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# Sewage sludge management options and civil society stakeholders' influence: first evidence from Italian cases

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**Abstract.** Sewage sludge management is a pivotal process in the path toward sustainability, broadening the scope of wastewater treatment from removing pollutants to recycle and recover resources. Water utilities can choose among several management options and treatment technologies. The paper focuses on the possible influence of civil society stakeholders on the decision-making process of water utilities, and to investigate it, inductive case studies were conducted in Italian water utilities adopting different management options. The analysis allowed us to capture the richness of observations and make interesting variables possible shaping the relationship emerged, as the role of regulatory uncertainty. The first results show how the investigated water utilities look at other Countries for robust solutions and select the less risky in terms of civil society's acceptance. Communication and involvement of civil society appear to be an important asset to mitigate possible negative relationships.

**Keywords.** Sewage Sludge Management; Circular Economy; Wastewater Utility; Civil Society Stakeholders; Case study.

## 1. Introduction

Sewage sludge management is gaining momentum in scientific literature, in terms of treatment techniques, and associated industrial and institutional changes [1]. The production of sludge is increasing as water treatment technologies improve - also due to stringent regulation on wastewater releases [2], and as an always higher number of households is connected to the wastewater treatment plants (WWTPs) in charge of the treatment of the sewage [3]. Further, traditional sludge disposal options - landfill and open-water disposal - are losing ground owing to stringent environmental quality targets and bans [4]. Sludge must be disposed of in an environmentally sound way, being largely composed of offensive substances [1]. At the same time, the Waste Hierarchy steered lawmakers to maximize resource efficiency, moving from a perception of sewage sludge as a waste to a source of valuable resources. The imperative of WWTPs thus shifts from the removal of pollutants to the recycle and recovery of the resources embedded in sewage sludge [5], in line with the Sustainable Development Goals [6] and Zero Waste Europe [7].

The paradigm-shift in the wastewater treatment [8] is leading to major changes in the ways wastewater and sludge are disposed, to the point that the selection of the wastewater management system should be strongly driven by choices related to the sewage sludge management option [9]. WWTPs thus become resources and energy recovery facilities, leading to potentially marketable sludge-based added



value products [10,11]. The options for transforming sludge into a resources are different [12]: 1) Reuse through spread on fields; 2) Recovery of energy or material, in terms of i) thermal energy; ii) nutrients (phosphorus, nitrogen); iii) construction material (cement, ceramic bricks). Other recoveries are possible during the sludge treatment process: i) biogas, from the anaerobic digestion of sewage sludge; ii) struvite, from dewatering side-streams or incinerated ashes. Selecting the type of recovery, the sustainable options for the long-term management of sewage sludge must be environmentally friendly, economically viable, and socially acceptable [13] – thus at the intersection of the three sustainability pillars [14].

Water utilities (WUs) are central players for the integrated management of water – water distribution, wastewater collection and treatment, sewage sludge treatment [15]. Making a decision on wastewater treatment technology, WUs might not limit themselves to comply with regulated standards [16] - traditionally quite innovation averse [17]. WUs managers, indeed, increasingly perceive society's representatives as an impactful player [18] and WUs may seek to be congruent with the concerns of the Civil Society Stakeholders (CSSs), or secondary stakeholders [19]. CSSs are stakeholders influenced by and/or that can influence a WU, without being counterparts of economic transactions (suppliers, customers) nor exerting the State's authority (regulators). Residents, politicians, media, or non-governmental organizations pressure and incite the WU to pursue environmental performances even beyond the regulated targets or toward unregulated aims - investing-up or over-performance. CSSs might change the WU's priorities and influence water infrastructure decisions [20], as the WU wants to obtain legitimacy from CSSs to justify its right to operate [21]. The topic started to be addressed for wastewater treatment technologies [16,18], but, aiming at integrating wastewater and sludge treatment technologies [9], the CSSs' influence on the selection of sewage sludge management options by WUs should be addressed as well. Anyhow, also following the legislative trend that is separating wastewater treatment from sludge treatment, it seems important to conduct an initially separate analysis for the sludge treatment processes. The social acceptance of the different recovery options began to be tackled, but mainly within the context of technical reports or focusing on a specific CSS or sludge destination at a time. In detail, sludge in agriculture is susceptible to public perception for the increasing awareness of health and environmental impacts of contaminants that might not be sufficiently tested before applying sludge on land [22]. As the contaminants might affect crop production [13], farmers may abandon this option [23]. As for biogas, CSSs' issues against the construction of new facilities were highlighted [24], while incineration mainly creates worries about pollution and toxic ashes [25], and possible negative impacts of the incineration plants on landscape and residents' lives [26], so that authorities seem reluctant in developing such facilities [27]. In this context, the landfill appears alas especially easy [28].

