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# Water Infrastructures and Local Power in Peripheral Urbanisation: New Insights from Urban Political Ecology in São Paulo

**Tade Rücker**

Christian-Albrechts-Universität zu Kiel, Geographisches Institut, Kiel, Germany; ruecker@geographie.uni-kiel.de

**Rainer Wehrhahn**

Christian-Albrechts-Universität zu Kiel, Geographisches Institut, Kiel, Germany; wehrhahn@geographie.uni-kiel.de

ABSTRACT: This paper explores how access to water in peripheral urban settlements is shaped by micro-scale power relations, material infrastructures, and collective organisation. Engaging with debates on infrastructure and peripheral urbanisation in the Global South, the paper conceptualises access to water infrastructures through the lens of Access Theory. The study examines two recent land occupations in São Paulo, Brazil, which differ significantly in their organisational structures. The comparison reveals that seemingly similar contexts of peripheral urbanisation generate profoundly divergent hydrosocial metabolisms through residents' differentiated approaches to self-built infrastructure development. It contributes to situated Urban Political Ecology debates by demonstrating how peripheral urbanisation produces heterogeneous socionatural configurations rather than uniform patterns of exclusion. This points to the need for nuanced approaches to 'informal settlements' and highlights residents as active producers of urban infrastructure and distinct territorial subjectivities.

KEYWORDS: Peripheral urbanisation, infrastructure, Urban Political Ecology, water, São Paulo, Brazil

## INTRODUCTION

In the Metropolitan Region of São Paulo (RMSP), large parts of the urban fabric are auto-constructed. This mode of urbanisation is based on collective initiatives, self-organisation, and the activities of residents who gradually construct their homes and infrastructure through transversal logics – navigating across and blending formal and informal systems and legal and extralegal practices, and engaging with official structures in flexible, improvised ways (Caldeira, 2017). While large parts of these areas are now consolidated and connected to a linear water and wastewater network, new informal settlements are developing on speculative, compensatory or conservation lands on the margins of metropolitan areas and their inhabitants are in constant risk of eviction. In such areas, new infrastructure configurations emerge that are composed of plural networks, artefacts, access modalities and maintenance conventions that attempt, separately and in combination, to ensure water supply for residents. Although the establishment of formal infrastructure in these areas can lead to tenure security (Hylton and Charles, 2018), residents often do not abandon their hybrid habits of water provision (Cawood et al., 2022).

The research perspective of Urban Political Ecology (UPE) recognises that urban worlds are shaped by capital flows and more-than-human processes; this perspective, however, often overlooks micro-scale changes in power relations (Lawhon et al., 2014). The aim of this article is therefore to show how water infrastructures in peripheral urban areas are embedded in situated power relations that are neither established nor stable. Conceptualising access and control using "Access Theory" (Ribot and Peluso, 2003) reveals how peripheral water infrastructure shapes specific hydrosocial metabolisms at the micro-level,

which produce new power relations beyond classical capital-labour contradictions but can also give rise to alternative hydrosocial imaginaries.

The article demonstrates how self-built infrastructures both reflect and reproduce social power at the micro-level. The comparison of the two case studies reveals how organisational differences give rise to distinct hydrosocial metabolisms and the paper argues that such alternative metabolisms can foster solidarity-based forms of urban life. It contributes to broader debates on infrastructure politics, peripheral urbanisation, and the contested nature of citizenship in Global South contexts.

Drawing from literature on theory and context, the paper is grounded in qualitative fieldwork conducted in the RMSP between 2022 and 2024. The research uses document and media analysis for contextualisation, structured expert interviews, semi-structured interviews with residents and community leaders, informal conversations and transect walks, as well as participatory observation in community meetings, cultural events and organisational meetings of social movements. In total, we analysed 10 different neighbourhoods with varying legal statuses and organisational forms. Two contrasting cases foreground a wide range of different infrastructure configurations in peripheral urbanisation. They were selected on the basis of their differing stages of water and land regularisation as well as on variations in their neighbourhood organisations' respective capacities for collective action. These differences reflect divergent conceptions of citizenship and, as a consequence, distinct relationships with the state.

The paper is organised into five sections. It begins with a UPE theoretical framing of infrastructure in informal neighbourhoods. This is followed by a conceptualisation of the unevenness of the urbanisation process. We then offer a situated reading of peripheral urbanisation in the RMSP. In the subsequent section, we present a detailed picture of the respective peripheral water infrastructure networks found in the two case study neighbourhoods. We conclude with a discussion on findings and with suggested directions for further engagements with this research topic.

