

Supplementary material to:

Achieving European water quality ambitions: Governance conditions for more effective approaches at the local-regional scale

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Results literature review

A literature review has been carried out to identify the knowledge on the different perspectives and their interactions and how they are related to current debates on water quality¹. The challenges to realizing water quality improvement in river basins is not limited to the European continent, but can be recognized worldwide. The range of the literature review, therefore, was wide, in order to gather studies of experiences from a variety of ecological, legal and social-economic circumstances. The review was carried out using the search engines Google Scholar, Scopus, Web of Science and Science Direct on the terms 'water quality' and 'governance' excluding studies focusing on water quantity, water supply, water reuse or sea basins. An earlier review of WFD Implementation made by Boeuf and Fritsch [1] was also used, as well as legal literature based upon EC publications, case law from the European Court of Justice (ECJ) and follow ups of references in the articles studied.

This resulted in a list of 122 articles (Table S.1), each of which uses one or more perspectives, implicitly or explicitly. Based upon the abstract, title and key words, an initial identification was made as to which of the perspectives were used in the article. If there was uncertainty regarding this observation, the article was read and the qualification adjusted accordingly. Articles using two or more perspectives were used to describe the interactions and their contribution to water quality.

One of the restrictions of this approach is that grey literature is only included on a limited basis; another is that the search focused on English-language publications only. These limitations set constraints on the results, especially with regard to legal and ecological studies, as these are often nation based, written in the national language and they are not found by search engines such as Scopus. Despite these limitations, the resulting list of papers does offer a wide overview of how scientific literature addresses the ecological, legal and social-economic perspectives on water quality governance and their interactions so far. Table 1 shows the results of the literature review.

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Table S1 Results literature review on ecological, legal and social perspectives on water quality management.

No.	Reference	Countries or continents studied	Perspectives		
			Ecological	Legal	Social
1	Andersson, <i>et al.</i> [2]	Sweden	-	-	X
2	Baaner [3]	Denmark, Sweden, Norway	X	X	-
3	Backes and Van Rijswick [4]	Europe	-	X	-
4	Behagel and Arts [5]	Netherlands	-	-	X
5	Behagel and Turnhout [6]	Netherlands	-	-	X
6	Benson, <i>et al.</i> [7]	England, Wales (UK)	-	X	X
7	Blackstock, <i>et al.</i> [8]	Scotland (UK)	X	-	X
8	Blackstock, <i>et al.</i> [9]	Scotland (UK)	-	-	X
9	Borowski, <i>et al.</i> [10]	Germany, France	-	-	X
10	Braioni, <i>et al.</i> [11]	Italy	X	-	X
11	Bremer, <i>et al.</i> [12]	Latin America	-	-	X
12	Brils, <i>et al.</i> [13]	Europe	X	-	X
13	Carpenter, <i>et al.</i> [14]	USA	X	-	X
14	Chang, <i>et al.</i> [15]	USA	X	-	X
15	Chen, <i>et al.</i> [16]	China	X	-	X
16	Chiang, <i>et al.</i> [17]	Chile	X	X	-
17	Comito, <i>et al.</i> [18]	USA	-	-	X
18	Cook [19]	Canada	X	X	-
19	Crabbé [20]	Belgium	-	X	X
20	Crabtree, <i>et al.</i> [21]	United Kingdom	-	-	X
21	Da Silva, <i>et al.</i> [22]	Portugal	X	-	X
22	deLeon [23]	No specific country	-	-	X
23	Dieperink, <i>et al.</i> [24]	Netherlands	-	X	X
24	Drazkiewicz, <i>et al.</i> [25]	Germany	-	-	X
25	Duncan [26]	New Zealand	-	-	X
26	EC [27]	Europe	-	X	-
27	ECJ [28]	Europe vs. France	-	X	-
28	ECJ [29]	Europe vs. Germany	-	X	-
29	ECJ [30]	Europe vs. Germany	-	X	-
30	Elofsson [31]	No specific country	-	-	X
31	Freriks, <i>et al.</i> [32]	Netherlands	-	X	X
32	Gani and Scrimgeour [33]	OECD countries	X	X	-
33	Grant (2000) [34]	Europe	X	X	-
34	Gu, <i>et al.</i> [35]	China	-	-	X
35	Guo, <i>et al.</i> [36]	China	X	-	X
36	Hagemann, <i>et al.</i> [37]	Ukraine	X	X	X
37	Hammer, <i>et al.</i> [38]	Sweden	X	-	X
38	Harmsworth, <i>et al.</i> [39]	New Zealand	-	-	X
39	Hering, <i>et al.</i> [40]	Europe	X	-	-
40	Hong and Chung [41]	South Korea	-	-	X
41	Howarth [42]	Europe	-	X	X
42	Huber-Stearns and Cheng [43]	USA	-	X	X
43	Hüesker and Moss [44]	Germany	-	-	X
44	Huitema, <i>et al.</i> [45]	No specific country	X	-	X
45	Hummel, <i>et al.</i> [46]	No specific country	-	-	X
46	Jin, <i>et al.</i> [47]	China	X	X	X
47	Jonsson [48]	Sweden	-	-	X
48	Kastens and Newig [49]	Germany	-	-	X
49	Kastens and Newig [50]	Germany	-	-	X
50	Keessen, <i>et al.</i> [51]	11 EU countries	X	X	-
51	Knieper and Pahl-Wostl [52]	Europe	X	X	X

