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Fragmented landscapes of water supply in suburban Hanoi

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ABSTRACT

Facing the challenges of city planning in the frame of rapid urbanization in the Global South, this study addresses the relationship between the urban development of Hanoi, Vietnam, and water supply including users' perception of water accessibility and satisfaction of coverage, quality, and cost. Because sociospatial disparities are particularly pronounced in suburban areas, these spaces epitomize unequal water access and uneven water quality. Based on the premise that (sub)urban water flows embody and mirror development dynamics and urbanization patterns, the objective is to analyze access to water splintered within the suburban typologies of Hanoi. We analyze the current state of domestic water availability and quality throughout suburban areas and specifically between a new urban area and a periurban village in Hanoi. Through the debates of splintering urbanism and periurban water supply, this paper discusses the differences in water service provision in suburban Hanoi. At the same time, the article considers suburban areas as spaces which reflect a broader spectrum of water supply solutions. Lastly, it informs on how to alleviate the pressure of the increasing demand of water in urbanizing areas by supporting sustainable urban water cycles to improve distributional justice and social equity.

1. Introduction

Environmental injustices, socioeconomic inequalities, and sociospatial fragmentations are intensifying in scale globally. Societies now face the challenges of rapid urbanization as the urban poverty rate may reach 45 to 50 percent by 2020 (Davis, 2004) and the world's population is expected to double by 2050 (UN DESA, 2008). Rapid urbanization in the Global South is magnifying existing issues such as urban sprawl, urban poverty, rising inequality and environmental degradation, among others (Zhang, 2016). Particularly suburban landscapes transform rapidly, as two thirds of the total inhabitants in the world are projected to populate urban areas by 2030 (UN Habitat, 2012) and the effects of socio-economic polarization are most evident in these spaces. In the Asian context, the concept of 'suburban' refers to the transitional areas between the rural and the urban which share a mixture of different urban typologies (see Trân et al., 2012; other authors use the concept of 'periurbanization,' see Winarso, Hudalah, & Firman, 2015). These subjoined areas may benefit from higher accessibility to the urban core, but suffer from the complexity of issues that suburbanization entails, including access to basic services, such as water and sanitation. In Hanoi, suburban areas include *new urban areas* and *periurban villages*, the former mirroring the upscaling competition of the city in a global economy (see 'extended metropolitan region; ' Ginsburg & Koppel, 1991), and the latter characterized by a conflicted interface with higher marginalization and lower access to services (Allen, 2010). As water infrastructures in Hanoi are highly differentiated in suburban areas, this research will unveil the current splintered infrastructure systems of centralized piped water schemes, privately owned wells, and additional solutions that users implement to make up for obtaining safe drinking water.

This paper frames the research of water supply in Hanoi within the challenges of urbanization and rapidly transforming urban and rural landscapes, contributing to the debates between water supply and (sub)urbanization of Global South cities (Adams & Zulu, 2015; Allen, 2003; Allen, Dávila, & Hofmann, 2006b; Díaz-Caravantes & Wilder, 2014; Gandy, 2008; Hofmann, 2013; Marston, 2014; Mehta & Karpouzoglou, 2015; Van Ewijk & Ehrhardt, 2016). We

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ask the question, how is access to water supply splintered between the different suburban typologies of Hanoi? To carry out this study, we analyze the local development of infrastructures, as well as water accessibility and satisfaction of coverage, quality, and cost perceived by residents of different areas in Hanoi, focusing primarily on new urban areas and periurban villages.

The article draws on qualitative and quantitative data from interviews and documentation provided by institutions directly or indirectly linked to water supply in Hanoi. These include the National University of Civil Engineering (NUCE), Hanoi University of Science and Technology (HUST), Hanoi Water Company (HAWACO), Vietnam's General Company of Construction and Export (VINACONEX), Ministry of Construction (MOC), Ministry of Agriculture and Rural Development (MARD), National Target Program (NTP3) of MARD and UN Habitat Vietnam. Additionally, informal interviews and conversations were carried out in the 37th WEDC (Water, Engineering and Development Center) Conference in Hanoi. More specifically, the present study of water supply in Hanoi focuses on: 1) the analysis of users' perception on accessibility, and satisfaction of coverage, quality and cost of water, through 100 questionnaires carried out through cluster sampling of the local population in 10 districts during August and September of 2014, conducted across Hanoi in the suburban districts of Đống Đa, Hai Bà Trưng, Thanh Trì, Hà Đông, Nam Từ Liêm, Hoàng Mai, Long Biên, Gia Lâm; the inner-city district of Hoàn Kiếm; and the rural district of Hoài Đức; and 2) the analysis of water quality which compares piped water and groundwater in two contrasting areas: the new urban area of Linh Đàm, in the urban district of Hoàng Mai, and the periurban village of Triều Khúc, in the rural district of Thanh Trì. The first analysis is based on a survey using 10 questions to obtain information on: a) water accessibility, b) users' knowledge of the source of water, c) type of water supply system and distribution company, d) satisfaction of coverage, e) satisfaction of quality, f) comparison of water supply coverage and quality with neighboring areas, g) cost of water per month, h) family income per month, i) appreciation of cost of water in relation to income, and j) community organization. The second analysis on water quality weighs environmental hazards in Hanoi's piped water and groundwater. These analyses help understand the contrasts between the different urban typologies of Hanoi's suburban areas and water supply schemes. On one hand, the semistructured interviews with local and international organizations, government offices, water-related enterprises, financial organizations, and academic institutions in Vietnam inform the institutional challenges of water provision. On the other hand, the empirical analysis of water supply in suburban areas illustrates direct field research and observations.

