Socio-technical conflicts and territorial justice in wastewater management

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1. *Introduction*

This article aims to contribute to the sociological study of water, focusing on the issue of sewage sludge, a less addressed topic both in scientific works and in public debate. If we look at the conflict and participation around the integrated water cycle, we discover how these are relevant in the upstream and downstream cycle phases. Water collection and disposal of wastewater are two moments in which the water system interfaces with external ones. However, while for the upstream phases of the water cycle there is a great deal of knowledge on related social dynamics (i.e., the contentions on the alternative uses of water – irrigation, tourism, civil uses, energy – that often put urban and rural systems against each other), there is little knowledge about the downstream phases. In particular, it was stressed in the literature (Drechsel *et al.* 2015; Saad *et al.* 2017), social aspects are overlooked in the wastewater management and most of the existing studies is limited to the social perception and public acceptance of wastewater reuse (Domènech, David 2010; Ross *et al.* 2014).

Here we focus instead on socio-territorial dynamics of the water cycle, specifically on the downstream phase. In most cases, wastewater is treated through mechanical purification systems, which produce large quantities of sewage sludge that need space to be disposed. Yet, the search for space generates socio-territorial conflicts. For this reason, the sewage sludge issue allows us to investigate the rural-urban relations that arise from the wastewater management. A theoretical approach that considers the socio-spatial dimension of water is represented by studies on

the hydrosocial territories or the production of territory from the structuring of the socio-material water networks (Boelens *et al.* 2017; Swyngedouw 2004). Hydrosocial territories are defined as «the contested imaginary and socio-environmental materialization of a spatially bound multi-scalar network in which humans, water flows, ecological relations, hydraulic infrastructure, financial means, legal-administrative arrangements and cultural institutions and practices are interactively defined, aligned and mobilized through epistemological belief systems, political hierarchies and naturalizing discourses» (Boelens *et al.* 2016, 2). In this frame, participation and conflict dynamics around water governance finds expression in encounters of diverse actors with divergent spatial and political-geographical interests (Bakker 2010; Damonte-Valencia 2015). Yet, the hydrosocial territories literature stops at water distribution without investigating the phase in which water, in a certain sense, changes state becoming land (sewage sludge). In this change of state, scientific controversies are lurking, which take socio-spatial features when sludge is designated for different future uses. It is precisely this phase that this article focuses on, investigating how a specific hydrosocial territory emerges as a result of the social construction of the risk on the use of sludge and the related socio-spatial conflicts. Focusing on conflicts, it is possible to clarify the dimensions produced by the disputes on sewage sludge, like the social injustice and environmental risk, both related to the technical solution chosen for the sludge disposal.

This article is organised as follows: in the first part, the sociological dimensions relating to the last phase of the integrated water cycle are discussed, providing some socio-technical aspects of sewage sludge; in the second part, four cases of mobilisation around the problem of sludge are analysed. From those cases, we can deduce the social-technical and spatial dimension of the conflict. In the third part, the aforementioned cases are discussed and some general indications are provided to frame the study of water from a socio-territorial perspective.

2. *Social sciences and the integrated water cycle*

The integrated water cycle is a set of all the activities that allow to obtain freshwater for human activities (i.e. civil use, irrigation, etc.) and to drain dirty water correctly. Specifically, we mean the

set of functions related to the collection, supply and distribution of water and the sewerage and purification system of wastewater.

The cycle that allows water supply for potable use can be divided into several phases. First, the resource supplying from aquifers through a system of wells or springs; second, the purification phase, in which the water is made suitable for human consumption; third, the distribution through a system of underground pipelines that brings water from plants to the tap. On the other hand, the sewerage cycle consists in collecting and transporting wastewater (from civil and production use, as well as the meteoric one) to the treatment plant. The water treatment in purification facilities is a pivotal phase in ensuring a virtuous water cycle because it reduces the polluting load on the natural environment. In short, the importance of water cycle to people's everyday life and the social system functions is very high. Despite that, sociology has paid little attention to the study of its social implications (see figure 1).

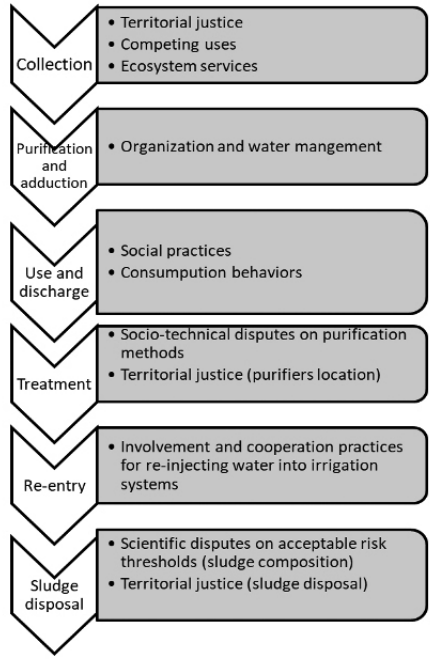


FIG. 1. Social implication in the integrated water cycle.

