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SPECIAL FEATURE: ORIGINAL ARTICLE

Networks of Action Situations in Social-Ecological Systems Research

Networks of action situations in point-source pollution: the case of winery wastewater in Aragon, Spain

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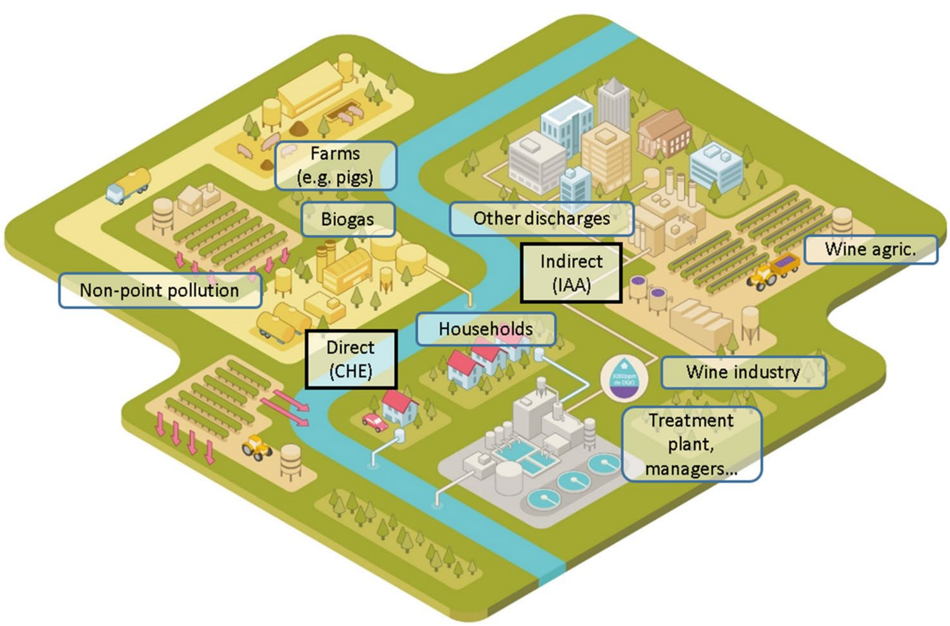
Abstract

In this article, we offer an analysis of point-source water pollution governance in the European agri-food sector. Specifically, we tackle the case study of the wine industry in Aragon (Spain) through the lenses of the networks of action situations approach. We unveil key strategic decisions of wine producers in relation to compliance with water discharge regulations and explore the feasibility and effectiveness of potential solutions. According to our quantitative and qualitative analyses, the problem of peak load discharges in the sector can be explained by the strategic behavior of wine producers in the context of enforcement deficits, as well as by particularities of the wine production process, and controversies around the construction and management of public treatment plants. Coordination among wine producers and public treatment plant managers to invest in in-house treatment infrastructure or to smooth discharges out so they fit the capacity of treatment plants would be a promising solution; however, economic incentives and tightened enforcement of discharge regulations would also be necessary.

Graphical abstract



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Keywords Networks of action situations · Point-source pollution · Winery · Wine industry · Wastewater · Aragon (Spain, EU)

Abbreviations

AS	Action situations
BOD_5	Biological oxygen demand (in mg O_2/l)
CHE (in Spanish)	Ebro Water Agency
CLC	Corine Land Cover
COD	Chemical oxygen demand (in mg O_2/l)
DGA (in Spanish)	General Council of Aragon
ECODES	Ecology and Development
ESM	Electronic Supplementary Material
EU	European Union
FNCA (in Spanish)	New Water Culture Foundation
GIS	Geographic Information System
IAA (in Spanish)	Aragonese Water Institute
IAD	Institutional Analysis and Development
IAEST (in Spanish)	Aragonese Statistics Institute
ICA (in Spanish)	Water pollution tax
INE (in Spanish)	National Statistics Institute
NAS	Networks of action situations
OECD	Organisation for Economic Co-operation and Development
PASD (in Spanish)	Aragonese Sanitation and Purification Plan
PDO	Protected designation of origin
PGI	Protected geographical indications
SDGs	Sustainable Development Goals
TN	Total nitrogen (in mg/l)
TP	Total phosphorus (in mg/l)
TSS	Total suspended solids (in mg/l)
UWWTD	Urban Wastewater Treatment Directive
WFD	European Water Framework Directive
WWTP	Wastewater treatment plant
ZINNAE (in Spanish)	Cluster for the efficient use of water

Introduction

According to Target 6.3 of the Sustainable Development Goals (SDGs) by 2030, we need to "improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally". The reality, however, is far from this goal. According to some estimations, only 32% of wastewater worldwide receives some type of treatment (Habitat and WHO 2021; Sato et al. 2013).

The European Union has been a leader in the implementation of the SDGs and in ensuring the sustainability of water systems (EEA 2018; Ritchie and Mispy 2018; Niestroy et al. 2019; Tsani et al. 2020; Kurrer 2021). The European Water Framework Directive (WFD) (EC 2000) represented a milestone in the regulation of wastewater discharges and treatment in the continent; however, well-known compliance issues remain, including issues associated with point-source pollution from agglomerations and industries. In Spain and other countries, these issues have mostly to do with compliance deficits during peak discharge periods.

Understanding why polluters fail to comply with environmental regulations is challenging. This article proposes to explore the causes and processes of compliance failure through an analysis of governance in the Spanish context. Many authors have looked at water problems through the governance lenses and highlighted the importance of, e.g., administrative fit between EU and national regulations (Borzel 2000; Ptak et al. 2020), coordination gaps across governance levels (Zikos and Bithas 2006; Vinke-de Kruijf et al. 2009), or local collective action challenges (Villamayor-Tomas et al. 2019; Dennis and Brondizio 2020). In this paper, we explore the extent to which incentives to comply with discharge regulations depend on strategic decisions made by both polluters and public authorities about wastewater production and treatment.

The research questions that guide the article are: Which technological, financial, and institutional constraints shape wastewater production, treatment, and discharge decisions by polluters? How are those decisions interrelated? Which solutions along the production–treatment–discharge chain might facilitate compliance with discharge requirements? To address these questions, we rely on the networks of action situations (NAS) approach (McGinnis 2011a; Pahl-Wostl et al. 2010), which understands the behavior of resource users as being interdependent and embedded in decision-making situations (action situations, ASs) that are interconnected. Also, we focus on the case of the wine production industry in the region of Aragon, which is well known in Spain for facing problems of discharge irregularities and the overloading of public treatment plants. To analyze the

