frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 06 August 2025
DOI 10.3389/fenvs.2025.1590166

OPEN ACCESS

EDITED BY
Emna Guermazi,
Gabes University, Tunisia

REVIEWED BY
Kristen Welsh,
University of The Bahamas, Bahamas
Philip Barnes,
University of Delaware, United States

*CORRESPONDENCE
Cheryl Marie Cordeiro,
cheryl.marie.cordeiro@ri.se

RECEIVED 08 March 2025
ACCEPTED 23 July 2025
PUBLISHED 06 August 2025

CITATION
Cordeiro CM (2025) EU water directives through a semiotic lens: framing quality, risk, and circularity.
Front. Environ. Sci. 13:1590166.
doi: 10.3389/fenvs.2025.1590166

EU water directives through a semiotic lens: framing quality, risk, and circularity

Cheryl Marie Cordeiro*

Division of Built Environment, Department of Infrastructure and Concrete Structures, RISE Research Institutes of Sweden, Gothenburg, Sweden

European Union (EU) water governance operates through structured regulatory discourse that constructs meanings around water quality, risk, and circularity. These semiotic framings shape how environmental law is implemented, how compliance is defined, and how sustainability transitions are managed. This study applies a triadic semiotic framework of Greimassian semiotics, Social Semiotics, and Ecosemiotics, to analyze 11 foundational EU water directives. Using legal text analysis supported by AntConc software, the study deconstructs how regulatory language encodes categories, assigns agency, and positions ecological processes. The analysis reveals that water quality is primarily framed through rigid binary classifications such as compliant versus non-compliant, while risk is spatialized through threshold-based mapping and delineations of responsibility. Circularity is positioned mainly as an industrial-efficiency paradigm rather than an ecologically embedded process. These framings provide legal clarity and facilitate enforcement, but they also limit flexibility and reduce alignment with ecosystem dynamics. Social semiotic patterns show a consistent privileging of state and industrial actors, often marginalizing local communities and multispecies perspectives. Ecosemiotic analysis suggests that governance models rarely reflect the adaptive and fluid nature of aquatic systems. As a result, regulatory language may hinder ecosystem-based and transboundary approaches to water management. This research demonstrates that semiotic structures play a central role in shaping how environmental governance is operationalized. It argues for increased semiotic flexibility in legal design to better accommodate ecological complexity, institutional diversity, and climate variability. By advancing an interdisciplinary method that links semiotic theory with regulatory studies, this work offers new insights into how legal discourse mediates environmental outcomes in the EU context.

KEYWORDS

water governance, EU water directives, environmental policy analysis, regulatory discourse, risk regulation and adaptive governance, climate adaptation and water resilience

1 Introduction

Water governance is a critical domain of environmental policy, shaping how societies manage, regulate, and conceptualize water resources (D'Odorico et al., 2018; Zhang et al., 2018; Lynch et al., 2024; Mercure, 2022). Within the European Union (EU), water policy is institutionalized through a series of directives that establish legal, scientific, and economic frameworks for water protection, quality control, and sustainability (Green et al., 2013; Giakoumis and Voulvoulis, 2018). However, beyond its regulatory function, EU water

governance operates fundamentally as a semiotic system (Maran and Kull, 2014; Maran, 2020), where core concepts such as "quality," "risk," and "circularity" are actively constructed, contested, and communicated through regulatory texts, compliance thresholds, and institutionalized discourse.

Recent scholarship in environmental governance and discourse analysis underscores that policy texts do not merely describe environmental realities; rather, they actively shape them by constructing meanings around what constitutes acceptable water quality, sustainable management, and environmental risk (Leipold et al., 2019; Hajer and Versteeg, 2005; Dryzek, 2021). For example, the Water Framework Directive (WFD, 2000/60/EC) (European Parliament and Council of the European Union, 2000) institutionalizes the notion of "Good Ecological Status" (GES), yet the parameters for achieving GES remain technocratic and politically contested (Zhang, 2024). Similarly, the Nitrates Directive (91/676/EEC) (Council of the European Communities, 1991) transforms environmental degradation into quantifiable legal thresholds, converting dynamic ecological processes into static regulatory classifications. These examples illustrate the significant role semiotic choices play in policy documents, as they frame policy implementation by reinforcing specific regulatory interpretations of water quality, risk, and sustainability.

This study employs a triadic semiotic framework comprising Greimassian structuralism (Schleifer, 1987; Tarasti, 2017; Greimas, 1988), Social Semiotics (Halliday and Matthiessen, 2014; Halliday, 1978), and Ecosemiotics (Maran and Kull, 2014; Maran, 2020) to analyze how EU water governance directives construct and frame the concepts of "quality," "risk," and "circularity." The selection of these concepts is founded on their central importance to contemporary water governance debates, policy objectives, and regulatory practices (Zhang et al., 2018; D'Odorico et al., 2018; Ghodsvali et al., 2022). "Quality" forms a fundamental and recurring theme across EU directives, representing a cornerstone for compliance monitoring and public health protection. The concept of "risk" is crucial as it underpins regulatory interventions aimed at preventing environmental and health hazards, forming the basis for managing uncertainty and enforcing accountability within water governance. "Circularity," increasingly prominent in sustainability discourse, reflects an evolving governance paradigm that emphasizes resource efficiency, ecological regeneration, and long-term sustainability (Figge et al., 2023). Together, these concepts capture the breadth of water governance goals, encompassing immediate public health concerns, long-term ecological sustainability, and adaptive management practices.

The triadic semiotic framework, comprising Greimassian structuralism, Social Semiotics (Hallidayan tradition), and Ecosemiotics, to analyze EU water governance. Greimassian structural semiotics exposes how regulatory texts construct rigid binary oppositions (e.g., compliant/non-compliant, polluted/clean), revealing deep ideological tensions embedded in EU policy discourse. Social Semiotics, following Halliday's (1978) approach, highlights how regulatory discourse assigns agency and power, uncovering how policies position certain actors, such as farmers and municipalities, as responsible for governance compliance, while rendering others, including local communities, as passive recipients of regulatory intervention. Ecosemiotics, drawing from Maran and Kull (2014), expands this critical analysis by considering how natural ecological processes are framed and represented within policy, demonstrating potential gaps between governance systems and ecological realities, particularly where regulatory frameworks enforce rigid categories that may not align with ecological dynamics.

The central research question this study addresses is:

How do EU water directives construct and frame the meanings of "quality," "risk," and "circularity"?

To answer this question, this study will:

- Analyze the semiotic structures embedded in EU water directives, focusing on the textual and discursive representations of quality, risk, and circularity.
- Deconstruct the ideological and power dynamics that shape definitions of sustainability and environmental responsibility in regulatory discourse.
- Evaluate how semiotic choices influence governance outcomes, including regulatory enforcement, stakeholder perception, and cross-sector coordination.

The paper proceeds as follows: Section 2 provides a review of semiotic theory and its application in environmental governance, positioning this study within broader academic discussions of regulatory meaning-making and circular economy frameworks. Section 3 outlines the methodological approach, detailing the semiotic analysis of the 11 EU water directives through the lens of the selected triadic framework. Section 4 presents the findings and discussion, illustrating how the EU directives construct meanings around water quality, risk, and circularity through regulatory texts and symbolic governance frameworks. Finally, Section 5 summarizes the study's key contributions, addresses limitations, and proposes future research directions.

2 Theoretical framework and literature review

This study employs a triadic semiotic approach to critically examine how EU water governance directives construct meanings around "quality," "risk," and "circularity." Each framework allows the research to address distinct yet complementary dimensions of governance discourse. The selection of these three semiotic frameworks is grounded in their demonstrated relevance to policy discourse analysis and environmental governance, as evidenced by prior research in semiotics and regulatory studies.

2.1 Greimassian semiotics and regulatory binaries in governance

Greimassian semiotics, developed by Algirdas Julien Greimas, focuses on binary oppositions as fundamental structures of meaning-making (Candel, 2020; Tamminen, 2017). This analytical lens is particularly useful for examining governance texts, as legal and regulatory documents often rely on structured dichotomies to categorize compliance, risk, and environmental status. Prior studies have applied Greimassian analysis to sustainability narratives and circular economy discourse,

revealing how binary structures shape public and institutional perceptions of responsibility and action (Borrello et al., 2023). While Greimassian semiotics has been explored in broader narrative structures, its application to policy frameworks and corporate environmental reporting remains an area for further study (Pelkey, 2017).

Within environmental governance, binary classifications such as "clean vs. polluted," "safe vs. unsafe," and "compliant vs. non-compliant" create regulatory clarity but may oversimplify ecological complexity. The Water Framework Directive (WFD) (European Parliament and Council of the European Union, 2000) exemplifies this approach by defining water quality in terms of "Good Ecological Status" (GES), which strictly categorizes water bodies as either compliant or failing (Directive 2000/60/EC, p. 7). Similar binary structures can be found in the Drinking Water Directive (Council of the European Union, 1998), which reduces water safety to a pass/fail threshold based on pollutant concentration limits (Directive 98/83/EC, Article 4, p. 35).