In the literature, we find several studies on the first phases of the integrated cycle, such as water collection, organization of its distribution, and use. The works on the collection phase study the issue of territorial justice between the upstream and downstream territories of the water cycle. Examples in this area are the research done on the problem of socio-spatial justice of dams (Fleischer 2009); the social interaction on the water competition for different uses, such as agriculture, tourism, energy and civic use (Hommes *et al.* 2016); if and how a payment system for the ecosystem services could be organized (Lundy, Wade 2011) in order to build a territorial cohesion between upstream water provided territories and downstream ones, in particular large urban agglomerations (Pigram 2000). A series of works also analyse water consumption and its related environmental issues through the frame of individual responsibility (Strengers 2011). In this case, the focus is on consumer behaviour and social practices of water use.

Conversely, the literature of social science mostly neglects the downstream phases of the integrated water cycle (Boato 2018; Carrosio 2013). For example, researches seem focused mainly on conflicts around the use of wastewater as a water source in countries or regional areas with high water scarcity and less industrial development (Naranjo Pérez de León, Biswas 1997; Weckenbrock *et al.* 2011). In these cases, the social conflict that emerges between the commodification process of wastewater and the emerging of health and environmental issues is analysed (Scott, Raschid-Sally 2012). However, if we consider the social implications of wastewater treatment and the disposal phase of sewage sludge, we can find many other elements of interest for social sciences traceable back to three families of approaches, in particular:

– socio-technical disputes on scientific controversies about purification methods and the risk deriving from the use of sludge;

– the frame of territorial justice on social conflicts for the location of the purifiers, the disposal of sludge and the re-entry phase of water into irrigation systems;

– cooperation between utilities and farmers, the latter being the primary users of treated water in the integrated cycle.

Our article aims to investigate the multiple dimensions of the conflict, which lurk around the purification and dismantling of sewage sludge. To do so, we have adopted Gallino's definition of «objective» and «subjective» conflict. A conflict is objective (or manifest) when it is observable by the researcher as «scarcity of resources of common utility existing within the same social field» (Gallino 1978, 252). However, conflict does not always become subjective and empirically observable in conflictual behaviour (i.e., it remains latent).

Moreover, following the literature on the hydrosocial frame (Boelens 2015; Boelens *et al.* 2016; Hommes *et al.* 2016), the conflict on water issues have to be described in a wider socio-material configuration. More precisely: «Hydrosocial territories (imagined, planned or materialized) have contested functions, values and meanings, as they define processes of inclusion and exclusion, development and marginalization, and the distribution of benefits and burdens that affect different groups of people in distinct ways» (Boelens *et al.* 2016, 4). In short, in this scheme, conflicts on water highlight the socio-spatial issues and material aspects involved in the definition of the hydrosocial territory. The frame takes into consideration the socio-spatial dimension where a technical option is placed – the social history of the territory and material/natural constraints (Elder-Vass 2015). Then, the analysis of water conflicts recall and allow us to detect both the issues of the *socio-territorial justice* and *socio-technical options* (Hommes *et al.* 2016).

It is important to report that the hydrosocial frame adopts research categories of the ANT (Latour *et al.* 1992), but it «assimilates elements of ANT – hybridity and networks – into a profoundly political economic framework [that] to an end it is difficult to imagine Latour approving» (Lave 2015, 216). Blanchon and Graefe (2012) observe that hydrosocial frame is a radical political ecology perspective that combines neo-Marxism and the ANT to highlight the relevance of material elements in the definition of the political ecology of water in a specific socio-spatial context and in its dynamics. In particular, hydrosocial scholars «rereading of Marxist notions [...] using ANT specific vocabulary such as [...] 'human and non-human actants', 'assemblages', 'collectives' [...]. It is therefore obvious that the theoretical formulation of the merger between actor network theory and Marxism remains difficult [...]. However,

the combined use of both 'toolkits' offers a highly relevant and convincing reading of local conditions» (Blanchon, Graefe 2012, 39). We can say that the hydrosocial frame uses ANT categories in a «weak version», as devices to describe the relations among social and natural elements[1].