The paper is structured as follows. In section two, the article presents an overview of recent scholarship on periurban water access and quality linked to the debate of splintering urbanism. In section three, water infrastructure development in Vietnam and (sub)urbanization in Hanoi is contextualized. The fourth section presents a comparative review based on first-hand information of users' perception of water, discussing accessibility, and satisfaction of coverage, quality and cost of water in Hanoi (100 cluster samples in 10 districts), as well as piped water and groundwater quality (8 water samples in 2 districts). Lastly, the discussion identifies suburban areas as spaces of opportunity in which sustainable urban water cycles can be developed.

2. Splintering of Hanoi's suburban waterscapes

Within Hanoi's continuous expansion, city planners and authorities are under massive pressure to adequately deliver services adequately to urban dwellers and meet the demand of the growing population and rapidly urbanizing suburban areas. Two typologies characterize these spaces. On one hand, so-called *new urban areas*, which house a growing business class as well as resettled former villagers (Labbé & Musil, 2014, p. 1156) and sometimes become "islands of wealth" (Monstadt & Schramm, 2013, p. 90). Here, local infrastructure networks operate as "satellite systems" (Monstadt & Schramm, 2013), exclusively catering to the residents of these estates. On the other hand, *periurban villages* in adjacent areas that remain excluded from external service provision are often stuck in an interface of "sustained poverty, poor infrastructure and a lack of institutional frameworks and governmental support" (Norström, 2007, p. 5). The contrasts between these two typologies can be explained through the concept of 'splintering urbanism' (see Graham & Marvin, 2001), which defines the fragmented growth of cities and the unequal access to services, such as water supply. This concept encompasses the complex, uneven, and intertwined economic, cultural and socio-technical processes behind the production and functioning of urban infrastructures and fragmented urban growth. Briefly, the concept of splintering urbanism aims to shed light on the social disparities and territorial imbalances found in cities around the world (Graham & Marvin, 2001, p. 56). It is through this examination of "space, technology, infrastructure networks and social power" that new (and much needed) mindsets on urban development will be brought forward (Graham & Marvin, 2001, pp. 53–54).

The effects of splintered urbanism are highly visible in cities of the Global South. While the benefits of developing estates equipped with their own water supply systems may be a step towards modernization, the patches of settlements all around suffer from the lack of connectivity to the central water network system and to their neighboring decentralized systems. The concept of 'periurban' areas, or periurbanization, emerges as a critical concept to understand what happens on the fringes of urban areas, in this case concerning water supply. Although there is no clear definition of 'periurban', the discussion amongst scholars tackles the spatially and politically undefined areas. Van Ewijk and Ehrhardt (2016, p. 2) state that: "It is not the proximity to towns, but the linkages and flow of goods, finance, labor and services between rural and urban centers that defines periurban." The challenges which these areas display are rooted in several causes, including the cost of water, which is the driver for most users in poorer areas to seek alternative sources. In most cases, informal practices are not taken into consideration by "formal systems" (Allen, 2003, p. 341). In this case, discussion arises between "policy-driven" and "needs-driven" approaches (Allen et al., 2006b), calling for a more sustainable program of water management. Scholars have specifically focused on urban water provision in these settings. Díaz-Caravantes and Wilder (2014), and Mehta and Karpouzoglou (2015), use the concept of 'periurban waterscape' to show the interconnected social, economic, cultural and political processes embedded in water supply in those areas between the city and the rural areas. In other words, the concept of 'waterscape' encompasses "social, natural, material and discursive processes" (Mehta & Karpouzoglou, 2015, p. 166). Allen (2003) refers to those spaces as "periurban interfaces" and also discusses the main challenges they present concerning water services. Water provision in periurban interfaces has been analyzed by Mehta and Karpouzoglou (2015) in the case of Delhi. Along similar lines, Adams and Zulu (2015) use the concept of 'periurban water supply' in the context of Sub-Saharan Africa. Allen et al. (2006b) specifically focus on the "periurban water poor" lacking adequate water services and water provision in "periurban interfaces" (Allen, 2003; Hofmann, 2013; Mehta & Karpouzoglou, 2015). Periurban waterscapes are implicitly mirrors of power relations (Gandy, 2008) and income inequalities (Mehta & Karpouzoglou, 2015). This gives a distinct importance to the study of water access and water quality in periurban areas, as it is

through the understanding of this material flow (Bakker, 2003) that we can recognize challenges in urbanization and development processes of cities in the Global South. In this paper, we will explore these questions through the case of suburban water supply in Hanoi.

3. Urbanization and the development of water infrastructure in Hanoi

Located in Southeast Asia, bordering China, Laos, and Cambodia, and situated along the coast of the South China Sea, Vietnam is a lower middle income country (World Bank, 2015) with an economic growth raising at a rate of 5.98% with respect to 2013 (GSO, 2014a), and a GINI coefficient of 0.37 which denotes moderate inequality (UNDP, 2010, p. 27). The country's total population is nearly 90 million (World Bank, 2013) with a poverty rate of 20.7% (Badiani et al., 2012, p. 67). Meaning “to renew” or “innovate,” the *doi moi* reforms of 1986 embody the shift of Vietnam's transition towards a socialist-oriented market regime (Han & Vu, 2008; Labbé & Musil, 2014; Quang & Kammeier, 2002; Turner, 2009). As result of these reforms, and of the country's insertion in the global economy in the 1990s, the boost of economic growth positioned Vietnam on the map for transnational trade and foreign investment (Labbé, 2013). Urbanization, rated 33% (UN, 2014), is now projected to reach 43.3%, as the total population may rise to 101.48 million by 2030 (Owen, 2012, p. 219).

Within this frame, Hanoi has played an important role as Vietnam's capital and largest city, leading the country through its economic transition (Han & Vu, 2008, p. 1098). Located in the North of Vietnam, the city is inhabited by 7 million people (GSO, 2014b), of which approximately 5% are living in conditions of poverty (Badiani et al., 2012, p. 96). The rapid expansion of Hanoi is fueled by the movement of people to urban areas and the subsequent increase of population, rising 3.35% per year (World Bank, 2011, p. 119), and density, with 2,134 of people per square kilometers of land in the city (GSO, 2014b). Formal and informal urbanization processes (see Minnery et al., 2013) have been largely subject to the availability of land shaped by land-use policies and a market-oriented economy, both consequences of institutional changes.

