except the sample from CBWS Cibatu collected in November 2015. Two CBWS water samples were contaminated with faecal coliform bacteria, two CBWS water samples were only contaminated during the rainy season (February 2016), and other CBWS water samples were found to be free from faecal contamination. The increased colour in the water samples may have been caused by an increase in silt particles, which is typically high during the rainy seasons. In addition, Lee and Schwab (2005) reported that water quality degradation can also be caused by intermittent service and leakages in pipe networks. These factors are present in all CBWS water supply systems, in addition to poor sanitation practices within the water catchments. For example, one CBWS water source was located near a farming area, while another was located near open solid waste dumping sites that may have leachate contamination issues.

The World Bank (1994) claims that due to inadequate sanitation, coliform bacteria contamination is a common problem in Indonesian water supply systems. Although this report was written more than two decades ago, conditions may not have improved significantly as Indonesia still deals with sanitation problems. This claim is supported by the fact that Indonesia is the second highest country in the world with regard to the number of people who practise open defecation (WHO & UNICEF, 2014). For example, the 2014–2015 PDAM's municipal water company's water quality monitoring showed that more than 20% of household water samples were contaminated with coliform bacteria. For this reason, many Indonesian households (41.8%) rely on bottled water for drinking (Statistics Indonesia (Badan Pusat Statistik—BPS) *et al*., 2013).

In addition to coliform contamination, some CBWS water samples exceeded physical and chemical standards (Table 3). For example, high turbidity was found in CBWS Cibatu, and high concentrations of iron were found in CBWS Cibatu and CBWS Pasirtanjung 1. Unlike coliform contamination that could threaten human health, the concentrations of iron found in the water samples were harmless to health, but may aesthetically affect the water. At these concentrations (Table 3), taste and odour issues could be significant, in addition to the potential to stain pipes and clothes (Colter and Mahler, 2006). From two water samplings, all CBWS water samples exceeded the drinking water standards. It is also common to find that PDAMs in Indonesia do not deliver the expected water quality at all times (BPPSPAM, 2015). This has led most Indonesians to boil water intended for drinking from piped supplies (Hadipuro, 2010). The worst water quality was found in CBWS Jayamukti. In addition to coliform bacteria and colour, TDS (total dissolved solids), chloride, sulphate and manganese (consistent with high TDS levels) exceeded government standards. The WHO guidelines for drinking water quality (WHO, 2011) states that there are no health effects for TDS concentration up to 1,400 mg/L; however, users may find such high concentrations disturbing, as evidenced from the number of complaints regarding salinity (CBWS Jayamukti, 22 October 2015). The poorer water quality found in some of the CBWS can be improved through simple methods of water treatment, for example, phosphate treatment to reduce iron concentrations (Colter and Mahler, 2006) and chlorination for disinfection (WHO, 2004). However, as mentioned earlier, the committees were unable to implement these measures due to a lack of technical knowledge. Assistance from the government would be helpful in improving this situation.

4.2.2. Tariff affordability

The Indonesian Ministry of Home Affairs regulation (*Permendagri* 23/2006) mandates a certain tariff on drinking water for the PDAM. The tariff should ensure affordability where water expenses for 10 m^3 consumption per household per month (a basic water requirement, according to the Indonesian government) do not exceed 4% of provincial minimum wage for labourers (Smets, 2012). In some provinces, for example West Java Province, the minimum wage is determined at the municipality level, resulting in a benchmark for tariff affordability. Although the regulation is intended for PDAM, in this article it will be used to check the affordability of the CBWS tariff.

Each CBWS sets a tariff for initial subscription and monthly water consumption (Table 4), which should be paid in the first week of each month. The financial arrangements are usually taken care of by an appointed treasurer who collects the bills from the users, pays salaries to the officials, and manages other operational expenses. In some CBWS institutions, however, the leaders also play the role of treasurer. Currently, the financial arrangements could ensure basic continuity of the CBWS institutions to fund their operational and management expenses. For three CBWS institutions, Cibatu, Pasirtanjung 1, and Pasirtanjung 2, savings made were used to expand coverage by building new systems to support older systems that could no longer supply enough water for the growing number of users (CBWS Cibatu, 23 October 2015; CBWS Pasirtanjung 1 and Pasirtanjung 2, 27 October 2015).