The legislation related to the sludge treatment is still evolving in many European countries, tailoring European Commission Directives into specific contexts. Parallely, a relevant role in the selection of the sewage sludge management option seems to be played by the relationships between the WU and CSSs, who, with different mechanisms than policymakers, might encourage WUs to enhance specific options from an environmental and social perspective, so to ensure the highest sustainable value. Whether and how the CSSs' concerns may diverge from regulated standards, and how CSSs may stimulate the over-performance in WUs are untapped areas of research. The present study wants thus to investigate how and to what extent the selection of a sewage sludge management options by a WU is influenced by the CSSs. Particularly considered the critical role of sludge treatment from a sustainability perspective, the aim is to highlight the relationships between the WUs and CSSs, focusing on the impacts of the specific management options, and understanding who are the most relevant CSSs.

## 2. Materials and Methods

The aim of the empirical investigation was thus to understand the CSSs' influence on the adoption of different sewage sludge management options. We chose to perform inductive case studies [29], with semi-structured interviews and secondary materials, so that we could capture the richness of observations without being limited by theory and/or specific relationships between variables. As a WU can adopt different management options, the unit of analysis is the single configuration in the context

of the WU. We relied on multiple case studies, treated as single ones with conclusions examined on their own [30]. Case studies were conducted in two Italian WUs (WU1 and WU2), located in different Regions but with similar characteristics – municipal ownership; serving >0.5 million equivalent inhabitants (e.i.); located in urbanized areas; owning about 50 WWTPs; high investment in research and development (R&D) – allowing a replication logic. Italy is deemed relevant for the study: i) it is the third European producer of sludge [31] - 41% of which still landfilled and only the 9% incinerated [32]; ii) the Italian legislation transposed the European Commission Directives into national laws, but the Regions can adapt the national laws to local situations; iii) sewage sludge is defined as a special, non-hazardous waste, thus being subjected to waste legislation; (iv) national laws set specific regulations for sludge landfilling and its reuse in agriculture, while sludge incineration falls under general incineration regulations [33].

We interviewed people involved in the decision-making process and knowledgeable of the impacts of the WU's activities and feedbacks from stakeholders: the Technical Area Manager (WU1-I1), the R&D Manager (WU1-I2) and the Planning and Control Manager (WU1-I3) in WU1; the Sewage and Wastewater treatment Manager (WU2-I) in WU2. The WUs were contacted by e-mail or telephone, and secondary data (utility websites, reports, etc.) was collected, particularly regarding projects, initiatives, and similar activities toward sludge treatment. We supplemented the case study protocol - aimed at minimizing the impact of contextual effects [34] - with questions and free comments emerging during the interview [35]. Interviews lasted about 2 hours and were coded and corroborated with secondary data and other findings emerged during the interviews, like field notes [36]. We conducted a content analysis, applying emergent coding [37], and using an open code [38]. As for methodological rigor [39], triangulation of multiple sources of evidence and the creation of an electronic folder containing all the data collected for each case led to construct validity [40]. Multiple case studies and the case study protocol increased the reliability, while also contrasting possible researcher bias [41]. The specification of the population and the use of multiple case studies strengthen the generalization [40].

