IOP Conf. Series: Earth and Environmental Science **158** (2018) 012005 doi:10.1088/1755-1315/158/1/012005

# From Informal to Formal: Status and Challenges of Informal Water Infrastructures in Indonesia

**S Maryati[1], A N S Humaira[1] and D M Kipuw[1]**

[1]Regional and City Infrastructure System Research Cluster: School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Ganeca 10 Bandung 40132, Indonesia

E-mail: smaryati@pl.itb.ac.id

**Abstract**. Informal water infrastructures in Indonesia have emerged due to the government's inability or incapacity to guarantee the service of water provision to all communities. Communities have their own mechanisms to meet their water needs and arrange it as a self-supplying or self-governed form of water infrastructure provision. In general, infrastructure provisions in Indonesia are held in the form of public systems (centralized systems) that cover most of the urban communities; communal systems that serve some groups of households limited only to a particular small-scale area; and individual systems. The communal and individual systems are systems that are provided by the communities themselves, sometimes with some intervention by the government. This kind of system is usually built according to lower standards compared to the system built by the government. Informal systems in this study are not defined in terms of their legal aspect, but more in technical terms. The aim of this study was to examine the existing status and challenges in transforming informal water infrastructures to formal infrastructures. Formalizing informal infrastructures is now becoming an issue because of the limitations the government faces in building new formal infrastructures. On the other hand, global and national targets state 100% access to water supplies for the whole population in the near future. Formalizing informal infrastructures seems more realistic than building new infrastructures. The scope of this study were the technical aspects thereof. Making descriptive and comparative analyses was the methodology used. Generally, most of the informal systems do not apply progressive tariffs, do not have storage/reservoirs, do not have water treatment plants, and rarely conduct treatment in accordance with standards and procedures as formal systems do, which leads to dubious access to safe water, especially considering the quality aspect.

## 1. Introduction

It has been estimated that around 1,1 billion people in the world at the beginning of 2000 lacked access to safe water. This has resulted in the challenge of providing access to safe water to all, particularly in developing countries [1]. The government alone in low- and middle-income countries seems unable to meet this international target as a consequence of engineering factors regarding high operating costs and under-utilized investments, unplanned or disintegrated access to basic services between legal areas in cities and illegal or unregulated settlements [2]. Moreover, multiple other factors, such as neglect by and poor capacity of central and local government authorities and no guarantee of cost recovery for high upfront financial and infrastructural investments in providing water to both rural and poor urban areas caused by insecure and uncertain land tenures as well as the terrain and dispersed poor communities complicate the condition of water provision [3].

This basic uncertainty of the water infrastructure that is supposed to be served and provided by the authorities has led to self-managed informal infrastructure provision or, adapting Allen's terminology, 'needs-driven practices', which are based on some form of collective action (within or between communities and the authorities) and/or those that are undertaken individually and may rely on solidarity among households and neighborhoods or on market-based mechanisms [4].

Since recently, informal water infrastructures as unofficial service provision is seen as a 'mode of urban governance' for the underserved population, which is largely allowed and even encouraged by governments because it is increasingly viewed as a necessary and acceptable mode of urbanism [5]. This practice of providing access to informal services in order to meet basic needs and filling the gap left by the government is widely implemented, especially in developing countries. It includes cases such as household water resale activities of alternative service providers and small-scale independent providers (SSIPs) in peri-urban areas of greater Maputo, Mozambique [6]; small-scale private bottled water supply in Dhaka-Bangladesh; commercially operated public toilets in Kano-Nigeria; licensed standpipe operators in Ouagadougou-Burkina Faso; pushcart water vendors in Delhi, India and Manila, Philippines; female water vendors in Honduras [7]; domestic private sector water service delivery in Tanzania [8]; *nyelang* (those without a piped water connection buy bulk water from their neighbours) and utilization of shallow and deep groundwater managed by individual households using bore wells in Jakarta, Indonesia [9]; a local initiative in community water supply in Ashanti Region-Ghana [1]; and community-public partnerships or other community-based water governance approaches for water supply in developing countries [3].

Informal water infrastructures in Indonesia have emerged due to the government's inability or incapacity to guarantee the service of water provision to all communities. To fill this gap, communities have their own mechanisms to meet their needs and arrange it as self-supply or self-governing water infrastructure provision. In general, infrastructure provisions in Indonesia are held in the form of: public as well as centralized systems that cover most urban communities; communal systems that serves some group of households, limited to a particular area (one or more neighborhoods); and individual systems. These communal and individual systems are provided by the communities themselves and can be classified as informal in the terms of the governance framework as well as in a legal context. This self-supply water infrastructure by communities is widely varied in the context of technical, management, and institutional aspects.