The maximum tariff for 10 m^3 consumption per household is an IDR 7,000 monthly maintenance fee and an IDR 30,000 consumption fee (total of IDR 37,000 is equivalent to USD 2.85), which is charged by CBWS Pasirsari. This tariff is 1.3% of the 2015 municipal minimum wage of IDR 2,840,000 (USD 204). According to government

Table 3. CBWS water quality

Parameter	Unit	Threshold*	Jayamukti		Pasirsari		Pasirtanjung 1		Pasirtanjung 2		Cibatu	
			November 2015	February 2016	November 2015	February 2016	November 2015	February 2016	November 2015	February 2016	November 2015	February 2016
Microbiology												
Total Coliform	Colony/ 100 ml	0	NCR (11)	NCR (46)	NCR (23)	NCR (>1,898)	NCR (4)	NCR (4)	NCR (>2,400)	NCR (95)	√	NCR (11)
Faecal Coliform	Colony/ 100 ml	0	NCR (4)	NCR (7)	√	NCR (26)	√	√	NCR (7)	NCR (14)	√	NCR (4)
Physical												
Colour	TCU	15	√	NCR (16)	√	NCR (18)	√	√	√	NCR (16)	√	NCR (32)
Temperature	^0C	Ambient temp ±3°C	√	√	√	√	√	√	√	√	√	√
Turbidity	NTU	5	√	√	√	√	√	√	√	√	√	NCR (10.48)
Total Dissolved Solids	mg/l	500	NCR (729)	NCR (1,400)	√	√	√	√	√	√	√	√
Chemical												
pH	-	6.5–8.5	√	√	√	√	√	√	√	√	√	√
Iron	mg/l	0.30	√	√	√	√	√	NCR (0.37)	√	√	NCR (0.95)	NCR (1.67)
Total Hardness as $CaCO_3$	mg/l	500	√	√	√	√	√	√	√	√	√	√
Chloride	mg/l	250	NCR (590)	NCR (253)	√	√	√	√	√	√	√	√
Chromium Total	mg/l	0.05	√	√	√	√	√	√	√	√	√	√
Nitrate as $N0_3$	mg/l	50	√	√	√	√	√	√	√	√	√	√
Nitrite as $N0_2$	mg/l	3	√	√	√	√	√	√	√	√	√	√
Sulphate	mg/l	250	√	NCR (253.8)	√	√	√	√	√	√	√	√
Manganese	mg/l	0.40	NCR (0.43)	√	√	√	√	√	√	√	√	√

Source: Authors' elaborations.

*According to *Permenkes* 492/2010 on drinking water standards. √ = complying result, NCR = non-complying result with value in the bracket.

Table 4. CBWS Tariff 2015

	Initial subscription fee			Consumption fee per m^3		
CBWS		**IDR**	**US$**		**IDR**	**US$**
Cibatu		500,000	38.5		3,000	0.23
Jayamukti	Before September 2015	350,000	26.9	Before September 2015	2,500 (for all users)	0.19
	Since September 2015	500,000	38.5	Since September 2015	3,500 (for commercial users)	0.27
					2,500 (for other users)	
				Additional monthly administration fee IDR 2,000 (US$ 0.15)		
Pasirtanjung 1	Before 2015	300,000	23.1		2,500	0.19
	Since 2015	500,000	38.5			
Pasirtanjung 2	Before 2015	300,000	23.1		2,500	0.19
	Since 2015	500,000	38.5			
Pasirsari	Before 2015	600,000	46.2	0–10 m^3	3,000	0.23
	Since 2015	800,000	61.5	11–20 m^3	3,500	0.27
				21 m^3 onwards	4,000	0.31
				Additional monthly administration fee IDR 2,000 (US$ 0.15) and subscription fee IDR 5,000 (US$ 0.38)		

Source: CBWS committees and authors' elaborations.

standards (*Permendagri* 23/2006), CBWS Pasirsari's tariff and other CBWS tariffs for minimum household consumption per month can be considered to be affordable.