## TOWARDS AN URBAN POLITICAL ECOLOGY OF PERIPHERAL URBANISATION

### Urban socionatures and hydrosocial transformations

Urban Political Ecology (UPE) understands the city as a socionatural formation where nature and society are co-produced by economic, social and political processes that result in deeply embedded uneven power relations (Swyngedouw and Heynen, 2003; Heynen et al., 2006). The shaping of the urban environment is driven by capital accumulation to metabolise nature, that is, to transform natural resources such as sand, water or copper into urban space (Harvey, 1996; Gandy, 2003; Swyngedouw, 2004; Smith, 2008). While the metabolism metaphor spans diverse research fields (Newell and Cousins, 2015; Gandy, 2025), UPE scholars understand these urban transformations by drawing specifically on Marx's theorisation of metabolism, with labour as the central mediating process. Transcending the nature/society dualism, however, UPE scholars conceptualise the city as a hybrid socionatural artefact that is full of contradictions and structured by conflict (Swyngedouw, 1996). According to this perspective, access to nature in cities is always political and always shaped by historically specific configurations of power, infrastructure and economic interest (Heynen et al., 2006).

Focusing on water provides a particularly powerful entry point into these dynamics. Concepts such as the hydrosocial cycle (Linton and Budds, 2014), waterscapes (Gandy, 2004; Flaminio et al., 2022), and hydrosocial territories (Boelens et al., 2016) reveal how water flows are embedded in, and actively shape, sociopolitical relations. Changes in water infrastructure or water quality alter social hierarchies and, in turn, are shaped by them (Linton and Budds, 2014: 173; Swyngedouw, 2009; Karpouzoglou and Vij, 2017). Embodied and spatial perspectives highlight the situated nature of hydrosocial relations in cities of the Global South; included here are Doshi's (2017) work on gendered water access and Silver's (2023) reflections on infrastructure beyond the single-network model. Together, these perspectives allow us to

examine how water and power are internally linked rather than externally opposed, and how urban nature is produced through everyday contestation and unequal relations across multiple spatial scales, that is to say, "from the scale of the body upward to the political ecology of the city to the global" (Swyngedouw, 2004: 29).

## Water infrastructures in the Global South

Infrastructures in cities of the Global South are often heterogeneous, fragmented and contested. Rather than conforming to universal service logics, urban water systems are frequently assembled through incremental (Silver, 2014), lively (Amin, 2014), and sociotechnically diverse (Jaglin, 2014) means. These infrastructures operate across legal/illegal and formal/informal divides – what Truelove (2019) calls "gray zones" – and they are produced through embodied and intersectional power relations that include class, gender, caste and religion. This literature rejects the formal/informal binary (Roy and AlSayyad, 2004) and conceptualises infrastructure as a social and political process that is continually reassembled through construction, breakdown, repair and maintenance (Furlong, 2014; Lawhon et al., 2018). The concept of heterogeneous infrastructure configurations (HIC) shifts attention to when and for whom infrastructure 'works', making visible the often uneven and dynamic nature of infrastructure provision (Lawhon et al., 2018: 730).

Water infrastructure also mediates state-society relations. In post-apartheid South Africa, for example, the introduction of prepaid meters in low-income areas has exposed enduring tensions around citizenship, service entitlement and neoliberal restructuring (von Schnitzler, 2008; Loftus, 2007; Rodina and Harris, 2016). Similarly, insurgent infrastructural struggles in peripheral areas can challenge state legitimacy and foster alternative forms of citizenship (Holston, 2008; Ranganathan, 2014). At the same time, infrastructure can function as a means of authoritarian environmental governance. In Guyana, for instance, an examination of flood control policies reveals how state authority is exercised through technocratic environmental interventions (Mullenite, 2019), and in Brazil and Mexico environmental hazards such as flooding or landslides intersect with clientelist governance, forcing marginalised communities to rely on informal patronage networks for basic services (Coates and Nygren, 2020). These examples show that the state's role in infrastructure provision varies, and can be both ambivalent and strategic. As Davis (2017) argues, states may withhold regulation or formalisation if it risks undermining their legitimacy, thereby embedding informality within governance structures. In Metro Manila, for instance, informal water access through pilferage or community distribution is co-produced by citizens and state actors and remains tolerated as long as it serves broader political interests (Hussain and Chaves, 2023).

This body of research forms part of a broader endeavour to 'provincialise UPE' by integrating insights from African urbanism (Lawhon et al., 2014) and South Asian urban studies (Zimmer, 2017). While Global South perspectives remain generally underrepresented in UPE debates (Gandy, 2022: 23), Latin American contributions are even more scarce (notable exceptions include Swyngedouw, 2004; Ruiz and Rodríguez, 2016; Arboleda, 2016; Vitz, 2018). We respond to these calls by engaging with Brazilian scholarship on auto-construction and peripheral urbanisation.

