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RESEARCH ARTICLE

Politics of the precautionary principle: assessing actors' preferences in water protection policy

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Abstract This paper analyzes the prospects for introducing the precautionary principle in water protection policy. In situations where a problem enters the political agenda and scientific uncertainties remain about causes or effects, political actors can justify state intervention based on the precautionary principle. It allows for public action even if risks related to the problem remain unclear. While the precautionary principle is widely applied in health and environmental policy fields all over the world, the mechanisms leading to its adoption are not fully understood. To close this gap, the paper investigates decision-makers preferences for the precautionary principle and further asks: Which factors promote political actors' preferences for precautionary policy measures? In order to answer this question we study the case of emerging micropollutants—a water quality issue that recently entered political agendas, where many uncertainties remain about sources and effects. We rely on data gathered through a standardized survey among the political elite in Switzerland, which represents one of the first countries that adopted policy measures to reduce micropollutants in water bodies, despite the uncertainties that remain. Results analyzed through a temporal network autocorrelation model reveal that actors embedded in collaborative governance arrangements have the tendency to prefer precautionary action. Certain aspects of policy design, such as problem prioritization and target group membership, also impact the prospects for introducing the precautionary principle.

Keywords Precautionary principle · Water protection policy · Uncertainties · Micropollutants · Policy preferences · Network modeling

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Introduction

Designing appropriate state intervention in highly complex fields such as biomedicine, emerging water pollutants, or unconventional gas extraction constitutes a challenge, because "standard" decision-making based on a clear causal chain between problem, effects, and impacts is difficult if not inappropriate (Manson 2002). Where uncertainties about the causes and effects of a problem, and about the probabilities of causes and effects exist (Resnik 2004), the replacement of standard decision-making by the application of the *precautionary principle* comes into play.

The most acclaimed definition of the precautionary principle can be found in the Rio Declaration (UNEP 1992): "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Despite this rather intuitive definition of the precautionary principle, its application has been widely criticized for being risk-aversive, unscientific (Resnik 2003), or too difficult to implement. Hindering its implementation are the challenges involved in balancing risks, costs, and political support for measures within a context of uncertainty (Manson 2002). Without scientific certainty, it is a challenge to define state intervention by choosing certain policy instruments over others (Vogel 2004). Even though the precautionary principle cannot overcome uncertainties, it still offers a viable policy strategy for taking into account uncertain risks "where scientific data do not permit a complete evaluation of the risk" (EC 2000), or where "there is doubt about an animal's or plant's exact conservation status" (Harvest Control Rule of the International Council for the Exploration of the Sea (ICES 1993)).

In this paper, we investigate under which conditions actors involved in political decision-making favor the precautionary principle as an appropriate means of state intervention. The research question we address is: Which factors enhance an actor's preferences for precautionary policy design? To answer this question, we first characterize the precautionary principle as a means of state intervention and, secondly, we explore factors that may affect its adoption. We investigate the case of emerging challenges in water protection policy related to micropollutants, which offers an ideal setting to study the precautionary principle for the following reasons: Due to the technological process in chemical analysis, it is possible today to detect increasingly small concentrations of pollutants in water bodies (Richardson and Ternes 2011), while there is only limited scientific evidence about their impact on humans and the environment (Hollender et al. 2008). Taking into consideration the large number of substances in use, the ongoing development of new compounds, and potential interaction effects of metabolites, it seems challenging, if not impossible, to obtain full certainty regarding associated risks on humans and the environment in the future. Rather, decision-makers will always deal with some degree of uncertainty when addressing the issue of micropollutants. In light of these uncertainties, policymakers face the decision of whether or not to take action—their dilemma rests on whether political measures are justified because negative consequences for humans cannot be ruled out, or whether measures are premature as long as negative impacts cannot be proven with absolute certainty.

We take the example of Switzerland here, because it represents one of the first countries that, despite existing uncertainties, adopted legally binding policy measures to reduce emerging micropollutants in water bodies. This case serves us in assessing the factors that promote or inhibit actors' preferences for precautionary action. Based on a standardized survey distributed among the political elite, we gathered data about policy preferences and actors' attributes. Through advanced network modeling, we assess which factors drive

Swiss political actors to support various precautionary policy approaches, including source-directed (e.g., incentives for substance use reduction) and end-of-pipe solutions (e.g., technological upgrade in wastewater treatment).