Although current CBWS tariffs are affordable, these rates limit the ability of the committees to improve CBWS services due to lack of funding. This problem has been identified in previous research (Jiménez and Pérez-Foguet, 2010), in which limited financial support could be a barrier in a system's operation and maintenance. In Cikarang, this caused CBWS Pasirtanjung 1 (CBWS Pasirtanjung 1, 27 October 2015) to opt for a cheaper replacement pump. The cheaper pump came with diminished performance and a shorter lifetime, resulting in the need for several additional replacements in the three-year operational period. Limited savings also meant CBWS Pasirtanjung 2 had to apply for bank credit to fund the building of a new system (CBWS Pasirtanjung 2, 27 October 2015).

There is a gap of approximately 2.7% (of provincial minimum wage) between current tariffs and government affordability standards. This gap can be used by the CBWS to implement a tariff increase to improve water services; however, the committees chose not to increase the consumption tariff out of consideration for the financial situation of its users, since most were deemed to be low income families (CBWS Jayamukti, 22 October 2015; CBWS Pasirtanjung 2, 27 October 2015). However, all CBWS institutions, except CBWS Cibatu, raised the initial subscription tariff following an increase of pipe prices and labour wages (Table 4).

The discussion about tariff affordability is to ensure that the prevailing tariff will not prevent vulnerable households from consuming water at the minimum requirement level either by decreasing consumption or by substituting it with water from unsafe sources (Hutton, 2012). In this case, we do not expect users to go back to pumping groundwater individually or fetching water from the river. However, average water consumption in the CBWS is 21 m^3 per household per month (Table 2), which is about double the government standard of 10 m^3 per household per month, and more than the minimum water requirement for fundamental human rights, which is 50 l per capita per day, or equal to 6 m^3 per household per month (Gleick, 1996). This implies that tariff vulnerability that leads to a decrease in water consumption is not a significant issue for most CBWS users. On the other hand, raising tariffs to a certain level could help avoid excessive consumption, because of the negative correlation between tariff rates and water consumption (Dalhuisen *et al*., 2003). This will eventually help the committees maintain groundwater sustainability by keeping households' water consumption at an adequate level.

Indeed, increasing tariff rates is a sensitive issue for CBWS, as illustrated in Mali, where high tariffs resulted in withdrawal from community participation (Gleitsmann *et al*., 2007). In CBWS Cikarang, the most acceptable reason for tariff increase might be to adjust current tariffs for CBWS Jayamukti, Pasirtanjung 1, and Pasirtanjung 2 to the tariff rates for CBWS Cibatu and Pasirsari. Another possible tariff increase is through the application of a progressive tariff, which is currently practised in CBWS Pasirsari. In Pasirsari, tariffs are differentiated per 10 m^3 of consumption, and constant after 20 m^3. However, this scheme was once refused in Pasirtanjung 2 (CBWS Pasirtanjung 2, 27 October 2015), prompting committees to become more guarded by socializing the benefit of a progressive tariff to the users before implementation.

Investigations on the second principle show that all CBWS institutions are weak with maintaining their systems, complying with drinking water standards, and balancing costs. The situation is the worst in CBWS Jayamukti, which produces water at very low standards and is unprofitable and therefore unable to maintain its system. These issues have led us to believe that the second principle is absent in CBWS Jayamukti.

4.3. Collective-choice arrangement

In some CPR institutions (van Ast *et al*., 2014), community participation in the creation or modification of rules usually takes place in a meeting among users, but decisions to modify rules are usually taken under the leader's approval. Quinn *et al*. (2007) show in their research that the leader dominates the rules regarding CPR institutions. Those arrangements are acceptable as long as the users still have the ability to contribute to the modification of rules (Ostrom, 1990, 2008a). An example of water supply community-driven projects (Adams and Zulu, 2015) showed that the users in the projects commonly play the role of paying customers rather than active users. Indeed, the function of a CBWS institution is similar to a water supply company: to deliver water supply to customers, to collect water bills from users, and to manage operational and management costs. As a CPR institution, the users are expected to be able to contribute in the arrangement to modify rules. In a water supply company, the arrangement is not recognized, but customers can still give feedback to the company, usually via a customer service line.