In accordance with the global target established in the sustainable development goals (SDGs), the government of Indonesia has set the main goal in the water sector, which is translated in the *National Medium-Term Development Plan* (RPJMN), as a target of 100% of all households having adequate access to safe drinking water. Adequate access in this context is defined as access to a water supply with a piping system according to regulations, standards and procedures, and normative principles in providing water infrastructure networks. In connection with the target set in RPJMN, the existing informal water infrastructure should be incorporated and transformed into a formal infrastructure. Referring to the water service provision in West Java Province (one of the leading provinces in Indonesia), in 2015 only 20% of households were served by the public provider *Perusahaan Daerah Air Minum* (PDAM). Meanwhile, 47% of households acquire water from a communal piping system, either delivered by the government or independently served, while the remaining 33% of households obtain their water from unprotected non-piping infrastructure networks.

Formalizing the informal is mostly done in land development. In this field, formalizing is supported by the theory of Soto in the form of granting land rights [10]. The absence of land rights limits the poor in increasing the value of their property. Formalizing informal land ownership is still being debated in relation to its effectiveness. In some cases the granting of property rights does not guarantee security of ownership. Infrastructure services have to be added to land rights to ensure a positive impact on landowners [11]. Formalizing the informal sector in infrastructure is mostly done in the waste management sector. The main reason for formalization is that the informal sector contributes greatly to waste management, but its presence is unknown in the formal system [12]. Especially for waste management, informal sector workers generally work in poor conditions.

The aim of this paper is to examine the existing status and challenges in transforming informal water infrastructures to become formal infrastructures with the main focus on technical aspects. This paper does not contribute to the debate on formalization in the context of land development but focuses on the next step after formalizing land status, which is formalizing infrastructure, in this case water supply infrastructure. Formalizing the informal has become an issue because of the limitations of the government to build new formal infrastructures. On the other hand, global and national targets state access to safe water for 100% of the population in the near future. Formalizing the informal seems more realistic than building new infrastructures. In this study, the water infrastructure system managed by PDAM as public water supply in the form of a centralized service is categorized as formal infrastructure. This 'formal' category refers to the governance framework. PDAM is the local water enterprise that has the authority to provide water through a public system. PDAM is owned by local governments. Water provision, in terms of providing a basic service, is an obligation of the government. Therefore, informal water infrastructure in this paper refers to water infrastructure systems that are not managed by PDAM. They can be managed by a community for a communal system and/or individually by each household, or they may be served by other parties or a partnership between stakeholders.

## 2. Methods

This study was focused only on the technical aspect of transforming informal infrastructures into formal infrastructures. Data were collected through observation of informal infrastructures in Indonesia and were documented based on related studies. Descriptive and comparative analysis were the methodologies used in this study. Descriptive-qualitative analysis was used to describe the status of the informal infrastructures, while comparative analysis was used to identify some challenges in transforming informal infrastructures into formal infrastructures. Comparative analysis was basically used to compare the current condition of informal infrastructures to an ideal condition, which is defined as formal infrastructure. Formal infrastructure in this context was not defined in legal terms, but more in relation to the fulfillment of the requirements for a formal infrastructure, which was defined more according to the physical aspects. The criteria for formal infrastructure are listed in Table 1.

This study first examined the typology of existing informal water infrastructures in Indonesia characterized by technical criteria in water infrastructure provision, consisting of the source, production, distribution/transmission, and water delivery service. This typology was extracted from a previous study. The first step in building the typology is identifying the core of the typology; in this research the core of the typology are the technical or physical criteria. The identified typology then was used as a tool to investigate the challenges in formalizing informal infrastructures. These challenges were formulated by comparing the existing status and the norms/standard in terms of the technical aspects in providing a formal water infrastructure, as defined in Table 1, with the current condition of each typology. The findings demonstrate a number of informal water infrastructure typologies in Indonesia and the status of water infrastructure in terms of a formal infrastructure.

## 3. Policy and technical guidance on DWSS

### *3.1. National policy of drinking water service in Indonesia*

Drinking water is a basic human need that must be fulfilled. The government is obliged to provide drinking water, including its infrastructure. Therefore, sufficient access to safe water for 100% of the population by 2030 is included in Goal 6 of the sustainable development goals established at the United Nations Sustainable Development Summit. In the context of Indonesia, this target is translated into various levels of policy documents, such as the *National Medium-Term Development Plan* (RPJMN) 2015-2019 that is derived from the detailing in the *Strategic Plan of the Directorate General of Human Settlements*, Ministry of Public Works and Housing. In this strategic plan, the target of 100% of the population having access to safe water by 2019 has been set as the main objective for the water supply sector [13].

