



Adaptive governance as bricolage

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Abstract. Adaptive governance is proposed as an analytical framework for understanding water distributions in the Anthropocene and for fostering transformative interventions. In this contribution, we demonstrate the usefulness of bricolage thinking for a more grounded and power-sensitive analysis of adaptive water governance. More specifically, we employ the notions of institutional bricolage and extend them to socio-technical tinkering to argue for an understanding of adaptive governance as an experimental practice. To develop our arguments, we draw from research on municipal water supply governance in Accra, Ghana, and in Mansfeld-Südharz, Germany – two regions where the modern ideal of a centrally managed large-scale infrastructure is in growing tension with more modest imaginaries. We demonstrate how residents and water providers adapt to local historical–geographical contexts and unexpected disruptions by using novel and existing multi-purpose institutional and infrastructural arrangements across multiple scales. Through the notion of water bricolage, we show how modest imaginaries and realities of municipal water supply infrastructure and governance emerge. In concluding, we suggest everyday engagements with rules, people and materials as a lens to further understand adaptive governance and identify spaces for transformative interventions.

1 Introduction

The Anthropocene thesis prompts researchers to fundamentally rethink social–ecological relations: with society being a geological force, no ecological process can be thought of without considering social processes, and vice versa. Relatedly, growing scholarship calls for further investigation as to how social–ecological relations can be (and are already being) transformed in order to avoid major collapse and to promote more just and sustainable social–ecological futures (Bai et al., 2016). Water is exemplary of the challenges that characterize the Anthropocene: social and ecological processes intrinsically shape both its quantity and its quality (Falkenmark et al., 2019). Moreover, water is both a source of severe disruptions when we think of floods and droughts and an enabler for adaptation to climate change (Srivastava et al., 2022). Today, water takes on a new meaning: it no longer exposes fluidity and circulation, seepage, and leak-

age in predictable ways. Instead, water challenges assumptions about water and society relations, e.g. by confounding the boundaries of land and water (floods) or by (toxic) inputs becoming constitutive for individuals and communities. This changes the conditions for future relationships, processes, power structures and meanings of materiality (Ballester, 2019). Analytical approaches are needed to reveal inequalities and pursue environmental justice (Zwarteveen et al., 2017).

Adaptive governance is an approach that is helpful to understand and (re)direct social–ecological transformations in the Anthropocene (Chaffin et al., 2014). Adaptive governance typically tries to find out how to achieve flexibility and how to promote learning in already existing governance settings in order to support societal adaptation (Schultz et al., 2015, also Adger et al., 2005; Dodman and Mitlin, 2011; Vogel et al., 2007). While adaptive governance approaches have increasingly been proposed for governing water (Falkenmark

et al., 2019), they have also been criticized for their tendency to be programmatic and to overlook the “cultural politics of resources and their embeddedness in everyday contexts” (Srivastava et al., 2022, page not indicated). Relatedly, growing scholarship calls for strengthening the analytical purchase of governance by examining how governance is actually done as opposed to how it should be done and by foregrounding how old and new power imbalances and vulnerabilities are (re)created (Cleaver and Whaley, 2018; Fünfgeld and Schmid, 2020; Mehta et al., 2019; Klepp and Chavez-Rodriguez, 2018; Zwartveen et al., 2017). Here, adaptive governance becomes a useful entry point for imagining and navigating trajectories towards more just and sustainable futures (Patterson et al., 2017). Yet, concrete proposals on how critical approaches to the study of adaptive water governance can be fruitfully integrated, or at least confronted with other more programmatic approaches, remain limited (Cleaver and Whaley, 2018; Whaley, 2022).

In this contribution, we respond to the call to promote power-sensitive analyses of how adaptation happens through the concept of institutional bricolage (Cleaver and Whaley, 2018). Institutional bricolage focuses on people and their collective organization and thus enables an analysis of the everyday implementation and shaping of rules in the constant interplay of routines and improvisation (Cleaver and Whaley, 2018). While institutional bricolage tends to focus on actors, rules and more generally social relations, we expand it to account for the role of material arrangements. Here, we draw inspiration from recent scholarship in water governance that analyses how bricolage and tinkering with (water) infrastructure ultimately shape decision-making with regard to water and its distribution (Kemerink-Seyoum et al., 2019; Mirhanoğlu et al., 2023; Alba and Bruns, 2022). Both approaches emphasize an understanding of governance as a process: together they are helpful to find out how everyday practices emerge, change, materialize and then ultimately affect water access, distribution and its governance. We explore forms of both piecing together and making do through the notion of water bricolage. We thus ask what we can learn from looking at adaptive water governance through the lens of bricolage. How can this perspective contribute to envisioning adaptive governance approaches that have transformative potential?

We developed the analysis by drawing on research on municipal water supply in two regions where the modern infrastructural ideal – the idea that water should be supplied by centrally managed large-scale technological networks that provide universal and standardized services (Graham and Marvin, 2022) – is being called into question. These are the city region of Accra, Ghana, and the region of Mansfeld-Südharz, Germany. While detailed analysis and description of the case studies are published separately (Alba, 2021; Alba et al., 2019, 2022; Alba and Bruns, 2022; Fehrs, forthcoming), in this article we take our findings on institutional and infrastructural practices in water governance as a start-

ing point to tease out dimensions of adaptive governance and discuss the potential of the bricolage perspective to inform different municipal governance imaginaries and transformative interventions.

