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How to cite

Moncayo-Riascos, M. C., Salas-Zapat, W. A. (2018). Perspective of the Actor-Network Approach on Studies about Water. [Italian Sociological Review, 9 (1), 43-63]
Retrieved from [<http://dx.doi.org/10.13136/isr.v9i1.217>]

[DOI: 10.13136/isr.v9i1.217]

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3. Article accepted for publication

Date: April 2018

Additional information about
Italian Sociological Review
can be found at:

About ISR-Editorial Board-Manuscript submission

Perspective of the Actor-Network Approach on Studies about Water

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Abstract

Current struggles related to water access and control require modifying how heterogeneous connections that water establishes with diverse technical, social and natural processes during its circulation are studied. Actor-network theory is a useful approach to this kind of analysis since it allows the researcher to observe the reality as a network of relationships among human and non-human actors. The use of this approach in studies about water is still relatively scarce, and its application may seem a bit difficult and abstract to those who are starting to adopt it. The aim of this work is to provide a methodological and conceptual background to researchers and students on the use of the actor-network theory in studies about water. The information extracted from the analysis of 13 studies included methodological aspects and descriptions of socio-technical networks deployed through urban or rural infrastructure, regulatory frameworks, and contractual arrangements. In conclusion, the studies allowed the visualization of the main interactions of analysis employed to follow actants and to examine their inscriptions in the hydrosocial networks.

Keywords: hydrosocial networks, actants, hybrid flow, systematic review.

1. Introduction

Different production sectors determine to great extent the dynamics of water distribution and circulation. These dynamics, together with the current demand for use and extraction of the resource, give rise to a tense

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competition over the access and control necessary to meet the demands of diverse industrial sectors and processes, provoking changes to be made to water flows, policies and regulatory frameworks. Human supply, energy, food, and biofuels production, together with the development of industrial and transport processes stand out among such demands. Consequently, specific hydrosocial networks are created to interconnect human actors non-human actors at different scales through the mobilization of water across fields and cities (Boelens, et al., 2016).

Therefore, problems related to water are complex, given the variety of interests, agencies, and processes that come together for its circulation. Zwarteveen (2015) sustains that current debates around water issues discuss the need to change the way it is studied and intervened and how its governance is planned and managed. Knowledge about water is largely instrumental and originates from engineering while being traditionally aimed at diagnosing problems compatible with the type of solutions it provides. The author states that this type of knowledge is rather prescriptive and fails at questioning or analyzing, not only water distribution and its connections with the development and construction of new projects, but also how it can be saved, conserved and allocated among competing users and uses, and how powers and responsibilities for decision making need to be reorganized.

In the same vein, and from the perspective of political ecology, critical studies concerning water problems argue that technical approaches, based on simple cause-effect relations, need to be replaced by others that allow analysts to understand and visualize the complex and interrelated social dimension of environmental issues (Budds, 2012). Water circulation is also conceived as a hybrid socio-natural flow, which combines current or historic social and physical processes (Larismont, Grosso, 2014).

Understanding water as a hybrid flow supposes a challenge for researchers accustomed to traditional approaches since procedural observation requires relational approaches and methodological tools that facilitate the mapping of heterogeneous actors. One of such relational approaches is the Actor-Network Theory (ANT), which assumes that technical and social aspects are mutually produced while outweighing the unnecessary dichotomy between humans and nonhumans (Amantino de Andrade, Cordeiro Neto, Dias Valadão, 2013).

ANT is neither a theory about the world nor a methodology for social sciences, but a label for a set of methodological, epistemic and fieldwork principles that proliferate the ontology of the study objects and how we articulate epistemologically, ethically and politically with them (López, 2012).

According to Law (2007), and like other semiotic-material tools, the ANT enables the representation of material and discursively heterogenous relations

produced and reorganized by all kinds of actors, which tend to be simplified or not acknowledged/known in their entirety (black box). These include objects, subjects, human beings, machines, animals, nature, ideas, organizations, inequalities, scales and geographical dispositions.

In addition, as a research method, ANT has at least four advantages over previous approaches: (i) it breaks down analytical barriers between human and non-human actors by focusing on their emerging interrelations; (ii) redirects the attention of the individual actors to their interrelations or connection networks; (iii) it does not suppose a hierarchical causality structure in which large-scale actors dominate or explain effects localized or experienced by smaller-scale actors, but conversely, it offers the possibility to localized processes, such as the adoption of technology, of enrolling and transforming other actors in order to cause large-scale effects (Beveridge, Guy, 2009; Birkenholtz, 2009; Roy, 2015; Wanvoeke et al. 2016); and (iv) provides useful information for project planning during the formulation, execution and implementation stages (Campbell, 2005).

TABLE 1. Key concepts of the actor-network approach.

Actor/actant	A semiotic term that denotes humans and non-humans defined by what they do, in other words, by their actions.
Collective	A term that refers to the associations between humans and non-humans. Project on assembling new entities.
Inscription	It is a general term that refers to all types of transformations, meaning those through which an entity materializes in the form of a sign, a file, a document, a piece of paper, a trace.
ANT Report	Narrative or description that keeps track of a network. A quality ANT report should focus on four elements: infra-language, objectivity, textual quality, power and domination explanation.
Intermediary	It carries meaning or strength without transformation. The definition of its input data is enough to define its output data.
Mediator	It transforms, translates, distorts and modifies the meaning of the elements it is supposed to transport.
Translation	A word that denotes all movements verified by actors whose mediation is necessary for any other action to take place. Rather than the concrete relation between 'context' and 'content', translation chains refer to the endeavors of actors to modify, move and translate their particular and opposing interests.
Network	It is a concept but not an object that exists. It is a tool employed to describe something but not what is being described. It designates a flow of translations. It is not defined in a concrete space and has no boundaries; defining a network is always arbitrary and related to the matter of study.