Adding to the sociospatial challenges of water supply, and despite the efforts of Vietnam's central administration to regulate groundwater extraction, overall overexploitation of aquifers in Hanoi has led to groundwater depletion and soil subsidence (Giao & Ovaskainen, 2000). An alarming 90% of urban sewerage discharges directly into rivers (Le Van, 2012, p. 4), affecting surface water exploitation. Although groundwater extraction became Hanoi's primary raw water source in the 1990s due to pathogenic bacteria found in surface water (Jessen, Jakobsen, Postma, & Larsen, 2009, p. 3), surface water has now become the main source again because of poor groundwater quality in the region (Jessen et al., 2009) and aquifer depletion (see “Hanoi's water supply 2030 master plan and 2050 vision; ” HAWACO, 2014a, p. 1).

Rapid urbanization and environmental challenges have affected the supply capacity for basic urban services such as drinking water and sanitation. Concerning the production of potable water in Hanoi, four water enterprises are responsible: VIWASUPCO, HAWACO, Son Tay Company, and Ha Dong Company. To keep up with the demand of water, HAWACO, Son Tay Company, and Ha Dong Company extract approximately 700,000 m^3/day of groundwater; and VIWASUPCO extracts approximately 300,000 m^3/day of surface water (HAWACO, 2014b, p. 17). The companies responsible for the distribution of potable water in Hanoi are: VIWACO, HAWACO, Son Tay Waterworks, and Ha Dong Waterworks. HAWACO is considered the largest water enterprise in Hanoi within the hierarchy of the companies' roles in water provision and has the highest distribution capacity, supplying almost three quarters of the total water supply (with 1,708 km of distribution lines, in comparison to 217, 171, and 627 km of distribution lines from VIWACO, Son Tay Company, and Ha Dong Company, respectively; see HAWACO, 2014b, p. 14).

In order to reduce the 70% of piped water coming from aquifers, two new surface water treatment plants are being built. These are to add to the surface water already extracted from Đà River, as the demand of water was projected to increase to 2.7 million m^3/day in 2015 and 3.3 million m^3/day in 2030 (HAWACO, 2014a, p. 1). The two new surface water treatment plants, to extract water from Hồng River and Đường River, are planned with an initial capacity of 300,000 m^3/day and are expected to expand to a production of 600,000 m^3/day and 900,000 m^3/day in 2050 (HAWACO, 2014b, pp. 1–3, 22). Fig. 1 provides a graphical summary of the existing institutional arrangements and actors who produce and distribute potable water in Hanoi, as well as the quantities and sources of water extraction, and the treatment and distribution processes that ensue.

The Ministry of Construction (MOC) and the Ministry of Agriculture and Rural Development (MARD) face difficulties to service the urban, suburban and rural population in Vietnam with safe water. The first has jurisdiction over urban areas, the second over rural areas. In addition to these two ministries, projects for the development of water supply in Vietnam are coordinated with other government dependencies involving the People's Committees of Provinces, People's Committees of Cities and Towns, and People's Committees of Districts. As People's Committees are part of the local state administration (Parenteau & Thong, 2005, p. 247), decisions concerning water supply mainly follow formal legislation, such as the Clean Water Supply and Environmental Sanitation program launched in 1995 by the National Environmental Agency of the Ministry of Science, Technology and Environment (MOSTE) (Owen, 2012, p. 219). The Ministry of Health (MOH) indicates water quality standards and the Ministry of Planning and Investment (MPI) must approve large-scale projects (Owen, 2012).

As the definition of suburban is jurisdictionally unclear in Vietnam, boundaries between the urban and the rural districts are negotiated between MOC and MARD. In Hanoi, the city develops water supply through master planning, agreed upon by Hanoi People's Committee (HPC) and approved by the Prime Minister. The planning, building, operation and maintenance of piped water supply systems in Hanoi results from a joint effort between urban- and rural-related ministries. Urban planning authorities design and construct water treatment plants through the approval of the central government, and the operation and maintenance of these systems is largely subject to the efforts of state programs that encourage rural households to connect to the piped water distribution network in urbanizing villages. As part of the key strategies lead by MARD, the Information, Education and Communications (IEC) department plays an important role by informing village dwellers on the advantages of the piped water scheme and promoting this technological system, now using “behavior change communication” supported by UNICEF's approach of Communication for Development (C4D) (Interview MARD, 2014). The IEC department assists users in selecting the ‘appropriate’ technology to ensure the financial sustainability and the operation of water treatment plants and water distribution networks to their maximum capacity (Interview MARD, 2014).

Besides the expansion of the piped scheme network system to supply safe water, maintenance of the existing infrastructure is a challenge. Within the current national average of water loss determined at 32% (IBP, 2016: 54), water losses of the piped distribution networks in Hanoi fluctuate between 20 and 32% (Owen, 2012, p. 221; HAWACO, 2014b, p. 17). Between preventing water

loss, and increasing coverage as needed in Hanoi, the country aims at increasing investment in water infrastructures and implementing a regulated tariff calculation based on water meters and identifying illegal connections (Owen, 2012, pp. 219, 221). In line with the World Bank's 2020 targets, Vietnam would expect to raise the existing 76% safe water coverage, according to the baseline value of 2011, to 85–90% in urban areas and from 37% to 75% (or 85% according to the Ministry of Foreign Affairs in Denmark, 2014) in rural areas (WSP and World Bank, 2014, pp. 5–6).

It is important to keep in mind that the development of water infrastructures in Hanoi faces technical and institutional challenges addressed by government dependencies, international organizations, and financial institutions, with participation of the private sector. At another level, the analysis of the particularities of residents' consumption patterns related to domestic water use is relevant to the aim of this paper. Hence, the next section will explore users' perceptions of water accessibility and satisfaction of coverage, quality, and cost, as well as the monitoring of water quality of piped water and the environmental hazards of groundwater accessed by privately owned wells in Hanoi.