In the next section, we trace the emergence of bricolage perspectives on adaptive governance of water. We move on to present our methodology and the two case studies in the context of recent transformations in the water sector. In Sect. 4, we explore elements of bricolage in moments of adaptive governance in Accra and in Mansfeld-Südharz. In Sect. 5, we discuss the analytical purchase of exploring adaptive water governance through bricolage, as well as the transformative potential this perspective may bring in combination with other more programmatic approaches. We conclude by highlighting the bricolage lens as a way to conceive of adaptive water governance as the constant reinvention of water supply imaginaries under the social–ecological conditions of the Anthropocene.

2 A bricolage view on adaptive water governance

Adaptive governance first developed from scholarship on uncertainty and complexity in social–ecological systems (SESS) and from research on community-based natural resource management. In its original definitions, “[a]daptive governance focuses on experimentation and learning, and it brings together research on institutions and organisations for collaboration, collective action and conflict resolution in relation to natural resource and ecosystem management” (Folke et al., 2005). Adaptive governance approaches have been picked up by multiple research strands in the wider field of sustainability studies (for a review see Chaffin et al., 2014, and Patterson et al., 2017) including water governance research. Here, research on adaptation has focused on dynamics and uncertainties related to climate change, such as groundwater replenishment or changes in water demand (Döll et al., 2015), as well as on social learning in institutions and knowledge in decision-making (Pahl-Wostl, 2009). Accordingly, the literature on adaptive water governance seeks to understand the formal, informal, visible and invisible elements that are shaping institutions, and it calls for promoting and developing flexible arrangements and policies that facilitate social learning (Döll et al., 2015; Huitema et al., 2009; Pahl-Wostl, 2009, 2019).

In recent years, several authors have warned against the risks of adaptive governance approaches that are understood and mainstreamed as “a sort of recipe of ingredients” (Cleaver and Whaley, 2018:49). Relatedly, they have called for further research on how adaptive governance works in practice, including paying attention to power relations and politics (Cleaver and Whaley, 2018; see also Chaffin et al., 2014). Cleaver and Whaley (2018) have proposed critical institutionalism as an approach helpful to analysing process, power and meaning in adaptive water governance. Crit-

ical institutionalism refers to research that considers institutions to “include designed arrangements of varying degrees of publicness and formality . . . , institutionalised interactions as embodied in kinship and social networks, relations of reciprocity and patronage and in norms and practices deeply embedded in habits and routines of everyday life” (Cleaver, 2012:14). This definition emphasizes the role of actors who are shaping institutions, both consciously and unconsciously. It implies that the relevance, character and legitimacy of institutions are continuously renegotiated among actors and through existing practices (Cleaver, 2012; Etzold et al., 2012). The distinction of “formal” and “informal” institutions no longer holds: institutions are hybrids of formalized and embedded elements (Pahl-Wostl, 2009; Bremer et al., 2019).

Drawing on the work by Claude Lévi-Strauss, Mary Douglas and Elinor Ostrom, Cleaver (2002, 2012) has developed the concept of institutional bricolage to analyse how people and institutions dynamically interact in water governance (Cleaver, 2002, 2012). Institutional bricolage has been similarly conceptualized in other fields of environmental governance (see Hassenforder and Barone, 2019, for a review). The concept embraces institutional dynamics and complexity by describing a myriad of ways in which institutional structures and the agency of people and institutions come together. With a view to water governance, the concept “attempts to analyse the functioning of institutions while accounting for the complex and changing interactions amongst the actors involved in water management as well as the dynamic nature of institutional governance in socio-hydrological systems” (Hassenforder and Barone, 2019:15). Analytical applications of institutional bricolage in water research expose processes in institutional transformations that affect social practices beyond the intended effect of institutional design, be it reducing flood risk (Frick-Trzebitzky et al., 2017) or co-managing fisheries (Nunan et al., 2015). These effects include the creation or reduction of people’s vulnerability to environmental risks (Frick-Trzebitzky et al., 2017).

In a recent paper, Mirhanoglu et al. (2023:72) suggested to “expand the concept of institutional bricolage and bring materiality to its heart”. Inspired by the analysis of the agency of materials in science and technology studies, they propose to combine institutional analysis with material-tinkering debates to further explain how new technologies are taken up in the context of irrigation. Such a perspective, they argue, is helpful to understand “how changes to infrastructure (re)shape the interactions among actors as well as water governance institutions and their entanglements with infrastructures” (Mirhanoglu et al., 2023:70). The work of Mirhanoglu et al. (2023) resonates with the practice-based analysis of water governance in which bricolage and tinkering are used to study how the interactions between people, rules and infrastructure shape water distribution systems (Benouniche et al., 2014; Kuper et al., 2017; Kemerink-Seyoum et al., 2019; Alba and Bruns, 2022; Chitata et al., 2021). Among other

things, Kemerink-Seyoum et al. (2019) show how attention to processes of socio-technical tinkering provides a lens to understand the messy, non-linear and never-ending character of processes of decision-making, designing, constructing, correcting, using, flowing, steering and adapting. Here, engineers and water users act as bricoleurs in adapting designs and constructions to political interests, local needs, etc. With this understanding, breaking infrastructures create new configurations that are both material (leakages of water that can become a new way to access water) and social (neighbours collaborate).