### 3. Results

The inductive case study allowed to identify important variables and the relationships and patterns among them [29]. The results from the two cases are here presented and will be discussed in Section 4.

#### 3.1. Water Utility 1

WU1 owns around 50 wastewater treatment plants, several of which were acquired. Thus, the technologies used in the plants often depend on the choices made by the former owners. As the plants have different sizes, for more than half of them (>20,000 e.i.) is economically reasonable to produce and treat sludge, while the sludge from the smaller plants is moved to bigger ones. The treated sludge is produced as stabilized dewatered sludge, while in three specific plants further treatment processes are operated: WU1.1, equipped with a dryer owned by WU1 but operated by a third party, produces dried sludge then managed by an external cement factory; WU1.2 and WU1.3, where the sludge is transformed in calcium carbonate - the process is managed by a third party who then reuses the calcium carbonate as fertilizer. As for now, almost 80-90 tons of dehydrated sludge is produced. From the highest quality sludge, fertilizers are recovered with a limit determined by the production capacity of WU1.2 and WU1.3. The other destinations are agriculture - currently suffering from legislation's targets and uncertainty; cement factories - after a drying process; co-incineration; landfill - only 2% of the sludge.

WU1 is currently developing a new project for the integrated platform WU1.4. It will have a line for the sludge treatment aimed at the energy recovery and the production of fertilizers, and a line for the anaerobic digestion of organic fraction of municipal solid wastes and the production of biomethane. The project embroiled since the beginning the involvement of public opinion and the citizenry of all the neighboring municipalities affected by the project, asking CCSs to express their opinions and concerns about the project. Behind the project there is an anticipative strategy, particularly regarding the recovery of phosphorus, as better detailed by WU1-I1: *“the reason why we are investing [...] is because phosphorus is becoming a critical resource, and some European countries obliged utilities to mono-*

*incinerate the sludge, producing ashes rich in phosphorus [...] there is not such a legislation in Italy, but I'm sure we will arrive there soon*". They later added that another strong push came from market risks, as WU1-I3 said *"the uncertainty of the market pushes us to be independent"*, adding that, although WU1's investment ranks high among Italy WUs, they are *"very far from European utilities, but [...] also in terms of tariffs"*. Developing the project, a relevant issue was represented by the residents' ex-ante propensity to express opposition, especially if incited by local politics. As WU1-I2 highlighted, generally *"they start from considerations that are not technical and arrive at conclusions that do not have any technical value"*. According to WU1-I1, this is an approach of the overall Country toward sludge: *"we export sludge to France, where the legislation on sludge in agriculture is looser than ours, and France is not the new guy in terms of environmental issues [...] we are the only Country exporting sludge"*. The interaction with the CCSs highlighted the concern of municipalities and citizens about the environmental impact of the project, as WU1 was requested to i) apply a strict control and total transparency on emissions in the atmosphere, odor, preservation of soil, rivers, and biodiversity; ii) assure the project's compliance with legislation, while also providing in-kind compensation through development of affected areas; iii) perform epidemiologic analysis in the area on the project. Although some requests go beyond legal requirements, WU1 promised to conform to them.

Asked to deepen the relationship with CCSs, the interviewees recognized the citizenry and the municipalities as the most critical CCSs. To interact with the citizenry, WU1 uses social media and organizes transversal meetings to build a constructive dialogue. As for municipalities *"they own our utility, so every request coming from Majors is considered, even if it goes beyond legal requirements"*, said WU1-I2. They also specify that *"the stakeholders' impact on our activities is extremely important"* and that WU1 *"deals with each CCS independently, with specific communication channels for each of them"*, also given that *"there is a relationship between citizenry, municipalities and other local authorities, but they don't leverage each other"*. WU1-I2 also arose a further interesting point as WU1 has to: *"try to convince citizenry that it is not in our interest to forgo without quality, but they [CSSs] don't trust us because they don't have knowledge [...] the first thing that they don't understand is that it is not the water service that decides what it is dangerous [...] they also don't understand that we are controlled in turn"*. WU1-I2 thus believes that the over-performance implemented by WU1 is related to its investments in R&D and innovative solutions.

