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Transition towards sustainable pharmacy? The influence of public debates on policy responses to pharmaceutical contaminants in water

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Abstract

Background: Despite clear-cut scientific evidence for pharmaceutical contaminants causing adverse effects in aquatic life, the regulatory response in Germany has been weak. In principle, there are different policy approaches to address pharmaceutical contaminants: German water protection policies mostly follows a control approach, complemented by end-of-pipe solutions in some German states. The approach leaves the activities of key target groups, such as the pharmaceutical industry, largely unaffected. A stakeholder consultation initiated in 2016 by the German Federal Ministry of the Environment did not lead to significant changes in regulation. Empirical research in political science has shown that analysing the public debate can be helpful in explaining policy responses and, in particular, policy change. This study follows this approach and investigates whether the German policy response to pharmaceutical contaminants can be explained by characteristics of the public debate on the issue.

Results: A discourse network analysis based on newspaper reporting in Germany was conducted between 2013 and 2017 to investigate the public debate on pharmaceutical contaminants. German newspapers actually paid considerable attention to the issue. In fact, the debate was not controversial, and participating organisations expressed similar views with regard to the risk of the contaminants, the causes of contamination and the approaches to be taken to mitigate the release of contaminants to the environment. The main narrative in the debate was supportive to the current policy approach applied in Germany. There were no concerted efforts by organisations such as environmental organisations or ecological parties to mobilise for an alternative policy approach.

Conclusions: The low level of polarisation in the policy subsystem and the absence of a strong narrative mobilising a major policy change may explain the persistence of the policy approach to pharmaceutical contaminants applied in Germany. A significant change to the current approach in the near future seems unlikely. Nevertheless, literature in political science shows that a polarised public debate and a strong pro-change actor coalition often preceded policy change. Actors with an interest in stricter regulation might want to reconsider their mobilisation strategies.

Keywords: Pharmaceuticals, Trace contaminants, Aquatic pollution, Discourse network analysis, Policy debate, Water policy, Policy change, Risk governance

Introduction

Despite significant improvements in wastewater treatment and water quality protection, the majority of European surface waters (rivers, lakes, transitional and coastal waters) is not in a good ecological condition [114] as required by the European Water Framework Directive

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[106]. Over the last 20 years, a decrease in fish populations has been documented for numerous river systems in Europe and North America [10, 13, 14], and further ecotoxicological studies revealed that pollution within rivers "is, indeed, significant enough to potentially affect fish populations" [33].

There is growing evidence that pharmaceutical residues in surface waters cause adverse effects in aquatic life [5, 17, 36, 69, 74]. Pharmaceuticals have been designed as biologically active agents to cure diseases and to manipulate biological processes within living organisms. Therefore, it comes with no surprise that such substances are likely to have an effect on non-target organisms in aquatic ecosystems, when present in surface waters even at very low concentrations. Although knowledge on how pharmaceutical residues affect fauna and flora is still limited, several studies indicate adverse effects [16, 18, 22, 59, 62]. Examples of substances with a high potential for ecotoxicological effects commonly detected in aquatic systems include analgesics such as diclofenac [63, 95], hormones such as 17α-ethinylestradiol and other steroids [1, 79, 103], antibiotics, antidepressants or antitumor agents (for reviews, see [41] as well as [5]). Pharmaceutical contaminants can meanwhile be detected in almost any environmental matrix all over the world [69]. They partly originate from municipal wastewater, since most currently installed wastewater treatment plants have not been designed to remove such trace contaminants [19, 86, 98, 102]. New technologies capable of eliminating these contaminants are still under development, and the number of wastewater treatment plants upgraded to such advanced purification technologies is still small [51, 96].

Despite the evidence for adverse effects in aquatic life caused by pharmaceutical contaminants, the regulatory response in Germany has been weak [25, 56]. In principle, stricter measures could be adopted by policy-makers since the precautionary principle, which is the guiding principle of the European Union for addressing uncertain risks, enables policy-makers to take regulatory action if preliminary evidence suggests that certain activities or substances are harmful to the environment or human health (see e.g. [87]). It remains open why the given scientific evidence in combination with the precautionary principle, which allows stronger regulatory measures, have not lead to a stricter policy response. The present contribution aims to better understand policy formation in this policy field by investigating the research question whether the public debate had an impact on the policy response to pharmaceutical contaminants in Germany. Empirical research in political science has repeatedly shown that the public debate can influence policy-making processes in democratic systems [20, 42, 45, 81, 88, 89]. The public debate represents a space where societal and political issues are publicly debated [70]. For instance, this space can be provided by the media such as newspapers. Within the public debate, political actors interact verbally about a given policy issue [44]. In this study, we argue that the presence of a non-disputed public debate, characterised by a hegemonic actor coalition and the absence of a strong actor coalition mobilising for major policy change, contributed to the persistence of the weak policy response to pharmaceutical contaminants.

In a first step, we present our theoretical argument on the relationship between the public debate and policy responses to pharmaceutical contaminants. The section concludes with two rivalling theoretical expectations. We then explain the data gathering process and the methodology used to investigate the formulated expectations. Subsequently, we present and discuss our empirical results on the relationship between the public debate and the policy response to pharmaceutical contaminants in Germany. Finally, we present concluding remarks and point to avenues for further research.

Theoretical considerations on the impact of the public debate on policy formation

Different policy responses to pharmaceutical contaminants in water are possible. These differ in the addressed target groups responsible for contamination and in the level of pressure exerted on the addressees. Policy responses can be based on different policy approaches, which vary with regard to the target groups addressed. Source-directed solutions focus on preventing contamination from the onset. They can address consumers, for instance by encouraging them to change to a more sustainable behaviour, the agricultural sector or the pharmaceutical industry directly. One possibility is to target already the production of pharmaceuticals, e.g. by incentivising or encouraging the production of sustainable, environmentally friendlier pharmaceuticals [39]. Research termed "green pharmacy" or "green toxicology" aims at developing novel production processes that follow a life-cycle approach and incorporate environmentally relevant properties, such as biodegradability, already when designing a new substance [15, 38, 40]. For instance, Rastogi et al. [71] illustrate that it is also possible to redesign many existing pharmaceuticals and improve their environmental biodegradability through small molecular modifications. Moreover, new predictive toxicology methods that apply in silico approaches could be used to predict the ecotoxicology of pharmaceuticals already when designing new substances [32]. End-of-pipe solutions aim at removing contaminants from water, mainly by improving wastewater treatment. These solutions mostly target the wastewater treatment sector. However, the costs for upgrading wastewater treatment

can also be passed to the other target groups. Control approaches represent preliminary strategies to monitor the level of contamination. Based on the monitoring, policy-makers may take further policy actions if deemed necessary [57].

In order to implement these approaches, different types of policy instruments can be used, which differ in the level of pressure exerted on the target groups. Relevant policy instruments can be categorised as voluntary, command-end-control, and market-based instruments [57, 93]. Voluntary instruments aim at changing behaviour without exercising coercion, for example by raising problem awareness among consumers or by negotiating voluntary agreements with the industrial sector [101]. These instruments typically exert only soft pressure on target groups, as non-compliance does not entail any direct consequences. Command-and-control instruments directly regulate or impose a desired behaviour, for example by increasing the strictness of authorisation procedures or by banning certain substances [48]. Here, the pressure on target groups is strong, since these are forced to comply with the rules. Market-based-instruments aim at encouraging a desired behaviour through "positive" or "negative" financial incentives [66, 75]. Subsidies for the development of more environmentally friendly production processes are an example for a positive incentive, whereas imposing taxes on less environmentally friendly products represents a negative incentive. The level of pressure on target groups can be regarded as intermediate, since these are not forced to comply with rules, but face certain economic disadvantages [57].

We argue that a change in the overall policy approach, i.e. from a control to a source-directed approach, or a significant change in the pressure put on target groups, i.e. from 'soft' voluntary measures to 'hard' command-and-control regulation, can be classified as a major policy change in this policy subsystem.