In all CBWS institutions, the rules on tariffs were created by each CBWS committee. Since the establishment of CBWS institutions, the most important rule, the consumption tariff, has never been raised, except in CBWS Jayamukti in order to differentiate groups of users. On the other hand, the initial subscription fee (for new users) has been raised in all CBWS institutions, except in CBWS Cibatu. The increase in tariffs was determined by the committee, without the involvement of users. According to the CBWS Pasirsari leader (CBWS Pasirsari, 6 November 2015), the decision was made according to the price of materials. In the early stage of the development of CBWS systems, materials were bought in large quantities, which kept the cost for pipe connections low. Subsequently, for each new user, the committee must buy material in smaller amounts at higher costs. In Pasirtanjung 1 (CBWS Pasirtanjung 1, 27 October 2015), there is a preapproved initial subscription fee, but for new users who live far from the distribution mains, the fee is usually discussed between the user and the leader of the committee, depending on the distance from the mains. The same scheme is also applied in PDAM for new customers who live outside the company's coverage area. The initial subscription fee is calculated separately, usually based on the distance from the company's pipe network.

User contribution to this research lays between their roles as members (in a CPR institution) and as paying customers (in a water supply company). Contributions to modify rules are not delivered in members' meetings, as is the case in CPR institutions. Rather, the committee is informed, usually via informal communication with the leader, similar to customers providing feedback to a water supply company. The leader then discusses the user feedback with other members of the committee. When this feedback is approved, it is then released to the users as a formal rule, as well as announced to them during monthly bill collections — or printed on the bills. In Jayamukti (CBWS Jayamukti, 22 October 2015), strong user opinions advised the committee to differentiate tariffs between business and household users (Table 4). In Pasirtanjung 2 (CBWS Pasirtanjung 2, 27 October 2015), protests from users resulted in the cancelation of plans to implement a progressive tariff. The formal and informal communication between users and committees is recognized in CPR institutions in villages (Quinn *et al*., 2007). It is important to ensure that despite the informal communication in contributing opinions, the modified rules should be delivered as formal rules to strengthen their function.

Users' contributions to modifying rules through informal communication with committees show that a strong bond of trust and connectedness between users and committees exists in the CBWS institutions. This is an element of social capital, discussed in Pretty (2003), and shows that the strength of this principle is strong among all CBWS institutions.

4.4. Monitoring

4.4.1. Monitoring user consumption

A water meter was installed in each user's home to record monthly consumption for every CBWS location. In the first week of the month, a committee member records water consumption from each household to calculate the monthly bill. This shows a strong effort to monitor user consumption of CPR, as well as indicates a strong value of this sub principle.

4.4.2. Monitoring groundwater sustainability

According to Indonesian regulations, any groundwater withdrawal, except for daily household consumption and individual farming, requires a permit from a government institution. Additionally, to maintain the condition of the aquifer, the government limits permits and the withdrawal amount, while ensuring adequate water recharge. Even though CBWS withdraw groundwater, they are not required to obtain permission to do so, and were not charged any tax for withdrawing water. This is based on the assumption that CBWS are not-for-profit institutions, and the water is used for daily household consumption. Exempting the CBWS from permits and taxes demonstrates a desire to support community involvement in managing water supply in the absence of public piped water services, if there is a reliable mechanism for monitoring CBWS extraction levels to achieve sustainability.

The recorded consumption for 2015 showed that each CBWS consumed about 1,469–7,736 m^3 of groundwater, with an average of 4,320 m^3 per month (Table 2). The highest CBWS monthly consumption, which is equal to the consumption of a middle scale factory, is not negligible. It raises some concerns because currently, industrial groundwater consumption has affected groundwater sustainability in Cikarang (Chaussard *et al*., 2013; ESDM JABAR, 2012). Apparently, some CBWS committees (CBWS Pasirsari, Pasirtanjung 1, and Pasirtanjung 2) also noticed diminishing quantities of groundwater during the 2015 dry season. At the time, users were complaining about lower supply levels to homes in the daytime, compared to the rainy season. This implies that cumulative CBWS consumption, including those of other CBWS projects in Cikarang, could diminish groundwater supply. Therefore, monitoring CBWS, in addition to industrial groundwater consumption, is necessary. Hence, there is a need for nested, cross scale/CBWS instructional arrangements.

Under current management, the CBWS might survive as institutions, as they provide strong mechanisms to monitor user consumption. Without monitoring however, the systems would not be sustainable if groundwater reserves diminish. Therefore, CBWS involvement in groundwater monitoring is necessary to ensure groundwater sustainability.