While this classification system enhances legal enforceability, scholars have pointed out that rigid regulatory binaries can constrain adaptive management strategies by failing to accommodate ecosystem variability (Voulvoulis et al., 2017). This study extends Greimassian semiotic analysis into the domain of EU water governance, identifying how such binary framings influence governance outcomes, including regulatory enforcement and stakeholder engagement.

2.2 Social semiotics and the power dynamics of governance texts

Social Semiotics, originating with Michael Halliday's systemic functional linguistics (Halliday and Matthiessen, 2014; Halliday, 1978) and expanded by Theo Van Leeuwen (Van Leeuwen, 2008; Kress and Van Leeuwen, 2021) focuses on how language constructs power, agency, and institutional authority in governance contexts (Halliday and Hasan, 1985). Unlike traditional structuralist semiotics, Social Semiotics is concerned with how meaning emerges in social contexts and how different actors are positioned within governance discourse.

Prior applications of Social Semiotics in governance studies have examined how policies construct actor roles, emphasizing the hierarchical distribution of agency in environmental decision-making (Mirzyńska, 2023). For example, research on EU agricultural policy discourse has shown how farmers are often framed as passive implementers of sustainability measures rather than active participants in shaping regulatory goals (Perusset, 2023). Similarly, discourse analyses of corporate environmental reports highlight how corporations selectively frame their environmental responsibility to align with policy requirements while minimizing accountability (Borrello et al., 2023).

Applying Social Semiotics to EU water governance, this study examines how directives assign responsibility among different stakeholders. The Nitrates Directive (91/676/EEC) (Council of the European Communities, 1991), for instance, can be seen to attribute a disproportionate share of responsibility for nitrate pollution to farmers, reinforcing a governance model where individual actors bear the regulatory burden, while systemic industrial pollution sources remain less scrutinized (Directive 91/676/EEC, Annex I, p. 7). Similarly, the Floods Directive (European Parliament and Council of the European Union, 2007) primarily frames flood risk as a technical problem to be managed by state agencies, limiting community-driven resilience strategies (Directive 2007/60/EC, p. 29). By analyzing these textual constructions, this study highlights the implications of semiotic framing for policy implementation and regulatory enforcement.

2.3 Ecosemiotics and the intersection of regulatory and ecological systems

Ecosemiotics, a field developed by researchers such as Winfried Nöth and Kalevi Kull, examines how ecosystems function as semiotic systems that communicate through environmental signals, interspecies interactions, and adaptive processes (Nöth and Kull, 2000; Maran, 2020). While Greimassian and Social Semiotics focus on human-constructed discourse, Ecosemiotics extends analysis to how governance frameworks either align with or disrupt natural ecological semiotic systems (Maran and Kull, 2014).

Prior studies have applied Ecosemiotics to sustainability discourse, showing how regulatory frameworks can either reinforce or marginalize ecological sign systems (Zengiaro, 2022). Research in forest governance, for example, has demonstrated how rigid classifications of protected vs. non-protected areas fail to account for the adaptive and self-regulating dynamics of ecosystems (Maran and Kull, 2014). In water governance, ecosemiotic studies highlight tensions between technical water management approaches and natural hydrological cycles, particularly in cases where regulatory language prioritizes infrastructure-based interventions over ecological restoration strategies (Kanda and Kirchherr, 2023).

This study applies Ecosemiotics to analyze how EU water directives conceptualize environmental processes. The Water Reuse Regulation (2020/741) (European Parliament and Council of the European Union, 2020) frames circularity in terms of industrial water reuse, prioritizing compliance with quality standards over broader ecological functions such as aquifer recharge and natural hydrological regeneration (Regulation 2020/741, p. 32). Similarly, the Groundwater Directive (European Parliament and Council of the European Union, 2006b) establishes fixed contamination thresholds but does not account for natural filtering capacities of soil and vegetation, illustrating a semiotic tension between administrative control and ecological adaptability (Directive 2006/118/EC, p. 21).

By incorporating Ecosemiotics into the analysis, this study contributes to understanding how EU water governance balances regulatory certainty with ecological complexity, offering insights into how governance frameworks might evolve toward more adaptive, ecosystem-aligned policies.

2.4 Contributions and research gaps

The application of Greimassian semiotics to environmental policy has typically focused on sustainability narratives and

corporate discourse rather than governance directives (Pelkey, 2017). Social Semiotics has been widely used to analyze media and institutional texts but has been less frequently applied to the linguistic structuring of regulatory compliance (Ferreira, 2021). Ecosemiotics, while emerging as a critical tool in environmental communication studies, has yet to be widely utilized in analyzing the textual and symbolic representations of ecological systems within legal frameworks (Maran, 2020).

This study, therefore, makes a significant contribution by applying these frameworks collectively to EU water governance, demonstrating how semiotic constructs influence both administrative decision-making and policy implementation (Ravelli et al., 2023; Selg and Ventsel, 2022). Furthermore, by linking semiotic analysis with governance outcomes, this study provides a foundation for future research on how regulatory language might evolve to incorporate greater ecological adaptability and participatory governance models.

3 Methodology: semiotic analysis of EU water directives

This study employs a structured semiotic analysis of 11 key EU water directives, examining how regulatory texts construct and institutionalize meanings around quality, risk, and circularity. The methodological approach is grounded in Greimassian semiotics, Social Semiotics, and Ecosemiotics, providing a comprehensive framework for analyzing the textual, discursive, and ecological dimensions of water governance. This section outlines the justification for legal text analysis, the dataset selection, the semiotic analytical approach, and considerations regarding research validity and scope.

3.1 Justification for legal text analysis in semiotic research

Legal texts serve a dual function in governance: they are both prescriptive and performative, defining governance expectations while actively shaping policy implementation (Schweinberg and Raspotnik, 2024; Kioupi and Voulvoulis, 2020). Unlike other forms of discourse, regulatory frameworks must balance clarity and flexibility, ensuring enforceability while accommodating diverse environmental conditions across EU member states. As such, they provide a valuable lens for examining how governance constructs meaning through language, symbols, and classifications.

Prior studies in environmental law and governance have demonstrated how regulatory texts construct compliance and shape stakeholder agency through linguistic framing (Ferreira, 2021). The use of binary oppositions in legal texts, such as "compliant vs. non-compliant" or "safe vs. unsafe," reflects the structural necessity of legal language to define enforceable categories (Pelkey, 2017). However, research in social semiotics and ecosemiotics has shown that such classifications may not fully capture ecological dynamism or the socio-political complexities of policy implementation (Maran and Kull, 2014; Zengiaro, 2022). By systematically analyzing EU directives, this study contributes to ongoing discussions on how semiotic structures within governance frameworks influence regulatory enforcement, stakeholder engagement, and sustainability outcomes.

Unlike other forms of environmental governance research that rely on empirical data such as stakeholder interviews or case studies (Irshad et al., 2023; Anshelm et al., 2018), this study focuses exclusively on legal texts as the primary dataset. This choice is justified by the central role directives play in structuring governance expectations across the EU. As legal instruments, directives codify the discursive and institutional foundations of water policy, making them ideal for semiotic analysis. While the limitations of legal texts are acknowledged (Kmiecicka et al., 2023; Kowalczyk, 2023), their analysis provides crucial insights into how governance discourses frame regulatory objectives and structure environmental management practices.

3.2 Dataset: EU water governance directives

The 11 directives selected for this study represent the foundational legal instruments that structure EU water governance. Selection was guided by their centrality to the European Union's water management framework, particularly their formal linkage to or operational integration within the Water Framework Directive (2000/60/EC). These directives were chosen because they define key regulatory standards for water quality (e.g., Drinking Water Directive, Nitrates Directive), address hydrological risk and resilience (e.g., Floods Directive), or promote sustainability transitions in water use (e.g., Water Reuse Regulation). The inclusion criteria were informed by existing academic literature that identifies these instruments as core to EU water policy architecture (e.g., Voulvoulis et al., 2017; Grinsven et al., 2016), as well as by references in European Commission reports and policy documents on water governance. All 11 legal texts were included in the semiotic dataset for systematic analysis. The 11 EU directives and regulations, which serve as the primary legal instruments governing water management across the European Union include:

Dataset list of EU Water Directives:

1. Water Framework Directive (WFD) (2000/60/EC) – Establishes a comprehensive framework for protecting and improving the quality of water resources across the EU (European Parliament and Council of the European Union, 2000).
2. Marine Strategy Framework Directive (MSFD) (2008/56/EC) – Aims to protect the marine environment across Europe by ensuring that marine waters remain clean, healthy, and biologically diverse (European Parliament and Council of the European Union, 2008b).
3. Floods Directive (2007/60/EC) – Aims to assess and manage flood risks to mitigate the adverse consequences of flooding on human health, the environment, and economic activities (European Parliament and Council of the European Union, 2007).
4. Environmental Quality Standards Directive (EQSD) (2008/105/EC) – Sets environmental quality standards for various pollutants in surface waters to safeguard aquatic ecosystems

and human health (European Parliament and Council of the European Union, 2008a).