## Theorising water access in peripheral urbanisation

In Latin America, and particularly in Brazil, large parts of the peripheral urban space are auto-constructed by residents (Caldeira, 2017; Santos, 1990; Fix and Arantes, 2022; Streule et al., 2020). Rooted in dependency theory, early understandings of peripheral urbanisation conceptualised the periphery as structurally subordinated to global centres, with rural-to-urban migration and industrial exploitation producing informal settlements (Castells, 1977; Durham, 1978; de Oliveira, 2003). These areas emerged as spaces of urban spoliation that were marked by uneven access to basic infrastructure and services (Kowarick, 2004). This unevenness is a manifestation of the uneven geographical development that

produces differentiated socionatural conditions across urban space. Recent contributions (especially from Caldeira, 2017) reconceptualise peripheral urbanisation as a mode of urban production that transcends spatial boundaries and formal/informal binaries. It is defined by the gradual, resident-led construction and transformation of urban space, often without clear legal status, but deeply embedded in everyday urban life. This lens highlights the agency of residents, while also acknowledging the structural conditions that shape uneven urbanisation. From a UPE perspective, this process can be understood as a distinctive mode of socionatural metabolism where residents actively co-produce urban nature through the incremental transformation of space and resources.

To analyse water infrastructure in these contexts, we draw on Ribot and Peluso's (2003) Access Theory, understood here through a hydrosocial lens. Rather than equating access with legal ownership, the theory defines it as the ability to benefit from resources in a way that is shaped by institutional mechanisms, material conditions, social relations and symbolic capital. It distinguishes between access acquisition, access control (the ability to mediate others' access), and access maintenance (the means to sustain access over time). These distinctions enable a more nuanced view of how hydrosocial territories are produced and contested through political and economic power (see also Ranganathan and Balazs, 2015; Cornea et al., 2016; Bartels et al., 2018). Applied to peripheral urbanisation, this approach allows us to examine how hydrosocial territories are strategically constituted by residents, politicians and institutions in contexts of uncertain land tenure, policy opacity and infrastructural precarity. Self-built water systems become key sites where the co-production of urban nature intersects with resource control, social recognition and political negotiation.

In short, peripheral urbanisation in Brazil is marked by hydrosocial transformations that reflect broader processes of uneven development while also representing localised forms of socionatural metabolism rooted in struggles over access, recognition and survival. Tracing these dynamics helps reveal who benefits, who controls, and who is excluded in the ongoing co-production of urban space and hydrosocial territories. Through comparative analysis of water infrastructure in São Paulo's peripheral land occupations, we can reveal how different organisational logics of hydrosocial territorialisation emerge despite shared conditions of tenure insecurity and infrastructural precarity.

## URBANISATION AND WATER IN THE PERIPHERIES OF SÃO PAULO

The RMSP consists of 39 municipalities with about 22 million inhabitants. While the region's urban fabric is increasingly heterogeneous, it remains shaped by a stark segregation between the central parts of the city and its peripheries (Santos, 1993). In the context of deindustrialisation, large-scale urban development projects have transformed both central and peripheral areas (Fix, 2011). These changes coincided with the emergence of urban social movements, which played a central role in shaping institutions after re-democratisation in 1985 (Holston, 2008). A key outcome was the 2001 City Statute, which established that urban property must fulfil a social function (Caldeira and Holston, 2005).

State-led housing programmes such as *Minha Casa Minha Vida* have absorbed social and economic pressures while producing highly standardised housing on the urban periphery (Simoni Santos, 2018). Some scholars have linked these developments to broader financial and legal transformations (Sanfelici and Halbert, 2016; Mosciaro and Pereira, 2019), but this paper focuses instead on the lived realities of the residents who navigate peripheral urbanisation. Many have faced rising rents, evictions and exclusion from formal housing programmes, prompting them to seek out land on the periphery for informal self-construction (Simoni Santos, 2023). This process differs from that of more-established peripheral settlements where tenure tends to be more secure and infrastructure more accessible.