In this paper, we take up the invitation by Cleaver and Whaley (2018) to strengthen adaptive governance analysis through critical institutionalism and the suggestion to expand the latter to take into consideration material relations (Mirhanoglu et al., 2023). We use the notion of water bricolage as an overarching term to refer to the piecing together and making do of institutions, norms, people, pipes, pumps, sand, waste, organisms and other beings. A bricolage view on adaptive water governance, we argue, allows for engaging with the everyday tinkering and processuality involved in managing and governing water and the underpinning uneven power relations. Inspired by the work of Cleaver (2012), we analyse different elements that shape the “room for manoeuvre” (see Hassenforder and Barone, 2019) people have when governing municipal water distribution systems. These include (i) *multi-purpose functioning* of institutions beyond specific sectors and thematic foci; (ii) *naturalization, leakage of meaning and invention of traditions* as modes by which symbols, acts or specific organizational set-ups are borrowed from existing institutions to legitimize new arrangements; (iii) *authoritative processes and their unequal outcomes* referring to how adaptive governance is shaped by power relations because individual and/or collective actions benefit some more than others; and (iv) *tinkering with materials*, that is the everyday making use of biophysical arrangements in water supply, which is often the creative work of engineers in fixing infrastructures (Kemerink-Seyoum et al., 2019).

Before moving on to describing the case studies and the research methods, it is worth noting that our research resonates with growing scholarship that seeks to question the so-called modern infrastructural ideal in relation to the provision of basic services (Kaika, 2005; Lawhon et al., 2018; Jaglin, 2014; Furlong, 2014). Instead of viewing limited networked supply as a failure, this literature takes up a practice-based approach to study how basic services such as water, energy and sanitation are actually provided and accessed. Such perspectives ultimately seek to advance understandings of (urban) socio-spatial inequalities (Silver, 2014; Alba et al., 2022) and to expose the politics involved in imagining, designing, representing and working with infrastructure (Larkin, 2013; Knox, 2017). With this scholarship, we share an interest in understanding how municipal water is actually governed. However, our aim is not to analyse the outcome of water governance processes in terms of unequal access and distribution.

Table 1. Characterization of the water supply in Accra and Mansfeld-Südharz: own compilation.

	Accra, Ghana	Mansfeld-Südharz, Germany
Local context	Climate extremes, rapid urbanization and rising water demands exceeding the capacities of the supply networks	Climate variability, water quality locally affected by uranium and nitrate, emergency supply from local sources uncertain, stagnating demographic and economic development
Historical transformations of the water supply	Colonial origin of the pipeline network and the supply system; construction of dams in the 1970s; privatization of the water supply network in the 1990s, currently managed by a public water company	Construction of the Rappbode Dam and the drinking water treatment plant of Wienrode in the 1950s
Recent changes in the water supply	Water supply through sachet water, tanker water supply, private pipe connections, water kiosks	Change from local groundwater resources to long-distance water supply
Governance mode	Public enterprise	Public enterprise, association
Long-distance water sources	Treated water is piped to Accra from the Densu River (about 30 km) and Volta River (about 70 km)	Treated water is piped to Mansfeld-Südharz from the Rappbode Dam in the Harz Mountains (about 60 km)
Administrative unit	Greater Accra region	District (<i>Landkreis</i>)

3 Case selection and research methods

The analysis presented below draws on research on municipal water supply that we carried out in Accra, Ghana, in the period 2015–2018 (Alba, 2021) and in Mansfeld-Südharz, Germany, in the period between 2021 and 2022 (Fehrs, forthcoming). We chose these two cases because they illustrate adaptation in municipal water supply in situations where, albeit with differences, the networked supply system's capacity to serve the respective municipalities with potable water in an acceptable quality and quantity has been called into question. In Accra, the public networked infrastructure is socio-spatially uneven, concentrated in the inner city and in higher-income neighbourhoods, resulting in almost half of the urban population not being connected to the piped system and in frequent interruptions of supply within the system. Among other aspects, this has to be seen in light of the colonial history of the city, the rapid urban growth of the last few decades and the neoliberalization of the water sector. In Mansfeld-Südharz, insufficiencies in water supply services relate to the prevalence of uranium and nitrate concentrations in groundwater, the local source of drinking water supply up to 2018. Here the network and service suffice to cover water demand on a regular basis because of the network's connection to the regional supply system. However, the resilience of the supply system is a local concern, since the water supply relies on one pipe only.

The cases represent diverse configurations of adaptation in municipal water supply in different social, geographical and historical contexts (see Seawright and Gerring, 2008); see Table 1. Water supply in Accra is representative of water

governance in a densely populated and growing “Globalizing City” (Grant, 2009) of the “Global South”. Here, it serves to show how water bricolage unfolds in a setting in which urban residents (have to) rely on a patchwork of formalized and non-formalized arrangements to meet their daily water needs. Water supply in Mansfeld-Südharz is characteristic of a small town in a region of stagnating demographic and economic development in the “Global North”. Compared to Accra, in Mansfeld-Südharz informal mechanisms and institutions in urban development have been less salient.

Both cases were explored in inter- and transdisciplinary research project settings with the objective of co-producing knowledge for sustainable development. The project WaterPower set out to integrate multiple perspectives on power relations, justice and governance to create a transformative understanding of water within the urban metabolism of Accra (see Universität Trier, 2023). The project “regulate” seeks to integrate knowledge on groundwater from natural, social and cultural sciences as well as from non-academic fields in order to envision transformative approaches to groundwater governance in Europe (<https://regulate-project.eu/>, last access: 16 August 2023). Within regulate, Mansfeld-Südharz serves as a model for knowledge integration in a transdisciplinary process of vision development (Frick-Trzebitzky, 2022). The commonality of both projects lies in the attempt to integrate different knowledge with the objective of addressing sustainability challenges in the water sector. Both projects have been funded as part of the programme for research into sustainability (Forschung für Nachhaltigkeit (FONA) funding).