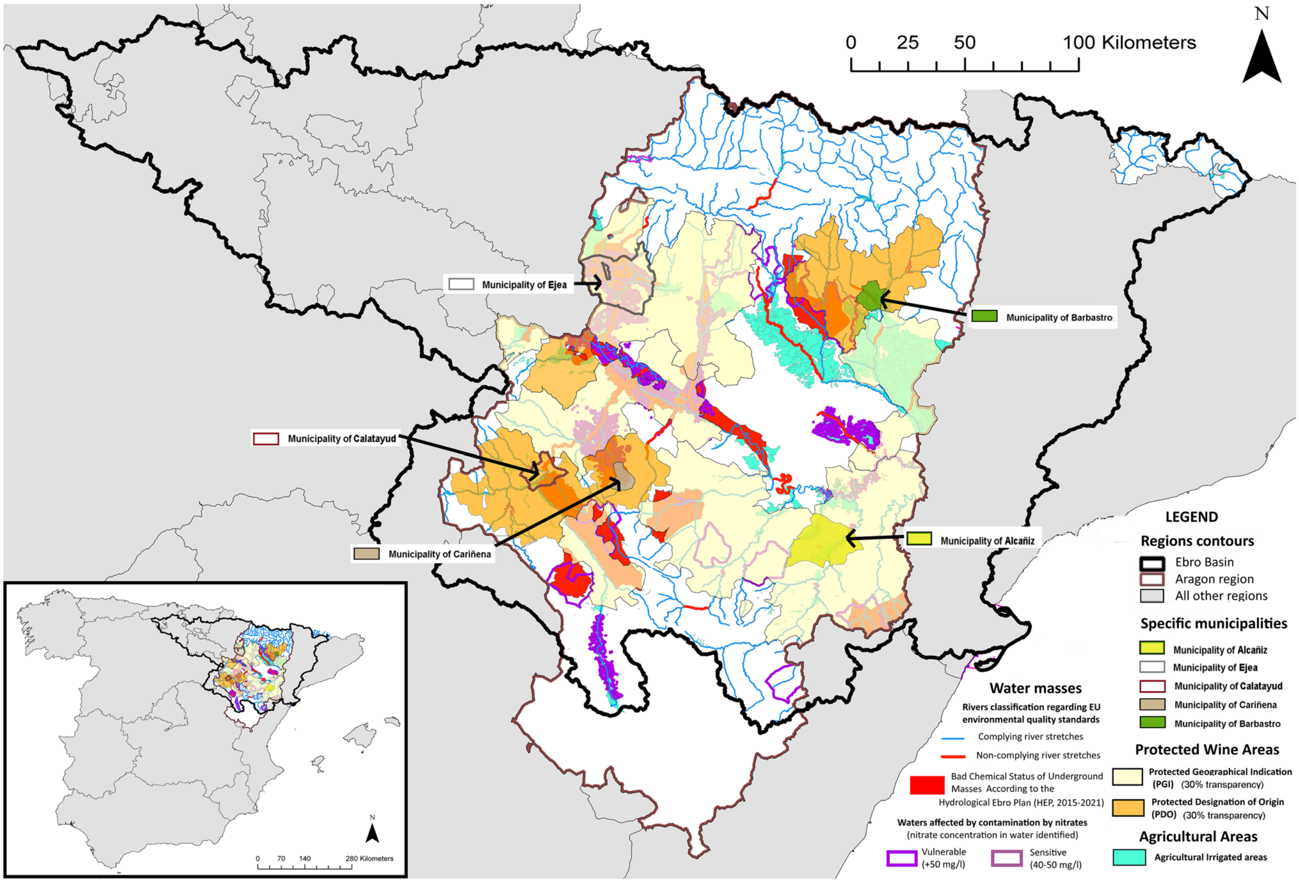

Fig. 1 Map of the Ebro basin (black contour), Aragon region (brown contour), showing (details in the text and note): wine areas (yellow and orange with transparency), agricultural irrigated areas (turquoise), vulnerable water masses and areas (red, purple and pink) and key municipalities (marked with arrows). Note: As detailed in the legend, the figure shows the wine Protected Geographical Indications (PGI) and the most important protected designation of origin (PDO) in the Ebro basin (thick black contour) and the region of Aragon (in thick brown contour). PGIs and PDO, represented in light yellow and orange, respectively (with transparency), overlap with groundwater masses in poor chemical status (red areas) and with nitrate vulnerable and sensitive zones (indicated in purple and pink contour lines, respectively). Many of the vulnerable and sensitive areas coincide with large agricultural farming (see in turquoise also particularly the important agricultural irrigated areas, typically of more production intensification). For example, the municipality of Ejea is covered by a PGI, which overlaps with nitrate vulnerable zones and underground masses in bad chemical status. The municipality of Calatayud falls within a PDO which overlaps with an underground mass in bad chemical status. Source: Own elaboration based on data from the Ebro Water Agency (CHE), Aragonese Statistical Institute (IAEST) and National Geographic Institute

case, we use quantitative and qualitative data obtained from interviews and public wastewater treatment data.

In the next three sections, we further contextualize the case and introduce the NAS approach (see also Electronic Supplementary Material) and methods, respectively. In the subsequent sections, we introduce and describe the ASs that are key to understanding the governance of wastewater treatment in the case, and we explore the feasibility and effectiveness of potential solutions, respectively.

Case background

Point-source pollution from the agri-food industry, and the wine industry in particular, have been less of a public concern than diffuse contamination from agriculture in Aragon. However, this may change in the future, given the recent promotion of large agri-food projects in some municipalities, and the expansion of the wine industry into areas that already suffer from diffuse pollution. Figure 1 shows in different colors the wine Protected Geographical Indications[1] (PGI) and the most important protected designation of origin[2] (PDO). These areas (indicated in yellow and orange, respectively) overlap with groundwater masses in poor ecological status (red areas) and with nitrate vulnerable and sensitive zones[3] (indicated in purple and pink contour lines, respectively; see note on Fig. 1 for more details). The wine-producing industry is highly concentrated in five regions, which represent more than 80% of employment in the sector in Aragon (Zaragoza, Cariñena, Somontano de Barbastro, Campo de Borja and Calatayud; the last four being PDO regions, see GA 2010; Duarte et al. 2012; Aragonesa de Consultoría 2016; IAEST 2020).

The main regulatory and planning instruments for wastewater treatment in Aragon are the Aragonese Sanitation and Purification Plan (PASD) (BOA 2009), and regulations governing wastewater discharges in municipal networks (BOA 2004, 2018a, b).[4] The positive impact of these instruments in the region is evident. From 2005 to 2019, the number of treatment plants in Aragon almost quadrupled. Furthermore, the concentration of pollutants from urban point sources has decreased and the water quality of discharges from many treatment plants in the region have improved (GA 2021).

Still, the ability of small municipalities to cope with occasional discharges coming from seasonal tourism or industrial activities remains a concern. Presently, around 200 (27%) of the 731 municipalities in Aragon rely on a Wastewater Treatment Plant (WWTP). Some municipalities have more than 1 WWTP, but many, especially small ones, have none. In the agri-food sector, 65% of the 199 municipalities within PGIs, and 72% of the 120 municipalities within PDOs, did not yet have a WWTP in 2019 (this number is near the average of 73% of municipalities in all Aragon without a WWTP[5]). In addition, some of the WWTPs have limited capacity. Discharges from wine producers and other activities are highly seasonal, and treatment plants, particularly those located in relatively small agglomerations, are not always able to guarantee optimal treatment during peak load discharges.

According to the Aragonese Water Institute (IAA), which is the main entity managing wastewater treatment plants in the region, average concentrations of pollutants (see note to Fig. 2) beyond standard limits are very infrequent, or non-existent. Statistics show that many WWTPs have exceeded in at least one month per year (maximum month) the pollutant load levels for which the WWTPs were designed (see bubbles that are > 1 in Fig. 2). This is particularly relevant in WWTPs that process large amounts of wastewater (see large size bubbles in Fig. 2), like those located in Ejea, Calatayud, and Alcañiz.

The NAS approach

The NAS is an approach to study governance. Governance analysis focuses on understanding whether and how governments, agencies, companies, and other governmental and non-governmental organizations coordinate to manage public goods (such as wastewater treatment). The NAS approach builds on the Institutional Analysis and Development (IAD) (Ostrom et al. 1994; McGinnis 2011a, b), which is widely recognized as one of the leading frameworks in the policy sciences (Weible and Sabatier 2018) and governance studies (Poteete et al. 2010; McGinnis 2011b; Cole et al. 2019). At the heart of the IAD framework is the AS, an abstraction of decision environments in which individuals and/or organizations make decisions that affect each other and, potentially, broader groups. A look at environmental problems through

[1] These are drawn in yellow (30% transparency): Bajo Aragón, Ribera del Jiloca, Valdejalón, Valle del Cinca, Ribera del Gállego-Cinco Villas and Ribera del Queiles.

[2] These are drawn in orange (30% transparency): Cariñena (also with the municipality of Cariñena in gray), Calatayud, Somontano (also with the municipality of Barbastro in dark green) and Campo de Borja.

[3] Directive 91/676/CEE of December 12, relative to the protection of waters against contamination produced by nitrates used in agriculture (Nitrates Directive), imposes on the Member States the obligation to identify the waters affected by contamination by nitrates of agricultural origin. It establishes criteria to designate vulnerable areas, as those territorial surfaces whose drainage gives rise to nitrate contamination, more specifically in the cartography compiled here from the National Geographic Institute, when the concentration of nitrates in water is greater than 50 mg/l. It is considered a sensitive area, where water is at risk, when the concentration of nitrates is between 40 and 50 mg/l. These identified areas are included in the Register of Protected Areas of the Basin Hydrological Plans.

[4] These are in turn based on the European Urban Waste Water Treatment Directive (EC 1991).