In our case we refer to hydrosocial frame in order to reflect on the controversy surrounding the choice of a purification technology or the definition of the risk deriving from the different methods of sludge disposal reported by the main conflicting «coalitions». The social conflict, on the other hand, reveals the dynamics between those who pollute and those who suffer the environmental costs, or rather how environmental goods and bads are produced and distributed[2]. In other words, wastewater conflicts can be manifest or latent, and they can arise due to territorial justice issues or around social-technical choices. These four dimensions are intertwined in the continuous redefinition process of the hydrosocial territory. Interventions in water management (the alteration of water flows, qualities and status) affect socio-spatial relations and structures, producing change and conflicts in the social fabric, which in turn affect further alterations and manipulations of water. In this sense, the concept of hydrosocial territories stresses the dialectical relation between water and society (Linton, Budds 2013).

[1] Noel Castree suggests that neo-Marxism and ANT can find contact points for social research only if a «weaker version of ANT [...] would concede the following points: that many actor-networks are driven by similar processes, notwithstanding their other differences; that these processes might be 'global' and systematic even as they are composed of nothing more than the ties between different 'localities'; that these processes are social and natural but not in equal measure, since it is the 'social' relations that are often disproportionately directive; that agents, while social, natural and relational, vary greatly in their powers to influence others; and that power, while dispersed, can be directed by some (namely, specific 'social' actors) more than others» (Castree 2002, 135).

[2] As Dobson (1998) suggests, social communities are differently exposed to high levels of environmental bads (such as toxic industrial facilities located around working class neighbourhoods) and they have different access to environmental goods (like public parks in middle class neighbourhoods). The unequal distribution of goods and bads refers to the social injustice and policies to reduce it.

3. *The socio-environmental dimensions of wastewater treatment and disposal*

The purification process removes pollutants from water and the residual presence of these substances returns within the parameters of the law. The pollutants removed from water are concentrated in so-called sewage sludge[3]. The quantity of sludge produced by purifiers is a function of the volume of water treated, the plant efficiency and the quality of the incoming and outgoing water. Sewage sludge contains, in variable amounts, heavy metals (mercury, lead, nickel, etc.), organic compounds, nitrogen and pathogenic microorganisms; their disposal is, therefore, a socio-environmental problem. Moreover, when the purifiers serve large urban agglomerations, the sludge produced is so much that it is necessary to dispose of them in distant places. Sewage sludge needs space both for the particular processing industries and landfills. Wastewater is transformed into mud and disposed of in areas that have not produced that pollution. In this way, an unbalanced relational dynamic is created between areas that produce pollution and those that, in different ways, collect and dispose of sludge.

Basically, there are four ways to dispose of/reuse sewage sludge:

– landfill disposal;
– incineration (with or without other types of waste);
– use in cement factories and the production of bricks;
– use in agriculture, directly or after composting.

All of these solutions are problematic. Landfill disposal re-proposes the theme of landfill saturation and the need for alternatives. Incineration is linked both to waste-to-energy and fine dust pollution problems. The use of sludge in bricks production can cause health problems for workers and, in the long term, release of pollutants caused by the deterioration of bricks (Rubbonello *et al.* 2009). The re-use of sludge in cement factories is probably the least problematic disposal system, even if there

[3] Sewage sludge is the solid fraction contained in urban and extra-urban wastewater removed in the purification plants during various mechanical-biological-chemical treatments. These treatments make clarified water compatible with their reintroduction into the natural environment without alteration risk for the ecosystem.

is a dangerous link between sludge production and overbuilding in the area. The use of sludge in agriculture is undoubtedly the most controversial. Despite their nutrient content – i.e. phosphorus, nitrogen and organic carbon – sludge can often contain no negligible amounts of heavy metals and other unwanted substances such as pathogens with harmful consequences for the environment and public health (Irer 2007).

The sector was regulated by Directive 86/278/EEC, implemented in Italy with the Legislative Decree n. 99/1992 which established in particular:

– the concentration limits of certain heavy metals both in soil and sludge;
– the agronomic and microbiological characteristics of sludge (i.e. concentration limits of phosphorus and salmonella);
– the maximum amounts of sludge that can be poured into the soil.

One of the feared risks is that the heavy metals present in sludge, if scattered on agricultural lands, can enter the food chain through direct production of food or indirectly through the livestock chain (Barghigiani, Ristori 1994; Perazzolo 2007).

The debate focuses on tolerable risk level: having no certainty about the real consequences, but only probabilistic hypotheses, the debate focuses on the amount of acceptable risk (Beck 1992; De Marchi *et al.* 2001; Sturloni 2006). Furthermore, sludge could worsen the fertility and the quality of the soils if the concentration levels of metals, organic and pathogenic compounds is too high (Mantovi 2003; Paolillo 2001). Another aspect linked to the disposal in agriculture is land availability. Sludge contains nitrates and according to the legislation can be scattered only on land that does not exceed the permitted thresholds for nutrient loading. In Northern Italy, the eligible areas are the most marginal ones, where important agricultural spaces still exist and there are no farm concentrations.