Coalition formation based on policy beliefs

In order to analyse the impact of the public debate on policy formation, we draw on theories of policy process. Empirical research in political science has shown that analysing the public debate can be helpful for explaining policy change [42, 44]. Policy-making takes place in a complex and intertwined setting that includes a variety of public and private actors with an interest in shaping public policy [37]. Policy process theories, most prominently the 'Advocacy Coalitions Framework' [78], suggest that these political actors express their policy beliefs in policy debates and form 'actor coalitions' based on competing policy beliefs. Thus, actors' policy beliefs structure coalitions in a policy subsystem. Actors with similar policy beliefs form coalitions and diverge from other coalitions

of actors with opposing policy beliefs [42, 76, 97, 100]. Coalition formation can, therefore, be measured empirically based on the policy beliefs actors articulate in the public debate in the media or other arenas [42].

Why do political actors reveal their policy beliefs in the public debate?

The different policy approaches and instruments discussed before address the behaviour of different actors. Most prominently, these include actors from the industrial sector, the agricultural sector, the water treatment sector, or consumers and consumer protection organisations as their representatives. Depending on the choice of policy instruments and their respective addressees, these actors are confronted with additional costs. Therefore, the different actors should have an interest in influencing the policy-making process proactively either to promote their preferred solutions or to prevent undesired policy instruments from being adopted. In addition, there are actors with an intrinsic interest in protecting the environment, such as environmental groups or ecological political parties that may evaluate certain policy approaches to be more effective than others.

Political actors use the public debate as a venue to influence policy-making [42, 44]. In fact, these actors participate in the public debate and articulate their policy beliefs for strategic reasons [81, 89]. There are various arguments in literature on how participation in the public debate can be influential on policy formation: First, new information can lead to policy learning, which has been identified as a driving force for policy change [42, 46, 77]. Thus, political actors participate in the debate in order to put forth their arguments or new information in order to trigger policy learning across coalitions. Second, through emphasising certain policy issues and solutions, but neglecting others, the public debate may have a profound impact on agenda-setting, making some policy issues and solutions more likely to be discussed in parliament than others [4, 83, 90, 92]. Third, the public debate can shape public opinion [73], which may then affect politicians in their decision-making [84]. In democratic systems, political actors are inclined to respond to public demands in order to secure an electoral benefit [8, 82, 83].

Which coalition structures make policy change more likely?

Depending on the participation of political actors and their articulated policy beliefs, different coalition formation structures arise. One can differentiate between three ideal types of coalition formation structures: (1) *adversarial* or *polarised* structures with opposing coalitions and little coordination, (2) *collaborative* structures with opposing but coordinated coalitions, and (3) *unitary* or
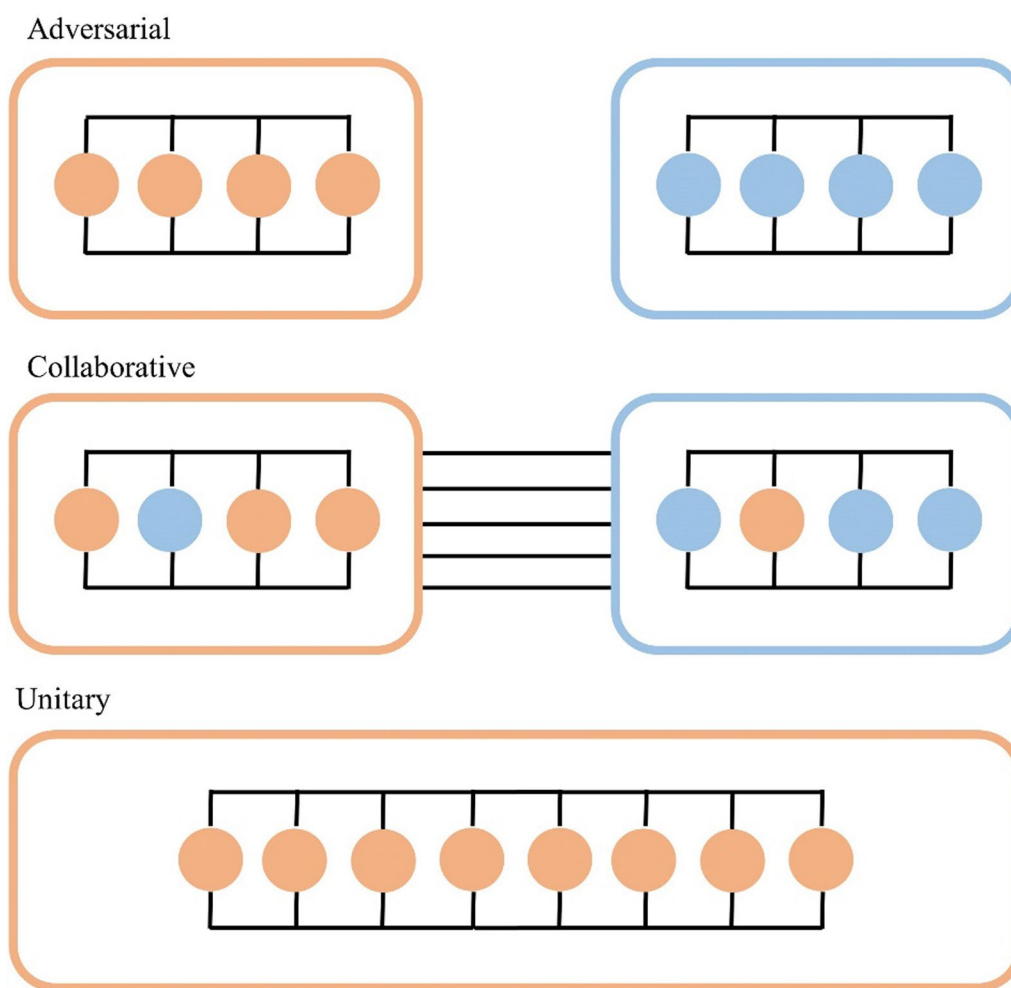
Fig. 1 Three coalition structures. Based on Metz [56]

hegemonic structures that consist of one dominant coalition [30]. See Fig. 1 for an illustration of the different coalition structures. Adversarial structures are typical for conflictual subsystems, whereas a unitary structure is indicative for the absence of conflict in policy formation [42].

Unitary coalition structures are usually stable over time [3, 4]. In a subsystem characterised by a unitary coalition structure, the hegemonic coalition has determined policy formation and, therefore, the current policy *status quo.* The structure will remain stable unless political actors outside the hegemonic coalition challenge the *status quo* and start to mobilise for a policy change [28]. This challenge would lead to a polarised coalition structure, which in turn could result in policy learning, a change in agenda-setting of parliaments, and increase pressure on decision-makers to respond to potential unfavourable public opinion. Thus, major

policy change should be preceded by a polarisation of the coalition structure. Complementary, the persistence of a unitary coalition structure should make a change to the policy *status quo* less likely [42].

These theoretical considerations lead to the following two competing expectations, which we will investigate in the remainder of this study:

Expectation 1a: The presence of a disputed public debate that is characterised by an adversarial or collaborative network structure and an actor coalition that advocates a change in the policy *status quo* increases the likelihood for a major policy change.

Expectation 1b: The presence of a non-disputed public debate that is characterised by a unitary network structure and a hegemonic coalition that supports the policy *status quo* decreases the likelihood for a major policy change.

Methods applied in the present study

We applied a *discourse network analysis* [43–45] to test the plausibility of our theoretical expectations formulated in the previous section. Due to the small-N research design, we conduct a plausibility probe, which may then guide future theory development [49]. Discourse network analysis has repeatedly and successfully been applied in the study of policy formation and policy change [20, 42, 43, 67, 72, 80, 89]. The process of policy-making is inherently a relational phenomenon where actors depend on each other to make collective decisions. Discourse network analysis can be used to investigate interdependencies between the actors that participate in policy-making. The approach combines qualitative content analysis with social network analysis and allows to analyse these interdependencies based on the policy beliefs actors articulate in policy debates [42]. Actors' policy beliefs are measured via s*tatements* they formulate in the public debate. These statements are text portions where actors indicate support of or opposition to a *concept* [42]. Therefore, actors' positions towards certain concepts, such as their stance on a policy approach or a policy instrument, represent an operationalisation of their policy beliefs. In this study, we defined actors as *organisations* that participated in the policy debate on pharmaceutical contaminants such as environmental organisations, political parties, government agencies, or companies. Network analysis then allows to analyse coalition formation based on these organisations' shared policy beliefs [42].