Source: Based on Latour (2001, 2008).

However, despite its advantages, the studies that use the actor-network approach to tackle water issues are relatively scarce, making it difficult for junior researchers and/or researchers that appeal to interdisciplinary

approaches to find empirical referents that serve as examples of the application of the concepts and methods involved.

In this context, a systematic review of the studies that have adopted the ANT constitutes useful input for those interested in understanding how its key concepts, methodologies, types of analysis are applied and reported in concrete cases related to water. In particular, this review was focused on aspects related with three categories: general descriptions of the studies, including country or place where each research took place and its publication year; methodological aspects, which include the methods and techniques employed in each research; and findings of the studies, for example, the socio-technical networks around water described in each research and the identification of the main interactions of analysis employed to follow the actants and assess their inscriptions. For better understanding, refer to the key concepts of the actor-network approach, defined in Table 1.

2. Methods

A systematic review of scientific literature was carried out in accordance with the PRISMA statement guidelines (Urrútia, Bonfill, 2010).

2.1 Search strategy

The search for published articles was conducted until August 31st, 2016 in the databases JSTOR, Scielo, EBSCO and Science Direct. The terms ‘actor-network’, ‘water’, ‘irrigation’, and ‘irrigated’ were entered in the ‘title’ and ‘abstract’ search fields in each database.

The publications were selected after identifying the articles registered in the databases through three search syntaxes including Boolean operators: (“actor-network”) AND (water); (“actor-network”) AND (irrigation); and (“actor-network”) AND (irrigated)).

2.2 Inclusion and exclusion criteria

Only articles that met three inclusion criteria were considered for this review: (i) original articles, (ii) that were written in English, and (iii) that employed the ANT. Regarding the latter, it was verified that the articles adopted the ANT as the theoretic referent of the research, and described the technology associated with the study as well as the research methodology. Once the articles under such criteria were selected, duplicates were removed.

On the other hand, (i) articles that did not employ the ANT in water-related issues despite mentioning it and (ii) essays or reviews were excluded.

2.3 Information collection and analysis

The information extracted was saved in an Excel database, which contained data about the categories, (i) general descriptions of the studies, (ii) methodological aspects, and (iii) findings of the studies, as described in Table 2. A qualitative synthesis of information was conducted in each category.

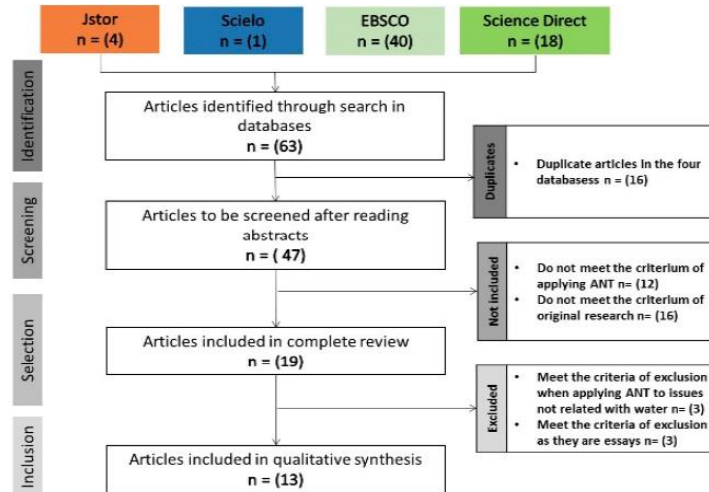
TABLE 2. Information extraction categories for qualitative synthesis.

General descriptions of the studies	Methodological aspects of the studies	Findings of the studies
1. Title	6. Research question/aim	9. Socio-technical networks
2. Author	7. Technology associated with the study	10. Interactions of analysis to follow actants and assess their inscriptions.
3. Year		
4. Country	8. Research methods	
5. Journal		

3. Results and discussion

At an early stage, 63 articles were found (Figure 1). After applying the inclusion and exclusion criteria, a list of 13 articles was obtained. The analysis of information was then conducted.

FIGURE 1. Algorithm for article selection.



Adapted from the PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies that evaluate Health Care Interventions (Moher et al., 2009).