There are two significant problems in the hydrosocial territory making process. One is related to the dimension of risk, which tends to de-spatialize the environmental problem; the other one concerns the spatialization of territorial injustice, whose boundaries are produced and reproduced by the interaction between socio-

technical disputes and local conflicts (Rodríguez-de-Francesco, Boelens 2017).

The first problem highlights how the dimension of risk tends to go beyond the territorial feature of environmental injustice. The hazard posed by heavy metals in sludge which get into the food chain does not affect only a well-defined territory but can potentially spread on a global scale. The incorporation of the risk in a product that can reach different areas of the globe (depending on market internationalization) makes spatial connotation of hazard indefinable. In this sense, the passage of water pollutants, as something visible and measurable, to agricultural land (sludge dissemination) up to the food chains through the absorption of heavy metals by crops, marginalizes territorial inequality. The risk embedded in food can affect anyone anywhere.

The second problem, on the other hand, shows how a technological solution – such as artificial purification – can solve an environmental problem creating others in the downstream phases of the integrated water cycle. The pollution that was previously concentrated exclusively in waters is now spread in technical solutions affecting territorial areas in different ways. The reuse of sludge in agriculture, its energy transformation or its disposal in landfills show how technical solutions generate different boundaries of territorial conflict, which somehow feedback into the technological solutions themselves (Seravalli 2011).

4. *Local cases of wastewater conflict*

In order to propose a reflection on the dimension of risk and the spatialization of territorial injustice in wastewater management, we have identified four different cases of dispute arisen in the last stages of the integrated water cycle. The aim is not to report detailed case study analysis, but to observe the possible manifestations of social conflicts around the sludge disposal describing their main elements. Using a consequential logic, we selected emblematic cases on different steps of the wastewater management to shed light along the sludge management chain. In this respect, we identified cases in the different steps of the sewage sludge management. They help us to unfold how the dimensions of the territorial injustice and environmental risk change in those different steps according to the disposal options

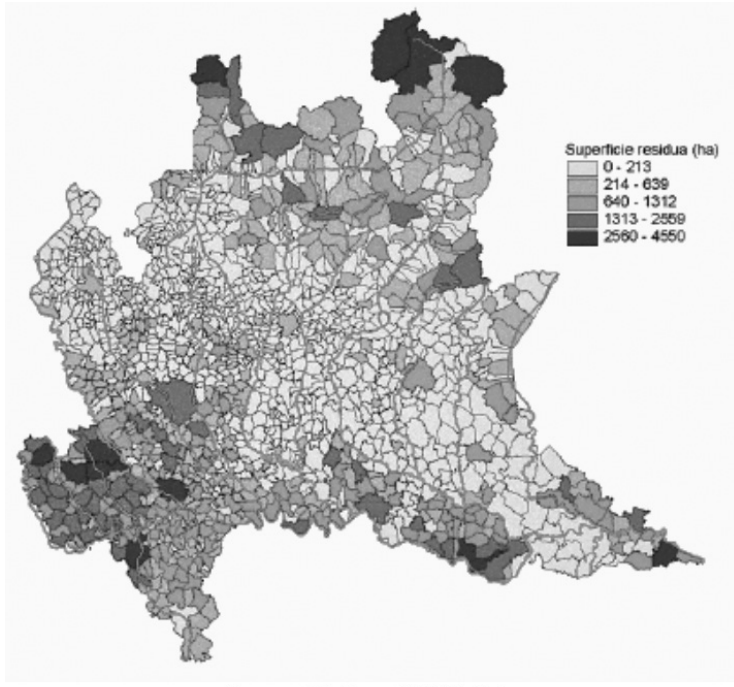
adopted. The purpose is to suggest how social conflict moves in space and how it changes with the used technology. Through these cases, it seems possible to follow the social conflict in its socio-territorial spread and evolution. To this regard, we present the cases following the phases of the wastewater management process (from water purification to sludge disposal) in order to clarify the dynamics of definition and redefinition of the hydro-social territory by describing the disputed elements.