No.	Reference	Countries or continents studied	Perspectives		
			Ecological	Legal	Social
52	Kochskämper, <i>et al.</i> [53]	Germany, Spain, UK	-	-	X
53	Kolinjivadi, <i>et al.</i> [54]	No specific country	-	-	X
54	Kotze and Silima [55]	South Africa	X	-	X
55	Lah, <i>et al.</i> [56]	South Korea	X	-	X
56	Le Bourhis [57]	France	X	-	X
57	Lee [58]	Europe	-	X	X
58	Leidel, <i>et al.</i> [59]	Ukraine	X	-	X
59	Lukacs, <i>et al.</i> [60]	USA	-	-	X
60	Mauerhofer, <i>et al.</i> [61]	No specific country	-	X	X
61	McLaughlin and Krantzberg [62]	Canada, USA	-	-	X
62	Metcalf, <i>et al.</i> [63]	Australia	X	-	X
63	Metz and Ingold [64]	Switzerland	-	-	X
64	Mihók, <i>et al.</i> [65]	Hungary	X	X	X
65	Moss [66]	Europe	X	-	X
66	Newig and Koontz [67]	Europe	-	-	X
67	Newig and Fritsch [68]		X	-	X
68	Newig, <i>et al.</i> [69]		-	-	X
69	Newson [70]	United Kingdom	-	-	X
70	Norman, <i>et al.</i> [71]	Mexico	X	-	-
71	Ostrom, <i>et al.</i> [72]	No specific country	-	-	X
72	Pahl-Wostl, <i>et al.</i> [73]	29 Basins worldwide	X	-	X
73	Pahl-Wostl, <i>et al.</i> [74]	No specific country	X	-	X
74	Parker [75]	USA	X	-	X
75	Parsons, <i>et al.</i> [76]	Australia	X	-	-
76	Pereira and Quintana [77]	Europe	-	-	X
77	Plambeck [78]	Europe	-	X	X
78	Plant, <i>et al.</i> [79]	Australia	X	-	X
79	Probohudono, <i>et al.</i> [80]	Indonesia	-	-	X
80	Raad van State [81]	Netherlands	-	X	-
81	Raadgever, <i>et al.</i> [82]	Netherlands	-	-	X
82	Rahaman, <i>et al.</i> [83]	Europe	-	-	X
83	Reeling and Gramig [84]	USA	X	-	X
84	Reinhard, <i>et al.</i> [85]	Europe	X	-	X
85	Richter, <i>et al.</i> [86]	Germany	X	X	X
86	Rissman, <i>et al.</i> [87]	USA	-	-	X
87	Roggero [88]	Germany	-	-	X
88	Ross and Connell [89]	Australia	-	X	X
89	Rutt and Bluwstein [90]	USA	-	X	X
90	Schindler [91]	USA	X	-	X
91	Schmidt, <i>et al.</i> [92]	China	X	-	-
92	Scholz and Stiftel [93]	USA	-	X	X
93	Scott [94]	USA	X	-	X
94	Scott [95]	USA	X	-	X
95	Scott and Trubek [96]	Europe	-	X	X
96	Smith and Porter [97]	USA	X	X	X
97	Somanathan [98]	South East Asia	-	-	X
98	Steiger-Meister and Becker [99]	USA	-	X	X
99	Storey, <i>et al.</i> [100]	New Zealand	-	-	X
100	Stuart and Gillon [101]	USA	-	-	X
101	Tan [102]	OECD countries	X	-	X
102	Taylor and Short [103]	USA	X	-	X
103	Trowbridge, <i>et al.</i> [104]	USA	X	-	X
104	Van der Heijden and Ten Heuvelhof [105]	Netherlands	-	-	X