[5] According to the data, the Population (of 2019) served by the 188 WWTP managed by the IAA is 430,000 people (32% of the population of Aragon in 2019). We may add the handful of municipalities with a WWTP not IAA managed, with only one large municipality (actually the largest), Zaragoza, with 675,000 people. By adding these, it becomes 84% of the population of Aragon served by a WWTP. Hence, most of the municipalities without WWTP are relatively small (in population). The quite small municipalities (with barely a few dozens of inhabitants) either do not have a treatment plant or they are municipal septic tanks (not accounted in the WWTP data) which tend to lack maintenance. There are no large water-polluting effluents in municipalities not covered by a WWTP. Still, medium-sized municipalities of a few hundreds of inhabitants are more of a problem, since although they may have a sewage treatment plant, they do not have nitrogen and phosphorus treatment (only mandatory for more than 1000 equivalent inhabitants, with the existing many municipalities—86% of the total—having less than 1000 inhabitants). Eutrophication, especially due to nitrogen, is the main problem.

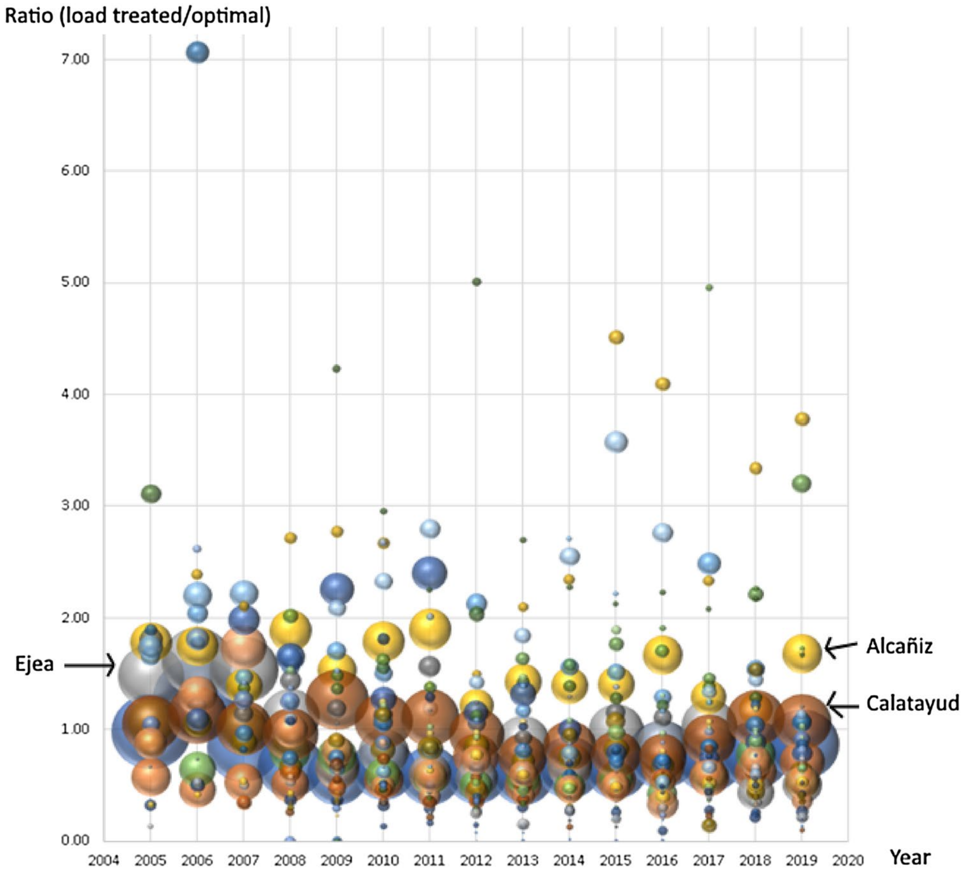

Fig. 2 Ratio between the load treated in the maximum month and optimal treatment load (both in terms of equivalent inhabitants) for several Wastewater Treatment Plants (WWTPs) in Aragon. Notes: The size of the bubbles reflects the size of the (average) load treated in the maximum month in each WWTP. Each color represents one of the 188 different WWTPs. Ratio > 1 indicates overload of the WWTP at some point in the year. According to the IAA, the main indicators of wastewater overloads are total suspended solids (TSS), biological oxygen demand (BOD5), chemical oxygen demand (COD), and, in sensitive areas, total nitrogen (TN) and total phosphorus (TP). The size of the bubbles reflects the size of the (average) load treated in the maximum month in each WWTP (measured in terms of equivalent inhabitants). Data corresponding to 188 WWTPs are illustrated [the most recent information suggests that there are around 220 WWTPs in Aragon (some are managed by companies in service contracts and through concessions)], and the data has been available since 2005 (many municipalities began to have WWTP and data from 2008–2009, illustrating similar values). Note also that the data refers only to municipalities with WWTPs. The Supplementary Material provides the original data. The optimal treatment load is defined as the design treating volume. As explained in full in IAA (2019), the criteria for obtaining the design volume is described in the Zonal Plans, in the projects that develop them, and in the Guidelines, General Urban Planning Plans, Partial Plans and instruments that develop them. The theoretical influent flow will be calculated by applying the following criteria: urban unit endowments, industrial unit endowments, livestock unit endowments, current average demand, current peak demand, future average demand, estimate of the inflow to the treatment plant. Source: Own elaboration from Open data IAA-Government of Aragon (GA 2022)

the lenses of AS allows limiting a problem to a particular set of actors and their decisions, as well as to the social, biophysical and institutional circumstances that shape those decisions (see Fig. 5 for a visualization of the ASs within the IAD framework).

Environmental problems are complex and usually involve several interconnected ASs. The NAS approach provides methodological guidance on how to analyze multiple ASs systematically (McGinnis's 2011a; Kimmich 2013; Kimmich and Villamayor-Tomas 2019). The "focal AS" is the situation most directly related to the outcome/s of interest (McGinnis 2011a). Once the focal AS is identified, the network is built by adding situations that can have an influence on the focal situation and on each other (Kimmich and Villamayor-Tomas 2019). Links between two situations occur when physical flows (e.g., of water), information or rules/policies emerging from one situation affect the behavior of actors in another situation (Kimmich 2013; Hoffmann and Villamayor-Tomas 2022, in this issue).

Here, we rely on the NAS approach for two reasons. First, the approach is instrumental to our interest in looking beyond the wastewater discharge decisions of polluters. Important decisions that polluters make other than discharge decisions may include, for example, wine production decisions and decisions about whether to invest in in-house treatment devices. The NAS approach can not only assist in the identification of those decisions, but also the analysis of how they influence wastewater discharge decisions. From the NAS approach perspective, polluters' decisions are interdependent[6] and shaped by incentives (i.e., costs and benefits) that can be evaluated. Second, the NAS approach can help in ex ante policy evaluation (Kimmich and Villamayor-Tomas 2019). Interventions aiming at correcting undesirable outcomes in one situation can be assessed with regard to (1) their indirect impacts on other ASs and (2) their ultimate ability to improve final outcomes. Here, we use the NAS approach to evaluate ex ante actions that could modify untreated wastewater discharges by wine producers.

Our review of the literature suggests that this is the first study that applies the NAS approach to the point-source pollution context (see also Kimmich et al. 2022, in this issue). Thus, we believe a first contribution of this study consists in the specification of key important ASs and their linkages in this context. We expect our study serves as a reference for similar ones in the future. This is not trivial because the IAD (and NAS approach) has been used to understand natural resource management problems (e.g., irrigation water use appropriation, monitoring, or infrastructure maintenance; Villamayor-Tomas et al. 2015), but not pollution problems. Also, our analysis contributes to illustrate the use of the NAS approach for ex ante policy analysis. Contrary to previous efforts (Kimmich and Villamayor-Tomas 2019), we assess the feasibility and effectiveness of policies that have actually been proposed by public authorities and stakeholders. Last but not least, this study combines qualitative and quantitative information in a systematic and meaningful way. In our understanding, few of the involved actors in this case had a full picture of the pollution problem and this had to do with the lack of quantitative and qualitative syntheses like ours.