4.5. Graduated sanctions

In all CBWS institutions, there are unwritten rules that regulate supply disconnection when payment is late or not made. However, in the five CBWS investigated, only CBWS Pasitanjung 2 has implemented this rule, and it was only carried out as a last resort due to irresponsible user behaviour (CBWS Pasirtanjung 2, 27 October 2015). Even though most committees stated that users' arrears were the biggest challenge in managing the system, none, except Pasirtanjung 2, chose to disconnect supply. Most committees were sympathetic, and had empathy for users who were financially constrained, despite the requirement of institutions to maintain system funding. In fact, most committees offered to assist users by allowing users credit facilities, even as they continued to remind users about the possibility of supply disconnection. Thus, of the five CBWS considered, only CBWS Pasirtanjung 2 had a strong principle of graduated sanction; the other four CBWS weakly implemented the principle.

4.6. Conflict resolution mechanism

In the five CBWS institutions, conflict resolution mechanisms are not well prepared, in written form or otherwise. In practice, the role of the committees is dominant, and most of the conflicts are resolved through communication between users and committees, especially with the leaders. For example, as described in the fifth principle, when a user delays payment for up to several months, the committee will not disconnect the supply, but will encourage the users to pay arrears in instalment.

There are some examples in which committees play notable roles in the system. In the initial stages, some households in CBWS Pasirtanjung 1 neglected to pay water bills because these households assumed that the system was built and funded by the government (CBWS Pasirtanjung 1, 27 October 2015). The leader patiently explained that the committee was responsible for operational and management costs, thus the need for a water tariff.

In addition to conflict resolution between users and committees, CBWS Pasirtanjung 1 also experienced conflicts with the power company. The committee did not pay the pump's electricity bill for three years of operation, since the assumption was that the CBWS system was a government project that might benefit from waivers from the power company (which is also government-linked). The amount in arrears was IDR 35,000,000 (US$2,692), and the committee leader was threatened with imprisonment. This conflict was resolved by paying the bills in instalments, and they were paid in full in 2015.

Other CBWS committees also experienced managing conflicts with their users or with other parties. All of these conflicts were resolved through communication between committees (usually by the leaders) and the conflicting parties. In more serious cases, village leaders were involved in the process. Again, these examples demonstrate strong social capital among villagers, and also strong efforts in managing the sixth principle.

4.7. Minimal recognition of right to organize

Despite the fact that the systems were built from the same programme, the ICWRMIP, each CBWS managed the decision on its own. After the operational stage, the appointed committees were capable of managing their individual systems. This included proposing initial subscription fees and maintaining water supply and distribution, without consulting the MHA or other government authorities. The right to organize can also be seen by different tariff rates charged and arrangements between the five CBWS institutions in Table 4. In extreme conditions, strong rights to organize were also demonstrated by a willingness on the part of the committees to take further responsibilities to manage its corresponding CBWS institution. For example, when CBWS Pasirtanjung 2 intended to build a new system, although funds were insufficient, the leader was willing to use his property as collateral to obtain a bank loan (CBWS Pasirtanjung 2, 27 October 2015).

4.8. Nested enterprise

In principle 4, it was shown that despite recording monthly users' water consumption, all CBWS institutions do not monitor their groundwater resources. According to Margat and Van der Gun (2013), it is important to provide reliable data to manage groundwater resources. Current water consumption data should be assessed together with data on groundwater deposits. With this information, CBWS institutions can keep their water consumption to an adequate level, without harming the groundwater resources. With adequate training and assistance, CBWS committees could also contribute to groundwater management, as the approach has been implemented in other CPR institutions around the world. In Lockyer Valley, Australia (Sarker *et al*., 2009), farmers were willing provide their own water meters to monitor their consumption. In Neemkheda, India (Kulkarni *et al*., 2004), farmers performed groundwater monitoring and planned their consumption based on the data collected. A study conducted by Gunn and Mora (cited in Cox *et al*. (2010)) also showed that community involvement in resources monitoring resulted in the sustainability of the resources.

The effort to support CBWS participation in managing groundwater resources could also help EMRA to address West Java groundwater problems. As the CBWS manages their groundwater sustainability, the agency could also be focusing on other parts of the province, handling diminished groundwater resources in Cikarang (Chaussard *et al*., 2013; ESDM JABAR, 2012), and addressing problems of unregistered industrial groundwater use (Abidin *et al*., 2009; Braadbaart and Braadbaart, 1997; Chaussard *et al*., 2013).