No.	Reference	Countries or continents studied	Perspectives		
			Ecological	Legal	Social
105	Van der Heijden, <i>et al.</i> [106]	Netherlands	-	-	X
106	Van Holten and Van Rijswick [107]	Europe	-	X	-
107	Van Kempen [108]	Europe	-	X	-
108	van Leeuwen and Sjerps [109]	Turkey	-	-	X
109	van Meerkerk, <i>et al.</i> [110]	Netherlands	-	-	X
110	Van Rijswick [111]	Germany	-	X	-
111	Van Rijswick, <i>et al.</i> [112]	Europe, 3 basins: Rhine, Meuse, Danube	-	X	-
112	Van Rijswick [113]	Netherlands	-	X	-
113	Vollmer-Sanders, <i>et al.</i> [114]	Canada, USA	X	-	X
114	Vörösmarty, <i>et al.</i> [115]	No specific country	X	-	X
115	Wang and Ongley [116]	China	-	X	X
116	Wardropper, <i>et al.</i> [117]	USA	X	X	X
117	Waylen, <i>et al.</i> [118]	Scotland (UK)	-	X	X
118	Webb and Martin [119]	Australia	X	X	X
119	Weible and Sabatier [120]	USA	X	-	X
120	Wright, <i>et al.</i> [121]	Australia	-	X	X
121	Yates, <i>et al.</i> [122]	Canada	X	-	X
122	Zingraff-Hamed, <i>et al.</i> [123]	France, Germany	-	-	X

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Comparison literature review and empirical research

The results from the literature review [1] and the empirical research [2-4] have been analyzed using the proposition that interactions between knowledge domains deliver important conditions for more effective water quality governance. Table S.2 shows what these interactions may entail (column 1 and 2) and how these interactions play a role in the results from the empirical research (column 3, 4, and 5) [5].

Table S2 Contributions to water quality improvement that take place within the interactions between knowledge domains and the governance conditions related to it, taken from the literature review [1] and the empirical research [2-4], table followed up on [5].

Contributions to water quality improvement		
Interactions between knowledge domains	Following up on the conceptual model [1]	Results from empirical research – case drinking water resources [2]
<u>Ecological – Legal:</u> Ecological issues and boundary conditions for legal system	Identify clear objectives that enable monitoring on effects Develop knowledge of possible interventions (doing the right things) Create fundamentals of ecological objectives in legal framework Use this as input to decide who to involve and how (relevant stakeholders and actors) Use this as information basis for societal debate on the value of ecology for society	Delayed system’s response complicates monitoring of effects; Emerging contaminants not yet regulated Limited understanding especially for actors upstream or from other sectors Yes, but not consistent in cross-sectoral legislation Not used yet, approach engages directly involved authorities and drinking water company Debate limited to the actors directly involved. Societal debate takes place beyond the scope of the governance approach
<u>Social-Economic – Legal:</u> Values and interests from society <u>Legal – Social-Economic:</u> Legally based participation processes	Identify societal context that may influence water quality management, develop knowledge of its impact on water quality to support societal debate Organize participation processes to get better informed, more efficient decision-making	Availability of good drinking water for all is a commonly shared value; Other (economic) values well known at the regional scale No formal approach, so no legally based participation process
<u>Ecological – Social-Economic:</u> Issues not addressed by the legal system	Awareness of issues, value of these issues to society, possible interventions and possibilities and constraints of legal framework in order to create engagement of society, agenda setting policy	Emerging contaminants regulated by general signaling values; Exceedance leads to further research on presence, risks and necessary measures; Presence often causes public concern, resulting in policy debate
<u>Legal – Ecological:</u> Legally based measures	Realize measures based upon knowledge of issues, possible interventions, their effects and legal framework Monitor effects on water quality, make it input for the debate on value for society	Mostly preventive measures to meet existing protection policy in direct vicinity of the abstraction; Current measures not directly linked to water quality improvement Monitoring according to Dutch Drinking Water Act for resource protection; Differences or exceedances lead to further research on presence, risks and necessary measures.
<u>Social-Economic – Ecological:</u> Voluntary based measures	Use knowledge of issues, possible interventions and their effects, for those interventions that are necessary to attain water quality objectives, but are not covered by the legal framework Monitor effects on water quality, make it input for the debate on value for society	Often starts with joint fact finding and then decide on necessary action; Those who have the means to act not always engaged in the process Delayed system’s response complicates monitoring of effects and thus the input for the societal debate