In Accra, research on water supply involved transect walks, participatory observations, semi-structured interviews and informal conversations with water tanker drivers and bulk water vendors operating in four different locations across the city (Alba et al., 2019). In Mansfeld-Südharz, semi-structured and narrative interviews were carried out with decision-makers and activists in the field of water supply. Participatory observation was conducted at a series of workshops as part of an ongoing transdisciplinary research initiative (Frick-Trzebitzky, 2022; Fehrs, forthcoming). While in other publications we have analysed these cases separately with different conceptual vantage points (Alba, 2021; Fehrs, forthcoming), we are now using them as a starting point for finding out about the mutual tinkering of institutions and infrastructures in adaptive water governance.

4 Results

4.1 Water and adaptation in Accra

Accra and its metropolitan area comprise one of the fastest-growing urban conurbations in sub-Saharan Africa (Akubia and Bruns, 2019). The public company managing the city's networked infrastructure, the Ghana Water Company Limited (GWCL), operates a network of pipes that covers about 70 % of the demand with many areas of the city only receiving water on an irregular basis (Oteng-Ababio et al., 2017). Networked urban water supply is unequal, reflecting wider urban socio-spatial inequalities. Expansion and maintenance of the network do not keep up with the spatial expansion of the city and the increase in population (Hart, 2021). Moreover, it is estimated that around 40 % of the residents do not have legal land tenure or a rental contract, one of which is a necessary condition to apply for a connection with the GWCL (Alba et al., 2019). This results in Accra's residents relying on a variety of possible arrangements in order to access water on a daily basis. These include the water company, tanker drivers and water vendors as well as self-supply through groundwater abstraction and storage.

4.1.1 Multi-purpose functions

Various forms of collaboration at the interface of informal arrangements and officially formalized institutions, what we refer to as twilight institutions (see also Frick-Trzebitzky, 2017), characterize water supply governance in Accra. The GWCL is the only legally recognized urban water provider in Ghana. While the GWCL's operations are regulated by formalized policies, the operations of secondary and tertiary providers are not formally regulated (Alba et al., 2019). The latter are for instance tanker drivers and vendors who abstract water from the GWCL and resell it in bulk quantities. Yet there are numerous arrangements of collaboration between the GWCL, tanker drivers and water vendors. For instance, the GWCL allows vendors to connect to the networked in-

frastructure, access pipe-borne water, and resell it to tanker drivers and individual residents provided that the vendors register as commercial customers and pay for the water (Alba et al., 2022). These (in)formalized arrangements can be seen as a way to adapt a formalized policy model (and discourse) that is inspired by the modern infrastructural ideal to local conditions which include profound urban socio-spatial inequalities, various colonial histories and rapid urbanization. Therefore, tolerating the presence of vendors and actively engaging in informalized arrangements can be seen as a form of local adaptation. That way, the GWCL covers multiple functions (and attempts) to achieve a variety of objectives: first of all, it fulfils its mandate to provide water to Accra's residents; secondly, it regulates the activities of private providers and limits illegalities; thirdly, it optimizes the pressure in the pipes; and lastly, it secures revenues (Alba et al., 2022).

4.1.2 Naturalization and leakage of meaning

During our work in Accra we came across and engaged with a diversity of associations like the associations of tanker drivers (Alba et al., 2019), of water vendors and of residents (Alba and Bruns, 2022). Typically, these associations emerge as a bottom-up initiative of their members, who join forces as a strategy to secure their interests, for example to access water. This was explained by one of the representatives of a residents' association during an interview:

We came together to form an association to enable us [to] seek our own interest relative to our property and other matters... For example, security [that] involves roads, street lights, making sure that we are safe within our own area. Another issue is sanitation, [which] we are mostly concerned about. We invested in our own residents and we want to live good. Put our money in the place to look good. You can find services like lights, water, garbage are issues that concern all of us".

Borrowing from the structure of state institutions, associations adopt formalized procedures like issuing regulations and setting up positions such as chairpersons, secretaries and treasurers, a process that Cleaver (2012) refers to as leakage of meaning. For instance, associations of tanker drivers were established by drivers, also following a suggestion of the GWCL, with the aim to secure access to bulk quantities of pipe-borne water. Tanker drivers' associations comprise between 10 and 100 drivers. They have headquarters and organizational structures including a chairperson, a treasurer and a secretary. These associations are not formally registered as water providers, but they are known to and consulted by local state authorities, including the municipal water company. Over time, they have become naturalized, and they are now seen as the natural way of organizing and regulating tanker water supply up to a point where according to the latest tanker driver regulations (as of August 2023, still a draft),

all tankers delivering water within the city should be registered with an association.

4.1.3 Authoritative processes and their unequal outcomes

Authoritative processes characterize the internal operation of associations: chairpersons are typically respected senior drivers who have the authority to influence the activities of other drivers, for example by ensuring that the regulations of the associations are followed (Alba et al., 2019). Drivers work with so-called mates, who in turn depend on the drivers not only for learning the job of driving a truck but also for receiving an income. Authoritative processes ultimately play a significant role in shaping water access. We found for instance that chairpersons play a role in selecting the type of water (treated pipe-borne or untreated groundwater), and they have a say in which sources tanker drivers are using and to which residents they deliver (Alba et al., 2019). Authoritative processes determine water access, since residents with a lower income are not entitled to obtain a direct connection to the centralized piped network. This is due to their temporary housing situations and because they cannot afford to pay for the connection fees. Thus, they rely on connections established by landlords or by neighbouring water resellers (Alba et al., 2019).