5. Groundwater Directive (2006/118/EC) – Provides standards for the protection and sustainable management of groundwater quality across the EU (European Parliament and Council of the European Union, 2006b).
6. Nitrates Directive (91/676/EEC) – Seeks to protect water quality by preventing nitrate pollution from agricultural sources through monitoring and regulatory measures (Council of the European Communities, 1991).
7. Drinking Water Directive (DWD) (98/83/EC) – Establishes strict quality standards for drinking water in the EU to ensure it is safe, clean, and free from contaminants (Council of the European Union, 1998).
8. Bathing Water Directive (2006/7/EC) – Regulates the management and quality of bathing waters in rivers, lakes, and coastal areas to protect public health (European Parliament and Council of the European Union, 2006a).
9. Urban Waste Water Treatment Directive (91/271/EEC) – Regulates the collection, treatment, and discharge of urban wastewater to minimize its impact on water bodies (European Parliament and Council of the European Union, 1991).
10. Industrial Emissions Directive (2010/75/EU) – Controls emissions from industrial activities to reduce their adverse effects on air, water, and land quality (European Parliament and Council of the European Union, 2010).
11. Water Reuse Regulation (2020/741) – Aims to promote the reuse of treated wastewater, particularly for agricultural irrigation, to enhance water resource efficiency (European Parliament and Council of the European Union, 2020).

These texts establish legal definitions, compliance mechanisms, and sustainability goals, providing a structured foundation for semiotic analysis. The selection of these directives is based on their fundamental role in structuring European water governance, with each directive addressing a specific aspect of water management, pollution control, risk mitigation, or sustainability.

The Water Framework Directive (2000/60/EC) serves as the overarching legal framework, integrating multiple water policies under a single governance system. Other directives, such as the Nitrates Directive (91/676/EEC) and Urban Waste Water Treatment Directive (91/271/EEC), regulate specific aspects of water pollution and treatment, while the Floods Directive (2007/60/EC) addresses risk management through probabilistic hazard mapping. The Water Reuse Regulation (2020/741) represents a contemporary governance approach that emphasizes circularity through industrial water reuse standards.

Previous studies in environmental governance have demonstrated how these directives interact and, at times, overlap in regulatory objectives. For instance, research on the Dutch implementation of the Water Framework Directive and Nitrates Directive illustrates the synergies and trade-offs between policy goals, particularly in balancing water quality targets with agricultural practices (Grinsven et al., 2016). By analyzing these directives collectively, this study provides a comprehensive perspective on regulatory discourse and governance strategies.

These directives provide a rich semiotic landscape for analysis, as they encompass definitions, compliance frameworks, and symbolic representations of governance.

3.3 Analysis approach: triadic semiotic framework

This study applies a tri-pronged semiotic analysis, integrating Greimassian semiotics, Social Semiotics, and Ecosemiotics to examine the construction of governance meanings across the dataset. The analysis proceeds in three stages:

1. Greimassian Semiotic Analysis – Identifies binary oppositions and structured meanings embedded in legal definitions. This stage examines how quality, risk, and circularity are framed through regulatory classifications, such as pass/fail compliance structures, pollution thresholds, and water quality assessments (Pelkey, 2017). For example, the Water Framework Directive constructs Good Ecological Status (GES) as a distinct category, simplifying complex ecological conditions into a legally enforceable classification (Directive 2000/60/EC, p. 7).
2. Social Semiotics Analysis – Investigates how agency and responsibility are distributed among different stakeholders. This stage examines how legal texts position actors such as governments, industries, and the public, reinforcing certain power relations while limiting others (Selg and Ventsel, 2022; Batu, 2012; Halliday and Matthiessen, 2014). For instance, the Nitrates Directive assigns primary responsibility for pollution control to farmers, framing regulatory compliance as an individual rather than a systemic burden (Directive 91/676/EEC, Annex I, p. 7).
3. Ecosemiotics Analysis – Assesses the alignment (or misalignment) between regulatory discourse and ecological systems. This stage evaluates whether governance texts acknowledge natural ecosystem processes, or whether they impose human-centric control mechanisms that may overlook environmental adaptability (Zengiaro, 2022; Maran, 2020). For example, the Water Reuse Regulation defines circularity through industrial water quality standards, but does not integrate broader ecological functions such as aquifer recharge or hydrological restoration (Regulation 2020/741, p. 32).

3.4 Research validity and scope

Rigor and transparency in this study are ensured by grounding its semiotic analysis in direct textual evidence from the directives. By systematically extracting explicit regulatory definitions, compliance mechanisms, and governance narratives, the analysis remains empirical and avoids speculative interpretations. The focus on legal texts allows for a structured examination of how regulatory language constructs meaning, shaping governance practices across EU member states.

However, legal texts constitute a distinct genre of governance discourse, designed primarily for clarity, enforceability, and compliance monitoring rather than adaptive ecological integration (Durant and Leung, 2019; Balogh, 2019). While semiotic analysis effectively reveals the structural and ideological underpinnings of governance language, it does not capture real-world enforcement challenges or stakeholder responses, which

TABLE 1 Greimassian semiotic analysis of EU water governance documents.[a]

Directive	Greimassian binary opposition	Direct quote and citation from text	Page/ Article
Water Framework Directive (2000/60/EC)	Good vs. Poor Ecological Status	"Good ecological status: the status of a body of surface water classified as good when both ecological and chemical statuses meet regulatory thresholds."	Article 2, p. 7
Drinking Water Directive (98/83/EC)	Safe vs. Unsafe Water Quality	"Water must be free from any microorganisms and substances which, in numbers or concentrations, constitute a potential danger to human health."	Article 4, p. 35
Floods Directive (2007/60/EC)	Flood Risk vs. Safety	"Flood risk means the combination of the probability of a flood event and of the potential adverse consequences associated with a flood event."	Article 2, p. 29
Groundwater Directive (2006/118/EC)	Compliance vs. Non-compliance	"Threshold values shall be established for groundwater pollutants, groups of pollutants and indicators of pollution . . . to protect groundwater."	Article 3, p. 21
Nitrates Directive (91/676/EEC)	Polluted vs. Unpolluted Waters	"Waters affected by pollution . . . contain or could contain nitrate concentrations greater than 50 mg/L"	Annex I, p. 7
Water Reuse Regulation (2020/741)	Circular vs. Linear Water Management	"Water reuse means the use of treated urban wastewater for agricultural irrigation in accordance with specific quality standards."	Article 2, p. 32

[a]Note: Binary distinctions listed in this table include both explicitly stated legal categories and analytically inferred oppositions based on the grammatical and modal construction of regulatory clauses. For example, clauses expressing legal obligations (e.g., "must be free from contaminants") imply thresholds that differentiate compliant from non-compliant states.

TABLE 2 Social semiotics analysis of EU water governance documents.

Directive	Direct quote from dataset	Social semiotic interpretation	Document & page
Water Framework Directive (2000/60/EC)	"Member States shall identify individual river basins lying within their national territory."	Assigns explicit agency to national governments, constructing them as responsible, compliant, and authoritative actors in governance	Article 3, p. 8
Nitrates Directive (91/676/EEC)	"Member States shall draw up action programmes in respect of designated vulnerable zones."	Positions agricultural stakeholders implicitly as defiant or problematic actors, requiring state-managed intervention	Article 5, p. 3
Drinking Water Directive (98/83/EC)	"Member States shall take the necessary measures to ensure that water intended for human consumption is wholesome and clean."	Centralizes agency and power in regulatory authorities; consumers are passive recipients, highlighting hierarchical power structures	Article 4, p. 3
Floods Directive (2007/60/EC)	"Member States shall, on the basis of the flood hazard maps and flood risk maps, establish flood risk management plans."	Frames national governments as proactive, compliant actors; implicitly excludes local communities as collaborative stakeholders	Article 7, p. 32
Water Reuse Regulation (2020/741)	"The operator shall ensure that reclaimed water complies at the point of compliance with the minimum requirements."	Confers significant agency on industrial operators, framing them as compliant actors entrusted with managing circularity, thus benefiting industrial stakeholders	Article 4, p. 34
Industrial Emissions Directive (2010/75/EU)	"Member States shall take the necessary measures to ensure that installations operate according to best available techniques."	Establishes state and industry as compliant actors working collaboratively to ensure adherence to technical standards, reinforcing centralized, technocratic governance	Article 11, p. 32

remain areas for future empirical research (Voulvoulis et al., 2017; Giakoumis and Voulvoulis, 2018).

To enhance analytical transparency, this study employed the concordance software AntConc (Anthony, 2024) to systematically identify recurring lexical patterns, collocations, and key terms related to quality, risk, and circularity across the eleven directives. AntConc enabled keyword-in-context (KWIC) analysis, helping isolate how legal texts lexically construct actors, agency, and normative expectations through repeated grammatical structures. For example, recurring modal verbs such as "shall," "must," and "may" were analyzed to infer obligation and discretion in regulatory commands. Active and passive constructions were used to assess agency assignment—revealing which actors (e.g., Member States, industries, the public) are tasked with implementation or compliance. These linguistic cues provided the empirical basis for categorizing semiotic patterns within the triadic framework. The use of AntConc also supports the replicability of the analysis and serves as a structured alternative to inter-coder reliability, which is less applicable in single-author, grammar-based textual studies. The methodological framework highlights both the strengths and constraints of regulatory language in balancing administrative clarity with ecological complexity, offering insights into how governance discourse influences water policy implementation.