To describe the case studies, we adopt a qualitative method collecting information from local newspapers and press releases produced by regional authorities, opponents and proposers/owners of wastewater treatment plants or projects. These documents (almost ten for each case study) refer to the period in which each social conflict on wastewater treatments emerged. An amount of eight semi-structured interviews were also conducted, two for each case study. We have identified main actors respectively in the coalition against and in favour of the disputed technology. The data were questioned in particular by identifying two macro aspects: the characteristics of the disputed technology (i.e., the type of technology employed, the territory basin served, the volume of sludge produced, etc.), the relationship between territory and wastewater sludge treatment highlighted by the actors (i.e., productive and economic efficiency, environmental benefits, ecological risks, form of territorial injustice, etc.). The data collection took place in the second part of 2019.

We have considered four case studies located in only one Italian region: Lombardy (Northern Italy). This allows us to have a single regulatory framework that affects a specific hydrosocial territory making process. In Italy, Lombardy is also the first area where the EU directive on water purification is being applied and where disputes over this phase of water management are emerging for the first time[4]. In addition, Lombardy is the first region in Italy in the producing sewage sludge and uses it in agriculture. Every year about 670 thousand tons of sewage sludge are disposed of in agriculture lands in Lombardy. This technical option is governed by a regulation that classified Municipalities

[4] In 1980, Lombardy adopted a regional law (L.R. 94/1980) on waste management, which also covered the disposal of sewage sludge in agriculture. This norm was approved two years before the national one (D.P.R. 915/1982), which transposed some European directives (75/442/EEC, 76/403/EEC and 78/319/EEC). On recent norms and problems on wastewater treatments in Lombardy: Blangiardo *et al.* (2019), particularly chapter six.

by the allowable amount of sludge per hectare. The criterion adopted considers the quantities of nitrates present in the soil. Where there are high levels of nitrates or the soils are already compromised in their quality, it is not possible to spread sludge. In figure 2, Municipalities of the Lombardy region are reported according to their allowable amount of sludge. As the colour intensifies, the quantity of sludge that can be spread on agricultural land increases. The main available areas are the marginal ones, which have remained on the margins of the process of industrial development and regional urban planning.



Source: IReR on SIARL data

FIG. 2. Available area for the sewage sludge use.

The first case concerns a dispute over the technologies and organisational models to adopt for water purification. The second case shows that technological solutions for sludge disposal shift

territorial conflicts about wastewater at this stage, but do not suppress them. The third case concerns a territorial justice issue highlighting a conflict regarding sludge use in Lomellina (an area where rice production is widespread). The last case highlights an objective, but also latent, conflict on the land use competition between farmers and the sludge disposal industry. Following are reported the main conflicting aspects and the opposition points between the competing groups emerged in the analysis.

4.1. *Distributed phytoremediation vs centralized activated sludge plant*

In 2013 the multi-utility AOB2 proposed a vast project of a centralized wastewater purificatory plant to serve seven municipalities in the province of Brescia (Barbariga, Longhena, Corzano, Dello, Mairano, Brandico and Pompiano, about 24,000 inhabitants). The intention of AOB2 is to replace all the existent municipal plants which have become inadequate due to the new regulation on water purification parameters. The new plant should treat wastewater through the activated sludge process.

The project, expensive and with a high environmental impact, has been contested by Legambiente (one of the largest Italian environmental associations), the Department of Environmental Economy of the University of Padua (which published a scientific report about it) and a specialized service company in wastewater management. An activated sludge plant has high construction costs (more than 9 million euros), needs 26,000 square meters of land, consumes a large amount of energy and produces tons of sewage sludge to manage. Alternatively, those who oppose the project propose to modernize the 12 existent municipal purifiers using the phytoremediation technology, a remediation technique of wastewater based on the use of green plants to remove, contain, inactivate or destroy harmful environmental pollutants (Schwitzguébel *et al.* 2002). It is not an expensive option, it has a low energy consumption and minimizes both the production of sewage sludge and soil use. Moreover, as some research report, the social acceptability of phytoremediation is overwhelmingly high. (Weir, Sharon 2016). Despite reasonable objections, the company continued to pursue the project, but after six years, the mega-purifier is still under construction. Moreover, the project has been significantly reduced because the Lombardy Region

has posed restrictions on the distribution of sewage sludge in agriculture land in municipalities where the purifier should work.

4.2. *Comitato Campagnoli vs biogasifier of sewage sludge*

The Comitato Campagnoli is a citizens' committee of Campagnoli, a Montichiari village (a community of 26,000 inhabitants), in the province of Brescia. In 2012, the committee started its protest against olfactory harassment arising from a sewage sludge treatment plant owned by the company Valli Spa. The company deals with the recovery of sludge from purifiers, its composting (aerobic digestion) and its use as soil amendment in agriculture according to regional legislation. In April 2013, the Province of Brescia authorized an impressive expansion of the sludge treatment plant (quadrupling the processing capacity, 210,000 tons/year of sludge), including a biogasifier (authorization n. 1335/2013), an equipment to produce energy through the anaerobic processing of sludge. The biogasifier is expected to solve some environmental problems in wastewater management, also producing energy from renewable sources.