4.1.4 Tinkering with materials

Tinkering with pipes, storage tanks and taps is a strategy for residents and water providers to adapt to the incremental and profoundly unequal character of Accra's urbanization. Examples are water filling points (WFPs) used by tanker drivers to access water in bulk quantities and by residents to fetch water by the bucket. WFPs involve various materials and social arrangements: they might for instance be overhead hydrants or a set of storage tanks and hoses. Some WFPs are connected directly with the piped network and managed by the water company, while others are connected to boreholes and managed by private vendors (Alba et al., 2019). It is important to note that the material and social set-ups of WFPs have changed over time, influenced by and influencing changing relations of cooperation or conflict between tanker drivers and their associations, the water company, local politicians, and other actors involved in municipal water supply (Alba et al., 2022).

4.2 Adaptive water governance in Mansfeld-Südharz

Mansfeld-Südharz is a municipality in the border region of the federal states of Thuringia and Saxony-Anhalt. The region is among those with the lowest precipitation rates within Germany (Hattermann et al., 2011). Municipal water supply is provided through a public water board, the Wasserverband Südharz. Climate change impacts have begun to alter hydro-

logical dynamics as well as the water demand in the region with many unknown developments still to emerge (Luetke-meier et al., 2021).

The water board has replaced the source for water supply in large parts of its supply system, most prominently in the town of Sangerhausen, from formerly local groundwater to water piped from the Rappbode Dam in the Harz Mountains, 60 km away. The shift in water sources for drinking water supply implies a strong reliance on the remote water supply system that extends over large parts of Saxony-Anhalt. The shift from local to regional sources of water supply was initiated by a public debate on the prevalence of uranium in local groundwater, a debate which unfolded around the threshold value of 10 µg. Uranium occurs naturally in the soils of the region. In 2008 it became publicly known that the uranium levels at some drinking water wells in Sangerhausen were far above the value of 0.01 mg L⁻¹, the non-binding target level stated in the drinking water ordinance at that time. The threshold was to become a limit value only in 2011; thus the water from the wells was in line with legal requirements. Nevertheless, a search for an appropriate solution for uranium-free drinking water for Sangerhausen became the focus of public interest (Dörries, 2012). After some back and forth between actors on different (political) levels, a decision was taken in 2013. Wasserverband Südharz would no longer provide local groundwater for Sangerhausen's drinking water supply but would receive water from the Rappbode Dam. By 2018, the local water supply system was connected to the regional supply system by a pipeline.

4.2.1 Multi-purpose functions

The above-mentioned "uranium debate" unfolded in newspaper articles and at public consultation events in which regional representatives of an international non-governmental organization (NGO; foodwatch), local residents, local and regional water providers and state government participated. In the course of the debate, representatives of the water sector had multiple functions: not only were they determined to keep water supply infrastructures and services functional while adhering to regulations, but additionally, the local supplier Wasserverband Südharz and the regional provider Elbaue-Ostharz increasingly had the function of representing public health and national security systems. This role was not deliberately chosen by the water providers but emerged from the public debate, which had framed uranium in drinking water not only as a health risk, but also in the context of nuclear risk. When in 2018 the connection of the supply system to the remote supply system was completed, the local water provider Wasserverband Südharz turned into an intermediary retailer of water, which it is now buying in already treated state from the regional supplier Elbaue-Ostharz.

During the decision-making process, a resident and leading figure in putting up the protest against groundwater use and advocating for a connection to the remote supply sys-

tem acted as a bricoleur. He acted as a key figure in tinkering with institutions to enhance his room for manoeuvre and was also referred to as a key figure by more formal stakeholders. Now that the supply is provided through the remote system, he no longer takes on this role. Meanwhile, the two representatives of Wasserverband Südharz continue to tinker with infrastructures in order to maintain emergency supply systems that function locally. They might take on the role of bricoleurs in future adaptations in the drinking water supply system.

4.2.2 Naturalization and leakage of meaning

The leakage of meaning and naturalization of improvised arrangements play out in a symbolic sense in the present case. Protesters referred to scientific articles, risk assessments and legal documents to argue for the substitution of the source of drinking water. Thus they borrow from the way arguments are made in setting thresholds in the drinking water ordinance itself. At a national level, the NGO had been pushing for strict limits to uranium levels in drinking water, referring to two environmental surveys, one of which also exposed the high level of uranium in Sangerhausen (foodwatch, 2008; Schulz et al., 2008). Media and public debate picked up both studies, to which national authorities and drinking water suppliers then reacted. The debate was decisive for the amendment of the drinking water ordinance in 2011, which made the level of $10\ \mu\text{g}$ a binding threshold (§ 6, 2; TrinkwV, 2023). Local protest in Sangerhausen picked up the debate to argue for substitution of the source of drinking water rather than to discuss alternatives for taking uranium out of the water through respective treatment. In these discussions, the meanings of issues around uranium were borrowed and leaked in multiple ways to establish an argument for substituting the source of local drinking water supply: following the line of argumentation of both studies, radiotoxicity is of no relevance when sourcing potable water from groundwater. Nevertheless, in local protests nuclear risks were woven into arguments, especially by one committed protester who repeatedly associated the risk from uranium in drinking water with radiation that might provoke cancer (Fehrs, forthcoming). Eventually, the pulling together of arguments around uranium in Mansfeld-Südharz was decisive in the redesign of infrastructures and institutional roles in municipal water supply despite the fact that, from a technical point of view, other factors and alternative considerations played a larger role.