4 Analysis and discussion

While all 11 EU water directives were systematically analyzed using the triadic framework, not every directive produced equally distinctive or illustrative patterns across the thematic categories of quality, risk, and circularity. The selection of directives presented in

TABLE 3 Ecosemitoics framing in EU water governance documents.

Directive/Regulation	Data-driven quote (exact from directive)	Ecosemiotic framing	Article & page
Water Framework Directive (2000/60/EC)	"Surface water and groundwater are in principle interconnected systems, and measures adopted... should be coordinated for the whole of the river basin district."	Recognizes interconnected ecosystems but operationalizes governance through fixed management plans, limiting adaptive ecosystem management	Article 3, p. 8
Marine Strategy Framework Directive (2008/56/EC)	"An ecosystem-based approach to the management of human activities while enabling the sustainable use of marine goods and services."	Frames marine ecosystems as dynamic and interdependent but constrains their adaptive potential within rigid monitoring frameworks and quantitative targets	Article 1, p. 20
Floods Directive (2007/60/EC)	"Flood risk management plans... shall take into account areas which have the potential to retain flood water, such as natural floodplains."	Acknowledges ecological resilience and adaptive flood management through natural floodplains but prioritizes engineering solutions	Article 7, p. 32
Groundwater Directive (2006/118/EC)	"Threshold values shall be established for groundwater pollutants... to protect groundwater."	Frames groundwater quality within static numeric thresholds, marginalizing dynamic ecological processes and adaptive groundwater management	Article 3, p. 21
Nitrates Directive (91/676/EEC)	"Waters affected by pollution are those ... which contain or could contain nitrate concentrations greater than 50 mg/L"	Frames ecological conditions strictly through numeric thresholds, simplifying complex nutrient cycling into rigid compliance categories, constraining adaptive ecosystem responses	Annex I, p. 7
Water Reuse Regulation (2020/741)	"Water reuse means the use of treated urban wastewater for agricultural irrigation in accordance with specific quality standards."	Defines circularity predominantly as industrial and technological water reuse, overlooking broader ecological regeneration practices such as natural aquifer recharge and wetland restoration	Article 2, p. 32

Tables 1–3 reflect those that provided the clearest or most representative semiotic constructions relevant to each dimension. Some directives contained minimal or peripheral references to the specific themes under analysis, while others demonstrated more explicit, patterned uses of regulatory language, actor positioning, or ecological framing that aligned with the semiotic categories. Therefore, the six directives highlighted in the results are not the only ones examined, but rather those that offered particularly salient examples of how semiotic structures function within EU water governance discourse. This selective presentation aims to ensure analytic clarity while still grounding the findings in the full dataset.

4.1 Greimassian Semiotic Analysis

Greimassian semiotic analysis systematically examines binary oppositions that structure regulatory language within the EU water governance directives (Tamminen, 2017; Candel, 2020). These oppositional constructs serve as foundational tools for simplifying complex environmental realities, translating them into legally manageable and enforceable categories. In applying the Greimassian lens, this study distinguishes between binaries explicitly stated in legal texts (e.g., "good vs. poor ecological status") and those inferred from the linguistic structure or regulatory logic. For example, modal constructions such as "water must be free from..." establish an implicit threshold, distinguishing between acceptable and unacceptable states. These analytical inferences are based on the grammatical function of obligation and the governance imperative to demarcate compliance boundaries, consistent with prior semiotic and discourse-analytical approaches in legal texts. Table 1 illustrates select examples of these binary oppositions, drawn directly from regulatory texts, highlighting how governance discourse simplifies ecological processes into clear-cut legal definitions.

The Water Framework Directive (2000/60/EC) exemplifies such binary structuring through its concept of Good Ecological Status (GES), explicitly defined as "the status of a body of surface water classified as good when both ecological and chemical statuses meet regulatory thresholds" (Directive 2000/60/EC, p. 7). This binary categorization is advantageous as it provides clarity for policy interpretation and straightforward compliance evaluation, thus enabling efficient enforcement across diverse EU contexts. However, this simplification is also disadvantageous, as it may neglect the inherent ecological variability of water bodies, potentially limiting adaptive environmental management practices.

Similarly, the Drinking Water Directive (98/83/EC) constructs a clear binary between safe and unsafe drinking water, requiring water to be "free from any microorganisms and substances which, in numbers or concentrations, constitute a potential danger to human health" (Article 4, p. 3). Such clear-cut distinctions effectively communicate health standards and enable uniform monitoring, creating widespread confidence in water safety regulations. Yet, the rigid binary approach can overlook gradations of risk and complexity in microbial and chemical interactions, potentially oversimplifying conditions that are inherently dynamic.

The Floods Directive (2007/60/EC) frames flood risk through a dualistic structure as "the combination of the probability of a flood event and of the potential adverse consequences" (Article 2, p. 29). This binary framing simplifies flood risk assessment into measurable probabilities and tangible outcomes, facilitating clear communication and efficient administrative responses. Nevertheless, this approach can reduce the nuanced and evolving nature of flood dynamics, potentially neglecting resilience-based and adaptive management strategies in favor of rigid hazard mitigation measures.

The Groundwater Directive (2006/118/EC) similarly employs strict "threshold values" to determine groundwater quality compliance (Article 3, p. 21). This approach has the practical

benefit of clearly delineating compliant from non-compliant water bodies, aiding straightforward regulatory oversight. However, these fixed thresholds may also fail to adequately reflect the complexity and temporal variability of groundwater systems, potentially impeding comprehensive ecological assessments and adaptive responses.

Likewise, the Nitrates Directive (91/676/EEC) defines pollution explicitly through numeric thresholds, categorizing waters as polluted when nitrate concentrations exceed "50 mg/L" (Annex I, p. 7). This numeric criterion effectively standardizes the assessment and enforcement of agricultural compliance. Yet, such rigid numeric criteria may oversimplify pollution sources and dynamics, potentially burdening agricultural stakeholders without adequately addressing systemic, cumulative environmental impacts.

Finally, the Water Reuse Regulation (2020/741) clearly contrasts linear and circular approaches, defining water reuse as "the use of treated urban wastewater for agricultural irrigation in accordance with specific quality standards" (Article 2, p. 32). This binary opposition serves to promote resource efficiency by clearly distinguishing desirable circular practices from unsustainable linear ones. Nevertheless, such framing may emphasize technocratic measures at the expense of broader ecological regeneration principles, potentially limiting more holistic, ecosystem-based circular solutions.

In general, the binary structures embedded in regulatory texts facilitate clarity, enforceability, and administrative efficiency, which are central features of legal genre discourse. However, these same binaries risk simplifying and constraining the inherently dynamic and complex ecological conditions they seek to manage, potentially limiting more nuanced and adaptive governance approaches.

4.2 Social semiotic analysis of EU water governance directives

Social semiotic analysis, utilizing Halliday's Functional Grammar (Halliday, 1994; Halliday and Matthiessen, 2014), explores how EU water directives linguistically assign agency, responsibility, and power to various stakeholders, thereby shaping the governance narrative around "quality," "risk," and "circularity." By closely examining textual examples from the dataset, this analysis highlights the subtle yet significant ways stakeholders are positioned as either compliant actors, defiant entities, or beneficiaries within EU water policy frameworks. Table 2 presents examples of text from the EU water governance directives. The clauses illustrate how regulatory language assigns agency, compliance roles, and responsibilities to stakeholders. The clauses highlight the hierarchical governance structures that reinforce the power dynamics between governments, industries, farmers, and local communities.

The Water Framework Directive (2000/60/EC) explicitly assigns significant responsibility and agency to member states, stating that "Member States shall identify individual river basins lying within their national territory" (Article 3, p. 8). In this clause, the national governments are constructed as active participants ("shall identify"), holding primary accountability for compliance and implementation. The repeated use of imperative modal verbs ("shall") reinforces state responsibility and positions national authorities as central compliance agents.

Conversely, the Nitrates Directive (91/676/EEC) predominantly assigns agency to agricultural stakeholders as contributors to pollution. The directive mandates that member states must designate vulnerable zones and implement action programs, explicitly noting that "Member States shall draw up action programmes in respect of designated vulnerable zones" (Article 5, p. 3). Through this language, farmers and agricultural enterprises become indirectly framed as defiant or non-compliant actors who require regulatory intervention, contrasting with the relatively passive framing of other industrial sectors. Such discourse highlights an implicit power dynamic, where agricultural actors bear disproportionate regulatory burdens.

In the Drinking Water Directive (98/83/EC), agency is concentrated predominantly among regulatory authorities and water suppliers. The directive specifies, "Member States shall take the necessary measures to ensure that water intended for human consumption is wholesome and clean" (Article 4, p. 3). Here, national authorities are positioned as proactive guardians of public health, while consumers are linguistically framed as passive beneficiaries rather than active participants. This distribution of roles implies limited scope for consumer-led initiatives or community engagement, implicitly reinforcing hierarchical governance structures.

The Floods Directive (2007/60/EC) positions member states explicitly as proactive risk managers, stating, "Member States shall, on the basis of the flood hazard maps and flood risk maps, establish flood risk management plans" (Article 7, p. 32). The directive frames risk management as a state-centered activity, with little linguistic acknowledgment of local community input or adaptive community-based resilience. Thus, communities are implicitly constructed as recipients of risk mitigation rather than collaborative participants, suggesting a preference for technocratic and centrally administered solutions.