5. Conclusion

This study shows that all five CBWS institutions were strong enough to sustain themselves. Even though they did not fulfil all aspects of Ostrom's design principles, the CBWS studied were able to make up for their shortcomings through alternative methods. For example, in the first principle, even though two CBWS supplied water to the same neighbourhood, they managed to distinguish their users through communication. In principle 3, the absence of regular meetings between the users and the committees was addressed by informal communication between the two. The communication proved to be effective in determining the tariff policy. Conflict resolution, which should exist based on the sixth principle, was replaced with the dominant role of the committee leader. However, having a leader who is too dominant could be risky if the leader is not capable of making sound decisions for the benefit of both the users and the system. Therefore, it is important to create formal arrangements not only for conflict resolution, but also for determining user boundaries and regular meetings. This is important in conflict prevention, and will encourage participation, ownership, and accountability.

Despite the state of strong CPR institutions, the CBWS water samples failed to show strong performance in achieving water quality targets and groundwater sustainability. In the long term, if both of these sub-principles continue to be absent or weak, the CBWS institutions will not be supporting the aim of SDG 6 to provide safe water to the community, which in turn threatens the continuity of the CBWS systems, when groundwater deposits diminish. Therefore, it is important for the government, in particular provincial and municipal agencies, to assist CBWS committees in maintaining a satisfactory standard of drinking water, as well as to support and assist the management of the system. Lastly, it is also important to involve CBWS committees to monitor and sustain groundwater supply in their locations to ensure sustainability.

Acknowledgement

The authors would like to thank the Australian Awards Scholarship for providing financial support for the first author.

References

Abidin, H.Z., Andreas, H., Gumilar, I., Wangsaatmaja, S., Fukuda, Y., Deguchi, T., 2009. Land subsidence and groundwater extraction in Bandung Basin, Indonesia. *IAHS Publication*, 20: 145–156.

Adams, E.A., Zulu, L.C., 2015. Participants or customers in water governance? Community-public partnerships for peri-urban water supply. *Geoforum*, 65: 112–124.

Agrawal, A., 2003. Sustainable governance of common-pool resources: Context, methods, and politics. *Annual Review of Anthropology*, 32(1): 243–262.

van Ast, J.A., Widaryati, A., Bal, M., 2014. The 'Adat' institution and the management of grand forest 'Herman Yohannes' in Indonesian Timor: The role of design principles for sustainable management of common pool resources. *Conservation and Society*, 12(3): 294–305.

Bakker, K., 2010. *Privatizing Water: Governance Failure and the World's Urban Water Crisis*. Cornell University Press, Ithaca.

Baland, J.-M., Platteau, J.-P., 1996. *Halting Degradation of Natural Resources: Is there a Role for Rural Communities?* Food & Agriculture Org, Rome.

BPPSPAM, 2015. *Kinerja PDAM 2015: Wilayah II Pulau Jawa [PDAM Performance 2015: Region II Java]*. BPPSPAM, Kementerian Pekerjaan Umum dan Perumahan Rakyat.

Braadbaart, O., Braadbaart, F., 1997. Policing the urban pumping race: Industrial groundwater overexploitation in Indonesia. *World Development*, 25(2): 199–210.

Brundtland Commission, 1987. *Our Fommon Future: Report of the World Commission on Environment and Development*. United Nations.

Chaussard, E., Amelung, F., Abidin, H., Hong, S.-H., 2013. Sinking cities in Indonesia: ALOS PALSAR detects rapid subsidence due to groundwater and gas extraction. *Remote Sensing of Environment*, 128: 150–161.

Colter, A., Mahler, R.L., 2006. *Iron in Drinking Water*. University of Idaho Moscow, Moscow, ID.

Cox, M., Arnold, G., Tomás, S.V., 2010. A review of design principles for community-based natural resource management. *Ecology and Society*, 15(4): 38.

CPMU Pamsimas, 2014. Evaluasi Pelaksanaan Program Pamsimas II TA 2014, Rencana Program TA 2015. CPMU Pamsimas, Batam, 26 August.

Dalhuisen, J.M., Florax, R.J., De Groot, H.L., Nijkamp, P., 2003. Price and income elasticities of residential water demand: A meta-analysis. *Land Economics*, 79(2): 292–308.

Dillon, P., 2005. Future management of aquifer recharge. *Hydrogeology Journal*, 13(1): 313–316.