Methods

Although there is no clear protocol about how to draw boundaries of ASs, some patterns start emerging in the literature (Kimmich et al. 2022). As hinted in the previous section, a common strategy is to first identify the focal AS and then observe the incentives[7] of actors that make decisions in that situation. In our study, the main concern among interviewees was the mismatch between wastewater discharges by wine producers and the capacity of municipal wastewater treatment plants to treat those discharges. A majority of the interviewees referred to the lack of on-site water treatment devices by wine makers as the most direct cause of such mismatch. Thus, we took this situation as the focal situation and named it as the "Upstream Treatment" situation (AS2). Then, to populate the NAS we followed the value chain of wastewater production, treatment and discharge stages, each of them potentially representing an AS.[8] Additionally, we observed key governance/managerial tasks associated with pollution treatment and control that could affect the on-site wastewater treatment situation (McGinnis 2011b).

To characterize incentives within each AS, we observed material, socio-economic and institutional conditions (Oberlack et al. 2018; Kellner and Brunner 2021). In terms of material conditions, we looked at quantitative data on the chemical status of water and the financial constraints of installing on-site wastewater treatment devices.[9] Regarding social conditions, we looked qualitatively at features of the winemaking industry in the area (including size, business type, or financial conditions), as well as the heterogeneity of interests among polluters and public authorities around wastewater treatment and enforcement. Institutionally, we collected qualitative information on existing rules (formal laws and regulations, subsidies for wastewater infrastructure provision), shared understandings regarding water use priorities, and informal standards and expectations about wastewater discharges and their timing.

We obtained quantitative data (on discharges and treatment, see Fig. 2; and location of wine producers, see Fig. 1) from public websites and data repositories (CHE 2021; GA 2021; IAA 2021b). Qualitative data were obtained from secondary documents (e.g., GA 2021; MAPA 2021; BOA 2004, 2018a, b) and interviews with key stakeholders, among other sources (see Table 1 in the Appendix). We interviewed 25 key informants from October 2020 to May 2021. Interviews addressed representatives of the main water governance organizations in the region (see Albiac et al. 2014; Bielsa and Cazcarro 2014; CESA 2003). We interviewed representatives of the Ebro Water Agency (CHE)[10] board, the Aragonese Water Institute (IAA), key agri-food and wine

[6] Wine producers are interdependent in the compliance/pollution emission decision, because as more wine producers control their emissions the need that others comply decreases.

[7] By incentives, we refer to the costs and benefits that affect individual and collective decisions, i.e., of wine producers and public authorities in a particular AS. For example, constraints that may shape incentives to, e.g., install on-site wastewater treatment plants by wine producers include the financial costs of those devices and the effective enforcement of discharge regulations.

[8] See Villamayor-Tomas et al. (2015) and Oberhauser et al. (2022) for other applications of the value chain heuristic to identify AS.

[9] On the cost of urban wastewater treatment in the South of Spain, see Pajares et al. (2019).

[10] The CHE has traditionally been the main water management authority in the Ebro River basin. This basin is the main one within the region of Aragon, and most of the rivers in the region flow into it.

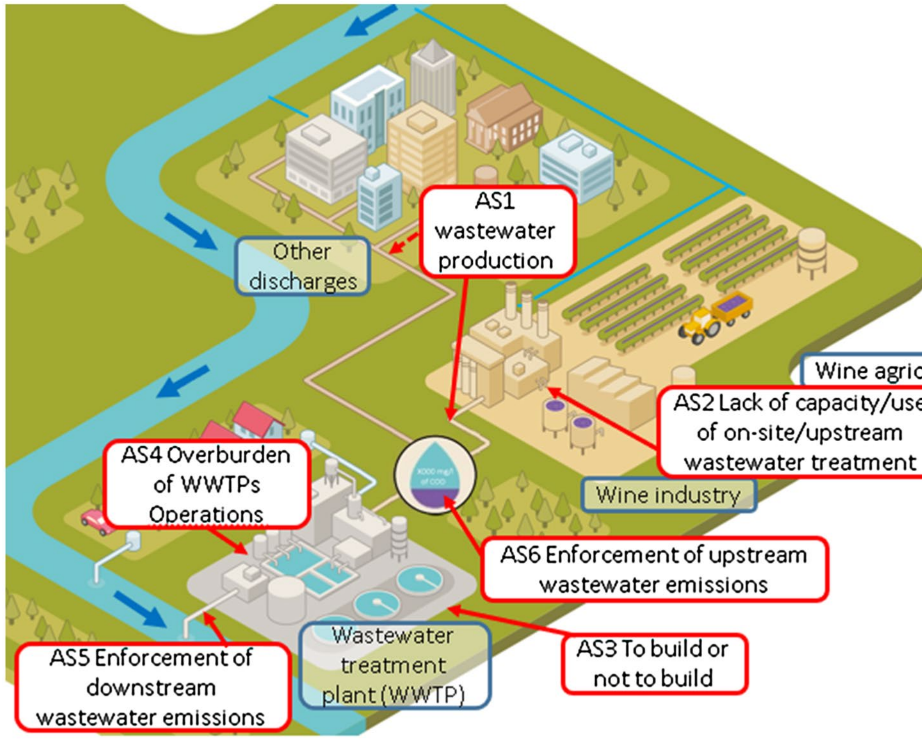

Fig. 3 Action situations (AS) associated with the schematic and spatial view of water intake, pollution and treatment flows. Note: The blue boxes indicate the wastewater treatment plant, the wine related discharges and "other discharges" (from industry, services, households, etc., which often are all gathered in collectors before reaching the plant). The red boxes try to approximate in space the places where the ASs mainly occur. WWTPs: wastewater treatment plants. Source: Own elaboration

clusters, wine producers, farmers' (irrigation) communities, the Cluster for the Efficient Use of Water (ZINNAE), and key wastewater treatment businesses and managers. Additionally, we interviewed researchers who were experts in the matter. Interviews were semi-structured and included questions about the history of wastewater treatment in Aragon; main management barriers or challenges; key agents/stakeholders "responsible" for the challenges; knowledge and opinion of other views, arguments, challenges, etc.; and solutions and their feasibility.

Results

In our analysis, we found the lack of upstream wastewater treatment capacity (or use) of wine producers as the focal AS (AS2). The wastewater is generated by wine producers (and depending on the context, especially in urban areas, also by other businesses), AS1. Two directly connected situations are: AS4—water pollution and overloads at the WWTPs from wine producers' discharge regimes (the detection of those overloads being the main warning of water treatment challenges); and AS6—wastewater treatment enforcement, which requires paying attention to the incentives and constraints of monitoring agents. The building and maintenance of treatment plants (AS3) allow us to explain the case with an eye on the historical development of the wastewater treatment industry in the region. Finally, the potential downstream incompliance is studied in relation to the regulations/enforcement and environmental harm (AS5). Figure 3 shows the spatial location of ASs. We identify these ASs individually in "ASs", the full network in "The NAS", and the appraisal of potential interventions in the "Discussion" section.

ASs

AS1: wastewater production

The wine-producing industry in Aragon has four important particularities connected with wastewater pollution. First, as indicated by the main representative of the agri-food (and wine industry) cluster, wine producers require high-quality water as an input for the production process. Second, and most importantly for us, the wine production process needs water for cleaning purposes. This water constitutes the main source of discharges and can be quite irregular throughout the year. The peak of discharges occurs during 'the vintage', which lasts around 3 months. After the vintage, the production process is less intense, but more irregular. It concerns the racking of wine and cleaning of deposits. These operations can discharge significant volumes of pollutants in very short periods of time, sometimes within one day, and can be more problematic to manage than vintage-related discharges. Third, as highlighted by the Head of the Water Quality Area of the CHE, although average loads from wine producers are not particularly high (as compared to pig farms, for example), they can be highly polluting. Water has a low pH and high sulfur, sodium and organic matter concentrations, all of which can severely threaten the eutrophic balance of rivers and aquifers, or affect/destroy the WWTPs' biological systems. Fourth, the wine sector enjoys a strong tradition and has significant economic weight in Aragon, albeit at a small scale, relatively atomized, and geographically dispersed (see also ESM for more details on each of these four aspects).

AS2: capacity and use of in-house/upstream wastewater treatment

Given the peri-urban location of many of the wineries, most of the discharges flow into municipal sewage systems or collectors connected to them. As highlighted by legal academics and WWTP managers, even if municipalities have wastewater treatment plants, the legislation requires that any polluter, including wine producers, install in-house treatment facilities when COD discharges are expected to go beyond 1500–2000 mg/l. However, as recognized and identified both by wine producers and wastewater treatment managers, producers are quite resistant to making these investments. They are considered as non-productive investments that jeopardize producers' returns and, in some cases, their capacity to break even.