4. Suburban water supply in Hanoi: users' perceptions, water quality and environmental hazards

According to the largest water distribution company in Hanoi, HAWACO (2014b, p. 17), 55% of the city's population, or 3.6 million users have access to piped water. HAWACO specifies that urban districts have full water coverage from the distribution network, while piped water reaches only 41.93% of suburban districts (HAWACO, 2014b, p. 17). At the urban scale, users consume 120–140 l/capita/day, double the national average of 50–70 l/capita/day (Owen, 2012, p. 219). Although piped water in urban districts is accessible, many households still rely on water from private vendors and privately owned wells. In 2010, the sources in urban households were recorded as follows: 70.6% piped water, 0.3% from private vendors, 26.3% from tube wells with pump, and 2.8% as other (UNDP, 2010, p. 80).

Pursuing modernization, MOC and MARD strategize the expansion of centralized piped water networks. MARD pursues the expansion of piped water into rural areas through its National Target Program (NTP) for Rural Water Supply and Sanitation (RWSS) (phase 3 from 2012 to 2015, also called NTP3). The NTP3

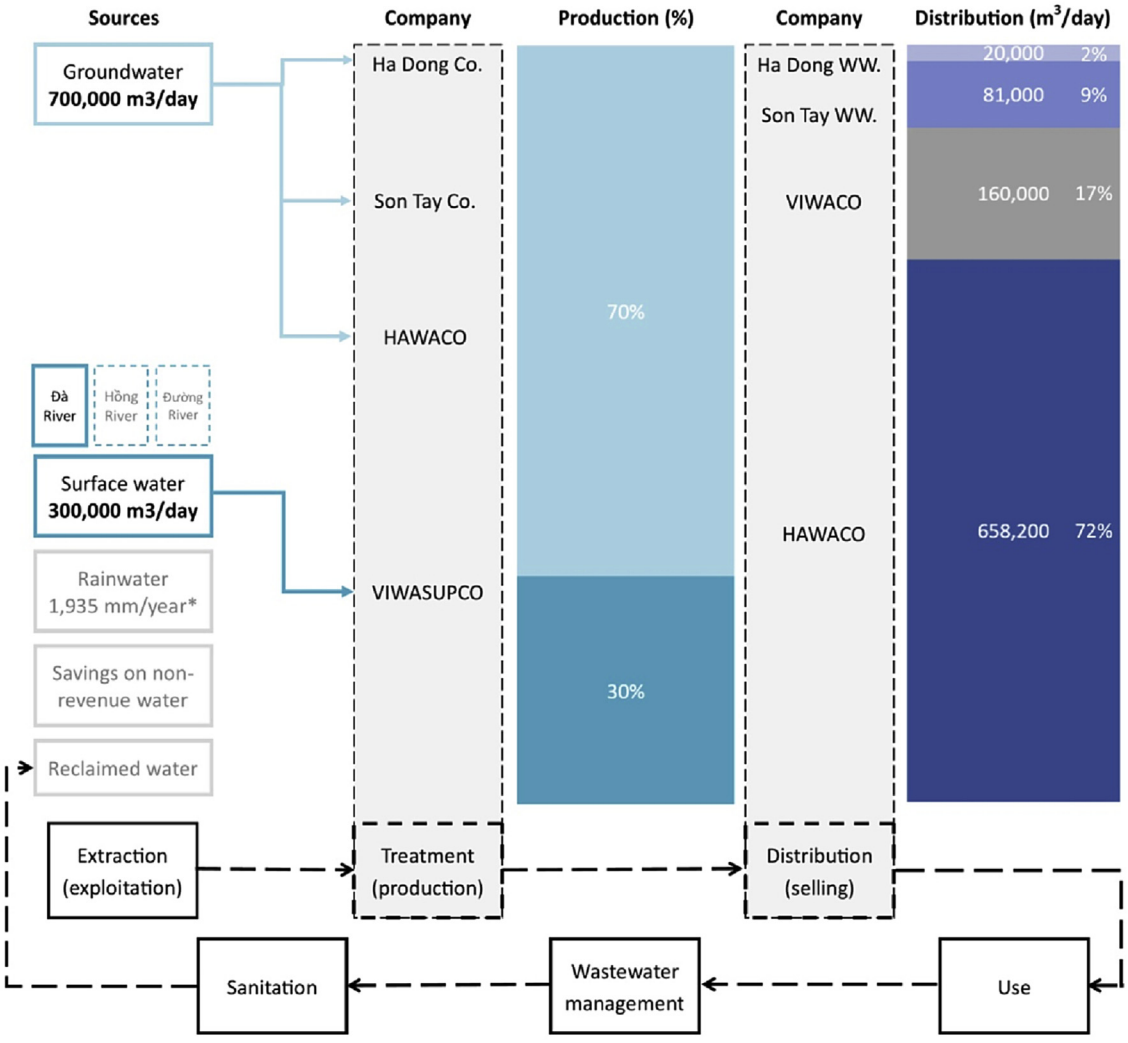

Fig. 1. Hanoi's water cycle and existing production and distribution companies.

program follows a results-based planning and financing approach, which promotes the piped water scheme in rural and suburban areas. At the same time, suburban dwellers attempt to gain control over their water consumption by accessing water through private and decentralized technologies. On one hand, despite the state's efforts to centralize, local managers of new urban areas often operate decentralized, private water treatment facilities. This is because of large distances to Hanoi's centralized piped water network, but also as a result of the competitive stance between construction companies managing infrastructure supply in the new urban areas and the water supply companies (Schramm, 2016). On the other hand, periurban villages rely on independent sources of water, alternating bottled water consumption and filtered well water. Interviewed users state that they complement their intake for drinking water with bottled water and 30% also filtered then boiled well water to drink or cook. The average intake of bottled water per week was 10–20 L, with a difference in cost reflected by the percentage of users complementing their consumption with water from privately owned wells; people who additionally used filtered and boiled well water spent around 0.44 US dollars (USD) per week, equivalent to 10,000.00 Vietnamese Dong (VND) at 22,300.00 VND for 1.00 USD, while people who relied only on bottled water spent up to 3.00 USD per week.