3.1 General descriptions of the studies

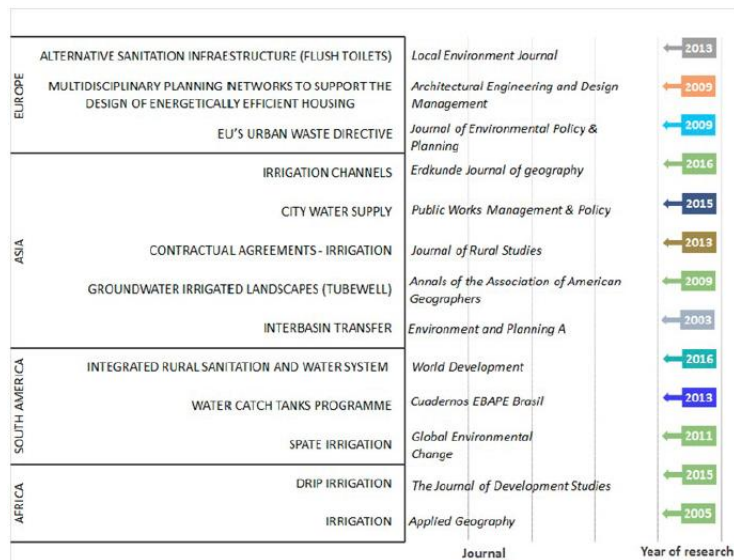
3.1.1 Distribution of studies according to research country, journal and year of publication

The studies were carried out in eleven countries (Figure 2). The highest number was conducted in Asia, with five studies (39%), followed by South America and Europe with three research works each (23%) and Africa with two (15%). In Europe, all three studies took place in urban contexts.

FIGURE 2. Geographical distribution of the studies included in the systematic review.



FIGURE 3. Distribution, topic, journal and publication year of the studies on water – ANT.



Considering journals, there was no tendency either. The 13 studies were published in 13 different journals (Figure 3). However, regarding topics, four works focus on geography, three on the critical analysis of policies, two on planning and development, one on social sciences and another on architectonic engineering and design management.

Regarding publication years, a total of 13 works published between 2003 and 2016 was found (83% since 2009). This number of works may be considered relatively low when the search was conducted without time limits. However, it can be observed that the actor-network approach is finding its way through diverse disciplines.

3.2 Methodological aspects of the studies

The methods employed in these studies are of a qualitative nature and include the use of interactive techniques while combining various information collection strategies (Table 3).

TABLE 3. Objectives, approaches, methods, and techniques - Research on water – ANT.

Research objective	Approaches and theories employed besides ANT/Methods	Techniques
To characterize changes arising from the application of the Integrated Water, Sanitation Rural System (SISAR) be it large-scale or intrahousehold. Brown, C. A., Pena, J. L. (2016).	Actor-network theory. Case studies: Two rural communities in the northeast of Brazil. Ethnography. Literature and documentary research.	Semi-structured interviews. Principle of saturation. Participant observation.
To outline the concept of 'adaptation assemblage' and explore its use in a study of adaptation to glacier changes in the mountains of the Karakoram. Spies, M. (2016).	Assembly theory. Case study: Arid or semi-arid valley in Northern Pakistan.	Open and semi-structured interviews. Field observations.
To understand and analyze the water supply system in Delhi through the ANT. Roy, D. (2015).	Socio-technical approach. No description.	Fieldwork. Unspecified.
To unravel the network of development actors that shape and support the promotion of drip irrigation in Burkina Faso, a country in the Sahel, Western Africa. Wanvoeke, J., Venot, J.-P., De Fraiture, C., Zwarteveen, M. (2015).	Practice-based innovation theory. Three case studies (Inclusion criteria defined).	Interviews. Field visits. Irrigation systems.
To discuss the understanding of alternatives to the development management practices related to the so-called social technologies. Amantino de Andrade, J., Cordeiro Neto, J. R., Dias Valadão, J. (2013).	Actor-network theory. Case study (Doctoral research) Rural communities in the semi-arid region of Juazeiro, Brazil.	Interviews.

Research objective	Approaches and theories employed besides ANT/Methods	Techniques
To study various contractual arrangements that commercial farms and semi-subsistence smallholders establish. Djanibekov, U., Van Assche, K., Boezeman, D., Djanibekov, N. (2013).	Contract theory and institutional economics perspective. Case study: Arid region of Khorezm.	Interview after random selection. In-depth interviews
To describe alternative sanitation systems for London (Combination of ANT and co-evolutionary framework). Teh, T.-H. (2013).	Socio-technical perspective. Co-evolutionary framework. Combination of conventional social sciences methods and design.	Semi-structured interviews. Discussion groups. Photographic diaries.
To provide an integrated analysis of the socio-ecological links and the development- change processes of spate irrigation. Zimmerer (2011).	Political ecology approach. Socio-technical perspective. Longitudinal field research. A case study in the semi-arid valley of Calicanto (Cochabamba, Bolivia). Ethnography.	Surveys. Interviews.
To understand why the application of the EU's Urban Wasterwaste Directive is often slow and seemingly erratic, despite the best efforts by those who seek to promote it. Beveridge, R., Guy, S. (2009).	Innovation approach influenced by actor-network theory. Case studies. Consulting company.	Semi-structured interviews.
To examine the changing relations between nature, society, and technology that take place in dynamic landscapes irrigated with groundwater. Birkenholtz, T. (2009).	Theories about technology adoption. Materialist approach. Three case studies in six villages of Jaipur, semi-arid northern Rajasthan, India. Documentary research.	In-depth interviews.
To explore the functions and competences that support the integration of sustainability in design solutions. Nielsen, S. B., Hoffmann, B., Quitzau, M.-B., Elle, M. (2009).	Actor-network theory Case studies on new and successful projects about innovation in building design	Interviews with actors.
To evaluate sustainability problems of local livelihoods surrounding local participation in irrigation technology. Campbell, M. O. N. (2005).	Actor-network theory Case Study: Weija Irrigation Company (WEICO) at random selection Documentary research (Meteorological information)	Interviews Surveys Debate / Focal groups Field visits
To identify the links between two	Actor-network approach	Narratives - Design and

obstinate concepts of scale and power through an empirical account of the Khong-Chi-Mun (KCM) interbasin transfer project. Sneddon, (2003).	Case studies: Khong-Chi-Mun interbasin transfer project	construction processes - Effects of the project
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The objectives of this study were proposed from two levels of analysis: characterization and descriptive-analytic levels. The aims at the first level were related with determining the network's actants, whereas the ones at the second level enabled the observation of changes that take place inside socio-technical networks as well as the explanation of their links and relations.