The Water Reuse Regulation (2020/741) constructs circularity as primarily industrially managed, emphasizing technical compliance. It states explicitly, "The operator shall ensure that reclaimed water complies at the point of compliance with the minimum requirements" (Article 4, p. 34). This construction attributes significant responsibility to industrial operators, positioning them as compliant actors entrusted with the technical and regulatory execution of circular economy principles. Simultaneously, this framing excludes community-driven or ecological regenerative approaches, benefiting large-scale operators and industries.

Applying Halliday's functional grammar, particularly the analysis of participants, processes, and modality, reveals that EU directives consistently assign high agency to state actors and industrial operators, emphasizing regulatory compliance through centralized, technocratic mechanisms. Farmers are linguistically framed as inherently defiant stakeholders who must be regulated, whereas local communities and individual citizens emerge predominantly as passive beneficiaries with minimal active governance roles.

The data-driven social semiotic findings highlight that the EU water governance discourse prioritizes clear regulatory structures, centralizing governance authority and accountability. While this provides administrative clarity, it concurrently marginalizes decentralized, community-based, or adaptive governance strategies, potentially limiting stakeholder engagement and

diminishing opportunities for more holistic, collaborative, and resilient water management practices.

4.3 Ecosemiotics Analysis

Ecosemiotic analysis provides an interpretive lens that examines how EU water governance directives align with or diverge from ecological processes, emphasizing the communicative and adaptive dimensions of ecosystems. Unlike Greimassian and Social Semiotics analyses, Ecosemiotics focuses specifically on whether the regulatory discourse acknowledges water as an inherently dynamic, self-regulating system. Table 3 shows a selection of examples of ecosemiotics framing from the dataset.

The Water Framework Directive explicitly acknowledges ecological interactions by highlighting the interconnectedness of water systems: "Surface water and groundwater are in principle interconnected systems," necessitating coordinated governance across "river basin districts" (Directive 2000/60/EC, p. 8). This statement recognizes the interconnected nature of ecosystems, yet the operationalization through fixed classification and management plans suggests a limited appreciation of ecological adaptability.

The Marine Strategy Framework Directive similarly recognizes ecological complexity, stating the need to consider the "ecosystem-based approach to the management of human activities while enabling the sustainable use of marine goods and services" (Directive 2008/56/EC, p. 20). Here, ecological systems are conceptualized as interactive and self-regulating entities. However, the directive primarily emphasizes measurable targets and monitoring of "good environmental status" indicators, potentially constraining a genuinely adaptive ecological management strategy within rigid administrative frameworks.

The Floods Directive explicitly acknowledges ecological dynamics, noting "the natural retention capacities of floodplains" (Directive 2007/60/EC, p. 29). Despite this acknowledgment, the directive's primary operational approach remains engineering-based flood risk management, highlighting tension between recognizing natural ecological resilience and prioritizing structural flood defenses.

In the Groundwater Directive, ecological dynamics appear somewhat marginalized by strict regulatory measures, as evidenced by its focus on maintaining "groundwater quality standards" via fixed "threshold values" (Directive 2006/118/EC, Article 3, p. 21). This regulatory structure suggests an ecological system viewed primarily through static thresholds rather than as adaptive processes that fluctuate over time.

The Nitrates Directive similarly frames ecological processes through static numeric thresholds, defining polluted waters by nitrate concentrations exceeding "50 mg/L" (Directive 91/676/EEC, Annex I, p. 7). This quantitative approach potentially limits adaptive ecological governance by constraining ecosystem dynamics within fixed numeric benchmarks, failing to capture natural variation and nutrient cycling complexity.

Finally, the Water Reuse Regulation explicitly defines "reclaimed water" as wastewater treated to meet precise standards for reuse (Regulation 2020/741, Article 2, p. 32). This conceptualization, while promoting resource efficiency, constructs ecological circularity primarily in industrial and technological terms, marginalizing more complex regenerative ecological processes such as wetland restoration or natural aquifer recharge.

Ecosemiotic analysis highlights a nuanced semiotic tension embedded within EU water governance directives. By their genre, regulatory texts necessarily prioritize clarity, enforceability, and administrative coherence, translating ecological complexity into explicit, measurable criteria. While such simplification enables effective governance across diverse contexts, it simultaneously risks constraining the adaptive flexibility essential for managing dynamic ecological systems. This tension reflects a broader challenge: balancing the administrative necessity of precise regulation against the ecological reality of inherently variable natural processes. Recognizing this balance is critical for assessing the effectiveness of regulatory language in capturing and responding to ecological dynamism within governance frameworks.

5 Discussion: framing quality, risk, and circularity in EU water governance

The analysis of EU water governance directives, guided by the triadic semiotic framework, reveals nuanced insights into how the concepts of quality, risk, and circularity are constructed and communicated within EU water policy. This section critically discusses how these semiotic constructions influence governance practices, stakeholder engagement, and sustainability outcomes.

5.1 Framing water quality: regulatory clarity vs. ecological complexity

EU directives predominantly frame water quality in explicit, binary regulatory terms, clearly defining acceptable standards to ensure clarity and ease of compliance monitoring. The Water Framework Directive (2000/60/EC) defines water quality through explicit regulatory thresholds such as Good Ecological Status (GES), categorizing water bodies into clearly delineated states of compliance (Directive 2000/60/EC, p. 7). Practical implementation of GES in the Rhine River Basin has demonstrated both the utility and the limitations of this framing. Authorities found that while fixed regulatory thresholds facilitated consistency and compliance across multiple jurisdictions, the diverse and dynamic ecological characteristics of the Rhine posed challenges, reflecting an underlying tension between regulatory clarity and ecological complexity (Voulvoulis et al., 2017, p. 360).

Beyond the Rhine, similar tensions arise in Southern Europe, particularly in Italy and Greece, where water scarcity and climate variability complicate the application of standardized quality measures. In Italy, for example, fluctuating seasonal water availability has impacted the ability to maintain GES in certain river basins, raising concerns about whether strict compliance thresholds are feasible in hydrologically unstable regions (Grizzetti et al., 2017). In Greece, where karstic groundwater systems are predominant, the interaction between natural hydrogeological processes and anthropogenic influences challenges the effectiveness of fixed chemical water quality indicators, revealing gaps in regulatory adaptability (Skoulikidis et al., 2011). These examples underscore how semiotic rigidity in

defining quality, while ensuring policy consistency, may inadvertently constrain context-sensitive governance approaches that account for regional hydrological conditions.

Similarly, the Drinking Water Directive (98/83/EC) constructs quality explicitly in terms of water safety, reducing complex biological and chemical dynamics into rigid numeric thresholds and categorical boundaries (Directive 98/83/EC, Article 4, p. 3). Implementation experiences from Eastern European countries revealed improvements in public health outcomes due to clear compliance criteria; however, they also highlighted difficulties in rural regions, where governance capacities struggled to sustain these rigid standards consistently (European Commission, 2014). Studies on drinking water governance in Bulgaria, for instance, show that smaller municipalities face financial and infrastructural limitations in maintaining strict quality controls, leading to disparities between urban centers with well-developed water treatment facilities and rural areas where compliance remains inconsistent (Toneva and Dimitrova, 2024). These cases illustrate the semiotic tension inherent in regulatory frameworks that simplify ecological dynamics to enhance administrative clarity and governance efficiency. Recognizing this tension invites reflection on how regulatory frameworks could better accommodate ecological adaptability without sacrificing the clarity necessary for effective governance.

5.2 Framing risk: balancing predictability and adaptive strategies

EU water directives frequently rely on structured regulatory categorizations and spatial delineations to define and manage environmental risk and uncertainty. This approach reflects an administrative priority for legal clarity, enforceability, and comparability across diverse national governance contexts. Among the 11 directives analyzed, several reference risk, but the Floods Directive (2007/60/EC) and the Nitrates Directive (91/676/EEC) provide particularly salient and widely debated examples for examining how risk is framed semiotically. Both directives translate complex environmental uncertainties into spatially and numerically defined management categories. For example, the Floods Directive employs probabilistic models to assess the likelihood and impact of flood events (Directive 2007/60/EC, p. 29). While these models characterize flood risk along a spectrum of probability, the resulting governance tools often reduce this spectrum into binary spatial classifications, such as areas designated as flood-prone versus those considered not at risk. This semiotic shift from continuous probability distributions to categorical zoning illustrates a structural simplification that supports administrative enforcement but may obscure the dynamic nature of hydrological risk. These regulatory framings, though valuable for establishing consistent policy responses, may hinder more adaptive or ecosystem-based flood resilience strategies, particularly in the face of climate variability and evolving land-use pressures (Baack et al., 2024; Eerd et al., 2015).

In highly flood-prone regions such as the Netherlands and Belgium, the semiotic framing of risk in the Floods Directive has played a central role in shaping infrastructure investment and adaptation strategies. The Dutch Room for the River program exemplifies an approach that, while operating within EU regulatory frameworks, extends beyond traditional flood defense mechanisms by integrating nature-based solutions to enhance resilience (Zevenbergen et al., 2015). However, some studies indicate that the directive's emphasis on probabilistic risk modeling and hazard mapping may reinforce a predominantly engineered approach to flood management, potentially sidelining community-driven adaptive measures that leverage local knowledge systems (Eerd et al., 2015). In Belgium, the implementation of the directive has been characterized by a strong reliance on zoning strategies, yet evaluations suggest that rigid demarcations of flood-prone areas have occasionally led to unforeseen social consequences, including property devaluation and limited urban expansion opportunities (Mees et al., 2016).