To better understand the overlapping of conditions in suburban areas, the following sections compare water accessibility and satisfaction of coverage, quality, and cost, between suburban districts, focusing primarily on the areas bordering between urban and rural districts, and considering users' perceptions and the effect of built environments on safe water access.

4.1. Accessibility and satisfaction of coverage, quality and cost of water

The following subsection analyzes the results of the 100 questionnaires applied throughout the districts of Hoàn Kiếm, Đống Đa, Hai Bà Trưng, Thanh Trì, Hà Đông, Nam Từ Liêm, Hoàng Mai, Long Biên, Gia Lâm, and Hoài Đức (see Fig. 2). These areas were chosen by selecting 80% of the samples situated in the suburban fringe surrounding the inner city; except for the district of Hoàn Kiếm, which corresponds to the main inner city district, and the district of Hoài Đức which corresponds to a rural district, used as points of comparison to fill the spectrum of the urban-rural range. The results in Table 1 show that access to piped water reaches 100% in 8 of the 10 districts; 90% in the suburban district of Gia Lâm, and 0% in the rural district Hoài Đức, where rainwater was the village's predominant source. It is important to mention that in the urban core district of Hoàn Kiếm, although access to water is 100%, there is an inclination towards water from privately owned wells. One respondent explains: "In 2000, each family had a private well and some families still prefer to use water from their tube or dug wells instead of paying the water tariff" (Interview Resident, Hoàn Kiếm inner-city district, Hanoi, 2014). Additionally, the user states: "Coverage is low, especially during rush hours—between 5 and 6 p.m. it is not enough". Preference to access water independently from the centralized network is observed clearly in Gia Lâm, where, although there is 90% of access to piped water, more than half of the population surveyed uses privately owned wells. The interviewees in Gia Lâm use wells as primary sources of water, but still have a connection to the piped network system. Thus, they pay a water tariff of between 0.70 USD to 3.60 USD per month in comparison to users who do not own wells and pay 0.50 USD to 15.70 USD per month. These expenses refer specifically to bills received according to the water tariff of each area and exclude any personal expenses on purification and filtration methods. In lower income areas, such as in Hà Đông, the cost of piped water is perceived to be more expensive (see relative cost to income in Table 1). Altogether, prices of water range from 2 to 28% of the average income of Hanoi's population, considering 104.00 USD per month (UNDP, 2010, p. 26).

Regarding quality, water was rated lowest in the suburban districts of Đống Đa, Hà Đông, Long Biên, and Gia Lâm. One interviewee in the commune of Vạn Phúc, in Hà Đông, expressed that the water supplied to his household connection is: "Dirty water, a lot of sludge, a lot of detergent [possibly chlorine, comment by authors]; the color of water is yellow or brown. I need to use a water purifier" (Interview Resident, periurban Vạn Phúc commune in Ha Dong district, Hanoi, 2014). In addition to comments regarding the bad appearance or odor of water, other users noted that they are aware of high levels of iron in their water, as indicated in the results of private tests they have conducted. Quality improves significantly when users invest in private water storage systems and treat their own water using additional purification methods. Generally, the interviewees expressed that there was little difference between the water quality in the area they lived in compared to adjacent districts, except in the rural district of Hoài Đức, which rated lower than average due to the lack of connections to the piped water network.

4.2. The relationship between urban typologies and measured water quality

To assess the difference in quality of water supplied in suburban areas, we selected the new urban area of Linh Đàm and the periurban village of Triều Khúc to test 8 water samples for hazardous chemicals that may affect users' health (see Table 2). Facilitated by the School of Environmental Science and Technology of the Hanoi University of Science and Technology in September of 2014, the results show that the quality of piped water remains similar between Linh Đàm and Triều Khúc, equally respecting the QCVN 01: 2009/BYT National Technical Regulation on Drinking Water Quality (SRV, 2009). However, the quality of the groundwater extracted from privately owned wells affects both areas regardless of the urban typology and the users' socioeconomic level. Groundwater in Linh Đàm displays almost twice the tolerated amount of ammonium (NH_4), more than 10 times the permissible level of arsenic (As), and 90 times the standard for iron (Fe). Groundwater in Triều Khúc shows more than twice of the tolerated amount of ammonium (NH_4), up to 30 times more of the permissible level of arsenic (As), and 45 times the standard for iron (Fe).

Considering the comparable risk found in groundwater quality in both Linh Đàm and Triều Khúc, the impact on users' health is rather dependent of the housing typologies and the built environment which limit or permit the use of privately owned wells. Marked by the high-rise buildings and built public space provided in Linh Đàm, privately owned wells are found in peripheral areas of the new urban area, if at all. As the built environment in Triều Khúc is more open to both formal and informal construction, the likelihood of accessing water from privately owned wells is higher. The connection between users' perception and actual water quality issues can be appreciated in the 100 cluster samples. Users stated that there is a general awareness of the presence of heavy metals in groundwater, which is why residents opt for an array of water sources for their different activities. If presented as an option, many will use groundwater for gardening, construction, or for washing. However, even when piped water is technically considered safe to drink, social perceptions show a mistrust of the water source. One resident mentioned: "My family has a water purification system because we are worried about the water source" (Interview Resident, new urban area of Linh Đàm in Hoàng Mai district, Hanoi, 2014). Depending on the level of income of the family, and considering saving on water bills, residents will opt to filter or boil