Regarding the methodological strategy, case studies and interviews were the most used, being reported in 11 out of 13 publications. Two studies explicitly mentioned the use of ethnography and three of documentary research.

In general, the research methods used are consistent with those that, at least theoretically, have been proposed for the application of the ANT. According to Shim, Shin (2016), the methods and techniques used in the field work of the ANT should include two main perspectives: 'follow the actor' through interviews and ethnographic research and 'examine the inscription'. The results of this review show that most of the research works used interactive techniques, such as interviews with the actors, to learn about diverse aspects of the processes around water.

3.3 Findings of the studies

3.3.1 Networks described in the studies

The research showed the existence of different social and technical networks around water, not only constituted by rural or urban infrastructure, but by regulatory frameworks or contractual arrangements established by heterogeneous actors, which represented the material and discursive relations under the time and space conditions of the studies. From the ANT perspective, empirical cases are not regarded as examples, but rather allow us to elaborate singular abstractions. The concepts developed are abstracted, extrapolated and somehow generalized, but always from the singularities that constitute a case study (Callén et al., 2011).

Six of the studies (42.6%) addressed the topic of irrigation systems (Birkenholtz, 2009, Campbell, 2005, Djanibekov, Van Assche, Boezeman, Djanibekov, 2013, Spies, 2016, Wanvoeke et al., 2016; Zimmerer, 2011). Five of them dealt with different types of infrastructure such as: water pipeline systems (Roy, 2015), integrated water and rural sanitation systems (Brown, Pena, 2016), water catch tanks for rural communities (Amantino de Andrade,

Cordeiro Neto, Dias Valadão, 2013) sanitation infrastructure (flush toilets) (Teh, 2013) and water transfer (Sneddon, 2003). Other studies addressed normative frameworks (Beveridge, Guy, 2009), and multi-actor planning networks (Nielsen et al., 2009). It is worth highlighting that water is not conceptualized as a hybrid in any of the publications.

i. Networks around irrigation systems

Studies about socio-technical networks for three types of irrigation technology (drip, sprinkler and tubewell irrigation) included different objectives of analysis and conclusions through the ANT. Wanvoeke et al. (2016) applied the ANT to describe the socio-technical networks that extended the small-scale drip irrigation technology over Burkina Faso, despite little evidence of its impact on the agricultural fields or in the livelihoods of producers.

This analysis meant a shift in analytical approaches since it followed mainly organizations involved in the 'implementation' of drip irrigation projects (employees of international and national development agencies, government officials, non-governmental organizations and private companies involved in the promotion of the technology), rather than small producers (project beneficiaries).

On the one hand, the socio-technical network implementation of the irrigation technology was excessively dependent on external financial sources provided by funds from bilateral and international agencies; on the other hand, it maintained a close relationship with the audiovisual communication network, in charge of producing videos and radio programs about success stories in demonstration plots. These were used as a means of dissemination to raise awareness among farmers and to convince donors of the results so that the flow of funds from development agencies could be maintained.

Therefore, the study evidenced a vicious cycle of mutual dependence among intermediaries in the development network (local and international NGOs, government agencies, private companies and local retailers), caused by development actors depending on donors and mutual authorization for their operations to continue. At the same time, drip irrigation represented a business opportunity for some local NGOs and even a source of financing income.

The researchers showed that the network of intermediaries secured internally the flows of money, equipment, ideas and staff among different projects. They created alliances and interdependencies by, for instance, signing contracts for equipment or training supply. The networks encouraged all those

involved to employ highly selective impact indicators and measures aimed at reporting their success in terms of sales and distribution volumes while overlooking the number of drip irrigation systems in use or the impact on farmers' livelihoods. Therefore, the authors claimed that the support coalition could function without the farmers.

Wanvoeke et al. (2016) concluded that feedback and accountability loops are distorted when development projects and agents are overly dependent on external sources of funding. In addition, they mentioned that this vicious network can be broken if the beneficiaries (end users) are allowed to co-determine how development cooperation funds are used, to include their opinions and feedback on projects, and to participate in accountability processes.

In the research on the adoption of tubewell technology (piped groundwater) in Rajasthan India, Birkenholtz (2009) used the ANT to examine changes in social power relations, environmental and socio-ecological practices caused by the adoption of technology. Besides showing that this socio-technical network was completely conditioned by the power supply network, the access to it and the interrupted provision of the service (6 hours/day), the study evidenced its dependence on borehole drilling companies and local consultants in Indian groundwaters.

Additionally, the implementation of technology gave rise to social institutions in charge of the construction and operation of the irrigation systems. Such institutions were significantly influenced by processes of ecological change (resulting from the high number of partner and the decisions of farmers to grow cash crops) and by changes in groundwater quality and access to the power supply network.