The citizens' committee opposes the plant extension through *protest campaigns* and presenting technical options during the authorization process. In particular, they stressed the persistence of olfactory harassment and the new plant size, considered incompatible with the peculiarities of the territory. Despite the initiatives of the Comitato Campagnoli, the Province authorization process ended with permission of plant expansion. Nevertheless, three years after, the new plant has not yet been finalised for two main reasons: 1) the hostile stance of many citizens and local administrations; 2) the incongruity between the potential volume of sludge treated and the authorised spreading threshold in the surrounding territories, decreased over years.

4.3. *Social mobilisation against sludge spreading in Lomellina*

Lomellina (in the province of Pavia) is a rural area famous for its renowned rice production. In the last few years, this territory has become the principal disposal zone of sewage sludge in Italy. About 400,000 out of 670,000 tons of Lombardy sludge

are disposed in Lomellina because soils in the province of Pavia can get the highest sludge rate spread per hectare due to its land features. In fact, the regional regulation allows disposal sludge on agricultural lands based on soil characteristic and not on sewage sludge property; only soils compromised by a high level of heavy metals and nitrates cannot hold sludge.

Started as a protest against olfactory disturbance and for preserving soil quality features, a social mobilisation of citizens and local admins posed the issue of territorial justice: areas that produce environmental bads dump them on other territories. Thanks to expert support, citizens presented technical reports to their regional authorities regarding the risk that pollutes contained in sludge can bring into the food chain. The protest pushed the Regional government to reduce the rate of spreadable sludge per hectare. However, rice growers oppose this decision because it decreases their earning as a consequence of spreading sludge on their land. Between 2017 and 2018, the dispute over the amount of spreadable sludge on agricultural lands led both to reducing the ecological pressure on the territory as well as to increasing it in areas that are even more marginal. Therefore, the environmental conflict in Lomellina has partially shifted to other areas, where the sludge spreading has begun. Through the fourth case, we highlight what shape the conflict takes in the Oltrepò Pavese territory.

4.4. *The competition for land in the Oltrepò Pavese*

Recently in the Oltrepò Pavese – a marginal area bordering Lombardy, Piedmont and Liguria regions – it has been challenging to find pasture land for small cattlemen, as it is difficult for organic farmers to rent land for their needs. The Oltrepò Pavese has suddenly shifted from a condition of excess land to scarcity. Some local farmers had rented their land at higher than market prices for disposal of sewage sludge. In a few years, these soils have become inadequate for spreading sludge because the nitrate rate has got very high. To continue to receive payments for sludge disposal, these farmers decided to rent the lands that were still usable for spreading activities. For this reason, from 2012 to 2018, land prices quadrupled.

This situation has not yet caused a manifest conflict because in the area farmers are not well organized as a lobby group, the population density is very low, and there is no geographical proximity between disposal and residential areas. Also, no longer able to have animals graze on land which became an area of sludge spread, some cattlemen began to buy hay on the market. On the other hand, small farmers are shifting their production outside of the regional borders, where regulations on sewage sludge are not causing competition regarding different land uses.

5. *Discussion*

The emblematic cases briefly described above highlight the different conflicts around the final stages of the integrated water cycle. They can be classified as: socio-technical controversies, environmental conflicts and competition on resources use.

The socio-technical controversies are related to the technological options on the wastewater treatments (case 1) and scientific disputes on the risk of the use of sewage sludge in agriculture (case 3). On the other hand, environmental conflicts refer to the distributive justice of environmental goods and bads: the territories suitable for sewage sludge disposal are also those that do not produce wastewater (cases 3 and 4). What is more, even if these conflicts arose about specific problems on the last stages of wastewater treatment, the arguments developed by the citizens' committees led to defining the issues on the socio-political terrain of the contrast between cities and countryside, centre and periphery. The competition on land use shows that in material relations between society and the environment – the phases in which material resources are mined and those in which they return to the environment – conflicts can rise regarding the alternative use of the environmental goods. If at the upstream of the integrated cycle of water, the water capture creates tensions between its agricultural and civil uses, at the downstream, the sewage sludge generates competition for the use of natural resources. Agriculture is also involved in the downstream steps, because there may be cases of competition between spreading sludge and grazing or agricultural use of land. If we consider socio-spatial and socio-technical connections that emerge in the aforementioned case studies, it seems possible to highlight how

the process of hydrosocial territory making is defined by the interaction between territorial and socio-technical conflicts.