Dirks, F., Rismianto, D., De Wit, G., 1989. Groundwater in Bekasi district, West Java, Indonesia. *Natuurwetenschappelijk Tijdschrift*, 70: 47–55.

Egis International, 2011. Report on implementation of social and environmental safeguards. In: *Program Management Support Integrated Citarum Water Resource Management Investment Program*. Balai Besar Wilayah Sungai Citarum, Indonesia.

ESDM JABAR 2012. Evaluasi Neraca Kesetimbangan Air Tanah pada Wilayah Padat Industri di CAT Bekasi-Karawang. In: ESDM JABAR (Ed.), Bandung: Dinas ESDM Jawa Barat.

Gleeson, T., Alley, W.M., Allen, D.M., Sophocleous, M.A., Zhou, Y., Taniguchi, M., VanderSteen, J., 2012. Towards sustainable groundwater use: Setting long-term goals, backcasting, and managing adaptively. *Ground Water*, 50(1): 19–26.

Gleeson, T., VanderSteen, J., Sophocleous, M.A., Taniguchi, M., Alley, W.M., Allen, D.M., Zhou, Y., 2010. Groundwater sustainability strategies. *Nature Geoscience*, 3(6): 378–379.

Gleick, P.H., 1996. Basic water requirements for human activities: Meeting basic needs. *Water International*, 21(2): 83–92.

Gleitsmann, B.A., Kroma, M.M., Steenhuis, T., 2007. Analysis of a rural water supply project in three communities in Mali: Participation and sustainability. *Natural Resources Forum*, 31(2): 142–150.

Gutiérrez, N.L., Hilborn, R., Defeo, O., 2011. Leadership, social capital and incentives promote successful fisheries. *Nature*, 470(7334): 386–389.

Hadipuro, W., 2010. Indonesia's water supply regulatory framework: Between commercialisation and public service? *Water Alternatives*, 3 (3): 475.

Hardin, G., 1968. The tragedy of the commons. *Science*, 162: 1243–1248.

Harvey, P.A., Reed, R.A., 2007. Community-managed water supplies in Africa: Sustainable or dispensable? *Community Development Journal*, 42(3): 365–378.

Hutton, G., 2012. Monitoring "affordability" of water and sanitation services after 2015: Review of global indicator options. A paper submitted to the UN Office of the High Commissioner for Human Rights, 20 March.

Isham, J., Kähkönen, S., 1999. What determines the effectiveness of community-based water projects. Social Capital Initiative Working Paper No. 14.

Jiménez, A., Pérez-Foguet, A., 2010. Building the role of local government authorities towards the achievement of the human right to water in rural Tanzania. *Natural Resources Forum*, 34(2): 93–105.

Kobayashi, K., Ari, I.R.D., Escobar, I.C., Schaefer, A., 2014. *Community Based Water Management and Social Capital*. IWA Publishing, London.

Kulkarni, H., Shankar, P.V., Deolankar, S., Shah, M., 2004. Groundwater demand management at local scale in rural areas of India: A strategy to ensure water well sustainability based on aquifer diffusivity and community participation. *Hydrogeology Journal*, 12: 184–196.

Lee, E.J., Schwab, K.J., 2005. Deficiencies in drinking water distribution systems in developing countries. *Journal of Water and Health*, 3(2): 109–127.

Leonard, R., Walton, A., Farbotko, C., 2015. Using the concept of common pool resources to understand community perceptions of diverse water sources in Adelaide, South Australia. *Water Resources Management*, 29(5): 1697–1711.

Mansuri, G., Rao, V., 2004. Community-based and-driven development: A critical review. *The World Bank Research Observer*, 19(1): 1–39.

Margat, J., Van der Gun, J., 2013. *Groundwater Around the World: A Geographic Synopsis*. CRC Press, Leiden.

Ministry of Public Works of Indonesia, 2011. *Multi-Village Pooling Project in Indonesia: Handbook for Community-Based Water Supply Organizations*. Ministry of Public Works of Indonesia, Jakarta.

Naryanto, H.S., 2011. Potensi Air Tanah di Daerah Cikarang dan Sekitarnya, Kabupaten Bekasi Berdasarkan Analisis Pengukuran Geolistrik. *Jurnal Air Indonesia*, 4(1): 38–49.