We selected newspaper articles as data source for our analysis, because our research interest focused on the public debate. For clarity, we underline that these newspaper articles served as a data source to measure actors' publicly articulated policy beliefs. We are not interested in how the media might present or frame the issue of pharmaceutical contaminants. Following Leifeld [42], we used the *Frankfurter Allgemeine Zeitung (FAZ)*, which is one of the principal nation-wide newspapers in Germany, as primary data source.[1] We further included articles from at least one principal regional newspaper from each of the German States (leading to 23 sources in total) in order to secure a sufficiently fine-meshed coverage (Additional file 1: Table S1 and Figure S1). We identified relevant articles by using a keyword search within the respective newspapers.[2] This search strategy resulted in 826 newspaper articles that dealt with pharmaceutical contaminants in surface waters published between January 2013 and December 2017. Within these articles, we coded 666 statements where organisations expressed relevant policy beliefs by using the software *Discourse Network Analyzer* [47]. All articles were encoded manually by one of the authors and two research assistants.
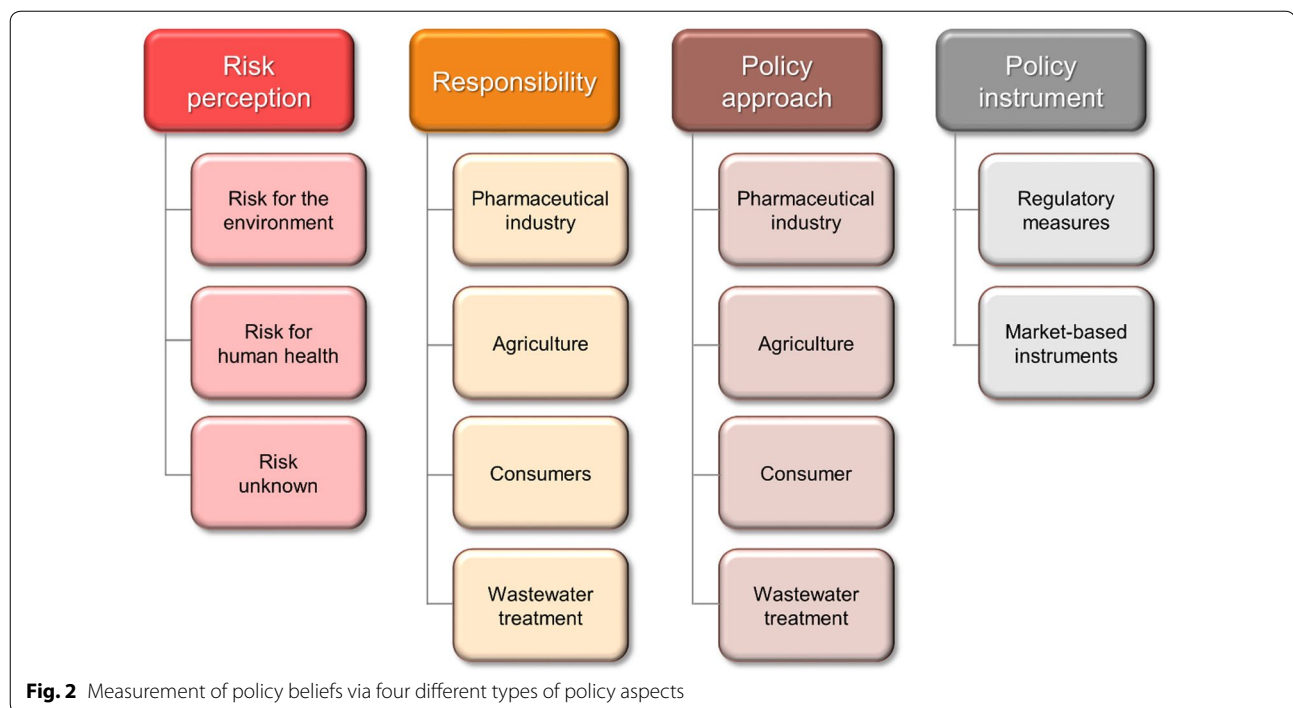
In order to measure actors' policy beliefs, we coded their stance on four different types of policy aspects relevant for this policy subsystem (see Fig. 2 for an overview). First, we coded actors' risk perception in order to capture whether they framed the issue of pharmaceutical contaminants in certain ways in order to increase or diminish attention to the topic. This included whether actors agree or disagree that pharmaceutical contaminants represent a risk to the environment or to human health or whether the risk is unknown. Second, we captured how responsibility for the entry of contaminants is attributed. More specifically, we coded whether actors assign responsibility either to the pharmaceutical industry, the agricultural sector, the consumers, or to the wastewater treatment sector. Third, we coded actors' positions towards possible policy approaches. Actors referred to three different target groups when mentioning source-directed approaches: the pharmaceutical industry, the agricultural sector and consumers. In addition, actors referred to the wastewater treatment sector when discussing an end-of-pipe approach. Fourth, we coded actors' preferences towards specific policy instruments. These included different regulatory measures, such as product bans or environmental quality standards, and market-based instruments, such as subsidies or taxes. We derived these four categories deductively based on our theoretical considerations and background knowledge on this policy issue. The codebook was then modified stepwise based on a first round of coding. Modifications mostly corresponded to specific policy instruments, which we then added to the codebook. Differences in policy beliefs as measured by agreement or disagreement with these policy aspects should, in principle, enable us to differentiate between actors who support a current policy status quo from those who mobilise for a policy change.

We then applied different methods to analyse the data: In a first step, we computed descriptive statistics to gain a first insight in what type of actors took part in the public debate and which policy beliefs predominated. For this purpose, we compared the actors' share of statements and the share of policy beliefs.

In a second step, we derived a *one-mode actor subtract network*, where we linked organisations depending on whether they shared positions on the four different types of policy aspects. The *subtract network* combined *congruence* and *conflict* networks, which means that they included both agreement and disagreement on policy aspects. In congruence networks, organisations are linked with an *edge* if they both share the same policy

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[1] The FAZ corresponds well with the "quality press" criterion of wide circulation and being politically moderate and reputable [2].

[2] A full list of these combinations is provided in the supplemental materials.

Fig. 2 Measurement of policy beliefs via four different types of policy aspects

belief, i.e. mutual agreement or disagreement with a policy aspect. The more beliefs two actors share, the higher their *edge weight*. In conflict networks, organisations are linked with an *edge* if two organisations have conflicting positions on the same policy aspect. The more policy beliefs two actors do not share, the higher their *edge weight* in the conflict network. The subtract network combines both approaches by subtracting conflict network edge weights from congruence network edge weights. We further normalised the subtract network by applying the *Jaccard similarity measure*, which is known for its normalising function. The measure divides each edge weight by the sum of the two respective actors' independent and joint referrals to the policy aspects [47, 50]. One-mode actor networks should be normalised, if the goal is to identify coalition structures, which otherwise could be masked because of different activity levels in the debate [44, 47]. The resulting matrix contained organisations in rows and columns, with cell values indicating the degree of shared policy beliefs and ranging from -1 to 1. High values indicated high belief similarity and low values low belief similarity. We then graphically portrayed this actor subtract network by placing organisations as *nodes* in a two-dimensional space using the *Fruchterman–Reingold force-directed placement algorithm* The algorithm is commonly applied in social network analysis and groups nodes, which share more connections to each other, closer together. At the same time it reduces overlap of nodes and, thereby, improves readability of a

graph [21, 65]. In the graph, nodes were only linked by edges, if they shared cell values greater than zero indicating a certain degree of belief similarity (see Nagel [61] for a similar application). This graphical approach allows to evaluate the structure of networks and to identify actor clusters, since actors with higher degrees of similarity are placed closer to each other [47]. In addition, we conducted a community detection analysis with the help of the *Louvain algorithm* to complement the graphical analysis of coalition structures. The method identifies communities within networks based on a modularity measure and a hierarchical approach [9]. Modularity measures the strength of community structures compared to a random network with identical sets of nodes and edges [52]. Communities are more similar subsets of nodes and may, therefore, represent actor coalitions as their similarity is determined based on their shared policy beliefs. In order to better understand the division between communities and to evaluate whether these can be interpreted as opposing coalitions, we added a qualitative analysis of their shared beliefs.