Regarding future scenarios and innovations, WU1-I1 stated: *"our fortune is that we have a European perspective, basically we are copying what they do in Europe"*, more in the specific *"we are investing in the thermal treatment because they do it in Europe"*. As for WU1-I3, considering the ban on landfill and the perception that the Ministry of the Environment will restrict spread in agriculture, *"they are pushing toward thermal treatment without making it explicit"*.

### 3.2. Water Utility 2

WU2 owns about 60 wastewater treatment plants. Among them, WU2.1, the only plant equipped with anaerobic digestion and vertically integrated into the stabilization phase, manages alone the 50% of the wastewater treatment capacity. In the other plants – that were all purchased, so that WU2 is restricted to the already installed technologies - the last processes of the sludge pre-treatment are managed by a third party. The sludge is brought to two waste-to-energy plants (WEP) for the generation of thermal energy (80% of the sludge) or to a bioreactor for the recovery in agriculture (20% of the sludge), all operated by a utility belonging to the same Holding as WU2. So far, no sludge is landfilled or destined for internal energy recovery.

WU2 is currently developing improvements in WU2.1, as it would like to process all the produced sludge in WU2.1, where a co-generator is about to be started. Particularly, WU2 would likely implement a lysis process so to increase the production of biogas - aiming at the energy self-sufficiency of the plant and produce better-sterilized sludge appropriate for the recovery in agriculture. After the lysis, WU2 may implement a further oxidation or a mono-incineration. Among the reasons supporting the mono-incineration, there are the general positive attitude of other European Countries toward it and the possibility to have a higher integration of processes and thus better control over them. However, WU2-

I stated: *“I don’t know whether the community would accept it”*: although they are *“sure that if a plant is properly developed and built, it can operate safely everywhere [...] we have to consider also other logics”*. WU2 thus would prefer the oxidation over the mono-incineration, sending then the dehydrated sludge to WEPs or brick industries. The improvements in WU2.1 started as WU2 is expecting a progressive toughening of regulations of sludge spread on fields *“I cannot say there is a direct causal link between WEPs and lack of recovery in agriculture, but undoubtedly there is”*. As this uncertainty led other WUs converging to the same WEPs as WU2, the WU2’s costs increased. The new configuration of WU2.1 should help in reducing OPEX, while also mitigating the risk of the WEPs not accepting WU2’s sludge. From WU2-I’s perspective, WUs *“should tackle this situation reducing the production of sludge, or at least, finding destinations other than WEPs, also from a circular economy perspective”*.

According to the interviewee, WUs need help for legitimizing the sludge treatment in the eyes of the Society: *“there is the need of a socio-political effort to make [CSSs] accepting the presence of sludge disposal facilities other than landfill”*. Parallely, *“effective and safe investments are needed [...] I would prefer a safe and organized system at the cost of increasing the tariff, rather than be in the current situation, sending wastes abroad”*. As the Holding spent € 80 million in plants’ renovation, the *“the population’s doubts about the chimney stacks are still difficult to manage”*. Luckily, the Holding has *“great attention toward the environment and the relationship with the civil society”* and *“advertises everything that has a positive impact on the environment”*, also using social media and fliers.

As for WU2-I, the recovery of energy and the reuse in agriculture are the best destinations for sludge; however, strict legislative thresholds are limiting the application in agriculture, while although WEPs are extremely important for saving energy, *“then we come back to the impact on citizenry”*. As the Holding’s vision is *“characterized by great attention and innovation”*, there is a huge effort to make CSSs accept the WEPs, and *“understand that WEPs are an action to use something that otherwise would be only a waste [...] a strong communication campaign toward citizenry is necessary”*.