This peripheral urbanisation process takes various forms. In some cases, occupations occur in a more 'spontaneous' manner, with urbanisation proceeding incrementally and gradually. Alternatively, informal land subdivisions may take place, in which settlers often acquire unofficial land titles through criminal organisations (Guerreiro, 2024). Urban social movements also exert significant influence, having been

active in Brazil's urban spaces since the democratisation process of the 1970s (Caldeira and Holston, 2005: 402). These occupation movements maintain an ambivalent relationship with the state; on the one hand, they demand equality on the basis of their constitutional rights (Friendly, 2024), while, on the other, they employ civil disobedience such as land occupations as a form of "transgressive citizenship" to assert their right to the city (Earle, 2012). The various housing movements advance particular conceptions of citizenship and differ in their degree of institutionalisation, political orientation and organisational structure; the nature of their relationship with the state varies accordingly (Earle, 2017; Zhang, 2020).

The first years of land occupation are shaped by insecurity and precarity. Dwellers are in constant risk of eviction, especially if an occupation is located in a Permanent Preservation Area (APP) or private property (Denaldi and Ferrara, 2018). Self-built infrastructure is thus often inadequate in the early years of land occupation, but it is constantly improved over time. This work is undertaken either by paid plumbers or electricians or through *mutirão* (joint effort). For most occupations and unregularised settlements, the goal is to regularise tenure; under Brazilian constitutional law, this is possible after a minimum of five years of uncontested possession for the purpose of housing (Macedo, 2008). Property rights take precedence over the right to housing, and tenure security in Brazil can thus only be achieved if the landowner is absent or does not challenge the occupation (Pimentel Walker and Arquero de Alarcón, 2018).

In São Paulo, the provision of water and sanitation services is primarily managed by the Companhia de Saneamento Básico do Estado de São Paulo (SABESP), a mixed-capital company in which the majority of shares are held by the state of São Paulo. SABESP is also publicly traded on the São Paulo Stock Exchange and listed on the New York Stock Exchange (Klink et al., 2020; Narzetti and Marques, 2021; Britto, 2025). The company operates in nearly all municipalities within the state and supplies water to approximately 30 million people. Although institutional water governance in São Paulo is considered progressive and includes participatory elements, it often operates in a top-down and supply-led manner, particularly during extreme events such as the 2014/2015 drought (Empinotti et al., 2019). In order to legalise a water connection on irregular land, close coordination with the municipality is required, as it is responsible for *regularização fundiária* (land tenure regularisation) (Hylton and Charles, 2018; Cawood et al., 2022).

Besides providing positive health aspects, the establishment of formalised infrastructure through the installation of water networks, meters and services can sometimes represent a pathway towards universal access to legal infrastructure such as electricity or public transport, and legal recognition of property ownership and housing rights (Hylton and Charles, 2018). Between 2016 and 2022, implementation of social programmes such as *Água Legal*, supported by the World Bank, enabled the local water-service provider SABESP to connect 680,000 people to a formal water network, and between 2012 and 2019 the Se Liga Na Rede programme connected nearly 30,000 people to the sewage network (SABESP, 2023). To receive a formal water network on disputed land, community members approach SABESP to regularise their water connection. The company then seeks permission to install the service from a municipal entity and from the landowner.

With the installation of formal water networks in informal settlements, families receive a water bill with the social tariff; this can serve as proof of residency and can thus diminish the risk of eviction. For SABESP, formalising irregular areas expands its customer base; it also results in less maintenance of the main networks, since formalised connections maintain higher water pressure, which is essential to prevent contaminants from infiltrating the system. Low-income households are granted either a 'social tariff' of R$10,21 or a 'vulnerable tariff' of R$7,79 for the lowest-income families (monthly income up to R$218 per person); both tariffs allow for consumption of up to 10,000 litres of water per household per month. In 2022, 480,087 families were in the social category and 388,387 in the vulnerable category (SABESP, 2023). Despite social tariff policies, there is a pronounced culture of non-payment of water bills, especially in regions where there is a high influence of organised crime groups like the *Primeiro Comando da Capital* (PCC). Most peripheral neighbourhoods with informal and formal water connections face

issues of low water pressure and multi-hour network shutdowns due to maintenance. This means that water storage tanks (*caixas d'água*) are used, although they are expensive to acquire and can only be installed on solid roofs (see also Millington, 2018).