Firstly, the kind of treated water and the different technical options for sewage sludge treatment can enlarge or minimize sludge disposal problems. For example, mechanical wastewater treatment compared to phytoremediation produces much more sludge. Secondly, the quantitative features of sludge, together with the acceptable risk defined by the regional law, set the spreading territorial size. As long as the spreading activity does not generate social disputes, the allowed sludge thresholds remain low and technological innovation is little. When the sludge spreading is contested, technological solutions are sought to overcome the questioned aspects (case 2), or the problem is shifted to space, looking for new areas to spread sludge into. In case 4, low population density and little protests make the Lombard sludge system feasible. The socio-economic marginality of Oltrepò Pavese allows the regional system to shift in time and space the overcoming of the sustainable threshold between the amount of sludge produced and the finiteness of the available territory.

Conflicts over risk thresholds set by norms affect both the spatialization of sludge spreading and technological innovation of wastewater treatment. The restriction of acceptable risk thresholds leads to an increase in the spreading area until a vast territorial opposition arises. In other cases, restrictions lead to a technological leap in sludge treatment: from sludge spreading in agriculture lands to incineration in waste-to-energy plants. Once sludge enters the waste cycle, the conflict becomes de-spatialized and the rhetoric becomes the typical one of waste cycle disputes.

In summary, the variables that act on the process of hydrosocial territory making are mainly two and strictly interrelated: saturation of space (namely, the land) and risk thresholds defined by law (often questioned by opponents). These two dimensions define the social conflict as well as the conflict changes their features. The definition of the risk thresholds set the geographical space of the conflict, which shifts from saturated areas to those not yet saturated with sludge. Conflicts retroact on technological treatment choices and allow the sludge spreading within the thresholds set by norms. This process can continue as long as there are suitable areas not yet saturated by sludge. Saturation shifts the sludge disposal issue to other domains, searching for new technological solutions that link the integrated water cycle

with other supply chains, such as the waste cycle and the energy production from renewable sources (see figure 3).

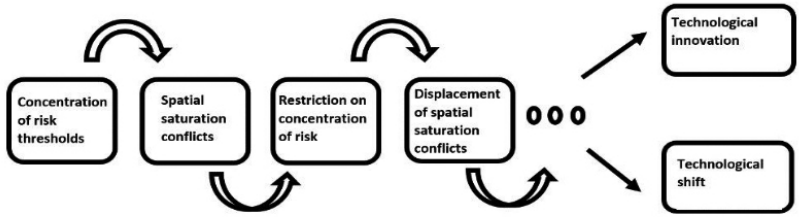


FIG. 3. Spatial saturation, spatial conflicts and technological changes.

The spatial scales of conflicts are therefore never fixed, but are perpetually redefined, contested and restructured in terms of their extent, content, and interrelations. Moreover, the cases allowed us to follow the conflict and its socio-spatial transformations in a longitudinal way. The mobilization around wastewater is able to modify a certain technology option related to a specific hydrosocial configuration.

Using the terminology developed in the Actor-Network Theory (Callon 1987; Latour 1987), we could say that a new hydrosocial configuration emerges only if there is a large coalition – of human and non-human actants – able to disrupt the ordinary ways of wastewater management through social conflict and/or supporting for new technologies. Boelens *et al.* (2016) have often taken up the frame of the ANT to show the process of hydrosocial making and how this is the product of a context-situated combination in which the norms, the availability of the water basins, the land capacity to house sludge, the extraction and purification technologies adopted, the interests of farmers, industry and civil uses, and the quantity and quality of treated wastewater, the smells and interests of the actors involved (economic, health and environmental issues) are modified by *social mobilization*. The ability to mobilize dismantles the existing connections and focuses on the technical parameters relating to water (the capacity for hourly extraction, the load capacity of the land, etc.) considered to be ordinary in a certain configuration.

However, the cases show how the conflict itself arises and is able to reconfigure the hydro-social territory in particular if the ecological constraint (the scarcity of land for different uses) is high. The consequences of the exhaustion of the available lands determine an *engagement* in the conflict of the same land and the counter-expertise (Pellizzoni 2011). Both allow to detect strong contradictions between the expected benefits from certain options and the collateral problems (the use of sludge as fertilizer and contamination of land and groundwater). In other words, the politicization of wastewater seems to be all the more disruptive and capable of pushing for a net technological improvement only if the available land tends to run out and it is no longer possible to displace sludge or competing activities in other places. Moreover, the conflicts considered seem to be limited to the terminal phase of the water cycle without adequately questioning the process that generates them. In this sense, as Martin Schmidt suggests (2014), it seems necessary to connect territorial management (which produces and receives sludge) to the integrated water cycle, since the sustainability of any technical solution - the mechanical treatment or the phytoremediation – is the effect of a socio-technical assembly that cannot be limited to the final phases of the process.