This target is to be achieved by combining approaches on the supply side (optimization and new development) and on the demand side (increasing efficiency of drinking water provision and creating a conducive environment) [13]. The first approach is done by facilitating drinking water supply systems (DWSS) managed either by PDAM or non-PDAM, developing new DWSS in some special areas, specifically urban slum areas (661,600 house connections), fishing areas (66,200 HC), and water prone areas (1,705,920 HC), and developing regional DWSS, DWSS in urban areas, and community-based DWSS.

The demand side approach is conducted by implementing the principles of water saving and water conservation, which are applied in all areas in Indonesia. This last approach was effectuated by formulating the *Master Plan of Drinking Water Supply System* (long term), the *Strategic Plan of Regional Drinking Water* (medium term), and the *Annual Plan of Drinking Water* (short term) for each region in Indonesia as a guidance in DWSS development, improving the management and organization of data and information regarding drinking water as a baseline in planning and budgeting, and facilitating the regulatory development in all regions that ensures the provision of drinking water services throughout the country.

### *3.2. Technical guidance for DWSS*

To ensure access to safe water, a series of technical aspects needs to be identified and then implemented to provide a guaranteed service of DWSS. From the literature and theoretical review (regulations, standards and procedures, and normative principles), a number of technical aspects resulted that must be addressed in developing DWSS, as illustrated and explained in Figure 1 and Table 1.

**Table 1.** Guidance of technical aspects for developing DWSS.

| No | Aspect | Explanation |
|---|---|---|
| 1 | Source | Sources of water utilized for drinking water can be divided into 3 categories, i.e. surface water, groundwater, and rainwater. Choosing the most suitable source depends on the raw water availability and sustainability in any season (dry and rainy) from the source closest to the service area [14]. |
| 1.1 | Surface water | Water that is open to the atmosphere and results from overland flow (i.e. runoff that has not yet reached a definite stream channel). In other words, surface water is the result of surface runoff. For the most part, surface water (as used in this context) refers to water flowing in streams, rivers, lakes, fresh ponds, and oceans [15]. Different types of intake (depending on the physical conditions) are used to collect the raw water from the surface water source to be utilized as drinking water [14][16]. |
| 1.2 | Groundwater | The precipitation that falls on land infiltrates the land surface, percolates downward through the soil under the force of gravity and becomes groundwater. Groundwater collected in saturated layers under the earth's surface is called an aquifer. Three types of aquifers exist: unconfined, confined, and springs [15]. Source catchment (spring), shallow wells (dug-well and tube-well), deep wells (bore-wells), etc. are the structures to catch the raw water from groundwater [14][16]. |
| 1.3 | Rainwater | Rainwater can be used and harvested as a second option or alternative for the areas that are classified as water prone areas with fluctuating availability of raw water. One of the requirements utilizing rainwater is a minimum precipitation of 1,300 mm/year [16]. Rainwater catchment basins are needed to harvest rainwater [14][16]. |
| 2 | Production | Production units are facilities and infrastructure that can be used to process raw water into drinking water through physical, chemical or biological treatment, including processing and equipment buildings, operational equipment, |

| No | Aspect | Explanation |
|---|---|---|
| | | measurement tools and monitoring equipment, and drinking water storage buildings [16]. |
| 2.1 | Treatment | The purpose of a water treatment system is to bring raw water up to drinking water quality. The treatment process will vary between sources depending on the quality of the source water [17]. |
| 2.1.1 | Complete treatment | Complete treatment for surface water [17]:<br>- Screening<br>Screening of the source is done to remove relatively large floating and suspended debris.<br>- Coagulation<br>Chemical treatment that adds a coagulant to the water in a mixing tank to encourage suspended solids to adhere to each other and form larger particles that settle more easily.<br>- Flocculation<br>The process of gently mixing the water and coagulant that allows the formation of large floc particles.<br>- Sedimentation<br>After flocculation, the water flows through a sedimentation basin or clarifier that is designed to hold the water for a long enough time so that gravity allows most of the suspended solids (floc) to settle down.<br>- Sludge processing<br>Where the mixture of solids and liquids collected from the settling tank are dewatered and disposed of.<br>- Filtration<br>The effluent from the tank is then filtered in a rapid-sand filter (better known as filtration unit), which consists of a number of layers. Other processes, such as adsorption, continued flocculation and sedimentation in the pore space, are also important removal mechanisms.<br>- Disinfection<br>The final step is disinfection of the liquid effluent to ensure that the water is free of harmful pathogens (kill any remaining pathogenic organisms because only a small amount of the bacteria are removed in the previous processes).<br>- Hardness removal<br>This process can be added to the generalized process if needed, yet surface water seldom has high hardness level, so it is not usually part of the water treatment process. A commonly used method in this final stage is chlorination. Chlorine is completely effective against bacteria and microorganisms.<br>In some larger systems, secondary disinfection may be required by maintaining chlorine residuals within the distribution system [18]. Besides, another approach should be implemented to process seawater into drinking water using seawater reverse osmosis (SWRO) [16].<br><br>Complete treatment for ground water [17]:<br>Ground water usually has high water hardness and alkalinity caused most notably by the presence of calcium and magnesium ions. Therefore, softening is a part of water treatment processes prior to disinfection (if needed). There are two common approaches to water softening:<br>1. Lime-soda process<br>Either quick lime or hydrated lime is added to the water, which will increase the pH to about 10.3 and convert soluble bicarbonate ions to insoluble carbonate. The carbonate will then be precipitated. Most of the precipitates formed are removed in a sedimentation basin. |