*Gatos*, or irregular connections to the main water networks, differ in materials used and in type and quality of implementation. The onward distribution of water from the connection point varies even more significantly because of uneven levels of expertise, knowledge, technical facilities and monetary resources. Most irregular connections to the main network use inadequate materials, but some are constructed with the same materials and techniques as a regular SABESP connection. Clandestine connections discovered during maintenance work on the regular network are destroyed, even though it is likely that the next day there will be a new one (Interview with a SABESP employee, 5 February 2024). Water exiting the official network through clandestine connections is counted as a physical loss, and there is an obligation to reduce such losses. Another challenge is the risk of contamination of the main network through irregular connections. Conducting maintenance operations in specific segments of its network, for example, involves SABESP implementing a pressurisation procedure; during this procedure, connections that are of substandard quality jeopardise the integrity of the system, particularly with regard to the potential infiltration of contaminants from inadequate sewage systems (Interview with a SABESP representative, 5 February 2024). SABESP thus finds it necessary to utilise chemical treatment methods to purify water, especially in regions with densely populated land occupations, and residents then often express concerns about skin irritations and deteriorating water quality due to the chemical water treatment processes (Interview with leaders representing a land occupation movement, 8 March 2024). We will return to these issues in the empirical analysis of the case studies.

## HETEROGENOUS WATER INFRASTRUCTURE CONFIGURATIONS AND UNEVEN PERIPHERAL URBANISATION

### Ocupação Anchieta

The first case study is located in Grajaú in the southern region of the municipality of São Paulo, a district with high population growth rates and high rates of poverty. It is located between the Guarapiranga and Billings water reservoirs. The whole area is part of the *Macroárea de Redução da Vulnerabilidade Urbana* (Macro-Area of Reduction of Urban Vulnerability), while the occupied area is located on land that is classified as Special Social Interest Zone 4 (ZEIS 4). While the Macro-Area promotes *Habitação de Interesse Social* (social interest housing), the ZEIS 4 typology designates vacant unbuilt land for restricted urbanisation. As Pimentel Walker and Arquero de Alarcón (2018) have shown, most ZEIS 4 zones have been developed or occupied since the introduction of the city's 2014 Master Plan.

The oldest parts of Ocupação Anchieta were occupied as early as 2013. Around 136,000 square metres (m²) of the 220,000 m² of occupied land is native Atlantic Forest and is an Environmental Protection Area (*Área de Proteção Ambiental*) that protects creeks and springs in the area. In 1997, the occupied land was donated by a development company (Cyrela Empreendimentos Imobiliários) to the non-profit organisation Instituto Anchieta Grajaú (IAG). Residents occupying the site had deforested parts of it to build homes and other structures, and in 2013 IAG filed a repossession lawsuit stating that the occupation would diminish the ecological quality of the land (Mendes de Oliveira, 2021). To institutionalise their struggle for housing, the inhabitants of the Anchieta occupation formed a residents association with links to housing movements, to other occupations in the region and elsewhere, and to architecture and urban planning departments. Anchieta now has about 2700 inhabitants. Most are socio-economically vulnerable and did not arrive directly from outside the city; around 58% moved to Ocupação Anchieta from neighbouring areas in Grajaú, 13% moved from other land occupations or informal settlements, and only 8% moved from rural areas to the occupied land (Pimentel Walker et al., 2023).

Although the occupation has not achieved land regularisation (*regularização fundiária*), in 2019 the landowner and municipal officials signed an order permitting SABESP to implement an official water

infrastructure through the *Água Legal* programme, to which about half of the households now have access. The expansion of the network was interrupted by the COVID-19 outbreak and by cuts in the programme due to company strategy.

### *Initial occupation*

A water network was established in the area shortly after the first families arrived to occupy it. To get access, each dwelling had to pay a fee to a local plumber who already knew where the regular water pipes were and how to construct an irregular connection to the network. The residents paid for the service and for the materials used. The earlier that people decided to connect to the official network the closer they were to the regular pipeline, and thus the more likely they were to enjoy high water pressure.

After the initial phase of settlement, later-arriving families who wanted to connect to the local network inside the occupied area did so through existing connections and were required to make a payment to the first-generation occupiers. Through having paid for the initial connections and materials, the latter had somehow become de facto owners of the network. As one early resident said in an interview (11 March 2024),

> Then there are people who say, "Oh, you're the owner of the network point!?" No. Who was the owner? It was another boy. So, when we came with the materials, the person had to pay for the materials (…) because we bought meters and meters of hose. So it's not fair for someone to come here today, when we've already reconnected the water before, and want to install their connector without paying anything, you know.

The local network faced problems with lack of water pressure; this tends to be a problem in consolidated peripheral neighbourhoods, but even more so on occupied land due to the lack of adequate materials. The low water pressure was a great point of conflict in the occupation, where especially first-generation occupiers were reducing flow rates in order to increase water pressure for their own dwellings. As one resident reported,

> It was really a struggle, because for those who live down here, if the illegal connection came from above and the water pressure was weak, the neighbour living upstairs would put a plug so that the water would flow weakly for us, while it would be strong for them. This happened a lot here (Resident interview, 11 March 2024).