Precautionary principle in political decision-making

The ways in which to appropriately design policies have previously been investigated in policy studies and analysis research. A major research concern within this field of literatures involves those tools that are able to effectively change target groups' behavior and fulfill defined policy goals (Howlett 2009). However, addressing this question is much more complicated when policymaking has to deal with increasingly intractable societal or environmental problems characterized by high uncertainty, complexity, and swift change (Crona and Parker 2012; Rockstrom et al. 2009). We outline below the challenges that policymaking faces in situations of uncertain risks and describe the precautionary principle as a means of state intervention to deal with uncertainties. We conclude this section by outlining factors enhancing actors' support for precautionary actions, borrowing insights from collaborative governance and policy design literature.

The precautionary principle in situations of uncertainty

Policy design in the twentieth century was dominated by the *scientific testing and regulation paradigm*, according to Vogel (2004). Health and environmental politics typically followed this paradigm and foresaw state intervention only in situations where harm to humans or nature was scientifically proven. To assume that decision-makers can acquire "full information or knowledge" about an issue certainly constitutes a strong form of evidence-based policymaking, since providing full scientific proof is burdensome and comes with several limits (Cairney 2016): In order to ensure that scientific evidence can inform political decision-making, the producer and the consumer of evidence must speak the same language, and their timing, interests, and aims must match (Choi et al. 2005; Edelenbos et al. 2011). Evidence-based policymaking can further reach limits in complex issues such as climate change, nuclear waste storage, or toxic chemicals in waters, where it remains open to question as to whether scientific proof or evidence can be considered fully obtained. In situations where complete certainty cannot be achieved, state intervention under the scientific testing and regulation paradigm is not feasible. Vogel's example on policymaking related to endocrine disruptors and chemical pollution in the USA shows that only dysfunctional regulation was produced under this paradigm, because the burden of proof was insuperable (Vogel 2004).

There exists a solution to deal with an insuperable burden of proof and handle scientific uncertainty—by accepting it. Following the *precautionary principle*, state action is justified if there is suspicion about potential risks to humans or the environment, but full certainty or consensus about causes, impacts, and interaction effects is impossible to achieve (Myers and Raffensperger 2006; O'Riordan and Cameron 1994). The precautionary principle applies in situations of uncertainty termed as "radical" (Funtowicz and Ravetz 1993) meaning that uncertainty is not solely an absence of knowledge and cannot simply be reduced through scientific research. Instead, risks are inherently uncertain because both the probability of a potentially harmful event occurring and the extent of damage of that event are uncertain (see risk typology by Klinke and Renn 2002).

According to Nowotny et al. (2001), uncertain risks are particularly prevalent in modern societies, which are characterized by innovation. However, the pace of change in innovative societies renders fully determining potential dangers impossible (van Asselt and Vos 2006). The precautionary principle is thus a way of handling situations where adverse effects are not entirely calculable (van Asselt and Vos 2006).

In cases where decision-makers wished to take responsibilities rather than postponing action to future reactive measures, the precautionary principle has been considered a viable option in national laws and in international treaties (Manson 2002) for the past three decades. Within the European Union, for example, the precautionary principle has been employed to legitimate decisions in contexts of uncertainty related to food crises such as BSE or to WTO requirements (Christoforou 2003, 2004; Jordan 2001; Morris 2000; Sandin 1999; Scott and Vos 2002; Wiener and Rogers 2002).

These instances of applying the precautionary principle reveal difficulties known as the "uncertainty paradox" (van Asselt and Vos 2006). Although the precautionary principle is tailored for situations where evidence for potential danger is not available (and maybe impossible to achieve), the precautionary principle rests upon a "knowledge condition." Accordingly, a certain level of proof is necessary to justify application of the precautionary principle (Fisher 2002; Manson 2002). The "knowledge condition" tends to trigger circumstances where policymakers demand evidence for whether a phenomenon (e.g., the introduction of new chemicals) poses risks (van Asselt and Vos 2006). Science, in turn, cannot provide certainty about inherently uncertain risks. Consequently, policy processes run into paralysis, i.e., a long back and forth of generating further information and acknowledging inherent uncertainties (see Pfizer case, van Asselt and Vos 2006).

Such deadlock situations are particularly difficult to solve, as the study by Weible and Sabatier (2009) suggests, because actors' deeply rooted values take on an even more important role in political decision-making where the scientific proof is incomplete. Actors defending diverse ideologies are likely to collide, especially in the case of preference for the status quo over a radically new logic of state intervention. In a complex and uncertain setting of decision-making, we asked what drives political actors to opt for precautionary action—when does precaution become a viable political option?