Finally, we complemented our analysis of actor coalition structures with an analysis of structures in the policy narrative. For this purpose, we derived a *one-mode concept congruence network.* In these networks, concepts represent the nodes which are linked by edges if they are co-referenced by an identical actor. Here, we linked any two policy aspects if they were co-referenced by the same organisation. More specifically, we subdivided the policy

aspects into agreement and disagreement (e.g. agreement with a risk for the environment and disagreement with a risk for the environment). The resulting matrix contained the subdivided policy beliefs in rows and columns, with cell values indicating the number of actors that articulated the same two policy beliefs (e.g. 22 of the organisations that stressed the responsibility of consumers also supported a policy approach that focuses on upgrading wastewater treatment). We also illustrated the concept congruence network by placing the subdivided policy beliefs as nodes in a two-dimensional space using the Fruchterman-Reingold force-directed placement algorithm. This approach enables an analysis of the structure of policy narratives. If two or more clusters of policy beliefs form in the network, then these can be interpreted as competing storylines in the policy debate [43, 44].

Results

In this section, we first evaluate the policy response to pharmaceutical contaminants in Germany and analyse whether a major policy change occurred over time. Subsequently, we analyse the public debate in Germany and evaluate its impact on policy formation.

Policy response to pharmaceutical contaminants

Since Germany is a member state of the European Union (EU), EU legislation needs to be translated into domestic legislation. Thus, legislation at the federal and the state-level is dependent on regulatory activity at the EU-level. This also applies to water legislation [25, 56].

The EU Water Framework Directive [106] is one of the EU's central water policies and relevant for the regulation of pharmaceutical contaminants. Its main goal is to achieve a good ecological condition of European water bodies. Among others, the directive aims at reducing the entry of priority hazardous substances into water. These substances are defined to have toxic, persistent or bio-accumulative properties or cause equivalent levels of concern to have adverse effects on human health or aquatic ecosystems [106]. EU member states are obliged to monitor these substances and to adopt measures to mitigate their entry into water. Measures should be based on the precautionary principle, primarily address the source of contamination, and follow the polluter-pays principle [106]. The priority hazardous substances are defined by a *priority substances list* that is meant to be updated regularly [109]. The list entails 45 priority substances since the last revision in 2013. In addition, the EU assigned an Environmental Quality Standard (EQS) to every priority substance on this list. These define concentration limits for the specific substance. In case a limit is exceeded, policy-makers are required to take measures in order to reduce the entry of the respective pollutant

[25, 56]. Until today, the list did not include any pharmaceutical substances [106, 108, 109]. However, the EU also laid down a *watch list of substances* that includes potentially hazardous substances for aquatic ecosystems [104, 105]. These substances are required to be monitored only by EU member states and will be added to the priority substances list upon decision by the European Commission Joint Research Centre if their occurrence in water bodies across Europe has been proven [26, 27]. Several pharmaceutical substances have been added to the list including sexual hormones (17-alpha-ethinylestradiol, 17-beta-estradiol estrone, and estrone), one painkiller (diclofenac), and various antibiotics (macrolide antibiotics, amoxicillin, and ciprofloxacin). Diclofenac has been removed from the watch list in the latest update in 2018, because its European-wide occurrence in environmentally relevant concentrations could not be proven [105]. Nevertheless, Hillenbrand et al. [26] emphasise that there are analytical difficulties to detect residues in water and point towards the high amounts of production and consumption of the substances on this list that actually point towards considerable emissions of these substances into water. Finally, the Water Framework Directive required member states to select *river basin-specific substances* and define EQSs. The EU did not specify the specific substances but left the decision to include the substances to member states[56, 106].

Altogether, EU legislation required Germany to adopt new water legislation that addresses the entry of hazardous substances into water [25, 56]. As laid down by the watch list of substances, potential hazardous substances also included pharmaceutical contaminants. These were only required to be monitored. However, the river basin-specific substance list gave Germany the opportunity to also take mitigating measures that address pharmaceutical contaminants present in German waters at environmentally relevant concentrations, such as Diclofenac [53, 85]. Finally, the directive was clear in its recommendation to primarily adopt a source-directed approach and put pressure on polluters via the polluter-pays principle [25].

Water policies at the federal level

The German Surface Water Ordinance [111], adopted in 2011, and the Federal Water Act [113], adopted in 2009, are the two main water legislations at the federal level in Germany. Both transpose the EU Water Framework Directive into domestic law [7, 25]. The OGewV is of main importance for this study because it regulates the entry of hazardous substances in water bodies in Germany. It has been designed in accordance with a control approach [56]. As requested by the Water Framework Directive, the ordinance specifies EQSs for a list of river basin-specific substances. The OGewV has two

significant limitations with regard to the regulation of pharmaceutical contaminants. First and foremost, the list of 67 substances does still not include a single pharmaceutical contaminant [111]. When the ordinance was drafted, opposition by the German states prevented the listing of some new river basin-specific substances, including pharmaceutical chemicals [56]. Second, the OGewV only states that further political measures need to be taken to mitigate immissions in case an EQS is exceeded. It does not specify what measures were to be taken and what sanctions polluters would face [56]. The approach mainly builds on point pollution where specific polluters can be identified on a case-by-case basis and then be held responsible. However, the entry of pharmaceuticals into water bodies is more complex and the identification of polluters is not unambiguous [5]. Thus, the behaviour of relevant target groups (like the pharmaceutical industry as an indirect polluter) would be difficult to address even if pharmaceuticals were added to the list in the future [56].

Source-directed approaches to address pharmaceutical residues in water are largely absent in Germany. Such an approach could target the producers of pharmaceuticals, for instance [27]. However, the authorisation of human medicines in Germany does not necessarily depend on a prior environmental risk assessment [64]. The authorisation procedure in Germany is regulated at the EU level under EU Directive 2001/83/EC [107] and Regulation (EC) No 726/2004 [112] and on the national level under the German Medicinal Products Act [110]. Although the authorisation of new pharmaceuticals requires an environmental risk assessment, the assessment is not decisive for an authorisation decision and, in addition, has only been mandatory for newly marketed drugs since 2005. In fact, most frequently consumed pharmaceuticals were authorised before 2005 [5]. Therefore, there is no significant incentive for the pharmaceutical industry to produce more environmentally friendly pharmaceuticals. With regard to end-of-pipe solutions, there is no legal requirement for wastewater treatment plants to upgrade their wastewater technology in order to be able to filter pharmaceutical contaminants. Improving the treatment technology has remained a voluntary decision by the operators [56].

In 2016, the German Federal Ministry of the Environment initiated a stakeholder consultation to develop a new federal strategy on micropollutants in water, including pharmaceutical contaminants. Invited stakeholders included industry representatives, agricultural associations, environmental groups, consumer protection organisations, representatives of the water treatment sector, scientists and representatives of the German states. The initiative had the potential to induce a change

regarding the regulation of pharmaceutical contaminants. However, the results of the stakeholder consultation represented in March 2019 do not suggest that a major change in the approach is likely in the near future [115]. Participating stakeholders were only successful in agreeing on voluntary policy measures such as a new round table and an information campaign that addresses consumers' consumption behaviour. Therefore, relevant regulation for pharmaceutical contaminants in Germany at the federal level still mostly follows a control approach with a strong emphasis on 'soft' voluntary measures.