| No | Aspect | Explanation |
|---|---|---|
| | | 2. Ion exchange process<br>Hard water is forced through a column containing solid resin beads made of naturally occurring clays called zeolites or synthetic resins. In an ion exchange unit, the resin removes Ca2+ and Mg2+ ions from the water and replaces them with sodium ions, which form soluble salts. These salts do not caused hardness. |
| 2.1.2 | Simple treatment | For the case of small-scale (communal and individual) DWSS, raw water treatment is still required, only using simpler methods such as filtering and disinfection, slow sand filtration, ultraviolet light, membrane filtration, peat water purification, infiltration galleries, distillation, and standard practices for household use [16]. |
| 2.2 | Storage | Raw water that has been processed into drinking water will then be stored in a reservoir or a basin before distribution. |
| 2.2.1 | Operational storage | Operational storage is used to provide water during normal operation when other sources of supply are not delivering water [18]. |
| 2.2.2 | Standby (or emergency) storage (optional) | Standby storage is used to provide water to a system during unusual or emergency conditions when a source of supply may be temporarily unavailable [18]. |
| 2.2.3 | Equalizing storage (optional) | Equalizing storage is used to supply the difference between peak-hour demands due to normal diurnal flow variations and the capacity of the source of supply [18]. |
| 2.2.4 | Fire flow storage (optional) | Fire flow storage is used to provide the required volume of water to meet fire-fighting needs within the water system's service area [18]. |
| 3 | Transmission and distribution | Transmission and distribution process depend on the terrain between the water source and the service area. A gravitation system, or pumping system, and/or combination of both gravitation and pumping can be utilized. On the other hand, the distribution system consists of a piping system (house connections) and also public hydrants/communal water taps/communal toilets. To choose between a house connection or a communal service depends on the demographic, economic, social, and physical characteristic of the service area. |
| 3.1 | Piping system (house connection) | The water transmission system consists of pump stations and larger diameter piping that conveys water from a source of supply to the point of entry into the distribution system. This point of entry may be a reservoir, pump station or the first service connection to the system. The distribution system consists of a network of pipes, booster pump stations and pressure-reducing valves that convey flow from the system point of entry to the users [18]. Some densely populated areas that have a predominantly flat terrain will be suitable for this type of water distribution system. |
| 3.2 | Public hydrant/communal water tap/ communal toilet | A communal drinking water service facility in the form of a reservoir of water placed above the ground or on a foundation [14]. Sparsely populated areas, low-income settlements, and countered areas are more suitable to implement public hydrants/communal water taps/communal toilets to distribute the water. |
| 4 | Water delivery service | Water delivery services must guarantee access to safe water with 3 main indicators, i.e. quality, quantity, and continuity. Besides, water is a basic right for human beings and therefore should be affordable yet the user/consumer also has the obligation to contribute in terms of operational and maintenance costs. |
| 4.1 | Tariff/billings | - All water customers/connections are metered [19].<br>- Written procedures for billing and collection [19].<br>- The water rate is structured among users (progressive tariff for residential, commercial and industrial users) [19].<br>- For domestic use, consider affordability for users according to the global standard of maximum 4% of their average monthly income [20]. |
| 4.2 | Safe access (quality, quantity, | - Quality (can meet the water-quality standard in accordance of required health standards) [21]. |

| No | Aspect | Explanation |
|---|---|---|
| | and continuity) | - Quantity (can meet the needs of daily water consumption) [21].<br>- Continuity (water is available for 24 hours, 7 days a week) [21]. |

Based on the literature review, the technical aspects of DWSS can be divided according to: source, production, transmission, and distribution. Major sources of water used in Indonesia are surface water, groundwater, and rainwater. The production system consists of treatment and storage; transmission and distribution system (piping system or non-piping system); water delivery service. The aspects of the latter that will be further explored in this study are water tariff and safe access.