6. *Conclusions*

This article has investigated a phase of the integrated water cycle, which is less studied by social sciences, observing in particular the conflict dynamics that arise in the intersection between the wastewater management system, the agricultural sector and the rural local communities that suffer the environmental bads downstream of the cycle. In these conclusions, briefly, we aim to highlight the outcomes of our reflection and some insights for further analysis.

First, the paper has shown that the sewage sludge issue often presents itself as a saturation crisis in which the environmental problem cannot be addressed without producing new environmental problems. Environmental problems are transformed, moved in time and space according to the environmental and technological choices that are adopted to deal with the problem of disposal. Considering the conflicts along with the different

disposal phases and the different technological options adopted, it has made it possible to show how the hydrosocial territories of the conflict take on variable and much larger dimensions, compared to the breadth in which the local committees are engaged. The hydro-social territories are, in fact, built from the set of interrelations that involve the integrated water cycle. Following conflicts through cases has therefore allowed us to look at the spatial dimension emerging from the chain of conflicts. From a theoretical point of view, it is interesting to note how the production of hydrosocial territories allows to connote socio-technical networks from a spatial perspective. The ANT approach, in fact, is traditionally de-spatialized and does not take into account the relationship between technical devices and the places (Lave 2015; Elder-Vass 2015).

Second, as already pointed out by Luigi Pellizzoni (2014) in the study on local conflicts, the movements activated around environmental problems often assume a parochial posture, without seeking forms of dialogue and solidarity with other collective actions insisting on the same theme. Following the sludge route, on the other hand, was possible to sew, at least from the ideal point of view, the collective actions of civil society within a hydro-social territory. Perhaps, it is within this dimension that is possible to overcome the localism of mobilizations, to find broader and more incisive forms of action for a more sustainable and equitable integrated water cycle.

The article has not taken into account virtuous forms of sewage sludge management, which remains an issue to explore. However, this is a fundamental issue, and the frame of the hydrosocial territory can offer analytical categories to identify elements to realize a sustainable and equitable management of water cycle. Marzena Smol *et al.* (2020) observe that a relevant issue of the integrated water cycle is to design it into the circular economy frame. The concept of circular economy refers to an economic system that aims to eliminate waste and keep products, equipment and infrastructure in use longer through a process of recovering resources from waste for other industrial processes and regenerating resources for nature, like the compost (Geissdoerfer *et al. 2017*).

In the case of water cycle there are six challenging steps to accomplish in order to realize a scheme of circular economy: reduction of wastewater generation, reclamation of pollutants

in wastewater, reuse of water for non-potable usage, recycling of wastewater for potable usage; recovery of resources from wastewater like nutrients and energy from water-based waste, and rethinking how to use resources. These steps define a new hydrosocial territory, a novel spatial configurations of people, institutions, water flows, hydraulic technology and the biophysical environment that revolve around the control of the integrate water cycle. For this reason the analysis of positive experiences on wastewater management could highlight not only the way in which the new hydrosocial territory can be established and organized, but also the possible latent conflicts inherent in this alternative option.

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Socio-technical conflicts and territorial justice in wastewater management

If we look at the dynamics of participation and conflict around the different phases of the integrated water cycle (water captation, aqueduct management, water distribution, sewerage network management, purification, reintroduction into the environment), we discover how they gather especially in the upstream phases and in those downstream. On the upstream phases there is a great deal of knowledge: the catchments generate environmental conflicts (for example due to the construction of dams) and on the alternative uses of water (irrigation, tourism, civil uses), often putting cities and countryside against each other. On the downstream phases, however, there is little knowledge. This is the management of wastewater: they are treated through mechanical purification systems, which produce large quantities of sewage sludge (in 2018, 3,2 million tons in Italy). Around them there is a scientific controversy on the risk related to the different forms of disposal. In this phase of the integrated water cycle the conflicts become more complex, because the spatial dimension of the conflict is closely linked to the socio-technical dimension: the types of purification plants and the risk thresholds that regulate the possible uses of sludge are socio-technical choices that have different implications in terms of environmental justice. For this reason, the paper wants to shed light on the phases downstream of the integrated water cycle. It will try to understand the dynamics of participation and conflict starting from four case studies, which will offer visual angles capable of highlighting different aspects of the problem.

Keywords: socio-technical conflicts, territorial justice, wastewater management, hydrosocial territories, water cycle.

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