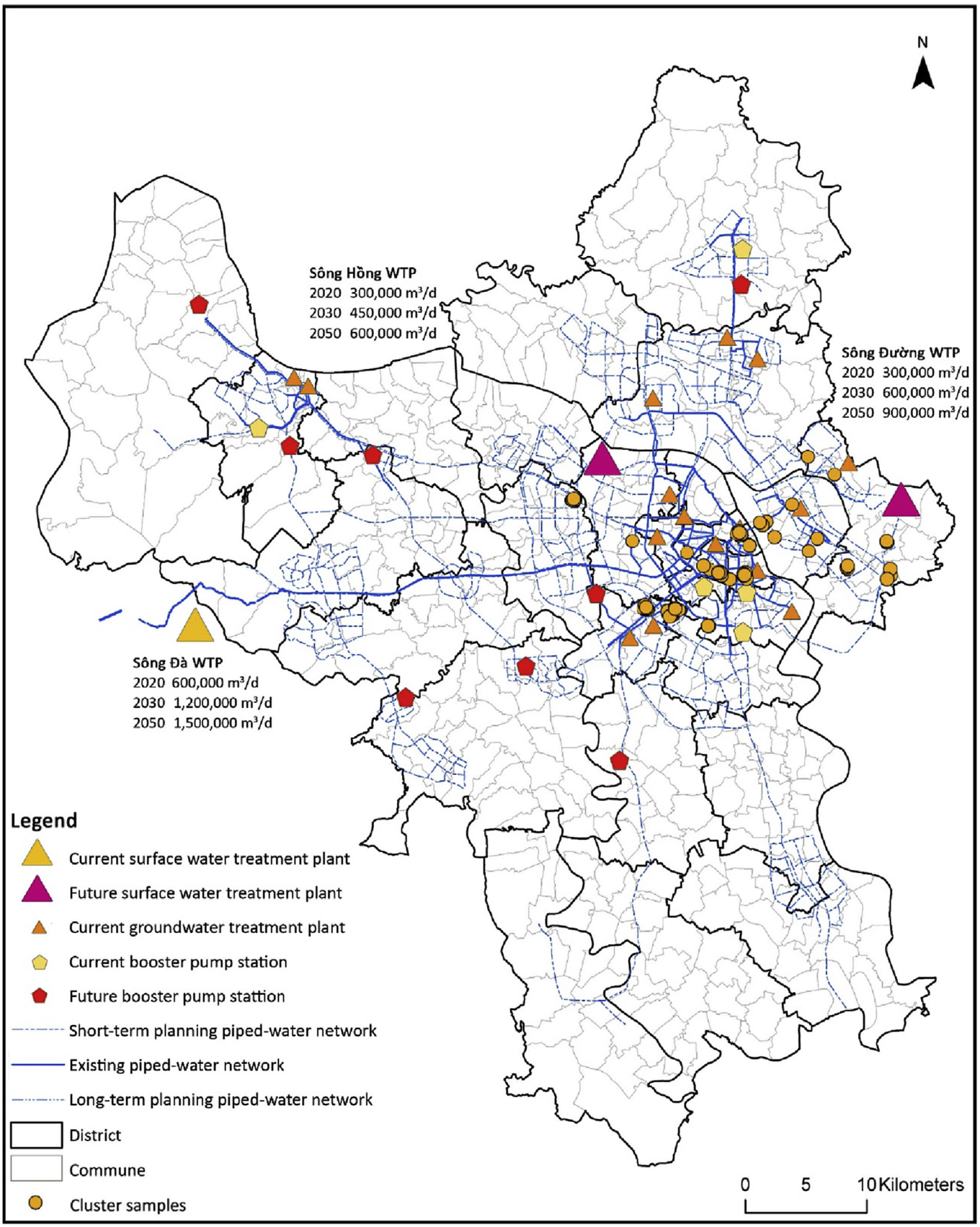

Fig. 2. Hanoi's water supply network, projections of expansion to 2020, 2030 and 2050, and location of cluster sampling.

Table 1
Results of surveys on accessibility and satisfaction of coverage, quality and cost of water.

District	Name Typology	Hoàn Kiếm City-center	Đống Đa Urban	Hai Bà Trưng Urban	Thanh Trì Rural	Hà Đông Urban	Nam Từ Liêm Urban	Hoàng Mai Urban	Long Biên Urban	Gia Lâm Rural	Hoài Đức Rural
			<- Suburban ->								
Case studies	Name Typology				Triều Khúc PUV			Linh Đàm NUA			
Location	Kilometers from city center (Direction)	0	3 (SW)	5 (S)	7 (SW)	8 (SW)	9 (W)	10 (S)	11 (E)	12 (E)	14 (W)
Household size	Number of inhabitants per household	3.9 (2 to 6)	4.1 (2 to 6)	3.8 (2 to 6)	4.7 (2 to 10)	5 (4 to 9)	4.7 (3 to 10)	3.8 (1 to 7)	4.1 (3 to 6)	4.1 (3 to 5)	4 (3 to 5)
Availability of water and sources	Access to piped water supply (%)	100	100	100	100	100	100	100	100	90	0
	Awareness of water source (%)	50	30	20	70	70	40	70	10	70	100
	Type of predominant water supply	Piped water +1 tube well	Piped water	Piped water	Piped water	Piped water	Piped water	Piped water	Piped water	Tube well / Piped water	Rainwater
Satisfaction of coverage and quality of water supply	Coverage [-](1 to 10)[+]	7.4 [s1.65]	7.1 [s2.02]	8.6 [s0.97]	8.4 [s0.84]	7.8 [s1.23]	8.2 [s0.92]	8.4 [s1.07]	6.9 [s3.21]	7.0 [s1.80]	1.7 [s0.67]
	Quality [-](1 to 10)[+]	7.9 [s0.99]	7.0 [s1.54]	7.6 [s1.26]	7.7 [s1.16]	7.0 [s1.41]	7.8 [s1.13]	7.1 [s1.79]	6.0 [s2.58]	5.9 [s1.33]	1 [s0.53]
	Comparison to adjacent areas [-](-2 to 2) [+]	0.6 [s0.71]	0.4 [s0.70]	0.9 [s0.42]	0.5 [s0.53]	0 [s0.46]	0 [s0.47]	0.7 [s0.67]	0.1 [s0.31]	0.1 [s0.73]	-0.4 [s0.52]
Cost and relative cost of water per household	Cost range (VND/month) (x1,000)	40-200	40-140	40-200	100-300	130-350	120-300	70-650	40-175	15-350	n/a
	Cost average (VND/month) (x1,000)	89	72	78	192	214	197	139	103	108	n/a
	Family income (VND/month) (x1,000,000)	> 4,000: 1 4-8,000: 3 8-12,000: 6	> 4,000: 2 4-8,000: 7 8-12,000: 1	> 4,000: 3 4-8,000: 4 8-12,000: 3	> 4,000: 3 4-8,000: 5 8-12,000: 2	> 4,000: 8 4-8,000: ? 8-12,000: ?	> 4,000: 1 4-8,000: 9 8-12,000: 0	> 4,000: 4 4-8,000: 4 8-12,000: 2	> 4,000: 5 4-8,000: 4 8-12,000: 1	> 4,000: 4 4-8,000: 4 8-12,000: 2	> 4,000: 5 4-8,000: 4 8-12,000: ?
	Relative cost to income [-] (1, 2, 3) [+]	1.8 [s0.42]	2 [s0.47]	2.2 [s0.42]	2.3 [s0.50]	2.6 [s0.52]	1.9 [s0.32]	2.3 [s0.67]	2 [s0.66]	1.8 [s0.50]	n/a
Community organization	Neighborhood organization (%)	100	100	100	100	100	100	100	100	100	100