Implementation at the state-level
The German states are responsible for the implementation of the rules set out by the OGewV and need to comply with the defined concentration limits at the federal level [25, 56]. Since the OGewV does not determine political measures in case EQSs are exceeded, the German states enjoy some freedom in their regulatory response. With the exception that the states are not allowed to develop own regulations that address the emission of substances [7, 25]. As there are no concentration limits defined for pharmaceutical contaminants at the federal level, the German states de jure do not need to take regulatory measures, except for monitoring [111]. Nevertheless, some German states have developed their own strategies on how to address the entry of pharmaceutical contaminants and implemented policy measures. These measures mostly follow an end-of-pipe approach, which aims at upgrading wastewater treatment technology at selected treatment plants, and a source-directed approach that aims at changing the behaviour of consumers through information campaigns. States that pursue an end-of-pipe approach include Baden-Württemberg [121, 122], Hessen [116], North Rhine-Westphalia [117], and to some degree Bavaria [120] and Saarland [119]. The former have provided financial support for operators who voluntarily upgrade their treatment technology, whereas the latter only have funded pilot studies or scientific research in the development of new treatment technologies. Information campaigns have been part of the strategies of Hessen [116], and North Rhine-Westphalia [118]. The remaining states have not taken any measures. Some of them explicitly state that they wait for further regulatory action at the EU-level before taking any measures [25, 56].

Major policy change?
Theoretically, we argued that a major policy change in the regulation of pharmaceutical contaminants would involve a significant change in the overall approach or in the pressure policy instruments put on target groups. As detailed above, Germany has adopted a control approach

Table 1 Frequency of organisations and statements per type of organisation in the public debate

Type of organisation	Organisations	Statements	Share of statements (%)
Agricultural association	3	4	0.6
Fishery association	1	1	0.2
Pharmacy association	7	14	2.1
Medicine association	3	3	0.5
Industry, retail	2	6	0.9
Water association, municipal utility	68	201	30.2
Water company	11	28	4.2
Environmental organisation	6	45	6.7
Consumer protection organisation	4	13	1.9
Green party	14	72	10.8
Leftist party	1	1	0.2
Social Democratic Party	4	9	1.4
Christian Democratic Party	6	7	1.1
Liberal party	3	3	0.4
Federal government	5	63	9.5
State government	18	64	9.6
Regional, local government	14	22	3.3
Science	30	110	16.5
Sum	200	666	100.0

at the federal level that has been complemented by end-of-pipe solutions by only a few selected German states. Over the course of time, there has not been a significant change to this overall approach. The pressure on target groups has been low. Command-and-control regulation that would force operators to update their treatment technologies have not been adopted. The same applies for market-based instruments that would push producers to develop more environmentally friendly pharmaceuticals or consumers to consume pharmaceuticals more environmentally consciously. Therefore, the emitters of pharmaceutical contaminants are not directly targeted and there is no pressure to change behaviour. The only measures taken were voluntary and can be expected to exert only 'soft' pressure on relevant target groups (see Metz [56] for a detailed evaluation). A significant change in the measures adopted could not be observed. To conclude, the policy status quo in Germany has been predominantly a control approach in combination with 'soft' policy measures. A major policy change did not occur.

Public debate and its impact on the policy response
In the subsequent section, we first provide some descriptive statistics on actor participation and the policy beliefs expressed in the public debate. We then turn to the main part where we analyse the coalition structure. In addition, we shed some light on the structure of policy narratives

in the public debate. We conclude by relating our empirical findings to our theoretical expectations with regard to an impact of the public debate on policy formation.

Participation of political actors
Overall, persons affiliated with 200 different organisations issued 666 statements on pharmaceutical contaminants in the selected newspaper articles between January 2013 and December 2017. Table 1 presents descriptive statistics for different types of organisations, including the number of organisations per type and the frequency of statements.

The public debate was dominated by political-administrative actors, science, and organisations affiliated with the sectors of wastewater treatment and water provision (together 73.3% of statements). Political-administrative actors from different regulatory levels contributed the second highest share of statements. Among these, actors representing the federal and state levels were most active (9.5 and 9.6%, respectively), which coincides with the fact, that responsibilities for water protection lie mostly on the federal and the state levels. The German Federal Environmental Protection Agency (UBA) was the most active single organisation with 52 statements (7.8%). Universities and other higher education institution accounted for 16.5% of the statements. The largest share of statements stemmed from wastewater treatment and

Table 2 Frequency of expressed policy beliefs in the public debate

Policy beliefs	Agreement		Disagreement		Total		
	Σ	%	Σ	%	Σ	%	
Risk for the environment	87	13.1	0		87	13.1	
Risk for human health	24	3.6	43	6.5	67	10.1	
Risk unknown	32	4.8	0		32	4.8	
Consumers responsible	115	17.3	0		115	17.3	
Agriculture responsible	38	5.7	1	0.2	39	5.9	
Pharmaceutical industry responsible	13	2.0	0		13	2.0	
Wastewater treatment responsible	74	11.1	0		74	11.1	
Policy approach: consumer	54	8.1	0		54	8.1	
Policy approach: agriculture	19	2.9	1	0.2	20	3.0	
Policy approach: pharmaceutical industry	42	6.3	0		42	6.3	
Policy approach: wastewater treatment	72	10.8	16	2.4	88	13.2	
Policy instrument: tax	3	0.5	1	0.2	4	0.6	
Policy instrument: subsidy	1	0.2	0		1	0.2	
Policy instrument: authorisation	14	2.1	1	0.2	15	2.3	
Policy instrument: application	4	0.6	0		4	0.6	
Policy instrument: product ban	1	0.2	0		1	0.2	
Policy instrument: EQS	10	1.5	0		10	1.5	
Sum	603	90.5	63	9.5	666		100.0

water provision (30.2 and 4.2%). These included water associations such as the BDEW (Federal Association of the Energy and Water Industry) and the DWA (German Association for Water Management, Wastewater and Waste), smaller municipal utilities or private water companies. Not only their share of statements, but also their number was largest compared to the other types of organisations. We identified 72 statements by the German Green party (10.8%), 45 statements by environment organisations (6.7%) and 13 statements by consumer protection organisations (1.9%). Only two organisations affiliated with industry or retail appeared in the public debate: the German Pharmaceutical Industry Association (BPI)[3] and the Association of Research-Based Pharmaceutical Companies (VFA). In total, these organisations made six statements equivalent to 0.9% of the sum of statements. The presence of organisations affiliated with agriculture was even lower (0.6%).