As the quote underlines, the first months and years of the occupation involved considerable conflict over water supply; however, water infrastructure also tended to become a proxy for other interpersonal conflicts. Residents reported antagonistic behaviour by unpleasant neighbours, including disconnections, reconnections and wilful destruction. One resident described occasions when, "there were people who, to cause trouble, would throw stones at the hose. So we wouldn't have water here, it would just drip. Wow, in the beginning, it was very distressing" (Resident interview, 11 March 2024).

### *Receiving a regular network*

In 2019, parts of the occupation received formal water infrastructure through the *Água Legal* programme. Initially, the introduction of monthly payments provoked reservations about regularisation; however, the programme employed an easily accessible contact person from the occupation to promote the benefits of regular water connections and address questions and concerns. All the families with water connections were also given the SABESP social tariff for at least two years. In other cases, some friendships even arose between residents and SABESP employees (Field notes, 3 December 2023).

Most residents were in favour of the regularisation of water and of the slightly more stable connections and higher water pressure, even though they still experienced nightly shutdowns. SABESP was not easily accessible however, especially since 2023 when they began to be more centralised. Because of their poor availability, and because of a general reservation about contacting officials,

residents instead paid a local plumber to do repairs, carry out maintenance, set up new connections for newcomers, and relocate water meters inside the occupation when dwellings were restructured. The plumber was already working for a SABESP subcontractor, but after 2019, SABESP did not add any more official connections to the regular network, so the new connections were 'informal' (Resident interview, 11 March 2024).

In the occupied settlement, there is a widespread practice of not paying water bills regularly. SABESP sanctions some residents for this failure by disconnecting them from the regularised network, placing a stopper in the dwelling's connection. A plumber can be hired to remove the stopper, thus some dwellers are able to enjoy unmetered use of the regular network (Field notes, 21 November 2023).

**Ocupação Esperança**

The second case study is located in the north region of Osasco, a municipality in the northwest part of the metropolitan region. Ocupação Esperança covers an area of about 48,000 m² in what is designated in the city's 2020 Master Plan as the Macrozone of Environmental Conservation and Sustainable Development. It is characterised by hilly topography and is in proximity to Pico do Jaraguá which, at 1,135 metres above sea level, is the highest mountain in the city of São Paulo. The area is close to an industrial zone in the south and to rural leisure homes in the north and west. The occupation is situated on privately owned land that belongs to individuals associated with an insolvent cosmetic corporation.

Since the beginning of the occupation in 2013, the 500 families residing there have set up a resident organisation with a strong political presence (Moncau, 2021). Similar to the Anchieta occupation, most of the dwellers had to leave their former housing because of evictions or rising rents in neighbouring districts. The majority of the residents of Esperança had previously been living with relatives or friends or had been paying up to half of the family's income on rent. For most poor families, the occupation represented a way out of a condition of persistent poverty and indebtedness. Most men worked in the construction sector in Osasco and São Paulo, while women were working as cleaners, kitchen assistants and domestic workers; due to their political organisation, the people referred to themselves as "working-class occupiers" (Resident interview, 16 December 2023). After a 2016 fire destroyed a quarter of the occupation, an urbanisation project was initiated by a university's planning and architecture department. With such cooperation in planning, participants in new land occupations try to demonstrate to public agencies that they care about sustainable growth, about increased regularisation, and about developing and improving infrastructure. Plot size is limited to 50 m² per family, and roads and free spaces have been left vacant so that future public vehicles such as school buses or garbage trucks will be able to circulate and regularised infrastructure can be installed (Field notes, 14 December 2023).

*Collective effort and infrastructure provision*

Because of their prior awareness of housing movements, residents were able to make advance plans for establishing basic infrastructure. In the first 10 months of the occupation, water was sourced from neighbouring districts, with residents filling large containers and organising trucks to distribute it within the settlement. Showers were taken in the houses of relatives elsewhere. Through the collective organising efforts of residents, a connection to the public SABESP network was established after about a year. A 20,000 litre water tank was purchased and installed in a central location in the neighbourhood, with the plan being to have a single connection to the network and distribute water centrally inside the occupation. This centralised water distribution proved insufficient due to water shortages, general low water pressure, and the growing number of households inside the occupation. Another three connection points to the SABESP network thus had to be established. Even though in practice the plan for the centralised water distribution failed, it showed a will to organise common infrastructure in irregular settings. As one community leader explained, "So we've always done things here collectively and through pooling resources. Everyone helps in whatever way they can. We organise ourselves, see who can do

what, who understands that area (…) goes there and does it" (Community leader interview, 7 March 2024).