4.2.3 Authoritative processes and their unequal outcomes

Various factors were raised to determine whether Sangerhausen should be connected to the long-distance water network or whether the local water board should treat the groundwater previously used for drinking water supply: wa-

ter prices were compared, and (the cost of) building a connecting pipeline vis-à-vis installing uranium filters was considered. The question of how to dispose of the filtered uranium-contaminated material also repeatedly played a role (Wasserverband Südharz, 2009). Here, authoritative processes were dominated by the state, namely what was then the Ministry for Environment, Agriculture and Energy, as well as by public-health arguments voiced by foodwatch. As long as the state ministry would not grant rights for the Wasserverband Südharz to dispose of the uranium that was filtered out, the preferred technical solution from the perspective of the Wasserverband Südharz would not have been feasible. An unequal outcome is the dependency of the local water supply system in Sangerhausen (and therefore the Wasserverband Südharz, who are responsible for water supply) on one single pipe, the treatment system, and the network and dam infrastructure as well as on the health of the ecosystem around the Rappbode Dam. In this context, the director of the water board has raised concerns, in particular with a view to the extended droughts in 2018 and 2022, when water levels in the reservoir fell. The situation of uncertainty is also emphasized by several actors with regard to forest health and algae growth as further variables that are subject to the impacts of climate change that influence water quality in the Rappbode system. These voices hint to potentially unequal or unsustainable future outcomes of Sangerhausen's recent connection to the Rappbode system.

4.2.4 Tinkering with materials

After the wells in question had been closed, the Wasserverband Südharz installed a filter system at one of the wells through which heavy metals could be almost completely extracted from the water. However, the uranium filter systems were not the only possible way of supplying uranium-free drinking water to Sangerhausen considered. At the time when the elevated uranium levels were measured at some drinking water wells in Sangerhausen, the long-distance water network had already been supplying many communities in southern Saxony-Anhalt (including Halle) with water from the Harz Mountains for decades. According to the technical director of the Wasserverband Südharz, the decision to connect Sangerhausen to the long-distance water network was technically not based on the levels of uranium in groundwater. It was rather the rising nitrate levels at Sangerhausen's drinking water wells that were crucial. Connecting Sangerhausen to the long-distance water network was not just a reaction to the uranium contamination of the groundwater but also a solution to water treatment issues in general. The ultimately adopted connection to the regional supply system necessitated the construction of an 8 km long pipe. The neighbouring municipality Nienstedt had been connected to the regional supply system in 2013, and the Elbaue-Ostharz enterprise had included the possibility for further connections in building that pipe.

5 Discussion

Water bricolage and its different elements allow for teasing out the multiple ways in which adaptation in municipal water governance takes place. The cases of Accra and Mansfeld-Südharz show adaptations that were not deliberately designed but had emerged in the tinkering with infrastructure and institutions when idealized ways of shaping and managing water supply were challenged by local historical–geographical contexts and unexpected disruptions from local, global, social and environmental processes. Both cases show how actors adapt to local contexts and challenges (i.e. a limited network coverage, the presence of informal providers, pollution risks) by covering multiple functions and at times exceeding their formal mandate, e.g. to supply water. In the case of Accra, the GWCL regulates the activities of private providers, although strictly speaking it is not mandated to do so by water policies. In Mansfeld-Südharz, the Wasserverband Südharz and the water provider Elbaue-Ostharz represent public health and national security systems in local debates. The two cases also illustrate how leakage of meaning from one institutional setting to another and the related naturalization (Cleaver, 2012) are crucial when it comes to adaptation. In Accra, the latter becomes obvious in the way tanker drivers adapted to a vacuum in formalized governance by creating their own associations, borrowing from formal institutions, and eventually these associations became the natural way of organizing tanker supply. The case of Mansfeld-Südharz shows how leakage of meanings plays out in a symbolic sense, as some actors took over the argument of uranium presence and related risks to argue for substituting the source of local drinking water supply, and they eventually succeeded. The two cases also show how uneven power relations shape institutional arrangements. Authoritative processes characterize not only the internal operation of a single institution, i.e. tanker associations, but also the relations between different institutions, i.e. the ministry and the public water board. These unequal interdependencies have significant outcomes for water distribution and access. For instance in the case of Accra, they shape the type (and quality) of water delivered by tanker drivers, or they create dependencies on single sources as in the case of Mansfeld-Südharz. Lastly, in both cases the bricolage lens exposes how adaptation already takes place in the everyday interactions between people, infrastructures and institutions.