their own groundwater. As a result of our study of hazardous metals found in the groundwater of the region, viewed in line with the built environments of both areas, this analysis shows that monitoring the use of low-quality water sources cannot be viewed separate from the urban form, since it is the latter which conditions the use of small-scale technologies.

Identifying reliable raw water sources, and protecting freshwater bodies from overexploitation and wastewater contamination, are some of the main user-related and environmental challenges to build a sustainable urban water cycle. Several studies (Berg et al., 2008; Jessen et al., 2009; Postma et al., 2007; and Winkel et al., 2010) have raised critical issues in relation to groundwater pollution and have presented evidence that arsenic (As) is affecting lives of between 7 to more than 10 million people living around the Red River Delta. Parting from the World Health Organization's guidelines which establish no more than 10 μg of arsenic (As) per liter in drinking water, some studies have found between 10 and 300 times more arsenic (As) than the established guidelines (Bainbridge, 2013). Being exposed to such amounts of arsenic (As) could cause severe and deadly diseases such as hyperpigmentation, skin cancer, heart attacks and cancer of internal organs due to arsenic poisoning or arsenicosis (Jessen et al., 2009).

5. Discussion

This research has aimed to understand how urban typologies and water accessibility interrelate and affect users in suburban Hanoi. This paper has analyzed: a) water access in suburban areas of Hanoi, and b) the splintered typologies between new urban areas and periurban villages. To do so, it has been important to discuss

Table 2
Results of water samples in districts of the new urban area of Linh Đàm and the peri-urban village of Triều Khúc.

District (NUA/PUV)		Hoàng Mai (Linh Đàm)				Thanh Trì (Triều Khúc)				
Water source		Piped water		Groundwater		Piped water		Groundwater		
Chemical / Sample		LDTP1	LDTP2	LDGW1	LDGW2	TKTW1	TKTW2	TKGW1	TKGW2	QCVN 01:2009
Amonium	NH4	BD	BD	5.68	2.404	BD	0.0321	7.05	0.204	3
Phosphat	PO4	0.23	0.316	2.736	0.758	0.104	0.141	0.835	0.235	?
Arsenic	As	0.0008	0.0055	0.1144	0.0541	0.0012	0.0007	0.276	0.0668	0.01
Lead	Pb	0.0009	0.0008	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0146	0.01
Cadmium	Cd	0.0004	0.0005	0.0005	0.0004	0.0005	0.0005	0.0002	0.0006	0.003
Iron	Fe	0.217	0.258	27.554	22.347	0.239	0.209	13.751	5.161	0.3
Manganese	Mn	0.002	0.011	0.737	0.318	0.016	0.009	0.069	0.13	0.3
Zinc	Zn	0.096	0.152	0.016	0.011	0.003	0.005	0.001	0.118	3
Copper	Cu	0.068	0.045	0.012	0.017	0.013	0.027	0.005	1.138	1

the consequences of rapid urbanization by exposing increasingly blurry boundaries between the urban and the rural, and the contrasts between new urban areas and periurban villages within the city's suburban fabric. Further on, the aim of the following section is to summarize from the analysis of Hanoi's 'splintering suburban waterscapes', users' perception on accessibility, and satisfaction of coverage, quality and cost of piped water, as well as the environmental hazards of groundwater accessed by privately owned wells.

Regarding the empirical analysis of water accessibility and satisfaction of coverage, quality and cost, the results of the surveys shed light on users' preferences for different water sources. The population that was surveyed relies not only on water from large networks, but also from small-scale systems, mainly because the flow of piped water is not always constant and, in some cases, due to their distrust of the quality of water supplied by the piped water network system. This means that, through a "needs-driven" approach (Allen et al., 2006b), in addition to having access to piped water, households maintain privately owned wells for daily-use in gardening, construction, or for washing. For drinking purposes, users will connect supplementary filtering systems to their intake of piped water. Due to the lack of round-the-clock water supply in some areas, as well as cost concerns, users will use alternative sources such as boiled groundwater extracted from privately owned wells or bottled water. However, buying bottled water for drinking highlights the tendency of selling water as a commodity opposed to granting its access as a basic human right. Residents of Hanoi base their choices of water sources on cultural preferences, shaped by social perceptions, and influenced by affordability, rather than just on the existing or available connection to the piped water network system.