Treatment costs depend on technologies, but are seen as high given the small scale of producers. Biological treatment, which is the cheapest option in terms of operational costs, faces high upfront costs due to the required water storage and retention infrastructure. Indeed, some producers may not have the financial resources, or space (e.g., water storage capacity), to install the treatment equipment within their premises, involving around 100,000–150,000 € on average (according to the wastewater treatment businesses and winemakers). Moreover, wine industry wastewater production is very seasonal, but the biological treatments require continuous maintenance throughout the year for proper performance. This could be seen as a waste of resources, given that the infrastructure is not regularly used (for further details on the costs and technologies, see the ESM).

In terms of in-house treatment facilities, there are a few large, very localized producers in Aragon who have invested in, and use, their own systems, e.g., Viñas del Vero in the Municipality of Barbastro and Bodegas San Valero in Cariñena. Outside the wine sector, the pulp industry is characterized by very large and spatially concentrated companies, all of which include in-house treatment facilities. Large, localized firms can afford research and innovation investments and enjoy scale economies, all of which can ultimately reduce treatment operating costs. However, this is not generalizable to most wine producers in the region due to their small scale, unless they pool resources.

AS3: building wastewater treatment plants

By default, the municipalities are responsible for wastewater treatment in the region. However, in the 1990s many delegated this responsibility to the IAA, due to their lack of financial capacity to build and operate the plants (for further information on this and the role of the EU, see the ESM).

The PASD, approved by the regional government (General Council of Aragon, DGA in Spanish) in 2001, organized the financing and construction of plants that would be managed by the IAA and set standards for all others. As indicated by IAA managers, the regional governments imposed a new water pollution tax (ICA in Spanish) to all the affected municipalities (GA 2019; IAA 2021b) to finance the WWTPs construction and operation. Indeed, nowadays the IAA obtains 90% of its budget (70 million euros) from this tax. Currently, few plants in the region are managed by the municipalities themselves and 220 are managed by the IAA (IAEST 2021a), a public agency dependent on the DGA.

The implementation process has not been entirely smooth. Some municipalities complained about pressure from the IAA to delegate the management in exchange for financing. Furthermore, there have been complaints about the public–private management model used by the IAA to operate the plants and collect the ICA (a tax with a highly disputed social response; see Lisbona 2021, which is to be replaced) and the preference given to multinational firms over public management. The PASD was supposed to be reassessed every 6 years; however, the first revision took place in 2009. In 2015 the government initiated an evaluation that was never finalized, and in 2017 organized a participatory process to reform it.

AS4: operations and maintenance of municipal/downstream wastewater treatment plants

Most of the systems used in municipal wastewater treatment plants rely on activated sludge biological treatment technologies, which are considered more robust against peak loads. In particular, according to the most up-to-date data, 82% of the WWTPs rely on activated sludge with some other combination of treatment (e.g., 77% of the total have activated sludge in prolonged aeration; IAEST 2021b; see also the type of treatment in each municipality, column X of tab "Data for Ratios" in the ESM). Peak discharges are not a problem in large municipalities that have large capacity treatment plants that are able to cope with very large and polluting discharges. Municipal governments are generally able to absorb overloads and to sanction producers for not having in-house treatment facilities. Imposing the installment of those facilities on producers would not only be a waste of resources, but would also prevent municipalities from gaining the extra income obtained from sanctions. (See also enforcement situation.)

The real issue (highlighted by several interviewed agents) emerges when producers and municipalities are small (i.e., the WWTPs). For example, in small municipalities within a wine area (say, e.g., Longares in Cariñena or Miedes in Zaragoza), the main wine industries (that employ around 25 people) produce relatively high-quality wine for export. The municipal sewage treatment plant is designed for only 500 or 1000 inhabitants in the village, so that when the wine producer hits a certain level of discharges, it surpasses the figure for equivalent inhabitants. This, at best, can decrease the efficiency of the WWTP and, at worst, overflow its capacity. The wine producer should therefore install in-house treatment equipment or be fined. Theoretically, the fine for not treating wastewater is higher than the treatment investment itself. However, fines may not be sufficiently discouraging if the wine producer considers the occupied (productive) space, the difficulties with storing water, the operational costs of treating the water and the need to treat non-storable volumes. We may add the fact that pollution limits are measured as concentration (g/ml), which creates incentives for wine makers to dilute the effluent. Moreover, producers at small municipalities must comply with the same concentration limits as those generating larger discharges (in absolute terms). Producers are often not capable of reaching the required concentration limits despite having low or no WWTP capacities and small discharges that are generally not dangerous to the environment. As a result, producers are more likely to be fined generating frustration and feeling of unfairness among producers.

AS5: enforcement of downstream wastewater emissions

The enforcement authority of wastewater emissions is shared between the CHE, the IAA and municipal authorities (Arrazola Martínez 2013). The CHE was originally the main authority until the approval of the Aragonese Sanitation Plan. Since then, the CHE has been responsible for direct discharges, while the IAA and the municipalities have been responsible for indirect discharges (i.e., discharges that are collected from various wastewater sources), including those from wine producers. Enforcement of wastewater treatment regulations involves two different sets of actors and, indeed, two different dynamics, depending on whether it applies to upstream (in-house, wine-producing plants) or downstream (WWTP) treatment plants. Thus, we conceptualize enforcement as involving two situations, considered here and in the next subsection (AS6).

The main enforcement authority of downstream discharges is the CHE, whose responsibilities have included water quantity and quality. The CHE (which also supplies the data for the National Census of Discharges; MITECO 2021) has an inventory of authorized direct wastewater discharges, including those from WWTPs (CHE 2021). Based on these data, one can observe that the largest yearly volumes (of authorized entities) are: the Industrial Refrigeration of the Nuclear Ascó-Vandellós II plant in Tarragona (1651 hm^3/year), several industrial fish farms (all below 160 hm^3/year) and urban or similar type installations with more than 50,000 habitants-equivalent discharges (typically in cities, all below 60 hm^3/year, including Zaragoza, Pamplona, Vitoria-Gasteiz, Lleida and Logroño). To obtain authorization, discharges need to fulfill standards of maximum pollutant concentrations according to the Urban Wastewater Treatment Directive (UWWTD) and the Drinking Water Directive. For most of them this means ensuring proper treatment. In turn, authorized discharges must comply with daily and annual load limits and rely on a self-managed registry of discharges and water quality measurements that are shared regularly and on-demand with the CHE. Furthermore, polluters need to pay a pollution monitoring fee depending on the discharge volume, the environmental conditions of the affected water system, and whether it is industrial or urban. The fee is used to protect and improve the water system. Last but not least, the CHE relies on a series of measurement stations within the basin to regularly collect water quality data and to flag transects within the Ebro River subjected to occasional high pollution concentrations.

In terms of interactions, the CHE can impose sanctions on non-authorized discharges or authorized discharges that do not comply with the standards. The CHE has acquired a reputation for being quite inflexible in sanctioning firms and municipalities, especially those that do not have treatment plants in place. Sanctions on these municipalities have created conflict with the CHE, as most municipalities had delegated the construction of their treatment plants to the IAA, but were still without them. In 2018, in recognition of the conflict, the CHE approved a moratorium on sanctions for those municipalities that continues today.

AS6: enforcement of upstream wastewater emissions

By default, municipalities have the authority to monitor indirect discharges, e.g., those flowing from wine producers into urban sewage systems and the WWTPs (where they exist). However, very few municipal governments have articulated this responsibility with regulations. Additionally, the IAA self-assigned the responsibility to manage WWTPs under its jurisdiction (i.e., delegated by the municipalities; BOA 2004). Based on this assurance, the ambition of the IAA is to run regular inspections. However, these inspections are mostly ad hoc reactions to events (e.g., overloads). Furthermore, the IAA inspection process relies mostly on the managers of the WWTPs themselves. In the interviews, managers monitor discharges into plants and releases from plants into water streams on a daily basis. Inflow peaks are not necessarily inspected, unless there is a high concentration of pollutants or relatively frequent. More importantly, there are no operating protocols, such as those of the CHE, for the IAA (or the municipalities) to obtain regular discharge information from polluters. Thus, even when the IAA initiates an inspection, it is very difficult to trace overloads back to the polluter, particularly in municipalities with multiple wine producers and/or other industrial polluters. Ultimately, the dispersion of polluters makes ad hoc monitoring very difficult, especially considering the IAA's limited resources for field monitoring.