Despite having four connection points to the official network, the water pressure was too low to fill the large tank and thereby redistribute water to all parts of the occupation. Residents whose houses could support an overhead water tank, or those who could afford to build a trestle for an elevated household tank made individual attempts to overcome water shortages and low pressure. The problem of poor water quality and low water pressure was often discussed at formal meetings and between residents, especially because of the topography of the occupation. While lower parts of the occupation had water, parts that were higher up hill had more frequent shortages. Some residents bought electric pumps to fill their own tanks and then loaned them within the occupation to fill up multiple other tanks, and residents who were unable to construct an overhead tank were helped by others in securing water (Field notes, 14 December 2023).

When irregularities occur, when conflicts arise over connection points, or when infrastructure malfunctions, a central figure in the association is informed via instant messaging. This person then decides on the next steps, sometimes reposting news of the malfunction in the association's messaging group. They may invite other inputs on that specific topic or they may commission the most suitable person to arbitrate a dispute or repair the malfunction. The problem may be solved by an individual or through a communal effort, but there is generally no compensation (Community leader interview, 7 March 2024).

### *Building reputation through infrastructure*

Though Ocupação Esperança is not regularised, the resident association insists that the city administration should declare the occupied area as a Special Social Interest Zone (ZEIS) in the new Master Plan. If offered a fair price, residents would be willing to pay for their plots. The occupation maintains close contact with surrounding neighbourhoods that are already established and regularised. This is important because, due to the establishment of new irregular connection points to the SABESP network, the water pressure has further decreased in areas that use the same provisioning pipe. Their argument is that a regularisation of their self-constructed network would also benefit the quality and quantity of water in other neighbourhoods (Community leader interview, 7 March 2024).

This connections with other residents associations and with people from nearby districts is also important for articulating problems regarding attitudes towards occupation and peripheral urbanisation in general. There have been problems, for example, with open sewage flowing from a higher part of the settlement to a recreational area close by; this led to efforts by the residents association to gather donations for a sewage pipe system. Thanks to communal efforts and to collective work on weekends, pipes were laid and individual accommodation units were connected to them. This practical and effective response build the reputation of the district and underscores the occupation's sense of responsibility for the negative environmental impacts caused by peripheral urbanisation. As a community leader points out,

> So we did a lot to help the residents who didn't have sewage, as well as to help the people at the club [recreational area], because it's bad for them and it's bad for us too, because we end up with a bad image, right? So we built this sewage network (Community leader interview, 7 March 2024).

Interactions with external actors also play a significant role in shaping local organisational structures through the agency of community leaders. The emergence of leadership figures in this case did not occur through formal appointment, but rather through their ability to mobilise community members and act as intermediaries between residents and external actors such as state agencies, non-governmental organisations or universities. Women in particular often take on central roles, especially in the fields of health and the environment. This is partly because they are more present in the settlement and take

disproportionate responsibility for childcare, while men tend to be absent due to long working hours and lengthy commuting times. Others build their positions through long-term involvement in grassroots movements or through partnerships with civil society organisations. Research into other occupations and informal settlements, however, shows that, unlike in Esperança, such leadership roles are not always aimed at neighbourhood improvement. Instead, individuals seeking to rise to leadership positions within their communities can find crucial support through connections to illicit actors such as drug-related criminal organisations like the PCC, or to evangelical churches that maintain a strong presence in the peripheries of São Paulo (Field notes, 28 February and 6 March 2022).

### Heterogeneous hydrosocial metabolisms and peripheral infrastructure

Analysis of the peripheral settlements Anchieta and Esperança demonstrates how structural contradictions within the metropolitan hydrosocial metabolism are mediated and negotiated at the local level through different 'bundles of power'. Both are irregular settlements without formal access to water infrastructure (though Anchieta is partially connected to the SABESP network), yet they develop distinct resource configurations for securing water access. These uneven hydrosocial metabolisms emerge through specific combinations of resources (capital, technical knowledge, social networks, technologies, labour) that function as mediating mechanisms between the structural logic of urban water metabolism and concrete everyday practices.

In Anchieta, the resource bundle is constituted primarily through capital (early investments in plumbing work), technical knowledge (irregular connections, maintenance), and infrastructural control (regulation of water pressure and flow). This resource combination enables early residents to establish temporally stable access positions, which they can then leverage against subsequent dwellers. Technical knowledge becomes a strategic resource for employment opportunities and income generation, while control over physical infrastructure shapes the local water metabolism. In Esperança, the resource bundle is formed through collective technical knowledge (instant-messaging-based problem-solving), shared technologies (loaned pumps and tanks), and coordinated labour (collaborative maintenance and repair work). This resource combination enables collective water access practices and generates forms of (hydro-)territoriality through mutually beneficial practices that redefine local meanings of water, rights and territorial identity, while transcending instrumental exchange relations.