Similarly, the Nitrates Directive (91/676/EEC) frames agricultural pollution through numerical thresholds and spatial delineations, such as nitrate-vulnerable zones (Directive 91/676/EEC, Annex I, p. 7). This approach has strengthened regulatory enforcement, making it easier to identify areas requiring intervention. Evaluations of its implementation in the Netherlands suggest that the directive has contributed to measurable reductions in nutrient surpluses and improved groundwater quality (Grinsven et al., 2016). However, studies also highlight the complexities of achieving sustained reductions, as nitrate levels in certain regions remain above regulatory thresholds due to factors such as soil composition, groundwater flow, and cumulative land-use effects (Abascal et al., 2022).

While these regulatory approaches provide coherence and legal certainty, they also reflect the balancing act between standardization and adaptability. The emphasis on clear categorizations ensures consistent application but may, in some cases, require complementary adaptive strategies to address site-specific ecological and hydrological conditions.

5.3 Framing circularity: industrial efficiency vs. ecological regeneration

Among the 11 EU directives analyzed, only the Water Reuse Regulation (2020/741) includes explicit and substantial provisions addressing circularity in water governance. As such, it serves as the primary illustrative case in this thematic analysis. In this regulation, circularity is framed predominantly through a technocratic and efficiency-driven paradigm. It emphasizes wastewater reuse for agricultural and industrial applications, underpinned by strict quality standards and performance monitoring requirements (Regulation 2020/741, p. 32). While this framing facilitates measurable compliance and encourages investment in reuse infrastructure, it simultaneously marginalizes broader ecological dimensions of circularity, such as aquifer recharge, wetland regeneration, and the restoration of natural hydrological cycles.

Empirical evidence supports this observation. Research on the implementation of circular water governance models in industrial ecosystems has shown that strict adherence to quality standards often leads to the centralization of water reuse in large-scale, technologically advanced treatment plants. This model limits opportunities for decentralized or community-led reuse strategies and deprioritizes ecosystem-based solutions (Kanda and Kirchherr, 2023).

In Spain, for example, the reuse of treated wastewater for agricultural irrigation has been successfully scaled in regions such as Murcia, where regulatory certainty facilitated investment in infrastructure and allowed for consistent water reclamation efforts (Pedrero and Alarcón, 2009). Murcia is recognized as a leader in water reuse, recycling approximately 90% of its treated wastewater through an advanced sanitation and purification system (Gómez-Ramos et al., 2024). However, while this model has strengthened irrigation reliability and improved water efficiency for agricultural and industrial users, critics argue that it prioritizes economic and technical objectives while overlooking more integrated landscape-based approaches that consider ecosystem restoration and natural hydrological cycles (Albaladejo et al., 2013). Similarly, studies in the Netherlands highlight how industrial reuse of wastewater aligns well with EU directives but often bypasses opportunities for ecological restoration due to the rigid classification of reclaimed water as an industrial resource (Kanda and Kirchherr, 2023).

These cases illustrate the semiotic framing of circularity within EU water governance. The dominant discourse constructs circularity as a technical-industrial process aimed at resource efficiency and compliance, rather than a holistic system that integrates natural cycles and ecological regeneration. A broader conceptualization of circularity, one that acknowledges not only economic and industrial efficiencies but also the ecological and social dimensions of water reuse, could foster a more integrated and resilient governance approach.

5.4 Synthesis: semiotic tensions and policy implications

The semiotic constructions identified through Greimassian, Social Semiotics, and Ecosemiotic lenses collectively highlight an overarching governance approach in EU water policy that prioritizes clarity, enforceability, and administrative simplicity. However, rigid definitions of quality, risk, and circularity may inadvertently constrain the adaptive responses necessary for long-term ecological resilience. Enhancing the semiotic flexibility of water governance frameworks by explicitly incorporating ecosystem-based, adaptive strategies could offer pathways toward more integrated, responsive, and sustainable water management.

6 Conclusion

This study applied a triadic semiotic framework to examine how EU water directives construct and institutionalize meanings of quality, risk, and circularity. Through a detailed analysis of regulatory texts, the study revealed how governance discourse structures environmental responsibility, compliance frameworks, and sustainability narratives. While EU water directives provide clarity and legal enforceability, their semiotic framing also introduces structural limitations that influence ecological adaptability and stakeholder engagement. By integrating semiotic analysis into environmental governance research, this study offers both methodological and policy-relevant insights into how regulatory language functions in structuring environmental management.

6.1 Contributions to semiotic methodologies in environmental governance

This research advances the application of semiotics in environmental governance by demonstrating how different semiotic lenses can be integrated to provide a multidimensional critique of policy discourse. While previous semiotic studies have primarily focused on cultural texts or political communication, this study extends semiotic methodologies to legal texts, illustrating how directives function as performative instruments that define policy while constructing meaning in ways that influence governance practice.

Specifically, this study contributes to semiotic methodologies in three key ways. First, it highlights how Greimassian binary oppositions structure regulatory texts, reinforcing distinctions between categories such as “compliant/non-compliant” and “safe/unsafe.” Second, it demonstrates how Social Semiotics reveals power asymmetries in governance, showing how directives assign responsibility unevenly among different actors, often privileging state and industrial entities over local and ecological agencies. Third, it applies Ecosemiotics to assess how regulatory discourse translates ecosystems into administratively manageable objects, sometimes overlooking their inherent adaptability.

These methodological contributions suggest that semiotic analysis is a valuable tool for environmental governance research, offering new ways to understand how regulatory language influences both policy implementation and ecological sustainability. Future applications of semiotics in governance studies could expand beyond textual analysis to include multimodal semiotics, exploring how visual elements, such as compliance maps, risk assessments, and environmental indicators, contribute to governance meaning-making.

Finally, it is worth acknowledging a reflexive dimension of this analysis. In critiquing the binary framings embedded in EU regulatory texts, the study itself employs dichotomous constructs, such as clarity versus adaptability, or technocratic versus ecological orientations as analytical tools. This mirrors the structural tendency of both policy and academic discourse to rely on binary distinctions for argumentative clarity. Recognizing this performative aspect reinforces the need for future research to explore more dynamic or continuum-based models of semiotic governance analysis.

6.2 Implications for EU water policy and governance adaptability

The findings of this study have direct implications for EU water policy, particularly in enhancing governance flexibility while maintaining regulatory clarity. One of the key tensions identified is the semiotic rigidity of current directives, which rely heavily on fixed compliance thresholds and categorical distinctions. While these regulatory features are necessary for legal enforcement, they

may also constrain ecological resilience and adaptive governance strategies.

One potential reform could involve integrating gradual compliance thresholds instead of binary categorizations. For example, instead of defining Good Ecological Status (GES) in the Water Framework Directive as a strict pass/fail condition, regulators could adopt a gradient-based assessment model that accounts for ecological transitions and seasonal variations. Similarly, the Nitrates Directive could introduce adaptive nitrogen management frameworks that allow for site-specific variations rather than applying uniform numeric thresholds across all nitrate-vulnerable zones.

Another policy implication is the need for greater alignment between EU water directives and broader sustainability initiatives, such as the European Green Deal and the UN Sustainable Development Goals (SDGs). This study has shown that while EU directives establish clear governance frameworks, they often operate in isolation, without fully integrating cross-sectoral sustainability concerns. Future revisions of EU water policies could explicitly incorporate ecological regeneration strategies, such as aquifer recharge, wetland restoration, and circular water use, that go beyond industrial efficiency-driven models.

Additionally, policymakers could benefit from semiotic impact assessments when designing new regulations. Just as environmental impact assessments (EIAs) are required for infrastructure projects, semiotic evaluations could be conducted to examine how proposed policies construct meaning and whether they risk reinforcing governance biases or excluding critical ecological perspectives.

6.3 Future research directions

This study opens several avenues for future research in both semiotics and environmental governance.

6.3.1 Expanding semiotic approaches to visual representations

While this study has focused on textual analysis, future research could explore how multimodal semiotics applies to governance visualization. Compliance maps, environmental dashboards, and digital monitoring systems play an increasingly central role in EU environmental governance. Investigating how these visual representations frame risk, responsibility, and ecological stability could offer additional insights into how governance meaning is produced beyond legal texts.

6.3.2 Comparative analysis of EU and international water governance

Another promising research direction is to compare EU water governance frameworks with international models, such as:

- The US Clean Water Act (CWA), which employs a mix of federal and state-level regulations but has faced challenges in balancing industrial exemptions with water quality standards (Copeland, 2016).
- China's Water Ten Plan, which integrates economic incentives and strict enforcement mechanisms to control water pollution but operates within a different political and administrative framework (Zheng et al., 2022).
- Australia's Murray-Darling Basin Plan, which applies a market-based water allocation system, raising questions about how semiotic constructs of ownership and resource distribution influence policy effectiveness (Hart, 2016; Colloff and Pittock, 2019; Horne, 2014).