Regarding sanctioning, the IAA and municipalities have been less strict than the CHE. The IAA is constrained by the already controversial situation generated around the construction and financing of WWTPs and conflicts related to the ICA. The municipalities, particularly small ones, are constrained by the dependence of their economies and population on the activities of polluters. This is clearly the case for wine producers and other agri-food industries, which make use of local or regional inputs, with strong backward linkages with the agrarian and related sectors.

Finally, there is the opportunistic behavior of wine producers. As far as could be ascertained from interviews, many producers are aware of the difficulties in tracing discharges back to the origin and reliance of the IAA on WWTP personnel for monitoring. Building on this knowledge, to reduce the chances of raising any flags, they tend to store discharges during the week and release them at the weekend when the WWTPs operate with minimum personnel. Moreover, since the legal limits are established by concentration (mass/volume), there is the incentive and practice to dilute wastewater (to produce less concentrated effluents) and disperse it over days. Additionally, producers know that sanctions are rare and factor this into their calculations of the risk of being caught and needing to pay a fine. Fines for first-time offences amount to approximately 3000€ and increase progressively as infractions become more frequent. Ultimately, the permit to discharge wastewater into the municipal sewage system can be revoked if infractions recur frequently, although this is rare. These circumstances can make infractions quite appealing, particularly when compared to the cost of installing an in-house treatment plant.

The NAS

As inferred earlier in this section, there are important connections across the ASs. The main alert on the existence of a water treatment challenge was found mostly to be AS4, which puts the focus on the ability of WWTPs to do their job and avoid out-of-law pollution discharges into the water system. These discharges are effectively monitored by the CHE (institutional link from AS5 to AS4 in Fig. 4), which is the main water management authority with responsibility for direct discharges into the system. The ability of WWTPs to keep treated water within the required standards is challenged by irregular peak loads coming from a large number of small-scale wine producers (physical link from AS2 to AS4), particularly where WWTPs are small.

As stated by the institutional agents, and by many people from academia and social organizations, wine producers should comply with the discharge regulations. To do so, in most cases, they should have (and use) an in-house treatment plant. They tend not to install them because the investment and operational costs appear disproportionate to them as compared to the cost (and probability) of being sanctioned for violating discharge standards (institutional link from AS6 to AS2). In addition, there is only partial information about the actual capacity of WWTPs. Many have been constructed by the IAA without clear criteria about dimensions and treatment technologies (information link from AS4 to AS2). The peak load issues appear at certain stages of the wine production process (physical link from AS1 to AS2) and are related to the relatively atomized structure of the industry (institutional link from AS1 to AS2). This makes the case of wine producers diverge from archetypal point-source pollution cases. Tracing pollution back to the source is difficult, because the industry is dispersed and there are not regular registries of wine producers' discharges into sewage systems (institutional link from AS5 to AS2). Furthermore, the economic and symbolic weight of industry in the municipalities (information link from AS1 to AS6), the conflict between municipalities and the IAA associated with the ICA tax (information link from AS4 to AS6), and the conflict between municipalities and the CHE (information link from AS5 to AS6) make sanctioning difficult. The complaints have forced the CHE to make sanctioning exceptions (information link from AS4 to AS5, and institutional link from AS5 to AS4), which originated when the IAA built the WWTPs. As a result, there is a dearth of treatment plants across the region and issues associated with cost optimization in existing WWTPs (physical link from AS3 to AS4).

Up to the last 10–15 years, the main outcome of this NAS was an evident failure to comply with the EU and national regulations on water discharges, both upstream and downstream. This has created additional costs for wastewater treatment plants and effluent emissions to the environment with potentially damaging levels. The current outcome in terms of the downstream discharge parameters compliance is much more optimistic than before, and further downstream enforcement (AS5) is not necessary. These good values are

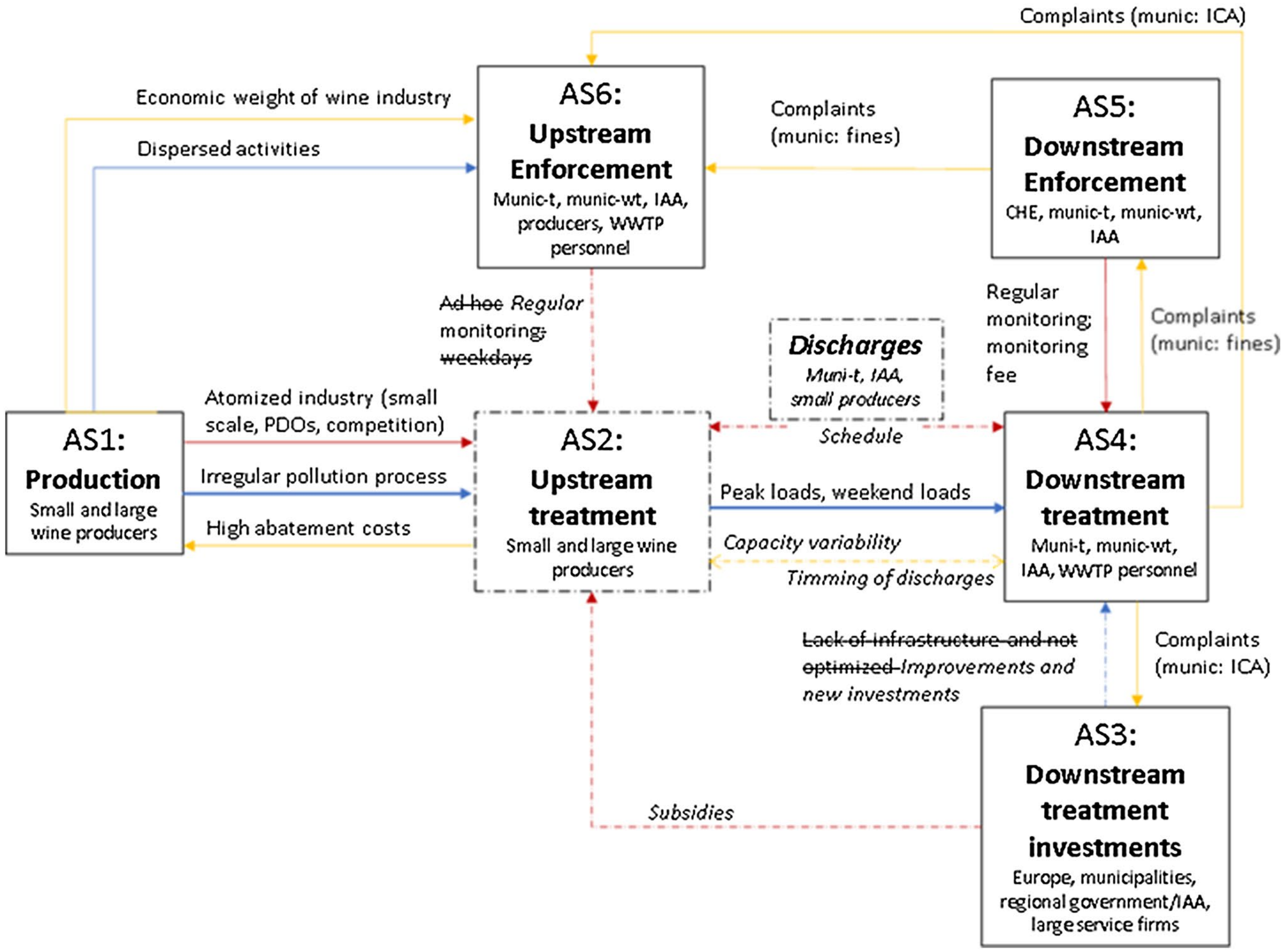

Fig. 4 Network of action situations (NAS), linking the physical, institutional and information links, including current and potential solutions. Notes: *AS* action situation, *Munic.* Municipality, *muni-t* municipalities with treatment plants, *muni-wt* municipalities without treatment plants, *CHE* Ebro Water Agency, *IAA* Aragonese Water Institute, *WWTP* wastewater treatment plant, *ICA* water pollution tax, *PDO* protected designation of origin. Blue arrows = physical links; red arrows = institutional links; yellow arrows = information links; dashed arrows = currently absent links that could be created as part of solutions; dashed boxes = ASs that could be part of solutions; crossed text = current features of links that would change as part of a solution. Source: Own elaboration

a result of some recent public and private investments in treatment. Still, some places without WWTPs show negative outcomes, and several places with WWTPs need to operate at high costs, decreasing efficiency. Also, conflicts still exist related to penalizations and to the discussion on the financial possibilities for public and private investments.