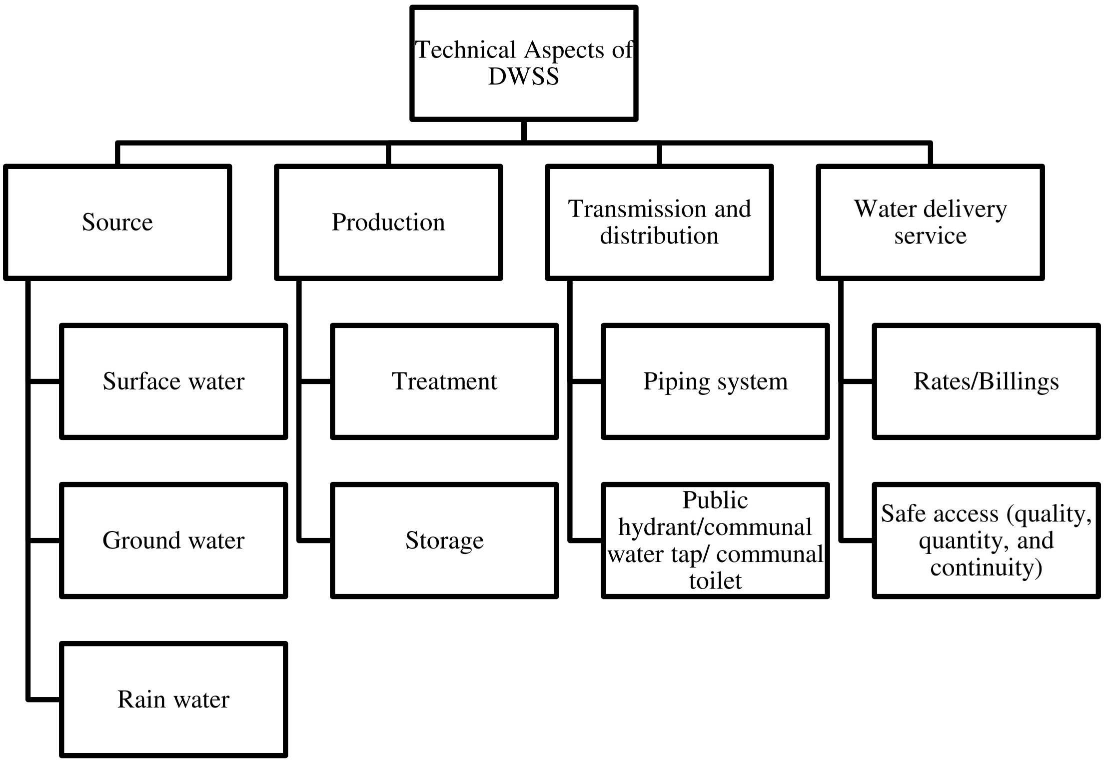


**Figure 1.** Technical aspects for developing DWSS

## 4. Discussion

### *4.1. Status of informal water infrastructure in Indonesia*

In 2015, only 18% of households were served by the public water supply system (PDAM), where most of the served consumers were living in urban areas. This condition is caused by the infrastructure not being optimally utilized, resulting in a large amount of idle capacity (37,900 liter/second) [13]. This is due to several factors, among others the decrease of raw water capacity, unoptimized operational capacity of production units, and unallocated budget of distribution pipes and house connection installment by local governments.

In terms of funding, current drinking water investments rely on government funding rather than alternative funding sources such as PPP (public private partnerships) or B-to-B (business-to-business) schemes. PDAM does not function optimally due to the ineffectiveness of the institutional system and the low drinking water tariff, which is below the production cost. In 2014, there were 182 PDAMs with good or 'healthy' performance, 103 PDAMs with 'less healthy' performance, and 74 PDAMs were categorized as having 'bad' performance. The Directorate General of Human Settlements has encouraged the development planning of drinking water infrastructure through the formulation of the *Master Plan of Drinking Water Supply System* (RISPAM), which thus far has been formulated in 468 regions in Indonesia.

On the other hand, DWSS that are not managed by PDAM (let us say 'informal DWSS') have shown a vast development (82%), but nevertheless their growth still requires assistance from the government and other parties. These informal DWSS emerge as a response as well as consequence of the inability of the government to provide water service to 100% of the population. Some of the informal water infrastructures have been appropriately established but most of the rests are not in accordance with the standards and procedures of DWSS from a technical point of view. Table 2 presents a brief description of the condition of informal water infrastructure in Indonesia seen from its technical aspects and divided according to provider.