Regarding the impacts of the WEPs, WU2-I said that the most perceived one by the CSSs is related to pollution. In WU2-I’s opinion, the pollution is due to the surrounding industrial system but often associated with the WEPs as they are *“a political topic often rode”*, underlining the need for an awareness campaign.

As for future scenarios and innovations, WU2’s benchmark is Europe, above all for legislative targets such as phosphorus recovery. While being confident in the legislator and that targets will be set, so far, they are looking abroad: *“if they act in a certain way in Europe, I don’t think they take a loss”*.

#### 4. Discussion and Conclusions

The results obtained are of great relevance to understanding the relationship between CSSs and WUs, providing new insights into the dynamics of this relationship. Notably, it emerged that CSSs influence the WUs choices related to the adoption of sludge management options, above all in a context of regulatory uncertainty, as the investigated one. Although the importance of a technological integration between water and sludge treatment technologies has been deemed as particularly important [9], both the WUs mainly treat sewage sludge in purchased plants- maintain the already existent technologies particularly for economic constraints, and have the sludge treatment process managed by a third party.

The innovative projects the WUs are currently implementing aim at increasing the vertical integration of the sludge treatment processes and make the WUs safer from possible market and regulation related risks. The projects embroil the adoption of technologies and processes widely accepted in Europe but are carried out in a period of legislative transient, with uncertainty about the timing of reforms for current regulations. In the development and implementation of these projects, the two WUs are facing problems with CSSs, that they are tackling in slightly different ways. WU1 is implementing a strong communication strategy involving municipalities, citizenry, and public opinion, focusing on their concerns on the project, that is improved and modified according to the requests and the suggestions received by the CSSs: the transparency is very high as is the WU1’s willingness to make the CSSs perceive the importance of the project. WU2 is more prone to choose the option basing on CSSs

influences, selecting the less chancy one in terms of CSSs' relationships. The WUs strongly highlighted the need for a higher national socio-political effort to make CSSs accept certain technologies and processes, also considering their widespread acceptance in Europe. Indeed, even if both the WUs are investing in technologies already adopted and applied in Europe, the WUs are facing some issues with CSSs' acceptance. The WUs, on the one hand, are implementing innovative investments that may not be covered by the water tariffs and without a clear regulatory framework; on the other hand, they have to legitimize the choice to the CSSs, although the investments are made also to provide a safer and more effective service to the community.

The most relevant and critical CSSs appeared to be the citizens (or association of them), followed by municipalities. The result may be influenced by the urban context in which the two WUs are located, as suggested by [16]. According to the WUs, the CSSs perceive as main impacts deriving from the sludge treatment process the emissions in the atmosphere, odor emissions, and health and safety repercussions on the population, confirming [25]. CSSs also ask WUs to overperform about specific legislation targets, endorsing [16]'s findings on the wastewater treatment process in urban areas. From the WUs' perspective, CSSs often seem to lack a specific knowledge to rightly influence technological decisions and to not understand that it is in the WU's interest to be compliant with the legislation.

The results underline the relevant role played by the CSSs in a context of a legislative transitory. Indeed, the investigated WUs take inspiration from other European Countries - some of which implemented the European Commission Directives in strict ways so that the management options implemented abroad seem to be less risky from a legislative viewpoint. The decision, however, has also to consider the CSSs' perspective and influence. Communication and involvement of CSSs appear important assets for the decision-making process. The WUs are somehow overlapping their role with part of the legislator's one, by informing and forming CSSs, and over-performing in the identification of robust solutions, tailoring them on internal strategies and focusing on the less risky ones from a legislative, technological, economic, environmental, and social perspective. Uncertain legislation, limited investment availability and somehow biased CSSs seem to make it tough for the investigated WUs to operate at the same level of as other European Countries.

To close the loop and provide theoretical replication, we deem as necessary to extend the present research to other European Countries so to better appreciate possible differences related to policies and social contexts. Similarly, it would be interesting to investigate WUs with different characteristics, as not located in urbanized areas or with a less innovative attitude than the two cases investigated.

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