The teasing out of water bricolage elements provides information that helps in learning about the emergent possibilities for what we might call a modest imaginary of municipal water supply infrastructure and governance according to Lawhon et al. (2023). This is to be understood as an imaginary

rooted in an acceptance of the realities of heterogeneity, uncertainty and the inability to truly know and control our world and others. Importantly, it is

not an *anti*-modern imaginary that rejects progress or the utility of knowledge, but an alternative imaginary outside the modern/anti-modern binary. (Lawhon et al., 2023:148)

A water bricolage perspective allows us to further understand how such a modest ideal might come into being through the interactions between people, institutions, infrastructure, water itself, pollutants, and local histories and geographies, to name just a few. In particular, it highlights the significance of borrowing from, taking inspiration from, and adapting existing institutions and infrastructure in order to craft something different that is perhaps more suitable to the specific time and place but still appears familiar. It also highlights the (always) uneven outcomes of adaptation processes. The juxtaposition of the two cases highlights two opposing ways to call the infrastructural ideal into question: in Accra, the large-scale infrastructure failed to reach all residents, and therefore other solutions became institutionalized through bricolage. In Mansfeld-Südharz, by contrast, small-scale tinkering with materials (filters) was not successful because the infrastructural ideal had a strong prevalence within the arrangements that emerged around combatting uranium in drinking water, which then led to the expansion of the large-scale infrastructure (in the form of a centralized regional water supply). Here the infrastructural ideal is being called into question by the local water provider with regard to infrastructure resilience under future conditions of the Anthropocene.

The bricolage perspective also points out opportunities for change. The way water truck driver associations copied their roles from formal institutions allows for identifying influential roles and/or individuals who can take a lead in changing routines, setting prices, or negotiating for taps and pipes. Such individuals are often active in piecing together institutions and infrastructures, paving the way for further adaptations. By doing so, they take on the role of a bricoleur (see also Frick-Trzebitzky, 2017). Bricoleurs are key actors in processes of adaptation. At the same time their position shifts over the course of an adaptation process, as we have seen in Mansfeld-Südharz where the key figure coordinating protest for connection to the remote supply system ceased to act as bricoleur once the connection had been established.

In exposing the embedded mechanisms and roles in water bricolage, we have collected entry points for effecting change in water supply systems. In the remainder of this section, we will discuss the transformative potential of these findings and that of understanding adaptive water policy through water bricolage more generally. By transformative potential we mean the capacity to redesign water supply systems in a more environmentally and socially just way (see also The Transformative Water Pact, 2023). Learning from what is already happening appears crucial to promote adaptation in water supply and beyond. Yet, in how far the analysis of water bricolage can be built into a more programmatic under-

standing and into policy designs and interventions aimed towards adaptive water governance remains an open question. Practical applications of the concept, i.e. in setting up institutions of adaptive water governance, are rare and raise the question “as to whether purposeful institutional change could or should be facilitated [by researchers]” (Hassenforder and Barone, 2019:801).

One challenge relates to complexity: while policies and formally recognized decision-makers – i.e. water utilities, government agencies – tend (and need) to reduce complexity, a bricolage view exposes the plurality of knowledge, practices and materials that people engage with in adapting to local, and at times unforeseen, circumstances. Indeed, bricolage shows how complexity and uncertainty unfold in knowing, describing, managing and governing water. In addition, the bricolage lens clearly shows how interventions may contribute to reinforcing unequal outcomes or to creating new power imbalances in relation to both formalized arrangements (including existing hierarchies and democratic decision-making) and informalized ones. Therefore, it raises the question of how to acknowledge power imbalances in the course of more programmatic approaches to adaptive governance.

The inter- and transdisciplinarity lens that determined the research context of both case studies aims at addressing challenges of social–ecological complexity, dynamics and power relations by integrating multiple disciplinary perspectives as well as perspectives beyond the scientific on the issue at hand (here, water supply). It serves to open up a dialogue across disciplinary boundaries and formal hierarchies in search of transformative solutions. This integrative perspective of inter- and transdisciplinarity, however, tends to sometimes gloss over deeper sources of friction between approaches, views and understandings (Fehrs, forthcoming). In such a setting, the bricolage lens may provide some insights that help address the above challenges. For instance, in the case of Mansfeld-Südharz the analytical lens of water bricolage contributed to highlighting differences and dynamics in the ways symbols and discourses were being used by different actors in the process of developing a joint vision for groundwater management. Being able to describe these differences allows for new entry points in designing the process of co-production, which means aligning with certain imaginaries or providing alternatives as well as disclosing multiple roles and addressing them explicitly.

The transgressing and transcending of disciplinary, spatial and temporal boundaries is crucial for enabling transformations in terms of sustainability with the aim to bring multiple forms of being and knowing into engagement (see also Vogel and O’Brien, 2022). However, bringing multiple forms of being and knowing into engagement does not equal integration. It rather means that enabling contestations and renegotiations of embedded power relations is crucial to make just transformations towards sustainability possible (Vogel and O’Brien, 2022). Here we see potential in research on bricolage to chal-

lenge the focus on integration in transdisciplinary research on adaptive water governance. The bricolage lens allows for embracing multiple instances of tinkering and messing with roles, materialities and norms. Here, working with the transformative potential of an understanding as seen through the lens of water bricolage puts a spotlight on the powerful role of the researcher and their moral duty in engaging with adaptive water governance. This means not only co-designing hands-on solutions but also importantly an involvement of multiple roles and norms from the very beginning of research collaborations.

6 Conclusion

In this paper, we explored different instances of adaptive (water) governance through the lens of water bricolage. Our work takes up the invitation by Cleaver and Whaley (2018) to strengthen a power-sensitive and processual understanding of adaptive governance through the lens of institutional bricolage while also accounting for the significance of material relations (Mirhanoğlu et al., 2023). We analysed adaptation in the context of municipal water supply, taking Accra (Ghana) and Mansfeld-Südharz (Germany) as case studies, two regions where the modern ideal of a centrally managed large-scale infrastructure has not delivered on its promises. Additionally, both cases reveal how the promise is fading in light of future social–ecological change. For both cases, we show how residents and water providers create novel multi-purpose institutional arrangements, borrowing from existing ones, and how they devise different infrastructural configurations. To conclude, we provide some reflections on the opportunities offered by a bricolage lens when it comes to further analysing adaptive water governance in relation to municipal water supply and beyond.