Newman, J., Pradhan, M., Rawlings, L.B., Ridder, G., Coa, R., Evia, J.L., 2002. An impact evaluation of education, health, and water supply investments by the Bolivian Social Investment und. *The World Bank Economic Review*, 16(2): 241–274.

Niamir-Fuller, M., 1998. The resilience of pastoral herding in Sahelian Africa. In: F. Berkes and C. Folke (Eds.), *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. Cambridge University Press, Cambridge. pp. 250–284.

Ostrom, E., 1990. *Governing the Commons: The Evolutions of Institutions for Collective Action*. Cambridge University Press, Cambridge.

Ostrom, E., 2008a. The challenge of common-pool resources. *Environment: Science and Policy for Sustainable Development*, 50(4): 8–21.

Ostrom, E., 2008b. Design principles of robust property-rights institutions: what have we learned? Paper presented at the conference on "Land Policies and Property Rights," Lincoln Institute of Land Policy, Cambridge, MA, June 2–3, 2008.

Padawangi, R., 2010. Community-driven development as a driver of change: Water supply and sanitation projects in rural Punjab, Pakistan. *Water Policy*, 12(S1): 104–120.

Pretty, J., 2003. Social capital and the collective management of resources. *Science*, 302(5652): 1912–1914.

Quinn, C.H., Huby, M., Kiwasila, H., Lovett, J.C., 2007. Design principles and common pool resource management: An institutional approach to evaluating community management in semi-arid Tanzania. *Journal of Environmental Management*, 84(1): 100–113.

Ricks, J.I., 2016. Building participatory organizations for common pool resource management: Water user group promotion in Indonesia. *World Development*, 77: 34–47.

Salkind, N.J., 2010. *Encyclopedia of Research Design*. SAGE Publications, Inc., Thousand Oaks, CA.

Sarker, A., Baldwin, C., Ross, H., 2009. Managing groundwater as a common-pool resource: An Australian case study. *Water Policy*, 11(5): 598.

Smets, H., 2012. Quantifying the affordability standard. In: M. Langford and A.F.S. Russell (Eds.), *The Human Right to Water: Theory, Practice and Prospects*. Cambridge University Press, Cambridge. pp. 276–299.

Starkl, M., Grassini, L., Raval, P., Grandi, S., Donnelly, T., 2003. Challenges towards sustainable urban water management in developing countries. Water21 Magazine, June 2003, pp. 49–54.

Statistics Indonesia (Badan Pusat Statistik—BPS), National Population and Family Planning Board (BKKBN), Kementerian Kesehatan (Kemenkes—MOH), ICF International, 2013. *Indonesia Demographic and Health Survey 2012*, BPS, BKKBN, Kemenkes, and ICF International, Jakarta, Indonesia.

The World Bank, 1994. *Indonesia Environment and Development: Challenges for the Future*. World Bank Publications, East Asia and Pacific Region.

Ujang, Z., Buckley, C., 2002. Water and wastewater in developing countries: Present reality and strategy for the future. *Water Science and Technology*, 46(9): 1–9.

UN, 2014. The human right to water and sanitation milestones. In: U.-W. D. P. O. A. A (Ed.), *Communication*. Available online at: http://www.un.org/waterforlifedecade/pdf/human_right_to_water_and_sanitation_milestones.pdf (accessed: 17 June 2011).

UN, 2015. Sustainable development goals. Available at https://sustainabledevelopment.un.org/?menu=1300 (accessed 21 January 2016).

UNDP, 2006. *Human Development Report 2006. Beyond Scarcity: Power, Poverty and the Global Water Crisis*. United Nations Development Programme, New York.

UNICEF & WHO, 2015. *Progress on Sanitation and Drinking Water 2015 Update and MDG Assessment*. UNICEF and WHO, New York.

Wade, R., 1994. *Village Republics: Economic Conditions for Collective Action in South India*. ICS Press, Oakland, OR.

WHO, 2004. *Guidelines for Drinking-water Quality Third Edition Volume 1 Recommendations*. World Health Organization, Geneva.

WHO, 2011. *Guidelines for Drinking-water Quality Fourth Edition*. World Health Organization, Geneva.

WHO & UNICEF (Ed.), 2014. *Progress in drinking water and sanitation 2014 update*. WHO & UNICEF (eds.), Geneva.