Such comparative studies could reveal how different governance cultures construct water-related meanings, offering insights into how EU regulatory discourse aligns with or diverges from global governance trends.

6.3.3 Semiotic perspectives on climate adaptation in water governance

Given the increasing urgency of climate change, future research could investigate how semiotic flexibility can support adaptive governance models. For instance, could directives be rewritten to incorporate climate-resilient water policies that shift from static regulatory thresholds to dynamic, ecosystem-responsive governance structures? Addressing this question could help policymakers design water directives that remain legally robust while allowing for greater environmental adaptability.

6.4 Final reflections

This study underscores the role of semiotic constructions in shaping governance discourse, revealing how EU water directives both enable and constrain regulatory flexibility. While directives serve as essential governance instruments, their textual and discursive structures influence not only legal enforcement but also how stakeholders perceive environmental responsibility, risk, and sustainability.

By employing a semiotic lens, this research has demonstrated how Greimassian structures, Social Semiotics, and Ecosemiotics together provide a multidimensional analysis of governance discourse, uncovering the implicit ideological frameworks that shape policy narratives. These findings suggest that a more semiotically aware approach to policymaking, one that actively considers how language, power, and ecological signification interact, could enhance the effectiveness and adaptability of EU water governance frameworks in a changing environmental landscape.

The semiotic study of regulatory discourse can be viewed not just an academic exercise but a practical tool for improving governance outcomes. By recognizing the ways in which policies construct meaning, future governance reforms can move toward greater inclusivity, resilience, and ecological integration, ensuring that EU water management frameworks remain effective in addressing both present and emerging environmental challenges.

Data availability statement

The datasets analyzed for this study consist of publicly accessible EU water governance directives and regulations. These documents are available in the EUR-Lex database, the official legal repository of European Union law. The full texts of the directives can be accessed at the following link: https://eur-lex.europa.eu.

Author contributions

CM: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review and editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This research was funded by the European Union's Horizon Europe programme under the FERTITEC project, Grant Agreement No. 101181513. The project is coordinated by RISE Research Institutes of Sweden AB and is funded under the Food, Bioeconomy, Natural Resources, Agriculture, and Environment cluster. The study contributes to EU policy priorities, including digital transformation, clean air, artificial intelligence, climate action, and biodiversity. DOI: 10.3030/101181513.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

References

Abascal, E., Gómez-Coma, L., Ortiz, I., and Ortiz, A. (2022). Global diagnosis of nitrate pollution in groundwater and review of removal technologies. *Sci. Total Environ.* 810, 152233. doi:10.1016/J.SCITOTENV.2021.152233

Albaladejo, A., Trapote, A., and Simón, P. (2013). *Energy consumption in an urban wastewater treatment plant: the case of Murcia region (Spain).*

Anshelm, J., Haikola, S., and Wallsten, B. (2018). Politicizing environmental governance – a case study of heterogeneous alliances and juridical struggles around the ojnare forest, Sweden. *Geoforum* 91, 206–215. doi:10.1016/J.GEOFORUM.2018.03.003

Anthony, L. (2024). AntConc (Version 4.3.1) [Computer Software]. Tokyo, Japan: Waseda University. Available online at: https://www.laurenceanthony.net/software/AntConc. (Accessed November 12, 2024).

Baack, F., Özerol, G., Vinke-de Kruijf, J., Halman, J., and Kuks, S. (2024). Implementing climate change adaptation through mainstreaming at the local Level—a comparative case study of two municipalities in the Netherlands. *Reg. Environ. Change* 24 (2), 49. doi:10.1007/S10113-024-02214-7

Balogh, D. (2019). The role of genres and text selection in legal translator training. *Stud. Log. Gramm. Rhetor.* 58 (1), 17–34. doi:10.2478/SLGR-2019-0015

Batu, B. (2012). An overview of the field of semiotics. *Procedia - Soc. Behav. Sci.* 51, 464–469. doi:10.1016/j.sbspro.2012.08.190

Borrello, M., Cembalo, L., and D'Amico, V. (2023). Narratives to revert overconsumption: human-nature interdependence and circular economy. *Agric. Food Econ.* 11 (1), 1–8. doi:10.1186/S40100-023-00259-6/METRICS

Candel, D. (2020). Extending the embodied semiotic square: a cultural-semantic analysis of 'follow your arrow. *Semiotica* 236, 275–295. doi:10.1515/sem-2018-0144

Colloff, M. J., and Pittock, J. (2019). Why we disagree about the murray–darling basin plan: water reform, environmental knowledge and the science-policy decision context. *Aust. J. Water Resour.* 23 (2), 88–98. doi:10.1080/13241583.2019.1664878

Copeland, C. (2016). Clean water act: a summary of the law. Available online at: www.crs.gov.

Council of the European Communities 1991. "EU Nitrates Directive." *Official Journal of the European Communities* L375, 1–8. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1561542776070&uri=CELEX:01991L0676-20081211. (Accessed October 8 2024).

Council of the European Union. 1998. "Directive 98/83/EC (Drinking Water Directive)." *Official Journal of the European Communities* L330, 32–54. Available online at: https://eur-lex.europa.eu/eli/dir/1998/83/oj/eng. (Accessed October 10 2024).

D'Odorico, P., Davis, K. F., Rosa, L., Carr, J. A., Chiarelli, D., Dell'Angelo, J., et al. (2018). The global food-energy-water nexus. *Rev. Geophys.* 56, 456–531. doi:10.1029/2017RG000591

Dryzek, J. S. (2021). *The politics of the Earth: environmental discourses* (Fourth edition). Oxford: Oxford University Press.

Durant, A., and Leung, J. H. C. (2019). Legal genres. *Lang. Law*, 11–15. doi:10.4324/9781315436258-4

Eerd, M. V., Dieperink, C., and Wiering, M. (2015). A dive into floods: exploring the Dutch implementation of the floods directive. *Water Policy* 17 (2), 187–207. doi:10.2166/WP.2014.025

European Parliament and Council of the European Union (1991). Directive 91/271/EEC (urban waste water treatment directive). *Official J. Eur. Communities* L135, 40–52. Available online at: https://eur-lex.europa.eu/eli/dir/1991/271/oj/eng. (Accessed October 10, 2024).

European Parliament and Council of the European Union (2000). Directive 2000/60/EC (water framework directive). *Official J. Eur. Communities* L327, 1–73. Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02000L0060-20141120. (Accessed October 10, 2024).

European Parliament and Council of the European Union (2006a). Directive 2006/7/EC concerning the management of bathing water quality. *Official J. Eur. Union* L64, 37–51. Available online at: https://eur-lex.europa.eu/eli/dir/2006/7/oj/eng. (Accessed October 10, 2024).

European Parliament and Council of the European Union (2006b). EU groundwater directive. *Official J. Eur. Union* L372, 19–31. Available online at: https://eur-lex.europa.eu/eli/dir/2006/118/oj. (Accessed October 10, 2024).

European Parliament and Council of the European Union (2007). Directive 2007/60/EC (floods directive). *Official J. Eur. Union* L288, 27–34. Available online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32007L0060. (Accessed October 10, 2024).

European Parliament and Council of the European Union (2008a). Directive 2008/105/EC (environmental quality standards in water directive). *Official J. Eur. Union* L348, 84–97. Available online at: https://eur-lex.europa.eu/eli/dir/2008/105/oj/eng. (Accessed October 10, 2024)

European Parliament and Council of the European Union (2008b). Directive 2008/56/EC (marine strategy framework directive). *Official J. Eur. Union* L164, 19–40. (Accessed October 10, 2024).

European Parliament and Council of the European Union (2010). Directive 2010/75/EU (industrial emissions directive). *Official J. Eur. Union* L334, 17–119. Available online at: https://eur-lex.europa.eu/eli/dir/2010/75/oj/eng. (Accessed October 10, 2024).

European Parliament and Council of the European Union (2020). Regulation (EU) 2020/741 (water reuse regulation). *Official J. Eur. Union* L177, 32–55. Available online at: https://eur-lex.europa.eu/eli/reg/2020/741/oj/eng. (Accessed October 10, 2024).

Ferreira, M. (2021). Compliance with EU law and argumentative discourse: representing the EU as a problem-solving multilevel governance system through discursive structures of argumentation. *Argumentation* 35 (4), 645–665. doi:10.1007/s10503-021-09548-0

Figge, F., Thorpe, A. S., and Gutberlet, M. (2023). Definitions of the circular economy: circularity matters. *Ecol. Econ.* 208, 107823. doi:10.1016/j.ecolecon.2023.107823

Ghodsvali, M., Dane, G., and de Vries, B. (2022). The nexus social-ecological system framework (NexSESF): a conceptual and empirical examination of transdisciplinary food-water-energy nexus. *Environ. Sci. and Policy* 130, 16–24. doi:10.1016/j.envsci.2022.01.010

Giakoumis, T., and Voulvoulis, N. (2018). The transition of EU water policy towards the water framework directive's integrated river basin management paradigm. *Environ. Manag. (New York)* 62 (5), 819–831. doi:10.1007/s00267-018-1080-z

Gómez-Ramos, A., Blanco-Gutiérrez, I., Ballesteros-Olza, M., and Esteve, P. (2024). Are non-conventional water resources the solution for the structural water deficit in mediterranean agriculture? The case of the segura river basin in Spain. *Water* 16 (7), 929. doi:10.3390/W16070929

Green, O. O., Garmestani, A. S., van Rijswick, H. F. M. W., and Keessen, A. M. (2013). EU water governance: striking the right balance between regulatory flexibility and enforcement? *Ecol. Soc.* 18 (2), art10. doi:10.5751/ES-05357-180210

Greimas, Algirdas Julien. 1988. *Maupassant: The Semiotics of Text: Practical Exercises*. Philadelphia; Amsterdam: Benjamins.