The results showed that despite the beneficial effect of irrigation on production at the beginning, the significant extraction of groundwater altered negatively water and soils composition while contributing to natural resources scarcity and social inequality. Birkenholtz (2009) concluded that this type of institutional-technological analysis sheds light on the emerging relationships between agricultural technologies and socio-ecological dynamics. This knowledge allows actions to be redirected towards socially more desirable goals since, according to the researcher, human beings ultimately have the capacity to rearticulate their network of relationships by displacing the associations along the way for their own benefit.

In the study conducted in Calicanto, Zimmerer (2011) adopted the ANT to show the spatial assembly of interconnected bio-geophysical flows, infrastructure, and socio-environmental processes of change generated by sprinkler irrigation in this region of the Bolivian Andes. The analysis of the transformation processes included the development of the concept of

landscape technology, which integrated ecological resilience, political ecology and the ANT.

The author mentioned the positive, even if complex, socio-ecological links encompassed by the social organization of water users. Said links were substantially influenced by demographic factors including the location of settlements, population density, the combined infrastructure of the overflow channel, the diversification of subsistence means, agrobiodiversity use and de facto conservation.

This was evident in the case of the irrigation of asparagus crops, equally influenced by socio-ecological adjustments to the complex precipitation variability, by soil moisture availability (ecology of resilience) and by social relations of power, institutions, and processes of development change. Thus, the author depicted the role of landscape technology as complex socio-environmental processes that contribute to improving livelihoods (for example, income diversification and locally expanded political power). However, the trajectories of technological change and the social consequences may vary widely.

Another study conducted by Spies (2016), made use of the ANT to show that individual leaders, the community, external agencies, construction materials, landslides and geomorphological features were the main components or actants in the successful and failed struggles towards the adaptation of irrigation systems after the thinning of the glaciers in Nagar, in northern Pakistan.

The author mentioned that non-human actants played active and contingent roles within a socio-material cluster, and suggested that climatic factors should be understood, among many others, as reactants in an adaptation cluster. In addition, the study evidenced the complex assemblages between glaciers, streams, irrigation channels, field terraces, farmers, rules, practices, development agencies, governmental institutions, and markets established over the past few decades along the country

ii. Networks around water pipeline systems

In the case of the analysis of the waterscape of Delhi, Roy (2015), used ANT to describe water supply socio-technical networks by exploring the complex interconnections between the various entities such as human beings, technological networks, institutions, geographical and political entities.

The author says that Delhi's water network is made up of various categories of people, such as bureaucrats, scientists, politicians, private companies, civil society members and domestic consumers, some of which are explicit, while others are in the network by being part of different organizations. Engineers, private tanker operators, water purification and

bottling companies, residents of diverse types of settlements, bottled water sellers, entrepreneurs and financial institutions are also part of the network, as well as statistics, documents, reports and infrastructures for water transport, hand pumps, illegal connections, the Yamuna river, the upper Ganga canal, the DJB pipeline, groundwater, bottled water and international organizations.

According to Roy, the socio-technical network may be significantly influenced by the intervention of political actors in certain areas. This was evident in the case of an active local representative that could make the DJB bend the rules to extend the pipeline up to unknown settlements while overlooking differential policies of water supply for the diverse types of settlements in Delhi.

The author concluded that the ANT helps find water solutions for urban communities and spaces in Delhi which go beyond the scope of the departments in charge of water issues. Therefore, the conclusion is also that this kind of situation clearly calls for a multi-sector response aimed at encompassing, among others, the entities responsible for urban development, marginal neighborhoods, and public works.

iii. Networks around normative frameworks

Beveridge, Guy (2009) employed the concepts of translation and intermediation of the ANT to describe the network of connections that occur once the European Union Directive on Urban Wastewater Treatment, made and issued in Brussels, makes its way through water sector in the north of England.

The socio-technical network to realign actors and reform water practices was examined as a process of multiple translations when the interactions of a small environmental consulting company were followed. The chain of actions was examined starting with the instructions in the directive up to the changes in water practices at the micro level and the innovations of the actors in response to them. This analysis showed that the directive takes on different meanings as it goes through a series of translations since it becomes dependent on the interpretations and actions of different sets of actors.

This way, the socio-technical network was strongly conditioned by the negotiations between the network's actants such as technology and performance experts, inventors, their invention, vendors, workers in the place, bosses, the regional water company, the visions and strategies of commercial organizations and the ideas about best practices and variety of services. Intermediary organizations that carried out a series of roles between actors and policies also affected the network, as they played a crucial role in the translation of environmental regulation objects and practices and in the constitution of new governance arrangements in the water sector.

In this case study, the researchers concluded that the implementation of the EU Directive resulted in different forms of power: power as a cause of action and power as an effect/result (power from the ANT perspective). Power as a cause of action is evidenced when the directive forces the actors to treat all wastewaters before discharging them. Meanwhile, from the ANT perspective, power affected a whole range of actors, thus becoming contingent and result of the negotiations in relation to the directive application, which was translated into new practices.