The main user-related and environmental challenges that impact Hanoi's population and natural water resources are the high levels of hazardous heavy metals and the overexploitation of groundwater. These two factors affect users with privately owned wells, as the state cannot monitor water quality nor the amount of groundwater that is exploited for domestic use at a small scale. For this reason, due to rapid urbanization and the increasing density in suburban areas, through a "policy-driven" approach (Allen et al., 2006b), the government has encouraged the development of centralized networks. Despite this effort, many users who maintain privately owned wells are aware of groundwater contamination and, in some cases, have no alternative to access safe water sources. As shown in the analysis of water samples, groundwater in the new urban area of Linh Đàm is as contaminated as groundwater in the periurban village of Triều Khúc. Both areas are located in the water supply zone that would receive treated surface water from Đà River (HAWACO, 2011: pp. 52–53). However, the built environment of the first area limits the use the privately owned wells, whereas the built environment of the village favors the use of well water with little or no attention to water quality. Still, in agreement with the city's master planning, the government allows for the supply of groundwater treated by private development companies which monitor and guarantee water quality. The same water served by different means and the contrasting urban typologies of new urban areas and periurban villages expose the discrepancy between the availability of water and the urban form which conditions the

access to safe water sources.

In line with the persistent pursuit of modernity, the hybrid, socialist, yet marketized state has continued to support private investment and welcome the exchange of foreign capital and knowledge to support technological advances. With the growing challenge of supplying fresh water to the rapidly expanding urban population, the central government delegates the implementation of national strategies to different state authorities who combine responsibilities supply water in urbanizing areas. Consequently, Vietnam attempts to expand centralized water supply networks in suburban areas which can hardly keep up with the speed of urbanization. Particularly since the categorization of water as a commercial activity in 2004 (Owen, 2012, p. 219), private entrepreneurship in Vietnam has been encouraged and is expected to raise from the 2% of private sector participation determined in 2012 to 12% in 2025 (Owen, 2012, p. 46).

As water treatment and production technologies advance to keep up with the demand of the water supply, greater access to safe water relies both on the improvement and support of adequate technological systems that correspond to different needs. It is necessary to consider a broader spectrum of combined delivery options, including small-scale and affordable sources (Allen, Dávila, & Hofmann, 2006a), decentralized management techniques to control pollution and hazardous effects on the environment and human health (Allen, 2010), treated wastewater as an alternative source (Kurian et al., 2013), sustainable sanitation systems (Nguyen, 2011), semi-centralized infrastructures (Schramm, 2011), and the combination of various scales of "networked and non-networked" solutions (Monstadt & Schramm, 2013). Funding for water and wastewater systems can also be aided by revenues from water resource recoveries, wastewater fees, and micro-finance programs to support the poor (Nguyen, 2013).

The coordination of actors involved in water supply should aim for a sustainable urban water cycle, defined by an efficient management of freshwater resources, forecast of demand of water use, water supply management including water reuse, wastewater management, sustainability of infrastructures, and maintenance of the systems in order to minimize water losses. Building a sustainable urban water cycle in Hanoi faces user-related, environmental, technological, institutional and economic challenges. The consideration of the users' water-use preferences is fundamental to control the quality of the sources of water that people use and address water coverage and water accessibility. Environmentally, the consideration of freshwater sources is essential as surface water in Hanoi is subject to microbial pollution, the overexploitation of groundwater has led to groundwater depletion and soil subsidence, and both groundwater and wastewater present high levels of heavy metals. Thus, monitoring small-scale systems is as important as the mitigation of pollutants and heavy metals from existing centralized water supply systems to ensure access to safe drinking water. In terms of technical issues, operation and maintenance are crucial to consider the long-term viability of a system, since piped water distribution networks need constant repair, possibly due to the quality of materials that have been used to build water supply networks and because of the lack of maintenance. At an institutional level, the urban/rural dichotomy reflects a complex coordination of the roles of MOC and MARD in urban development and water service provision. Regarding lower income populations who perceive a relatively high cost of water, it is important to recognize that users are active in seeking alternatives of water consumption next to piped water. Altogether, the provision of safe water through a sustainable urban water cycle depends on the capacity of all stakeholders to meet the demand of the population, despite the limitations of the natural resource, challenges of maintenance and operation of the current technological systems, and the cost of water, while considering users' needs and water consumption patterns.

6. Conclusion

New urban areas and periurban villages display unequal access to water following splintering urbanism processes. The contrasting urban typologies and built environments condition access to safe water, while cultural preferences influenced by users' perceptions of water quality and affordability demand a wider array of solutions. This reveals the complexity of urbanization patterns and water governance trends.

As the growing demand of water is not easily met with the current arrangements of large-scale production and distribution of water, recognizing a broader range of environmentally-friendly and cost-effective water sources for consumption and use is imperative to argue in favor of distributional justice and advocate for inclusive decision-making. With the purpose of alleviating the pressure of the existing means of water production, at one level, we argue that it is crucial to prioritize wastewater management and include reclaimed water as a viable source in cities' urban water cycles; and, on another level, it is important to promote water reuse and water conservation practices at household levels to reduce average water consumption rates. As Vietnam's urban household groups and rural villages prove to be effectively organized, involving the community in the earlier stages of design and planning, as well as in the implementation, operation and management of water supply infrastructures, could be essential to increase their sense of ownership and commitment towards promoting and maintaining new technological systems. Parallel to this, experts from civil society organizations and higher education institutions can also represent a great value as their role in facilitating knowledge and resources can help solve national development issues.

Through a call for sustainable development, this study instigates fellow researchers to discuss the direction of planning visions of other cities; create tools to map and visualize the social, environmental, technological, institutional and economic challenges of water provision; re-evaluate processes; and advocate for equitable distribution of resources and services to increase distributional justice and social equity.

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