Regulation and compliance solutions are on the table and they might be key to improving the outcomes of the NAS. "Monitoring and evaluation" are highlighted as key processes for proper water management and its continuous improvement. To achieve this, building confidence and engagement with the regulatory framework agents will be of utmost importance. For example, many interviewees voiced the importance of engagement to ascertain and consult on the issues. Doing so would aid in the development of appropriate regulatory indicators and an improved regulatory framework and system (which would be represented with additional yellow arrows in Fig. 4), to develop the regulatory framework (taking into account local circumstances, needs and capacities), etc. This case study (in particular for wine producers) has found that the private sector requests stable and clear regulatory frameworks that allow planning (e.g., investments needed to address AS2) in the medium and long term. These aspects also relate to the desirable principle (OECD 2015) of "integrity and transparency" practices across water policies for greater accountability and trust in decision-making.

Discussion

Appraisal of mainstream compliance solutions

Our findings about the strategic behavior of wine producers and public authorities can inform the environmental economics literature on enforcement and compliance. Standard enforcement theory would predict a direct relationship between the political benefits of inspections (e.g., good social image, damages avoided) and their frequency, but findings do not always align with predictions (Gray and Shadbegian 2004; Cai et al. 2016). Similarly, although enforcement is an important predictor of regulatory compliance, evidence shows that polluters (e.g., pulp and paper mills, steel plants, oil transport activities) react to a diversity of enforcement modes (e.g., lagged inspections and/or sanctions, threats of inspections) showing contradictory responses (Earnhart 2004). We have not systematically focused on the factors that explain polluters' decisions, but we have studied how these decisions are affected by decisions made in other stages of the value chain or by other actors (i.e., public authorities). As mentioned above, the strategic non-compliance of wine producers can be explained by specificities of in-house treatment capacity, but also by features of the wine production process and monitoring deficits inherited from a particular history of government decisions related to investment in wastewater treatment.

When asked about solutions to the problem of wastewater discharges, most interviewees suggested two potential solutions that align with the above literature. The first was the strengthening of monitoring and sanctioning (see dashed arrow/institutional link from AS6 to AS2 in Fig. 4). The second was the use of subsidies to finance investments in treatment capacity (see dashed arrow/institutional link from AS3 to AS2 in Fig. 4). The first solution could emulate the CHE's system of self-reporting and information-sharing protocols. However, even assuming that the IAA had the necessary resources, this solution would still face the issue of discharge variability. As shown by previous studies, regulatory enforcement in contexts of discharge variability can result in inefficiencies due to overcompliance with emission standards (see Brännlund and Löfgren 1996; Bandyopadhyay and Horowitz 2006). This would be assuming that polluters have the capacity to comply, which is not even the case for many small wine producers in Aragon. Furthermore, depending on the severity of sanctions, producers might still prefer to pay the fines than comply with regulations (see costs link from AS2 to AS1).

Subsidizing in-house treatment facilities or improving WWTPs are possible solutions to the issue of discharge variability. The subsidies would balance the costs of new investments for polluters (i.e., as compared to the costs of being sanctioned) and encourage polluters to make those investments. As discussed in AS3, the possibility of combining biological and non-biological treatment technologies could facilitate reducing fixed and operational costs of in-house facilities. Additionally, producers could use the sludge for agricultural and energy generation purposes (see more information in the ESM on bio-factories). The refurbishing of WWTPs would make sense in cases where WWTPs suffered from design issues and need updates, but would be more problematic to justify in WWTPs that work well under average discharge conditions. More importantly, both interventions could contradict the "polluter pays" principle and face adaptability issues in the long term depending on the evolution of discharges (see physical links that connect AS1, AS2 and AS4).

All the above connect with previous works pointing to the necessary, but insufficient role of regulatory action. Regulations matter greatly, but they do so "less as a system of hierarchically imposed, uniformly enforced rules than as a coordinative mechanism, routinely interacting with market pressures, local and national environmental activists, and the culture of corporate management in generating environmental improvement while narrowing the spread between corporate leaders and laggards" (Kagan et al. 2003, p. 51). Indeed, our assessment indicates that bottom-up coordination among polluters and/or with WWPT managers could be a relatively cost-effective solution as compared to other solutions.

Coordination could involve only *producers* (see dashed outline of the AS2 box in Fig. 4) or both *producers and WWTP managers* (see "Discharges" box in Fig. 4). Small and large wine producers could partake in cooperative arrangements to share resources and technology for wastewater treatment. Governments could promote the process by issuing collective pollution rights, covering some of the coordination and information-gathering costs, or promoting "trust and engagement" activities among polluters (Villamayor-Tomas et al. 2019; OECD 2015). Additionally, producers and WWTP managers could schedule discharges, adjusted to WWTPs capacity.

All the above would require that producers develop their own rules and monitoring systems to allocate financial responsibility and ensure that schedules are complied with, which would involve transaction costs (see Gorelick et al. 2019, for an assessment of capacity sharing agreements among water utilities). Additionally, producers would need to disclose discharge information, which they may resist to do. Moreover, not all WWTPs have equal leverage to adapt to producer's discharge needs (physical link from AS3 to AS4), and current relationships between the IAA and municipalities are not favorable for collaboration (complaint links from AS4 to AS3, and from AS4 to AS6).

Moving beyond single situations and solutions in the study of water pollution and treatment

One take home message from the above is that it is unlikely that one solution alone solves the pollution problem in the Aragon case. Solutions focusing on a single AS risk to be undermined by or result in unattended effects in another AS. This sounds intuitive by default, but was not necessarily internalized by our interviewees. Most of them either focused on one solution or saw the solution of the problem out of their reach. Only interviewees from organizations without authority to act, such as academics or people from social organizations, pointed to the existence of shared responsibilities across situations, like WWTP building (AS3) and upstream enforcement (AS6).

The study of multiple AS can also inform us about the complexities involved and the risks of extrapolating solutions across contexts. We believe our study can help other studies in different contexts, but with certain similarities, e.g., in other Southern European regions (see, e.g., the similarity of attitudes toward the environment in Portugal and Italy; EC 2021; Rodríguez 2021). However, our findings may not be valid in other contexts. Major water systems around the world do not count on public water treatment capacity or have endemic corruption problems associated with infrastructure investments.[11]

More broadly, our study questions reductionist approaches to environmental policy making. According to De Geest and Dari-Mattiacci (2013), economic incentives can be particularly effective in two situations: when lawmakers lack sufficient information to monitor and sanction individual behavior; and when compliance requires significantly bigger efforts from some citizens than others. Our study, however, shows that solutions are less straightforward. We found consensus around the application of the "polluter pays" principle, but also around the involvement of governments as co-participants in solutions. International organizations like the OECD have indeed emphasized the importance of promoting policy mixes and co-responsibility on the basis that environmental problems tend to be more complex than initially expected by the stakeholders and policy makers involved. Looking for example at the Overview of OECD Principles on Water Governance (OECD 2015), "trust and engagement" has a role to play in enforcement; and "integrity and transparency", "stakeholder engagement", or "information-sharing and consultation" also contribute to policy planning. These aspects would be key in the solutions discussed above about the possibility that *producers and WWTP managers coordinate to co-manage the problem.*

Conclusion

Wastewater produced by the wine industry can be easily located, identified, and controlled. Yet, it has generated severe problems in the past and still does in the present. In this study, we have applied the NAS approach to understand issues associated with peak load discharges by wine producers in the region of Aragon, Spain. The questions driving the study were: Which technological, financial and institutional constraints shape wastewater production, treatment and discharge decisions by polluters? How are those decisions interrelated? Which solutions along the production–treatment–discharge chain facilitate compliance with discharge requirements?