**Table 2.** Typology of water informal infrastructure practice in Indonesia based on technical aspect

| Provider | Typology and location | Technical aspect | | | | | |
|---|---|---|---|---|---|---|---|
| | | Source | Production | | Transmission and distribution | Water delivery service | |
| | | | Treatment | Storage | | Tariff/ billings | Safe access |
| **Individual** | **Typology A:** Household in Lebak Siliwangi, Bandung City, West Java | Shallow groundwater | No | No | Pumping system | No | No lab test |
| | **Typology B:** Household in Lebak Siliwangi, Bandung City, West Java | Artesian well (deep groundwater) | No | No | Pumping system | No | No lab test |
| | **Typology C** [9]: *Nyelang* (buy from the neighborhood or person to person agreement) in Penjaringan, North Jakarta | Artesian well (deep groundwater) | No | No | With hose and water bucket | No fixed rate, rough estimation (Rp13,000 to Rp89,000 per $m^3$) | No lab test |
| | **Typology D** [9]: *Nyelang* (buy from the neighborhood) in Penjaringan, North Jakarta | From PDAM | Yes | No | With hose and water bucket | No fixed rate, rough estimation (Rp13,000 to Rp89,000 per $m^3$) | Yes (with lab test) |
| | **Typology E:** Solidarity-based (water as a gift in special cases) in Lebak Siliwangi, Bandung City, West Java | Groundwater (shallow and deep) | No | No | With hose and water bucket | No (free) | No lab test |
| | **Typology F:** Solidarity-based (water as a gift in special cases) in Lebak Siliwangi, Bandung City, West | From PDAM | Yes | No | With hose and water bucket | No (free) | Yes (with lab test) |

| Provider | Typology and location | Technical aspect | | | | | |
|---|---|---|---|---|---|---|---|
| | | Source | Production | | Transmission and distribution | Water delivery service | |
| | | | Treatment | Storage | | Tariff/ billings | Safe access |
| | Java | | | | | | |
| | **Typology G*** [22]**:** Individual in Margahayu Raya Bandung City, West Java | Artesian well (deep groundwater) | Slow sand filter | Yes | Piping and pumping systems | No | Yes (with lab test) |
| **Communal** | **Typology H** [23]**:** Community-based in Ciburial Village, Bandung Regency, West Java | Spring water | No | Yes | Piping and gravitational systems | Fixed rate (no water meter) | No lab test |
| | **Typology I** [23]**:** Community-based in Griya Bukit Mas Residential, Bandung Regency, West Java | Artesian well (deep groundwater) | No | Yes | Piping and pumping systems | Progressive block tariff systems with water meter | No lab test |
| | **Typology J:** Community-based in Lebak Siliwangi, Bandung City, West Java | Artesian well (deep groundwater) and shallow well | No | Yes | Pumping systems, communal toilet, public hydrant and water tap | Fixed rate (daily, weekly, monthly) | No lab test |
| | **Typology K:** Community-based in Lebak Siliwangi, Bandung City, West Java | From PDAM | Yes | Yes | Communal toilet, public hydrant and water tap | Fixed rate (daily, weekly, monthly) | Yes (with lab test) |
| | **Typology L*** [22]**:** Community-based in Pesantren Oemardyan, Indrapuri, Aceh Besar Regency, Aceh | Stream intake (surface water) | Yes, slow sand filter | Yes | Pumping and piping system | Fixed rate (no water meter) | Yes (with lab test) |
| | **Typology M*** [22]**:** Community-based in Wisma Sanita,Pejompongan, Jakarta Pusat | Shallow and deep groundwater | Yes, slow sand filter | Yes | Pumping and piping system | No | Yes (with lab test) |
| | **Typology N*** [22]**:** Community-based in Giri Cahyo Village, Gunung Kidul Regency, Yogyakarta | Underground river | Yes, PV pumping system | Yes | Pumping and piping system | Fixed rate (no water meter) | Yes (with lab test) |
| | **Typology O*** [22]**:** Community-based in Oheitel Tual Village, Maluku Province | Groundwater | Yes, infiltration galleries and PV | Yes | Pumping and piping system | Fixed rate (no water meter) | Yes (with lab test) |

| Provider | Typology and location | Technical aspect | | | | | |
|---|---|---|---|---|---|---|---|
| | | Source | Production | | Transmission and distribution | Water delivery service | |
| | | | Treatment | Storage | | Tariff/ billings | Safe access |
| | | | pumping system | | | | |
| | **Typology P*** [22]**:** Community-based in SP Transmigrasi Jejangkit Cs, Barito Kuala, South Kalimantan | Peat water (surface water) | Yes, peat water filtration and PV pumping system | Yes | Pumping and piping system | Fixed rate (no water meter) | Yes (with lab test) |
| **Water vendors** | **Typology Q:** Refill water in Sukajadi, Bandung City, West Java | Refill water from groundwater | Yes (RO, UV, UF, ozone, etc) | Yes | Gallon package | Rp4,000- per gallon | No lab test |
| | **Typology R:** Branded bottled water in Sukajadi, Bandung City, West Java | Spring water | Yes (filtration, UV, and UF) | Yes | Gallon package | Rp15,000- per gallon | Yes (with lab test) |
| | **Typology S:** Water push cart seller in Kota Tua, Semarang City, Central Java | Shallow groundwater | No | No | Jerry can and push cart | Fixed rate per jerry can | No |

Note:
*Categorized as best practice along with 20 other best practice cases of informal DWSS in Indonesia, which are not discussed in this study. These cases seem infrequently implemented, so that they can be referred to for other informal DWSS in other locations with similar characteristics.