Political support for precautionary measures

Research on political behavior has demonstrated that attitudes can deviate from actual political (voting) behavior (Ajzen and Fishbein 1980). With regard to the distinction between attitudes and behavior, we employ the term "policy preferences" here to refer to actors' attitudes (in favor or against precautionary action) in early stages of the policy-making process, i.e., during policy formulation, where actors review and debate diverse policy alternatives, but do not yet vote for one option or the other. Policy preferences reflect the type of policy instruments that actors involved in policy formulation accept and are therefore an important pre-condition for the materialization of successful policies (Dermont et al. 2017). Besides showing the tenor of a political debate and potential ideological conflict lines, policy preferences also inform policy design. Where a large part of political actors including the target group prefer a certain instrument, one can expect an increased ease in the instruments' implementation (Mayntz 1979; Goggin et al. 1990; O'Toole 2000). The literatures points to several factors that influence whether or not political actors *prefer* precautionary policy intervention.

Following the literature on *collaborative governance*, collaborative institutions and arrangements are able to create mutual understandings and learning, bridge ideological

divides, and promote joint problem-solving initiatives for involved and engaged actors (Henry 2011; Doris 2007; Leach et al. 2002). In their work, Weible and Sabatier (2009) distinguish between collaborative types of subsystems and adversarial ones, the former being characterized by a common understanding of the issue, joint problem-solving initiatives, and an intermediate level of conflict among involved actors. They argue that in such collaborative settings actors develop trust and engage in understanding the rationales behind other actors' policy preferences. Mutual understandings provide a fertile context for learning and the development of a shared knowledge base (Weible and Sabatier 2009). Similar arguments have been put forward in the literatures on adaptive governance and sustainability (Dietz et al. 2003; Lubell 2004; Norton 2005). In their study, Leach et al. (2014) find that especially in cases where scientific uncertainties about an issue remain, actors' are more likely to acquire knowledge through collaborative processes. They interpret results such that actors' social interactions may help in understanding scientific uncertainties and in developing suitable policy strategies. Hence, exchanges with other actors in the policymaking process may create a sense of urgency to act and foster actors' insight that precautionary measures are necessary (Koppenjan and Klijn 2004). In sum, actors who collaborate, or more broadly speaking interact,[1] with others in complex settings are exposed to political discourse, which can raise their awareness about any given issue and positively induce learning (Voss et al. 2009) about the adequateness of precautionary measures where uncertainties about an underlying policy remain.

Based on these insights, we deduce our first hypothesis:

H1 The more actors collaborate with others during policy formulation, the more they tend to prefer precautionary action.

Policy actors meet, collaborate, and exchange information when they commonly participate in policy arenas, venues, or platforms. Venues and arenas increase opportunities for the exchange and negotiation between actors and their positions (Fischer 2014). Such arenas can be official stages in the decision-making process, for example through public hearings or consultations, but they can also include informal institutional arrangements (Fischer and Leifeld 2015). When the political issue under consideration is of international importance, such as the case for climate change mitigation or water quality management in international transboundary rivers, participation in international arenas (e.g., cross-border water basin organizations) can deploy collaborative governance effects as outlined above: learning and awareness about the issue is facilitated, and thereby, a common understanding of the issue, its urgency, and the necessity to act can come to fruition (Metz and Fischer 2016). As a consequence of exchanges in these arenas, preferences of internationally active actors can be fostered toward precautionary action, which leads us to hypothesize:

H2 Actors involved in international arenas tend to prefer precautionary action.

Not only social interactions and institutions, but also policy design aspects, may impact policy choices and actors' preferences (Howlett 2014; Andersen 2001). Policy design aspects embrace the rules and circumstances under which policy choices are taken, such as the ways in which actors perceive a problem when it arrives on the political agenda and which level of salience they attribute to it. Policy issues compete for prioritization on political agendas such that certain issues, even if important, are still lower in priority than others due to resource restrictions (Baumgartner and Jones 1993; Jones and Baumgartner

[1] We employ the term "social interactions" as an umbrella term which includes different types of relations between actors such as collaboration, negotiations, advice-seeking, information exchange.