Likewise, the authors showed that innovation departs from a predictable linear model, in which change arises almost inevitably once the non-technical barriers have been eliminated. On the other hand, the attempts to establish new arrangements and to inscribe the actors to a new network, resulted in constant competition, resistance or redefinition among the actors according to their points of view and practices. Therefore, the EU Directive is an unpredictable and non-linear 'series of iterations' (Hennion, 1989: 422 cited by the authors) that serves to highlight the contingent character of environmental rules expected to be imposed from a distance.

iv. Networks around the successful implementation of sustainable design solutions

Nielsen et al. (2009), employed ANT to analyze the functions and necessary competences to achieve change in two networks that integrated sustainable design solutions in the construction and water sectors in Denmark. The socio-technical networks were observed as translation processes focused on the reorganization of the existing networks and the development of new skills and competences during the whole planning, design and implementation processes.

In the case of the construction sector, the researchers followed the translation process related to the establishment of low-energy housing in the municipality of Egedal. This project was considered innovative and successful despite the obstacles in sustainable buildings design, such as the minimal compliance of the energy performance requirements listed in the Construction Code for new buildings, the low impact of local planning documents in concept adoption and redesign technologies, as well as the vicious cycle formed by the low demand from clients and the poor supply from producers in the sustainable buildings market.

This socio-technical network meant real change for the development of innovative design solutions for practices inside the construction industry. Such process demanded an extensive exchange of knowledge and ideas among the technical partner (Cenergia), politicians, construction companies, clients, suppliers and national experts.

According to the authors, the politicians and municipal officials developed new planning and network creation strategies, skills and competences for innovation. These allowed the transformation of the strategy focused on the compliance of the applicable regulations at the time, into one that made the buyers of construction plots fulfill the energy efficiency requirements established for the easements.

In the case of the municipality, the role of the first translator belonged earlier on to an official, to be played later by a small group of the municipality. When the network grew, and the project was considered a success, other actors in the network such as the construction material producers were also seen as translators of low-energy design solutions in other projects and construction networks.

In the same way, the study evidenced the role of the municipality as a mediator between the clients and the new housing construction industry, which resulted in the construction of a model house to initiate dialogues with future inhabitants and the construction material suppliers. As a consequence, the network went through changes aimed at promoting the design of new solutions for low-energy buildings.

Regarding the other design solution network, Nielsen et al. (2009) adopted the ANT to study the socio-technical network aimed at the innovation (strategies and practice) in landscape management of stormwater. This type of management integrates retention capacity in the urban landscape, making use of parks, roads, squares, stadiums, etc. to reduce the amount of stormwater that enters the sewage system and treatment plants.

The socio-technical network aimed at the implementation of landscape-based stormwater management was, according to the researchers, directly influenced by non-human actors (heavy rain, storms, rainy seasons, floods and oxygen depletion). Severe flooding of houses and roads, caused by intense rains and lack of infrastructure capacity, resulted in an increased demand for alternatives to wastewater management in Denmark.

The study identified that the innovation network was mainly characterized by multi-actor coordination. This was evident within the municipalities, in multidisciplinary teams, sewage planners and roads and parks administrators working in the different urban departments. Externally, the network was represented by the negotiations on the need for investment among researchers, politicians, real-estate agents, house owners, urban space users and health and security authorities. In addition, the research showed that innovation was promoted by users as part of an innovative society and with the obligation to face climate change consequences while developing new urban qualities.

On the other hand, the functioning of the socio-technical network required, according to the authors, new skills, as well as a redefinition of the actors' roles and tasks at the first stages of the planning process. Such skills included the ability to communicate with different actors, to identify other actors' needs and to facilitate new discussion processes, shared understandings, and networks to develop action possibilities.

3.3.2 Main interactions of analysis

The synthesis of the studies allowed the identification of three useful interactions of analysis for following the trace of the actants, and the intertwined links of water networks: (i) Interaction between infrastructure and water administration; (ii) Dynamic interaction between roles, formal and informal rules (what is not allowed); and (iii) Interaction between technical objects and the water distribution network.

i. Interaction between infrastructure and water administration

The research showed that the analysis of the population neglected in the infrastructure (lack of coverage) and the relations established beyond the limits of the infrastructure allowed the visualization of interactions with another type of non-explicit actants. For instance, actants with the potential of helping or hindering the functioning of the infrastructure, as well as agents, mediators, and intermediaries that transformed the meaning of these aims into viable practices (Beveridge, Guy, 2009), or that proposed different alternatives (The, 2013).

In relation to the neglected population, Roy's research (2015) on the public water supply infrastructure in Delhi showed that following supposedly passive users of the infrastructure provided insight into the diverse informal socio-technical arrangements of negotiation they use. Those range from small private service suppliers to services managed by the community while acting as intermediaries between the official technological system and the users. This ability to create alternative socio-technical arrangements coincides with the rich creativity of social and technical associations to benefit from the service and is at the same time, an indicator of social inequalities due to the disparity in access to infrastructure (Amantino de Andrade et al., 2013).

The analysis of the relations established by the infrastructure beyond its limits offered insight into the interconnections with other actants. The case of the KCM water transfer project, in the northwest of Thailand showed that such project had inscribed and reconfigured non-human entities as well as complex groups of discourses and practices that extended over the area, and that included a great variety of landscapes, waterways, aquatic ecosystems, irrigation channels and dams (Sneddon, 2003).

Accordingly, the analysis of the interactions created around water infrastructure could include the following guiding questions: How has the network changed over time? Who or what has the potential to help or hinder the infrastructure operation? Which actants are related beyond the limits established by the infrastructure? Which networks of actors are not covered by the infrastructure? And, what kind of arrangements are involved?

ii. Dynamic interaction between roles, formal and informal rules (what is not allowed)

The works showed that relations with water are not static, and are mediated by formal, informal and/or not allowed frames. It was also evidenced that, in some cases, crucial connections transgress formal roles and rules.