Table S1 Continued.

Contributions to water quality improvement		
Interactions between knowledge domains	Results from empirical research – case freshwater ecosystems [3]	Results from empirical research – case urban bathing water [4]
<u>Ecological – Legal:</u> Ecological issues and boundary conditions for legal system	<p>Delayed system’s response complicates monitoring on effects</p> <p>Responses of the water system and the ecosystem to measures are complex and take time</p> <p>Yes, for the assessing ecological status, but not for the nutrients (regional policy)</p> <p>Not used yet, water authorities focused on measures within their jurisdiction so far</p> <p>Information doesn’t find its way into the societal debate. Primarily input from agricultural sector and other economic interests</p>	<p>BWD lists few parameters for monitoring. In urban environment other parameters can be an issue.</p> <p>Unknown sources of pollution (e.g. sewage, water bottom) lead to unforeseen water quality issues</p> <p>BWD offers too little guidance for urban bathing water policy and practice</p> <p>Not used yet, in an urban environment those are not the only water related actors</p> <p>Information doesn’t find its way to the societal debate. Debate limited to the actors directly involved.</p>
<u>Social-Economic – Legal:</u> Values and interests from society <u>Legal – Social-Economic:</u> Legally based participation processes	<p>WFD implementation content driven by specialists, societal context comes in at the decision-making stage and this might be too late to engage</p> <p>Participation process WFD based</p>	<p>Citizens’ wish to bathe and recreate near their homes feeds this approach.</p> <p>Difficult to balance with concerns from public authorities on risks.</p> <p>No formal approach, so no legally based participation process</p>
<u>Ecological – Social-Economic:</u> Issues not addressed by the legal system	<p>Regional objectives for nutrients reduction are being realized at a voluntary base; Limited effect due to low percentage of participation;</p> <p>Information doesn’t find its way to the societal debate</p>	<p>Only addressed if there is political willpower and/or opportunities to create co-benefits</p>
<u>Legal – Ecological:</u> Legally based measures	<p>Focus on measures within the jurisdiction of water authorities so far, e.g. regarding wet cross section, aquatic vegetation, migration of fish</p> <p>WFD monitoring on status and trends not suited to identify effects of specific measures and thus inform the societal debate</p>	<p>Monitoring and risk assessment of candidate bathing water site</p> <p>BWD monitoring not suitable to report on actual water quality issues to the public (e.g. cyanobacteria) or effects of specific measures</p>
<u>Social-Economic – Ecological:</u> Voluntary based measures	<p>Regional objectives for nutrients reduction are being realised at a voluntary base; Limited effect due to low percentage of participation</p> <p>Empirical material highlights the importance of targeted monitoring to create engagement to take action</p>	<p>Dependent on political willpower (can be fed by citizen’s initiative) and/or opportunities to create co-benefits</p> <p>BWD monitoring not suitable to report on actual water quality issues to the public (e.g. cyanobacteria) or effects of specific measures</p>

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