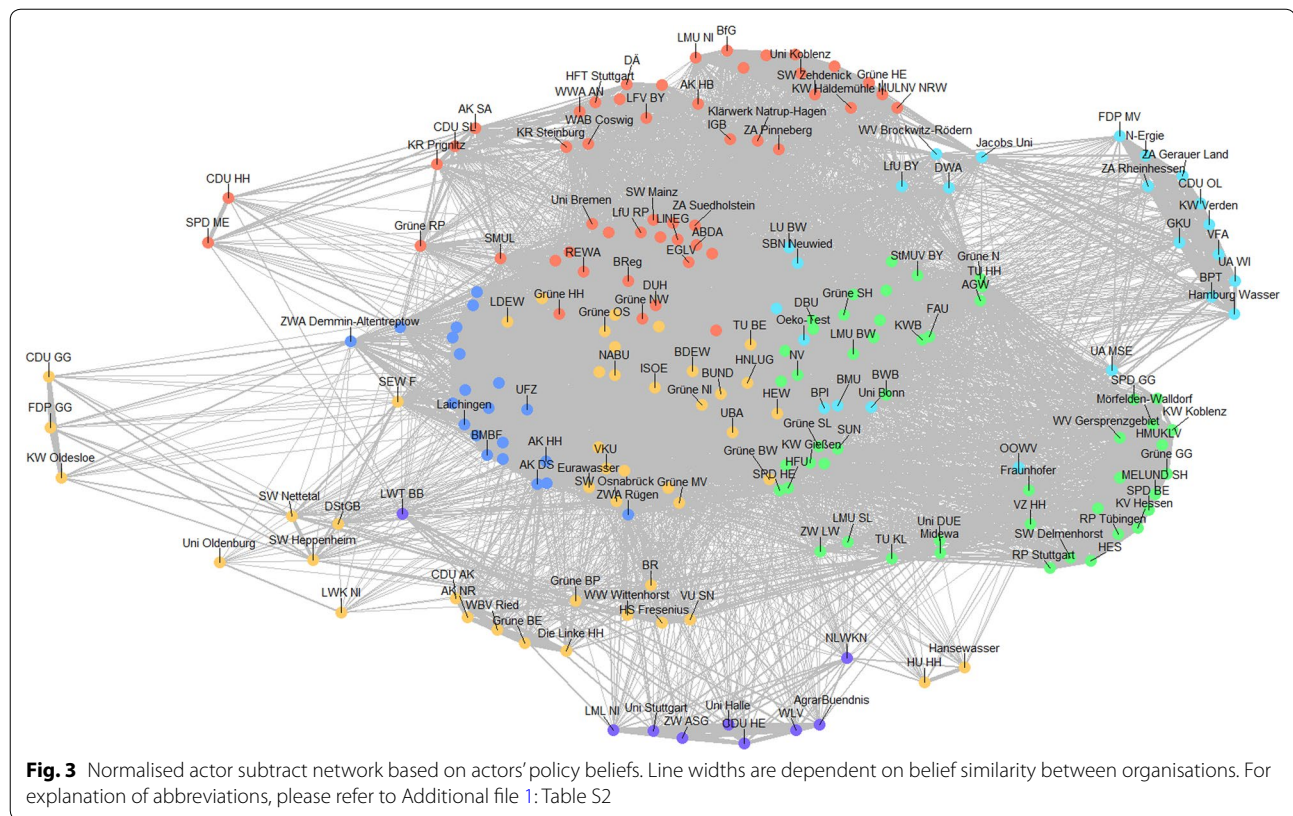### Policy positions taken in the debate and degree of dispute
We further give some insights into the policy beliefs actors expressed in the debate. Table 2 shows how frequent actors referred to the different policy aspects, either with a supportive or opposing stance. The table reports absolute numbers of statements as well as percentages on the total number of statements. Overall, the policy beliefs expressed in the debate indicate a low level of conflict. Most statements indicated a supportive stance towards the various policy aspects (90.5%). Only a small number of statements revealed opposition towards discussed sources of pollution, policy approaches, or policy instruments (9.5%).

The majority of statements on policy approaches advocated for addressing consumer behaviour (8.1%) or upgrading wastewater treatment (10.8%). Opposition towards these approaches was low. However, the end-of-pipe approach faced some opposition (2.4%)—mainly by actors representing municipal utilities or water associations such as the BDEW (Federal Association of the Energy and Water Industry). Within these statements, organisations mostly did not per se argue against upgrading wastewater treatment, but against prioritising the end-of-pipe approach while neglecting source-directed approaches. The share of statements that advocate source-directed approaches in the pharmaceutical industry or agriculture was comparatively smaller (6.3 and 2.9%, respectively).

The pattern was similar with regard to identifying the sources of pollution and attributing responsibility. Most statements saw the responsibility with consumers and wastewater treatment (17.3 and 11.1%, respectively). Organisations held responsible (1) the consumers

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Fig. 3 Normalised actor subtract network based on actors' policy beliefs. Line widths are dependent on belief similarity between organisations. For explanation of abbreviations, please refer to Additional file 1: Table S2

for pollution mainly because of inappropriate disposal behaviour and (2) the wastewater treatment sector for not being able to eliminate contaminants from the sewage water. Responsibility was comparatively less often attributed to the pharmaceutical industry or the agricultural sector (2.0 and 5.7%, respectively).

Statements on particular policy instruments were rare and issued only by a few organisations. EQSs characterise the current water policy in Germany to a large degree, and some organisations advocated for applying new limits for pharmaceutical residues (1.5% of statements). A slightly larger share of statements showed approval for restricting the authorisation of pharmaceuticals (2.1%), with only one opposing statement by the BPI (0.2%). Restricting the application of certain pharmaceuticals, another command-and-control measure, was hardly debated (0.6%). Market-based instruments, including taxes and subsidies, were mentioned only five times (0.9%). Overall, the public debate did not pay much attention to tangible policy instruments.

Finally, there was general agreement that pharmaceutical residues pose a risk for the environment (13.1%) or that the risk remains unknown (4.8%). The main exception from this pattern was actors' position on a possible risk for human health. The majority of statements explained that pharmaceutical residues do not pose a risk

to human health (6.5% compared to 3.6%). These statements were mostly related to discussions on drinking water quality, which, in fact, can be rated as very good to excellent due to Germany's very high standards for drinking water protection [94].

Actor coalitions in the policy debate

The analysis of coalition structures revealed a unitary network structure without conflicting actor coalitions. Figure 3 visualises the actor subtract network with nodes representing organisations and edges their degree of similarity with regard to their policy beliefs. The node colours indicate the organisations' membership to six different communities as determined by the Louvain algorithm.

A first visual inspection of the network graph with regard to the location of nodes and edges reveals a unitary coalition structure. Most actors cluster in the middle of the graph and share many policy beliefs as indicated by the high density of edges linking the nodes. There are only a few smaller groups on the outside which are characterised by higher belief similarity compared to other actors in the network. The visual interpretation does clearly indicate the absence of an adversarial coalition structure. If present, the graph would show two clearly separated clusters characterised by many edges within

coalitions and no, or at least only a few, edges between coalitions.

Community detection with the help of the Louvain algorithm suggests that, in fact, six different actor groups were present in the network. These consisted of three large groups with 50, 49 and 45 actors, two medium-sized groups with 24 and 21 actors, and one small group consisting of 9 actors. Subsequently, we analysed these groups and their shared policy beliefs in detail in order to investigate whether they represent adversarial actor coalitions. Additional file 1: Annex C contains visual overviews of actors' policy beliefs for each group separately.