Our analysis shows that the issue of peak loads is not a simple problem that can be addressed through more enforcement. The issue stems from a particular configuration of actors, their characteristics, interrelationships, their incentives for action (or lack of it), and the consequent impact on enforcement, pollution, investment and treatment decisions. Ideally, wine producers should have in-house treatment plants; however, they do not have them due to the disproportionate investment and operational costs required, compared with the risk of being sanctioned and fined for violating discharge standards. The wine producers' discharges into sewage systems are not monitored and it is difficult to trace the pollution back to specific producers because of the dispersed nature of the industry. Furthermore, sanctioning is hindered by the economic and symbolic power of the industry locally, the conflictual relationship between public authorities in charge of the WWTPs and other local actors, and the deficits in the WWTP monitoring capacity. Enforcement solutions alone would not be effective if not complemented by other interventions that, e.g., promote the coordination between large and small polluters with the treatment plant operators.

To our knowledge, this is the first study that applies the NAS approach to a point-source pollution case. Further research is needed to validate the relevance of the selected situations and the usability of the NAS approach for ex ante policy evaluation in other contexts. Although we have briefly discussed the environmental economics literature on enforcement, further work is needed to integrate this vast and rich literature within the lens of governance analysis and the NAS approach.

Appendix

See Table 1 and Fig. 5.

[11] 20% of discharges in Australia and New Zealand, Europe and Northern America, 35% in Eastern and Southeastern Asia, Northern Africa and Western Asia, 60% in Latin America and the Caribbean, and close to 75% in central and southern Asia and sub-Saharan Africa are not treated (UN 2021; Sato et al. 2013; Mateo-Sagasta et al. 2015). Also, according to the World Health Organization and World Bank, globally 20–40% of water sector finances, in the range of USD155 to 700 billion annually, are lost to dishonest and corrupt practices (UN 2021).

Table 1 Quantitative and qualitative data collected and methods of analysis

(a)

Type of quantitative data	Source
WWTP data on the treated volume (equivalent inhabitants of the maximum month), the optimal treatment load (equivalent inhabitants), the year of starting of operation and the municipalities in which the WWTPs are located and serve	Own elaboration from Open data IAA-Government of Aragon (GA 2022). For details see also (IAA 2021a): 1.1. Treatment plants, general data 1.2 Treatment plants, population centers served 1.3 Treatment plants, annual data: treated load and volume, discharge quality
Population in 2019 where the WWTP is located or municipality served (if any)	IAEST (2021b)
WWTPs data on the reported input (into the WWTP) and output (out of the WWTP) water concentrations for several parameters (BOD_5, COD, TSS, TN, TP)	Open data IAA-Government of Aragon (GA 2022)—see also (IAA 2021a): 1.3. Treatment plants, annual data: treated load and volume, discharge quality
Discharge census for each business (industrial or urban or similar) indicating the characteristics, volume, category, and receiving area type	CHE (2021)
Main legislation on maximum admissible water concentrations for several parameters	BOA (2004, 2018a, b)
GIS (Geographic Information System shapefiles) data on water and related areas: protected zones, vulnerable and sensitive areas to nitrates; linear surface masses noncomplying river stretches; chemical status of underground masses (Hydrological Ebro Plan, 2016–2021)	Own elaboration based on data from the CHE and the National Geographic Institute. The vulnerable and sensitive areas are derived from these sources. Rechecked with the data on WWTPs, in which the area of water discharge is also characterized as normal or as sensitive area
GIS (shapefiles) contours and auxiliary information (population, INE codes, voting results, etc.)	CHE (Ebro basin). For the municipalities and associated data by the INE, IAEST and Interior Ministry (voting results) and databases elaborated by Prof. Ángel Pueyo from the Department of Geography and Spatial Planning
GIS (shapefiles) data on irrigated areas	Corine Land Cover (CLC) from (Copernicus 2021) and HYDE 3.2 (Klein Goldewijk et al. 2017)
GIS (shapefiles) data on PGI (Protected Geographical Indications) and PDO (protected designation of origin) contours	Own elaboration based on the PGI and PDO definitions (GA 2021; MAPA 2021), generic and specific PGI and PDO webs, and merging municipalities' contours
Quantitative and qualitative data on the type of contracts (exploitation, concession) and budgets of WWTPs. List of signed contracts for the operation of the treatment plants, indicating the effective dates of each contract and the management model used. List of WWTPs in the exploitation or concession contracts	Own elaboration from Open data IAA-Government of Aragon (GA 2022), see also (IAA 2021a): 1.4. Contracts, general data 1.5. Contracts, treatment plants included 1.6. Contracts, annual expenses

(b)

Type of qualitative data interviews/reports	Main role of person interviewed/invited to present in conference/press and reports insights
Ebro Water Agency (CHE)	Interview with the main Head of the "Water quality" department
Aragonese Water Institute (IAA)	Interview with the main responsible person (Head) on water treatment and WWTP management
Agri-food and wine clusters	Discussion with/from the Aragonese main representative of the agri-food cluster, belonging to the wine-producing sector
Wine producers	Interviews and discussions with personnel who work or have worked in wine producing industries in Aragon
Cluster for the Efficient Use of Water (ZINNAE)	Interviews with the main representative (manager), who provided information, talks, press notes on the topic and from stakeholders in the cluster
Wastewater treatment businesses and managers	Interviews with several representatives (of different businesses providing depuration solutions (e.g., *Ingeobras* S.A., *Geezar* S.A., *PAMA* group)
Farmers' communities	Interviews and discussions with/from the technicians, e.g., of the Water Supply, Environment and External Relations of the largest farmers confederation

Table 1 (continued)

(b)

Type of qualitative data interviews/reports	Main role of person interviewed/invited to present in conference/press and reports insights
University and research centers	At least two people interviewed from each of the following expert areas: wine economic history, wine business management, water economics, water governance, water treatment solutions, law and environment
Social organizations	Interviews and discussions with organizations such as the New Water Culture Foundation (FNCA), Ecology and Development (ECODES) and Ecologists in Action
Type of tool	**Software/sources**
Text and data processing	Office software, *Happyscribe* and *Dictation.io* to convert audio/video to text
GIS processing and analysis	*Arc Map 10.5* as the main Geographical Information System (GIS) software
Text mining and Natural Language Processing (NLP) tools	*Google cloud*, *Python* (Natural Language Toolkit), to create classification of concepts, counting vocabulary, simple statistics and frequency distributions. This was done for all the discourses from interviews and for selected (audio and video) conferences and text (articles, journals)

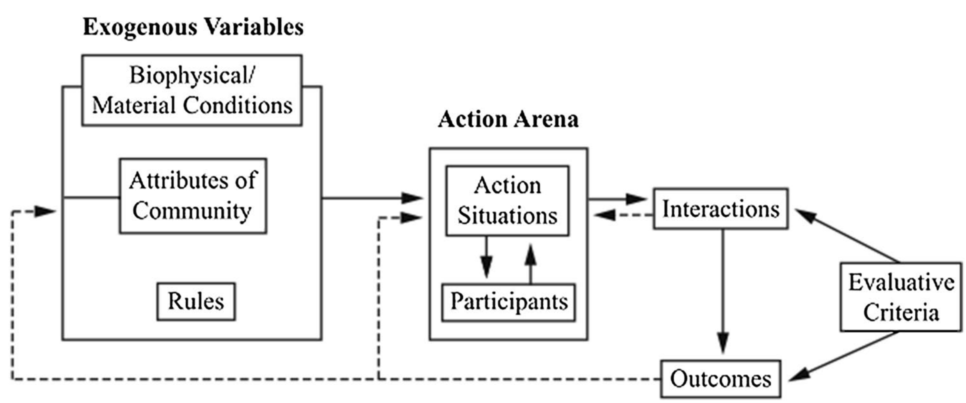

Fig. 5 Institutional analysis and development (IAD) framework. Source: Ostrom (2005), adapted from Ostrom et al. (1994)

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Data availability Data supporting the results reported in the article comes from the cited public sources and is available in the Supplementary Material. Also, the authors can make accessible additional information and data upon reasonable request.

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