First, a bricolage approach exposes adaptive governance as an experimental practice that involves both institutional and infrastructural arrangements, as our analysis of the case of municipal water supply in Accra and Mansfeld-Südharz shows. It demonstrates how the agency in water bricolage travels between formally designed institutions and regulations, embedded institutions that emerge in reaction to infrastructure failures, infrastructures, and substances in the water. Juxtaposing the two cases exposes this travelling of agency as multidirectional: water bricolage can be explored from different starting points, namely from either material transformations or social transformations. It leads to new questions, such as how to define what a functioning infrastructure, institutional arrangement or municipal water supply system is for whom. Materialities exert agency by changing the biophysical conditions for tinkering, and they are of course highly affected by climate change if we think for instance of where and when water flows and in what quality and quantity. These materials unfold agency in a mutual relation: in Mansfeld-Südharz, not only have materialities of water (and its chemi-

cal composition) and pipes redefined where water flows and with what quality, they also play a key role in shaping who has a stake in municipal water governance. We see potential in further expanding the analysis of water bricolage to account for and conceptualize the agency of more-than-human actors in shaping both institutional and infrastructural arrangements. This would include for instance investigating what kinds of roles are played by not only water itself but also sediments, chemicals, pipes and non-human species in what Bourguignon et al. (2023) explore as co-becoming with water, its distribution and its meaning in social–ecological relations.

Secondly, water bricolage exposes adaptations that have not been deliberately designed but that have emerged over time as different actors tinker with institutions and infrastructure in their effort to respond to a range of social and ecological changes. The perspective points at how priorities (what people and infrastructures adapt to) constantly shift, creating unique dynamic settings. Unexpected material conditions, such as the prevalence of uranium in groundwater, have triggered adaptation in Mansfeld-Südharz. Here, Anthropocene conditions play out beyond climate change impacts as contested anthropogenic change in response to which infrastructures are redesigned. Analysing water governance as an adaptive process highlights many unknown factors, uncertainties, and social and material dynamics that exceed water (and are hardly related to climate change). It underscores for instance the significance of urban development and policy change, such as the amendment of pollutant thresholds stated in the drinking water ordinance. Here, climate change is likely to add another layer and to bring new scales into ongoing processes of adaptive governance (see Falkenmark et al., 2019). However, it appears difficult to single out these effects from other circumstances that trigger adaptation. Hence compared to literature proposing adaptive water governance as a way of responding to the particular challenges originating from climate change, the bricolage lens focuses on the fact that the reasons for why adaptation unfolds in water governance are manifold and in constant flux. How these adaptations at multiple fronts relate to the grappling with the escalation of overlapping social–ecological crises and vulnerabilities (see Mahanty et al., 2023; Sultana, 2021) comprise a timely research agenda that deserves further attention.

Thirdly, interactions between people, institutions and infrastructure take place in particular historical–geographical and political contexts and are shaped by uneven power relations that people explicitly or implicitly address in their everyday tinkering with norms, regulations and infrastructures. Power imbalances exposed in this processual analysis allow for a more profound engagement with matters of justice in water governance because they shed light on and engage with less influential imaginaries more explicitly (Frick-Trzebitzky, 2017; see also Cleaver and Whaley, 2018). Here, the bricolage lens provides a complementary understanding to that of (urban) political ecology studies of water gov-

ernance: while the latter is interested in practice-based approaches to understand how (urban) socio-spatial inequalities are reproduced and in exploring the structures and patterns of injustices arising due to (adaptive) water governance (see Rusca and Cleaver, 2022; Alba et al., 2022), the former provides insights into how water governance works as a process. We see potential in expanding the analysis of water bricolage beyond municipal water supply, focusing, for instance, on regional and global water governance arrangements (i.e. the latest United Nations Water Conference) as well as on other fields such as management of hydrological extremes or the nexus between water, food and energy.

Lastly, water bricolage analyses have the potential to go beyond critique because they contribute to the understanding of spaces and practices of experimentations. They support a pluralistic view and involve the understanding and making visible of uneven power relations (who and what unfolds agency). They thus identify key entry points for interventions. It is important to note that this implies that the knowledge generated through such analysis is quite sensitive: instances of tinkering often run counter to formal regulations. This type of analysis also contributes to imagining possible future developments in a way that recognizes plurality in knowledge, social dynamics, power relations and processuality, as well as biophysical dynamics that are accelerated by climate change. We see opportunities in bringing bricolage approaches into engagement with transdisciplinary research modes and experimental research approaches that challenge established conceptions of who and what to involve in research and action aimed at greater justice in water governance. Research at these interfaces is much needed to further develop and enact alternative visions for just and sustainable water governance such as those articulated in the Transformative Water Pact (2023).

Data availability. The empirical vignettes that illustrate and support our conceptual argument were based on data we collected from interlocutors on the condition of anonymity. As such, there are no publicly available datasets associated with this publication.

Author contributions. Conceptualization: FFT and RA; supervision: FFT; data collection and analysis: RA and KF; writing initial manuscript: FFT (lead) and RA and KF (support); review and editing: FFT and RA (lead) and KF (support).

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