Based on Table 2, the informal systems can be classified as systems with and without treatment, systems with and without tariff, and systems with and without storage. Most systems are systems with treatment and tariff. The systems in this category are: bottled water, community-based water supply with river as water source, and water from vendor. Most systems do not have a reservoir. Systems that apply a tariff system usually use a fixed rate; only one system applies a progressive tariff. Figure 2 shows the classification of the systems mentioned in Table 1.

| | |
|---|---|
| **Treatment, No Tariff**<br><br>Typology F, G, M | **Treatment, Tariff**<br><br>Typology D*, L, N, O, P, Q, R |
| **No Treatment, No Tariff**<br><br>Typology A*, B*, C*, E* | **No Treatment, Tariff**<br><br>Typology H, I, J, K, S* |

Note: *system without storage

**Figure 2.** Classification of Informal System Typology

### *4.2. Challenges of formalizing the informal water infrastructure in Indonesia*

As stated above, in this study, the formal water infrastructure system refers to the technical practices conducted by PDAM in providing drinking water to its customers. Thus far, most PDAMs conduct procedures in accordance with the standard established in many regulations in Indonesia as well as the normative guidance as listed in Table 1. Based on Table 2, there are various typologies seen from a technical point of view that can at least portray informal water infrastructure practice in Indonesia conducted by individual households, community, and water vendors. Among these, production (no treatment and no storage) and water delivery service (tariff/billings: no water meter and rough estimation; safe access: no laboratory tests even though most of the consumers reveal that they are quite satisfied with the water consumed in terms of quantity, quality, and continuity) are technical factors that seem to be absent from informal DWSS. Yet, among the informal practices there are several best-practice cases that meet the requirements of the technical aspects of developing DWSS such as implemented in a formal system by PDAM among others.

In order to implement the formalization of informal systems in the context of their technical aspects, the current informal practices face some challenges in duplicating the formal infrastructure system. First of all, it is necessary for the government to have a simultaneous monitoring and control of the aquifers exploited by communities for drinking water and relay that information to society in order to raise awareness of water saving, water reuse, and water conservation. Most of the informal practices (70%) rely on groundwater in fulfilling daily consumption, yet society often ignores that the availability of raw water has been decreasing year by year.

Secondly, many simple methods and technologies of water treatment can be applied in small-scale DWSS, both at household and at communal level. Technical assistance and guidance should become routine homework for the government and transfer of information and knowledge on simple and basic water treatment should be widely spread to society. Thirdly, developing and implementing regulations for applying water meters in any informal installation, both in piping systems (house connections) and public hydrants/water taps or communal toilets. That way, water theft can be reduced and rough estimations can be avoided with a more fair calculation system. Besides, with a proper billings method, affordability, fairness, cost recovery, water efficient consumption, protection of raw water, and transparency as well as accountability can be provided [20]. Lastly, regulations are also needed for informal practices to oblige all water consumers to test their water in a laboratory to ensure its quality, which must meet the health standard established by the Minister of Health to guarantee that the water consumed is safe enough.

## 5. Conclusion

Seen by the comprehensiveness with which they meet the formal criteria, several informal cases in different locations were found to be practically the same as the formal system, with some interesting notes to be explored. These cases tend to be best practices and can be a good model to be duplicated in other locations with similar characteristics. Generally, as far as the technical aspects are concerned, most of the informal systems do not apply a progressive tariff, do not have a storage/reservoir, have no water treatment plant and rarely conduct treatment in accordance with the standards and procedures that the formal system uses. It was also found that informal systems mostly provide dubious access to safe water, especially according to the health quality standard, since most of the informal systems do not test the water utilized for drinking water with laboratories tests. Government as an enabler, provider, regulator, and facilitator supported by and cooperating with other stakeholders (donors, NGOs, and private sector parties) has a central role to play in guiding society to attain access to safe water, especially in the production and water service delivery aspect. The most important improvement is transforming informal systems into formal systems in terms of water quality standard and water tariff.

## 6. Acknowledgments

The research, on which this article is based, is funded by Institut Teknologi Bandung under the scheme of ‘Program Penelitian, Pengabdian kepada Masyarakat dan Inovasi (P3MI) ITB 2017’. The title of the research is ‘Can Informal Infrastructure Overcome Infrastructure Provision? Case: Provision of

Infrastructure Informal Lebak Siliwangi'. The authors would like to thank all the stakeholders involved in this program. However, the authors alone are responsible for any mistakes and shortcomings.