The largest group is coloured in red in Fig. 3. Many actors in this group shared the beliefs that wastewater treatment and consumers were responsible for contamination by pharmaceuticals and that these represented a risk to the environment. However, these actors mostly did not articulate their preferred policy approach or policy instruments to regulate the issue. The second largest group is coloured in green in Fig. 3 and can be termed as the "end-of-pipe-coalition". Actors in this group all shared the belief that policy measures should address wastewater treatment. Some also favoured solutions that address consumption behaviour. Although these actors seemed to be united in how they preferred pharmaceutical contaminants to be addressed, they did not take a clear position on what type of policy measures should be implemented. The group of actors coloured in orange in Fig. 3 is more difficult to classify since actors in this group shared many positions but also had divergent policy beliefs. Apparently, some of the actors in this group explicitly rejected the end-of-pipe approach. Most of these actors were water associations. Furthermore, actors in this group mostly pointed towards the responsibility of consumers and suggested to follow a source-directed approach that addresses consumption behaviour. This group could have represented a counterpart to the "end-of-pipe-coalition" described before. The group of actors coloured in dark blue in Fig. 3 appears to be similar to the one coloured in orange. Actors in this group all shared the belief that consumers were responsible for contamination. The group consisted mostly of water associations, municipal communities or water companies, and science. However, this group also did not indicate clearly their preferred policy approach or policy instruments. The group of actors coloured in light blue in Fig. 3 was characterised by their shared belief that pharmaceutical contaminants do not represent a threat to human health. Some of these shared the belief that there is a risk for the environment. However, there is no clear pattern with regard to the attribution of responsibility and the preferred policy approach. Finally, there
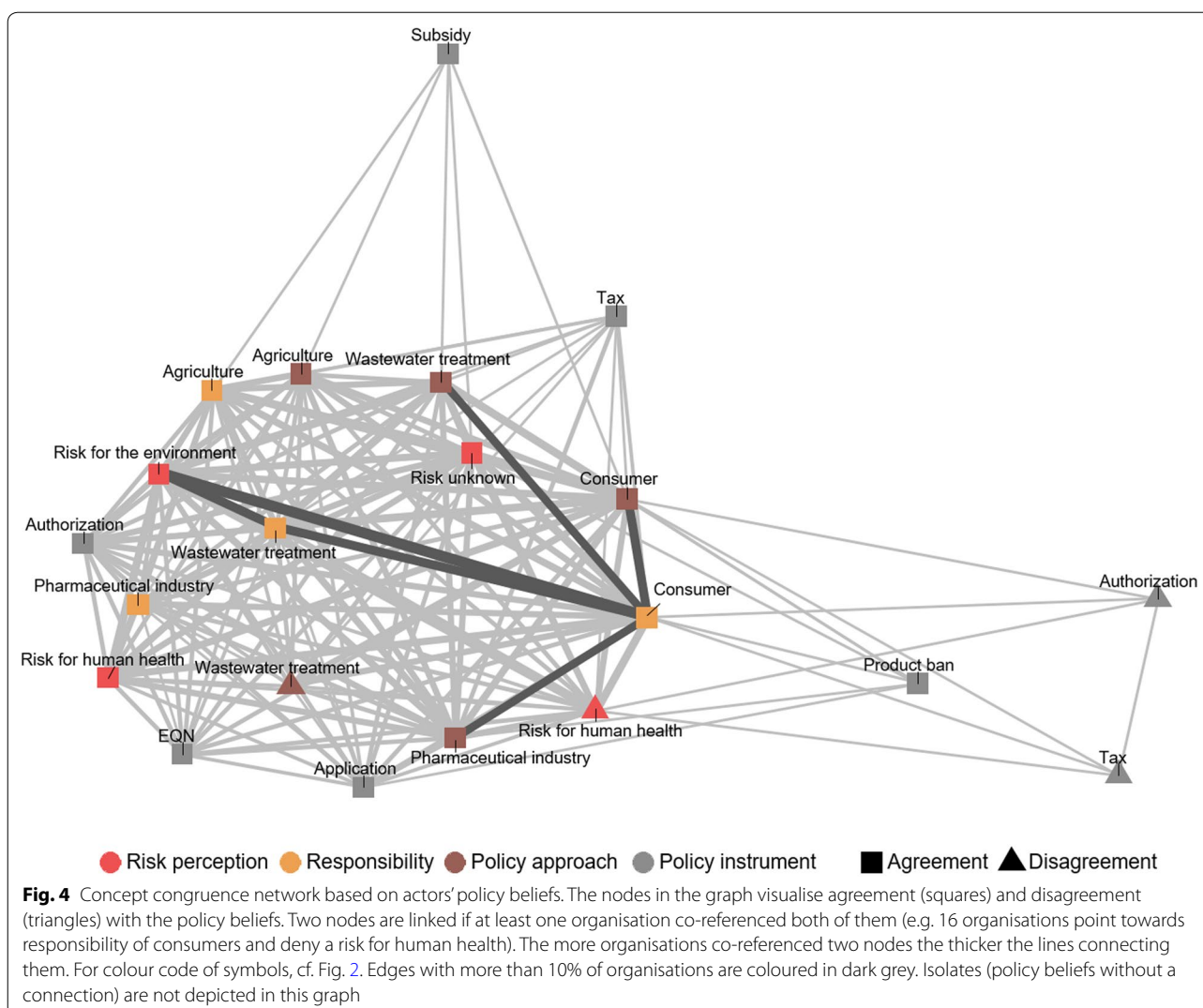
is one small group of actors, coloured in purple in Fig. 3. Actors in this group all shared the belief that the agricultural sector is responsible for water contamination by pharmaceuticals.

Finally, we analysed the distribution of actor types across the identified actor groups. Normally, one would expect similar actors (such as different environmental organisations) to be more likely to share policy beliefs and to be part of one actor coalition. In fact, the type of actors is not a strong predictor of group membership. All actor groups are characterised by a heterogeneous composition regarding the types of actors. Furthermore, a differentiation between types of organisations did not reveal significant differences in their policy beliefs. In fact, the different types of organisations held surprisingly similar policy beliefs. The majority of organisations agreed that the discharge of pharmaceutical contaminants into aquatic ecosystems was primarily a problem of consumer behaviour that should be tackled by addressing consumption and disposal behaviour and upgrading wastewater treatment. This mirrors the control approach that is currently in place at the federal level and efforts of some German states to improve wastewater technologies on their territory.

Altogether, the qualitative analysis of the determined communities suggests that these did not represent adversarial actor coalitions. The identified actor groups diverged in their policy beliefs to some degree. However, an actor coalition that clearly mobilises for a major policy change could not be identified. The computation of a modularity score of 0.312 supports the interpretation that community structures in the network were not very strong. The modularity score ranges between -1 and 1 with higher modularity scores indicating stronger community structures [52]. The graphical layout by the Fruchterman–Reingold algorithm also supports this interpretation since many actors of the different communities were placed close to each other and communities partially overlap in the centre of the graph.

The supplemental materials provide the results of a robustness test for the graphical analysis where we gradually removed lower edge weights, i.e. edges between organisations with fewer shared policy preferences (Additional file 1: Annex B). These edges tend to mask underlying network structures. The robustness test further substantiates our findings on the coalition structure: even when we remove the edges with lower degree of similarity, organisations still cluster in one main group and then dissolve into many smaller subgroups.

To conclude, the results of the graphical analysis and the community detection point towards a unitary coalition structure as defined in the theoretical section.

Fig. 4 Concept congruence network based on actors' policy beliefs. The nodes in the graph visualise agreement (squares) and disagreement (triangles) with the policy beliefs. Two nodes are linked if at least one organisation co-referenced both of them (e.g. 16 organisations point towards responsibility of consumers and deny a risk for human health). The more organisations co-referenced two nodes the thicker the lines connecting them. For colour code of symbols, cf. Fig. 2. Edges with more than 10% of organisations are coloured in dark grey. Isolates (policy beliefs without a connection) are not depicted in this graph

Policy narratives in the policy debate

The analysis of policy narratives substantiates our previous findings. Competing storylines in the policy debate on pharmaceutical contaminants in surface waters could not be identified. Figure 4 visualises the concept congruence network where two policy beliefs are linked by edges if they were co-referenced by at least one organisation. The more organisations co-referenced two policy beliefs the higher their similarity. The graph shows a similar unitary network structure we identified previously for the actor subtract network. There is only one big cluster in the centre with many edges connecting the different policy beliefs. We also performed a robustness test for the concept network where we gradually removed edges with lower similarity (i.e. fewer organisations). The unitary structure persisted, even when we normalised the network (Additional file 1: Annex C and D). The test also revealed that organisations not only mentioned

the responsibility of consumers most frequently but also most often in combination with the following policy beliefs: responsibility of the wastewater treatment sector (15.5% of organisations), policy approaches that address consumer behaviour (13.5%), wastewater treatment (11.0%), and the pharmaceutical industry (10.0%) as well as a risk for the environment (17.0%). The edges between these policy beliefs are coloured in grey in Fig. 4.

This combination of policy beliefs can be interpreted as the dominant narrative in the policy debate, which coincides to a large degree with the current water policy approach in place in Germany. The combination of consumer responsibility and a policy approach that targets the pharmaceutical industry is the only exception. Overall, the absence of a second cluster of policy beliefs indicates that the dominant policy narrative was not challenged by a competing storyline that could have advocated for policy change.

Altogether, our empirical findings support our Expectation 1b. The policy status quo in the regulation of pharmaceutical contaminants in Germany has been characterised by a focus on a control approach that has been complemented by support for wastewater treatment upgrades and information campaigns for consumers in selected German states only. Implemented policy measures included mostly voluntary measures with 'soft' pressure on target groups. Over the course of time, a major policy change did not take place. The empirical findings on the public debate suggest that the observed coalition structures did not challenge but rather contributed to the persistence of the policy status quo. The debate was characterised by a unitary coalition structure without adversarial actor coalitions. Although identified actor groups showed some level of disagreement on whether the current control approach should be complemented by a stronger focus on end-of-pipe solutions, there was nearly no debate on how to implement the approach, i.e. policy measures, and whether the pressure on target groups should be increased. Thus, it was mainly the absence of an actor coalition publicly mobilising for major policy change that explains why the policy status quo has not been challenged.