These diverse resource bundles do not emerge arbitrarily, but rather are co-constituted by material conditions that include topographical location, proximity to formal networks, intermittent water pressure, and characteristics of the built environment. These sociomaterial entanglements demonstrate how self-built water infrastructures function as heterogeneous sociotechnical configurations that are continually reconfigured through maintenance, repair and social negotiation. Both settlements address the same structural exclusion, yet their specific resource combinations produce different hydrosocial metabolisms. This differentiation illustrates that peripheral urbanisation does not lead to homogeneous 'excluded practices'; instead, it generates diverse local forms of negotiating metropolitan contradictions, the particulars of which depend on what resources are available and how they are combined.

The integration of 'bundles of power' into UPE analysis reveals how structural inequalities in urban water provision are mediated through situated resource configurations beyond the network. The resource bundles function as an analytical bridge between broader patterns of uneven urbanisation and the micro-practices of everyday resource appropriation. This underscores the necessity of understanding hydrosocial metabolisms as relational, situated and continuously negotiated, rather than as static configurations.

## CONCLUSION

We analysed how socionatural water flows are embedded within the heterogeneous processes of peripheral urbanisation in São Paulo. Both of the case study neighbourhoods, Anchieta and Esperança,

are irregular settlements without formal access to water infrastructure, which has compelled residents to engage in self-built infrastructure provision as an integral component of their urbanisation process. This empirical setting demonstrates the relevance of infrastructure *beyond the network,* not as a mere theoretical abstraction but rather as a necessary framework for understanding how residents actively produce urban environments that extend far beyond housing to encompass complex sociotechnical configurations (Lawhon et al., 2018).

Our analysis reveals that peripheral urbanisation is not a homogeneous process of informal settlement; rather, it generates heterogeneous hydrosocial metabolisms through residents' diverse strategies of urban space production. Urbanisation of the periphery actively produces uneven access to infrastructure, yet residents respond through differentiated practices of self-built infrastructure development that fundamentally shape their neighbourhoods' sociomaterial organisation. In Anchieta, residents developed resource configurations that were centred on technical knowledge and individual infrastructure control, while in Esperança residents generated collective approaches involving shared technologies and collaborative maintenance practices that constitute forms of (hydro-)territoriality.

These differences underscore that peripheral urbanisation encompasses the comprehensive production of urban environments by residents themselves, where water infrastructure becomes a constitutive element of neighbourhood formation rather than an external addition. The resulting hydrosocial metabolisms are not simply responses to exclusion from formal networks; instead, they are active productions of alternative urban socionatures that emerge from residents' situated practices of city-making and their capacity for imagining different hydrosocial metabolisms (Swyngedouw, 2009: 9). This challenges simplified categorisations of 'informal settlements' and highlights how residents' infrastructure practices generate qualitatively different forms of urban metabolism.

Conceptually, this study enriches Urban Political Ecology by demonstrating how peripheral urbanisation's heterogeneity produces diverse hydrosocial metabolisms rather than uniform patterns of exclusion (Silver, 2023). Our findings reveal how seemingly similar contexts of land occupation generate profoundly divergent socionatural configurations through residents' differentiated approaches to infrastructure development. This heterogeneity challenges deterministic accounts of 'informal infrastructure' and emphasises the creative, situated and varied nature of resident-led urbanisation processes (Tonucci and Castriota, 2022).

By focusing on residents as active producers of urban infrastructure rather than passive recipients of services, this research reveals the constitutive role of self-built infrastructure in peripheral urbanisation. These infrastructure practices function as co-constitutive processes where water infrastructure development and the formation of urban subjectivities mutually shape each other. In Anchieta, hierarchical water control practices foster individualised urban subjects, while in Esperança collective water management generates mutually beneficial, territorial subjectivities (cf. Schwarz and Streule, 2024). Through these differentiated practices, residents create locally embedded hydrosocial territories that subtly give 'water', 'territory', 'rights', and 'identity' new local meanings specific to their neighbourhood contexts (Boelens et al., 2016).

Understanding these heterogeneous processes and the diverse hydrosocial metabolisms they generate is vital for recognising how peripheral urbanisation encompasses not only the material production of urban environments but also the formation of distinct urban subjectivities and meaning systems. This moves beyond simplistic binaries of formal/informal or included/excluded to appreciate the multifaceted ways that residents actively shape both their material conditions and their social identities through everyday infrastructure practices.

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