## References

[1] Nyarko K B, Awuah E, and Ofori D 2009 Local initiative in community water supply: Case study in Ashanti Region, Ghana *J. Desalination* **248** 650-65
[2] Allen A, Davila J D, and Hofmann P 2006 The peri-urban water poor: citizens or consumers? *J. Env. & Urb.* **18** 333-351
[3] Adams E A and Zulu L C 2015 Participants or customers in water governance? Community-public partnerships for peri-urban water supply *J. Geoforum* **65** 112-124
[4] Allen A, Hofmann P, Mukherjee J, and Walnycki A 2016 Water trajectories through non-networked infrastructure: insights from peri-urban Dar es Salaam, Cochabamba and Kolkata *J. Urb. Research & Practice* **10** 22-42
[5] Wutich A, Beresford M, and Carjaval C 2016 Can informal water vendors deliver on the promise of a human right to water? Results from Cochabamba, Bolivia *J. World. Develop.* **79** 14-24
[6] Matsinhe N P, Juizo D, Macheve B, and Santos C D 2008 Regulation of formal and informal water service providers in peri-urban areas of Maputo, Mozambique *J. Phys. And Chem. of the Earth* **33** 841-849
[7] Kjellen M and McGranahan G 2006 *Informal water vendors and the urban poor* (London: International Institute for Environment and Development-IIED)
[8] United Nations Development Programme 2011 *Services and supply chains: The role of the domestic private sector in water service delivery in Tanzania* (New York: United Nations Development Programme)
[9] Kooy M, Walter C T, and Prabaharyaka I 2016 Inclusive development of urban water services in Jakarta: The role of groundwater *J. Hab. Int* 1-10
[10] De Soto H 2000 *The mystery of capital: Why capitalism triumphs in the west and fails everywhere else* (New York: Basic Books)
[11] Choplin A and Dessie E 2017 Titling the desert: Land formalization and tenure (in)security in Nouakchott (Mauritania) *Habitat International* **64** 49-58
[12] Aparcana S 2017 Approaches to formalization of the informal waste sector into municipal solid waste management systems in low- and middle-income countries: Review of barriers and success factors *Waste Management* **61** 593–607
[13] Directorate General of Human Settlements, the Ministry of Public Works and Housing 2016 *Strategic plan of the Directorate General of Human Settlements 2015-2019* (Jakarta: Directorate General of Human Settlements, the Ministry of Public Works and Housing)
[14] Ministry of Public Works and Housing, Indonesia 2016 *Evaluation standard document. Attachment IV Regulation of Public Works and Housing Minister Number 27/PRT/M/2016 regarding development of drinking water provision* (Jakarta: Ministry of Public Works and Housing)
[15] Spellman F R 2003 *Handbook of Water and Wastewater Treatment Plant Operations* (Boca Raton: CRC Press LLC)
[16] Directorate General of Human Settlements, the Ministry of Public Works and Housing 2007 *Development of Simple Drinking Water Supply System* (Jakarta: Directorate General of Human Settlements, the Ministry of Public Works and Housing)
[17] Masters G M 1991 *Introduction to Environmental Engineering and Science (*Englewood Cliffs: Prentice-Hall, Inc)
[18] HDR Engineering Inc 2001 *Handbook of Public Water Systems*: *Second ed* (New York, Chichester, Weinheim, Brisbane, Singapore, Toronto: John Wiley & Sons)
[19] US EPA 2002 *Capacity Checklist for Public Water Systems* (Washington DC: US EPA Archive

Document)
[20] Ministry of Home Affairs, Indonesia 2016 *Regulation of Home Affairs Minister Number 71 2016 regarding Calculation and Stipulation of Drinking Water Tariff* (Jakarta: Ministry of Home Affairs)
[21] Ministry of Public Works and Housing, Indonesia 2016 *Evaluation Standard Document. Attachment IX Regulation of Public Works and Housing Minister Number 27/PRT/M/2016 regarding Development of Drinking Water Provision* (Jakarta: Ministry of Public Works and Housing)
[22] Directorate General of Human Settlements, the Ministry of Public Works and Housing 2014 *Buletin Ciptakarya: Karya Cipta Infrastruktur Permukiman Ed.11/Tahun XII/November 2014* (Jakarta: Directorate General of Human Settlements, the Ministry of Public Works and Housing) pp 26-33
[23] Maryati S and Humaira A S 2015 Co-benefits of community based water supply management *Proc. Int. Conf. on The 5th Environmental Technology and Management Conference "Green Technology towards Sustainable Environment" (Bandung)* OP/NR/018-2-7