Discussion

We can compare our findings to two strands of literature. The first includes studies on the relationship between public debates and policy change. The second involves public policy research on the policy subsystem of pharmaceutical contaminants and, on a more general level, on contaminants of emerging concern or micropollutants in water. Research in political science on pharmaceutical contaminants is very limited. However, a few empirical studies have been published on the topic of micropollutants or contaminants of emerging concern.

Several studies have identified polarisation of the public debate in a policy subsystem as an enhancing factor for subsequent major policy change. For instance, Leifeld [42] showed in a study on pension politics in Germany how a prior phase of polarisation in the public debate preceded major policy change. Similarly, Fisher et al. [20] investigated climate politics in the United States and showed, based on Congressional hearings, how a phase of polarisation and a subsequent phase of dominance of a climate change supporting actor coalition preceded the adoption of the first climate change bill in th 111th Congress. Rinscheid [72] was able to show for nuclear energy policy-making that, similarly to our case, a unitary coalition structure inhibited major policy change in Japan in the aftermath of the nuclear crisis after the Fukushima accident. On the contrary, a polarised coalition structure enhanced major policy change in

Germany. Thus, our findings are in line with literatue that investigates the relationship between public debate and (the absence of) policy change.

The level of belief similarity among political actors was surprisingly high. Normally, there are significant differences in policy beliefs between political actors in areas of environmental policy [29, 88, 89]. One possible explanation revolves around the character of the policy issue. The issue of pharmaceutical contaminants is complex and characterised by a high degree of uncertainty with regard to consequences [34]. The complexity of the issue implies that there is not the one solution able to solve the problem [35], which might explain why actors with an interest in stronger environmental protection do not mobilise for a certain policy solution or policy approach. In fact, Metz and Leifeld [57] and Metz et al. [58] observe a similar pattern in a study on the regulation of micropollutants in Switzerland. They find that environmental organisations, as well as other actors such as water associations, do not prefer specific policy solutions but take a positive stance towards most types of policy intervention that would help to improve water protection. Metz [56] also investigates political actors' policy beliefs in Germany during the drafting of the OGewV between 2008 and 2011 based on survey data. She also finds comparatively high similarity in actors' policy beliefs on the issue of micropollution, which further supports our observation that the policy subsystem is characterised by an absence of strong conflict lines. Schaub and Metz [80] more systematically compare coalition structures in the policy subsystem of micropollutants in Germany. The authors compare two different types of data used to measure policy beliefs, survey and media data, and show that the analysis of both data sources lead to the identification of a policy subsystem characterised by a similar unitary coalition structure.

Compared to other policy issues, media attention to the issue of pharmaceutical contaminants was lower. For instance, the issue of fracking received about twice as much attention in the FAZ in a similar time period [88]. In general, policy issues compete for attention [99]. The complex and often very technical nature of the issue of pharmaceutical contaminants could be a barrier for increased attention, for instance by political parties. This also could be an explanation why the Green party was not more active in the public debate and did not pursue a more coherent mobilisation strategy with a stronger focus on stricter and source-directed policy measures. Similarly, environmental organisations are confronted with many environmental issues and might lack the resources to run sophisticated public campaigns on every single issue, especially if these are complex and technical in nature. Related to this point, these actors might prefer other venues, such as stakeholder consultations, in their

attempt to influence policy on pharmaceutical contaminants. In principle, the stakeholder consultation initiated by the German Federal Ministry of the Environment in 2016 provided such a venue. It should also be kept in mind that—at least at the scientific and technological levels—intensive *internal* technical discussions take place. For instance, a scientific discussion about the best strategy for the enforcement of wastewater treatment plants has been initiated quite a while ago and is ongoing at a world-wide scale (for examples, see [6, 12, 23, 24, 54, 55, 60, 102]. However, it remains questionable whether stakeholder consultations and non-public scientific discussions will lead to a change in the policy response to pharmaceutical contaminants. Unfortunately, the results of the federal stakeholder dialogue published in 2019 cement a continuation of the current policy approach. The disillusioning outcome suggests that future regulations on pharmaceutical contaminants in Germany are likely to remain 'soft' despite claims from the scientific community that the current control approach should be complemented by an and end-of-pipe and a source-directed approach [27] and that a mix of policy instruments would be favourable for achieving environmental goals [11, 68].

The low level of politisation of the public debate might also coincide with the strong presence of political-administrative actors. Their high activity in the public debate suggests that agenda-setting took place *top-down* to a large degree. Federal and state ministries and agencies, such as the Federal Ministry of the Environment or the German Environment Agency, apparently concluded that this particular issue needed to be addressed and, therefore, initiated a policy-making process. The federal stakeholder consultation may serve as an example for such a top-down agenda-setting process. Similar top-down activities could be observed in some German states, including Baden-Württemberg [121, 122], Hessen [116], and North Rhine-Westphalia [117]. In contrast, politicised public debates often coincide with *bottom-up* agenda-setting. In this case, political actors, e.g. environmental organisations or citizen initiatives, try to create attention for an issue in order to place the issue on the political agenda [4, 31, 91]. The comparatively low presence of organisations with an interest in environmental protection, e.g. environmental organisations or the Green party (e.g. compared to [61] or [89]), in the public debate suggests that bottom-up agenda-setting was weak in comparison. However, it is bottom-up agenda-setting that mostly leads to major policy change whereas top-down agenda-setting is rather associated with only small incremental changes [4]. These findings also resonate with Metz [56] who finds that the Federal Ministry of the Environment, the German Environment Agency

and representatives of the German states played central roles in the formulation of the OGewV, which in turn was largely motivated by policy-making at the EU-level [56].

Conclusions

Despite clear-cut scientific evidence that pharmaceutical contaminants cause adverse effects in aquatic life and pose a risk for drinking water resources, the regulatory response in Germany has been weak. This study investigated the impact of the public debate on the policy response to pharmaceutical contaminants in surface waters in Germany. Thus, the study contributes to public policy research in environmental policy. More specifically, it contributes to literature on pharmaceutical contaminants in water by analysing current regulation and policy-making processes in this policy subsystem with a political science research design, coupled with insights from the environmental sciences. The main aim was to investigate whether the public debate on pharmaceutical contaminants had an impact on the observed policy response to pharmaceutical contaminants in Germany. Overall, the empirical findings suggest that the observed actor coalition structures revealed in the public debate contributed to the persistence of the regulatory response. Strong bottom-up mobilisation by an adversarial coalition could not be observed. Reasons could be the complex and technical nature of the policy issue, which makes it more difficult to conduct sophisticated public campaigns. Related to this, political actors with an interest in policy change might resort to other venues, such as lobbying or stakeholder consultations, to influence policy-making on the regulation of pharmaceutical contaminants. Our findings suggest that policy formation was largely influenced by top-down agenda-setting by political-administrative actors, instead. Based on our findings and the insights of previous research, we expect only small incremental changes to the current regulatory response likely to occur in the near future. Nevertheless, empirical research in political science has repeatedly shown that the public debate can have an impact on policy formation and trigger major policy change. Thus, political actors with an interest in stricter regulatory measures and a prioritisation of source-directed approaches might want to reconsider their strategies.

Despite the insights offered, the current study bears some limitations: First, the findings of this case study do not allow causal conclusions, since the study has exclusively been focused on Germany and, therefore, lacks comparison with other cases. Future studies might build on the results of this pre-test and compare different cases, which would allow to systematically vary the independent variable and control for other influences. A comparison with Switzerland appears fruitful where the adoption

of the new Water Protection Act in 2016 meant a change to an-end-of-pipe approach combined with strong regulatory measures. Selected operators have been forced to upgrade their purification technologies to the so-called "fourth treatment stage" over the next 20 years [56]. Second, the study focuses on the role of the public debate and neglects other venues political actors might use to influence policy-making. Other venues may include lobbying activities behind closed doors, stakeholder consultations or legal confrontations. Further studies could investigate the strategic behaviour of specific political actors based on interviews, for instance. Third, we had to leave other potentially influential factors aside. These factors include the role of the EU or the influence of the German states in Germany's federal political system. Future studies might, e.g. investigate long-term and long-range EU policy-making processes and their impact on national responses to pharmaceutical contaminants.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12302-020-00423-5.

Additional file 1. Supplemental materials.

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