Djanibekov et al. (2013), showed that de facto subleases between small-scale and commercial farmers, although not permitted and based on informal rules, played a major role on the contractual arrangements in the case study by Khorezm in Uzbekistan. Similarly, the research on participation processes and changes that took place during the implementation of irrigation systems in the coastal savannah of Ghana showed that the historical prescriptions that became regulations over time were changing, creating and recreating new spaces through negotiation. Campbell (2005) mentioned that the evaluation of these processes from perspectives firmly prescriptive or negotiated by actors would hinder the analysis of the continuous dynamic of decision-making.

The questions proposed for the analysis of the interaction between roles tackle organizations in charge of water administration, sectorial rules that regulate water use (formal rules), and elements that affect the water supply.

iii. Interaction between technical objects and the water distribution network: Following mediators and intermediaries.

As water use entails the participation of multiple actants, observing the network of relationships that is established between the technical elements aimed at its distribution and the network that facilitates its distribution, allows the identification of the mediators and intermediaries involved in both its formal and informal management, as well as the comprehension of its transformative capacity. This is evident in the case of the Integrated Water and Sanitation Rural System (Sistema Integrado de Agua y Saneamiento Rural, SISAR).

The SISAR was studied in two rural communities in Brazil. Brown, Pena (2016) found that water meters and monthly bills were two crucial non-human actants in the connections between users, local representatives, and management system administrators. Water meters were proven to be the only actant involved in the translation of a reality that for a long time had been

only related to pipes and objective information. At the same time, these meters led some users to tamper with or obstruct them to avoid being charged for the service.

For their part, Beveridge, Guy (2009) suggest that the search for intermediaries could often reveal a series of actors and other forms of interaction frequently neglected in water studies. They also mention that a keener sense to detect the transformative capacity of actors, mediators, and intermediaries would shed more light over the unequal application of policies and the seemingly opaque processes behind policies failure since intermediaries that sometimes play an invisible role would be evidenced and actors covered by the objectives would be assisted.

The studies showed that the observation of technical objects allows the identification of multiple connections between different types of actors while tracking both formal and informal chains of command that manage water systems. In this respect, it can be asked: what type of technical objects regulate the network? Who has control or access over these, formally and informally? How? What type of relations are created around technical objects?

4. Conclusions

ANT is a means that allows the surpassing of classical actor analyses by mapping the relations established between water circulation and both human and non-human actors, and its insightful analysis of their interests and processes. In this way, it exposes both intermediary actors and those that are not visible because of their seemingly 'unimportant' or 'scantly evident' character, which originates in their failure to comply formal roles and rules.

The analysis of change in technical objects and infrastructure networks provides hints about the actants involved over time, decision makers, chains of command and socio-technical processes giving shape to their functioning. Therefore, it is necessary for studies about water to open the black box containing traditionally simplified technical objects, infrastructures and arrangements. In this sense, the application of technography and artifact ethnography may be useful to strengthen its study.

Concerning the analysis of impact evaluation or the studies on the success or failure in the adoption of technologies, these works introduced a shift in the analytical approach and questioned valuation variables, drawing attention to social inequities, abilities, and functions that generate changes on the network, and at the same time, to the contradiction of interests that may characterize the use of water technologies.

The results make it possible to rethink the concept of scale and interrelations by providing other descriptions, that go beyond the geographical or directional determinism behind categories such as *large scale* and *small scale*. This questions the status quo and the power networks and subverts the approach to certain types of phenomena.

On the other hand, even if ANT shows indirectly actants that do not make part of the network of relations, understanding how and why is not plausible through research. In addition, following actors that do not comply with formal roles and rules may limit research, given the risk their visibility poses for them.

References

- Amantino de Andrade, J., Cordeiro Neto, J. R., Dias Valadão, J. (2013), 'Sociotechnical associations and management practices in development: analyzing traces through the route of P1MC', *Cuadernos EBAPE.BR*, 11(4): 274-294.
- Beveridge, R., Guy, S. (2009), 'Governing Through Translations: Intermediaries and the Mediation of the EU's Urban Waste Water Directive', *Journal of Environmental Policy & Planning*, 11(2): 69-85.
- Birkenholtz, T. (2009), 'Irrigated Landscapes, Produced Scarcity, and Adaptive Social Institutions in Rajasthan, India', *Annals of the Association of American Geographers*, 99(1): 118-137.
- Boelens, R., Hoogesteger, J., Swyngedouw, E., Vos, J., Wester, P. (2016), 'Hydrosocial territories: a political ecology perspective', *Water International*, 41(1): 1-14. Available from: https://www.researchgate.net/publication/292213790_Hydrosocial_territories_a_political_ecology_perspective (accessed 1 February 2016).
- Brown, C. A., Pena, J. L. (2016), 'Water Meters and Monthly Bills Meet Rural Brazilian Communities: Sociological Perspectives on Technical Objects for Water Management', *World Development*, 84: 149-161. Available from: <http://www.sciencedirect.com/science/article/pii/S0305750X15300127>.
- Budds, J. (2012), 'La demanda, evaluación y asignación del agua en el contexto de escasez: un análisis del ciclo hidrosocial del valle del río La Ligua, Chile', *Revista de geografía Norte Grande*, Pontificia Universidad Católica de Chile (52): 167-184. Available from: http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-34022012000200010&lng=es&nrm=iso&tlng=es (accessed 18 April 2016).
- Callén, B., Domenech, M., López Daniel (2012), 'Transiciones hacia otra(s) teoría(s) del actor-red: agnosticismo, interés y ciudad', in D. López, F.