Grinsven, H. J. M. V., Tiktak, A., and Rougoor, C. W. (2016). Evaluation of the Dutch implementation of the nitrates directive, the water framework directive and the national emission ceilings directive. *NJAS - Wageningen J. Life Sci.* 78, 69–84. doi:10.1016/J.NJAS.2016.03.010

Grizzetti, B., Pistocchi, A., Liquete, C., Udias, A., Bouraoui, F., and Van De Bund, W. (2017). Human pressures and ecological status of European Rivers. *Sci. Rep.* 7 (1), 205–211. doi:10.1038/s41598-017-00324-3

Hajer, M., and Versteeg, W. (2005). A decade of discourse analysis of environmental politics: achievements, challenges, perspectives. *J. Environ. Policy and Plan.* 7 (3), 175–184. doi:10.1080/15239080500339646

Halliday, M. A. K. (1978). *Language as social semiotic: the social interpretation of language and meaning*. London: Edward Arnold.

Halliday, M. A. K. (1994). *An introduction to functional grammar*. London: Edward Arnold. 2nd ed.

Halliday, M. A. K., and Hasan, R. (1985). *Language context, and text: aspects of language in a social -Semiotic perspective*. Oxford: Oxford University Press, 15–23.

Halliday, M. A. K. (1978). *Language as Social Semiotic: The Social Interpretation of Language and Meaning*. London: Edward Arnold

Hart, B. T. (2016). The Australian murray–darling basin plan: challenges in its implementation (part 1). *Int. J. Water Resour. Dev.* 32 (6), 819–834. doi:10.1080/07900627.2015.1083847

Horne, J. (2014). The 2012 murray-darling basin plan – issues to watch. *Int. J. Water Resour. Dev.* 30 (1), 152–163. doi:10.1080/07900627.2013.787833

Irshad, A. R., Safdar, N., Younas, Z. I., and Manzoor, W. (2023). Impact of corporate governance on firms' environmental performance: case study of environmental sustainability-based business scenarios. *Sustain. Switz.* 15 (10), 7775. doi:10.3390/SU15107775

Kanda, W., and Kirchherr, J. (2023). Systems and ecosystems in the circular economy: what's the difference? *JCE* 1 (3). doi:10.55845/RMDN3752

Kioupi, V., and Voulvoulis, N. (2020). Sustainable development goals (SDGs): assessing the contribution of higher education programmes. *Sustain. Switz.* 12 (17), 6701. doi:10.3390/SU12176701

Kmiecicka, E., Michalska, E., and Osiejewicz, J. (2023). Legal communication and the idea of plain language: possibilities and limitation. *J. Int. Leg. Commun.* 10 (3), 72–78. doi:10.32612/uw.27201643.2023.10.3.pp.72-78

Kowalczyk, J. (2023). Legal communication. The sociolinguistic value of plain language rules. *Fachsprache* 45 (3–4), 131–144. doi:10.24989/FS.V45I3-4.2184

Kress, Gunther R., and Theo Van Leeuwen., (2021). *Reading Images: The Grammar of Visual Design*. Third edition. London; New York: Routledge.

Leipold, S., Feindt, P. H., Winkel, G., and Keller, R. (2019). Discourse analysis of environmental policy revisited: traditions, trends, perspectives. *J. Environ. Policy Plan.* 21 (5), 445–463. doi:10.1080/1523908X.2019.1660462

Lynch, C., Simsek, Y., Mercure, J. F., Fragkos, P., Lefèvre, J., Le Gallic, T., et al. (2024). Structural change and socio-economic disparities in a net zero transition. *Econ. Syst. Res.* 36, 607–629. doi:10.1080/09535314.2024.2371306

Maran, T. (2020). Ecosemiotics: the study of signs in changing ecologies. *Elem. Environ. Humanit.* Available online at: https://www.cambridge.org/core/elements/ecosemiotics/D29658F0C2E12040454C776F82627253.

Maran, T., and Kull, K. (2014). Ecosemiotics: main principles and current developments. *Geogr. Ann. Ser. B Hum. Geogr.* 96 (1), 41–50. doi:10.1111/GEOB.12035

Mees, H., Crabbé, A., Alexander, M., Kaufmann, M., Bruzzone, S., Lévy, L., et al. (2016). Coproducing flood risk management through citizen involvement: insights from cross-country comparison in Europe. *Ecol. Soc.* 21 (3), art7. doi:10.5751/ES-08500-210307

Mercure, J.-F. (2022). "Complexity economics for environmental governance." in *Complexity economics for environmental governance*. doi:10.1017/9781108553650

Mirzyńska, A. (2023). Actors in environmental discourse: the discursive institutionalism perspective. *J. Public Gov.* 65 (3), 5–19. doi:10.15678/PG.2023.65.3.01

Nöth, W., and Kull, K. (2000). Discovering ecosemiotics. *Sign Syst. Stud.* 28, 421–424. doi:10.12697/SSS.2000.28.23

Pedrero, F., and Alarcón, J. J. (2009). Effects of treated wastewater irrigation on lemon trees. *Desalination* 246 (1–3), 631–639. doi:10.1016/j.desal.2008.07.017

Pelkey, J. (2017). Greimas embodied how kinesthetic opposition grounds the semiotic square. *Prepr. Semiot.* 214 (1), 277–305. doi:10.1515/sem-2016-0188

Perusset, A. (2023). A reappraisal of the marketing offerings: consumer experience from the perspective of post-structural semiotics. *Soc. Semiot.* 34, 656–670. doi:10.1080/10350330.2023.2178294

Ravelli, L., Van Leeuwen, T., Höllerer, M. A., and Jancsary, D. (2023). *Organizational semiotics: multimodal perspectives on organization studies*, 246.

Schleifer, R. (1987). *A. J. Greimas and the nature of meaning: linguistics, semiotics and discourse theory*.

Schweinberg, M. J., and Raspotnik, A. (2024). Slaying the toothless tiger: social equity as the legal element of the blue economy. *J. Environ. Dev.* 33, 475–492. doi:10.1177/10704965241238290

Selg, P., and Ventsel, A. (2022). Cultural semiotics as the foundation of political semiotics. *Soc. Semiot.* 32 (5), 671–688. doi:10.1080/10350330.2022.2158619

Skoulikidis, N. T., Vardakas, L., Karaouzas, I., Economou, A. N., Dimitriou, E., and Zogaris, S. (2011). Assessing water stress in mediterranean lotic systems: insights from an artificially intermittent river in Greece. *Aquat. Sci.* 73 (4), 581–597. doi:10.1007/s00027-011-0228-1

Tamminen, H. (2017). Four ways of triadic 'sign-Ness' on two semiotic squares. *Sign Syst. Stud.* 45 (1–2), 162–180. doi:10.12697/SSS.2017.45.1-2.11

Tarasti, E. (2017). The semiotics of A. J. Greimas: a European intellectual heritage seen from the inside and the outside. *Sign Syst. Stud.* 45 (1–2), 33–53. doi:10.12697/SSS.2017.45.1-2.03

Toneva, D., and Dimitrova, D. (2024). Some aspects of the water crisis in Bulgaria. *Vide. Tehnol. Resur. - Environ. Technol. Resour.* 1, 373–377. doi:10.17770/ETR2024VOL1.7972

Van Leeuwen, T. (2008). *Discourse and practice: new tools for critical discourse analysis*. Oxford University Press.

Voulvoulis, N., Arpon, K. D., and Theodoros, G. (2017). The EU water framework directive: from great expectations to problems with implementation. *Sci. Total Environ.* 575, 358–366. doi:10.1016/j.scitotenv.2016.09.228

Zengiaro, N. (2022). From biosemiotics to physiosemiotics. Towards a speculative semiotics of the inorganic world. *Linguist. Front.* 5 (3), 37–48. doi:10.2478/lf-2022-0019

Zevenbergen, C., Rijke, J., van Herk, S., and Bloemen, P. J. T. M. (2015). Room for the river: a stepping stone in adaptive Delta management. *Int. J. Water Gov.* 3 (3), 121–140. doi:10.7564/14-IJWG63

Zhang, C., Chen, X., Li, Y., Ding, W., and Fu, G. (2018). Water-energy-food nexus: concepts, questions and methodologies. *J. Clean. Prod.* 195, 625–639. doi:10.1016/J.JCLEPRO.2018.05.194

Zheng, P., Wang, H., Wei, D., Pu, C., and He, Z. (2022). Environmental governance capability and water quality: a quasi-natural experiment based on the ten-point water plan. *Urban Clim.* 41, 101050. doi:10.1016/J.UCLIM.2021.101050