- Tirado (eds.), *Teoría del Actor-Red: Más allá de los estudios de ciencia y tecnología*, Editorial Amentia, Barcelona, 157-187.
- Campbell, M. O. N. (2005), 'Actor networking, technological planning and conceptions of space: The dynamics of irrigation farming in the coastal savanna of Ghana', *Applied Geography* 25(4): 367-381.
- Djanibekov, U., Van Assche, K., Boezeman, D., & Djanibekov, N. (2013), 'Understanding contracts in evolving agro-economies: Farmers, dekhqans and networks in Khorezm, Uzbekistan', *Journal of Rural Studies*, Elsevier Ltd 32: 137-147. Available from: <http://dx.doi.org/10.1016/j.jrurstud.2013.05.003>.
- Larismont, R., Grosso, V. (2014), 'Aproximación a los nuevos conceptos híbridos para abordar las problemáticas hídricas', *Revista del departamento de Geografía*, 27-48.
- Latour, B. (2001), *La esperanza de pandora. Ensayos sobre la realidad de los estudios de la ciencia*. Science Studies, Barcelona: Gedisa editorial.
- Latour, B. (2008), *Reensamblar lo social: una introducción a la teoría del actor-red*. Buenos Aires: Manantial.
- Law, J. (2007), Actor Network Theory and Material Semiotics1, (April): 1-21. Available from: <http://www.heterogeneities.net/publications/Law-ANTandMaterialSemiotics.pdf>
- López, D. (2012), 'Transiciones hacia otra(s) teoría(s) del actor-red: agnosticismo, interés y cuidado', in: D. López, F. Tirado (eds.), *Teoría del Actor-Red: Más allá de los estudios de ciencia y tecnología*, Editorial Amentia, Barcelona, 157-187.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Group, T. P. (2009), 'The PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies That Evaluate Health Care Interventions', *PLoS Medicine*, 6(7): 1-6. Available from: <http://dx.plos.org/10.1371/journal.pmed.1000100> (accessed 14 October 2016).
- Nielsen, S. B., Hoffmann, B., Quitzau, M. B., Elle, M. (2009), 'Mobilizing the Courage to Implement Sustainable Design Solutions: Danish Experiences', *Architectural Engineering and Design Management*, 5(1-2): 53-61. Available from: <http://www.tandfonline.com/doi/abs/10.3763/aedm.2009.0906%5Cnhttp://www.tandfonline.com/doi/pdf/10.3763/aedm.2009.0906>
- Roy, D. (2015), 'Understanding the Delhi Urban Waterscape Through the Actor Network Theory', *Public Works Management & Policy*, 20(4): 322-336. Available from: <http://pwm.sagepub.com/cgi/doi/10.1177/1087724X14553851>
- Shim, Y., Shin, D. H. (2016), 'Neo-techno nationalism: The case of China's handset industry', *Telecommunications Policy*, Elsevier 40(2-3), 197-209. Available from: <http://dx.doi.org/10.1016/j.telpol.2015.09.006>.

- Sneddon, C. (2003), 'Reconfiguring scale and power: The Khong-Chi-Mun project in northeast Thailand', *Environment and Planning A*, 35(12): 2229-2250.
- Spies, M. (2016), 'Glacier thinning and adaptation assemblages in Nagar, Northern Pakistan', *Erdkunde* 70(2), 125-140. Available from: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84968645188&partnerID=40&md5=caa001fa22dcf5858910b580d9d182d9>.
- Teh, T. H. (2013), 'Bypassing the flush, creating new resources: analysing alternative sanitation futures in London', *Local Environment*, 20(3): 335-349. Available from: <http://www.tandfonline.com/doi/full/10.1080/13549839.2013.847409>
- Urrútia, G. Bonfill, X. (2010), [PRISMA declaration: a proposal to improve the publication of systematic reviews and meta-analyses], *Medicina clínica* 135(11): 507-11. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/20206945> (accessed 12 July 2014).
- Wanvoeke, J., Venot, J. P., De Fraiture, C., Zwarteveen, M. (2015), Smallholder Drip Irrigation in Burkina Faso: The Role of Development Brokers. *The Journal of Development Studies* 388(November): 1-15. Available from: <http://www.tandfonline.com/doi/full/10.1080/00220388.2015.1107048>
- Zimmerer, K. S. (2011), 'The landscape technology of spate irrigation amid development changes: Assembling the links to resources, livelihoods, and agrobiodiversity-food in the Bolivian Andes', *Global Environmental Change*, Elsevier Ltd 21(3): 917-934. Available from: <http://dx.doi.org/10.1016/j.gloenvcha.2011.04.002>
- Zwarteveen, M. (2015), Regulating water , ordering society Regulating water , ordering society Practices and politics of water governance. *In Inaugural Speech (pp. 4–34). Inaugural Speech*. Amsterdam: University of Amsterdam