2005). Prioritization is partly a matter of framing (Nelson 2004). An issue could, for example, be framed as environmental or health related, where the latter would eventually gain higher priority since public health ranks as a prime concern on the agendas of most western societies. Actors who attribute high importance to an issue might favor immediate state intervention, even if there is not yet full scientific certainty and complete understanding of the problem. Therefore, we hypothesize:

H3 Actors who attribute high priority to an issue on their political agendas tend to prefer precautionary action.

Another crucial aspect of policy design is the identification of adequate target groups and to introduce instruments that change the behavior of these actors (Howlett 2009). At the same time, however, it can be costly for target groups to change their behaviors in accordance with an introduced policy, or even detrimental to their image to be made responsible for issues such as pollution. As target groups are the subject of introduced policies (Knoepfel and Bättig 2007), they tend to prefer instruments that keep their costs low and their flexibility in implementation as high as possible (Landry and Varone 2005). To circumvent costs or avoid blame, actors tend to impede the adoption of policy instruments that would target them. Potential target groups of precautionary measures in particular can easily impede political action by arguing that inherent uncertainties about causes of a (pollution) issue remain, which render it impossible to identify appropriate causes and justify political measures. Applying this logic to decision-making would entail target groups of precautionary measures preferring instruments that target others and thereby maintaining their low costs and responsibilities.

H4 Target groups of precautionary action tend to opt against it.

Although we present our hypotheses consecutively for reasons of clarity, the mechanisms outlined above may nonetheless interplay. For example, the more that actors collaborate (H1), or the more they interact in an international arena (H2), the more they may be aware of an issue and prioritize it on their agendas (H3). The interplay between actors' interactions and their awareness and prioritization could in turn drive them to support the precautionary principle.

Case

Before introducing the political decision-making process investigated here (Swiss amendment of water protection act and ordinance regarding micropollutants), we highlight the reasons why the issue of micropollutants still comes with a significant amount of scientific uncertainty regarding causes and effects. We also illustrate what types of precautionary measures are currently in the policy debate.

Issue of micropollutants

The issue of micropollutants represents an emerging policy field. Precautionary action is a way of handling the inherent uncertainties related to micropollutants that challenge the conventional scientific testing paradigm in water protection.

Micropollutants

Micropollutants are chemical organic substances detected in surface waters at concentration levels as low as nanograms per liter (ng/L) to micrograms per liter (μg/L). This phenomenon is defined in contrast to aquatic macropollutants—compounds present at the level of micrograms per liter (μg/L) to milligrams per liter (mg/L). Macropollutants are the traditional target of water protection policy, while micropollutants are rather new to political agendas and constitute a complex policy issue (Metz and Ingold 2014). In Europe alone, there exist about 100,000 synthetic substances in use, and an additional 1000 new chemicals enter the market every year (Götz et al. 2010). Each compound is associated with a unique combination of factors determining its usage, entry-path into waters, and behavior in the environment, which complicates the task of assessing its impacts on the ecosystem or human health.

The conventional testing and regulation paradigm in water protection

Today's water protection policies build on a scientific testing and regulation paradigm according to which exposure and toxicity levels must be assessed compound-by-compound prior to regulation. If risk assessment reveals that a compound is present in water at higher levels than would be safe for the environment, an environmental quality norm can be established, and the substance can be proposed for inclusion in future monitoring. When monitoring reveals that the environmental quality norm is exceeded, it is then necessary to implement emission reduction measures (Schwarzenbach et al. 2006). This target-based monitoring approach (i.e., monitoring a substance that is already known and regulated) limits detection to "conventional" pollutants, i.e., lists of known pollutants, which typically comprise industrial chemicals and pesticides, but are only a very small portion of the chemicals to which organisms experience exposure. Additionally, current water protection can regulate only those substances for which chemical analysis possesses tools for detection and monitoring. However, current detection and toxicity tests are ill-adapted to the large number and diversity of micropollutants, as well as to their low concentrations, metabolites, or interaction effects between substances mixed in water bodies.

Challenges to conventional policy paradigms

The scientific testing and regulation paradigm, on which water protection policies have so fare relied, has come under considerable stress with regards to the future of water pollution. An inherent drawback to the monitoring approach is the lack of analysis of compounds for which no information exists concerning their exposure and toxicity. Even if such a substance were deemed hazardous and were frequently present in surface water, no such monitoring would take place, and thus no data could be obtained that would justify including the substance in future testing. Therefore, the substance would remain unanalyzed and unregulated (Von der Ohe et al. 2011). This void particularly pertains to micropollutants since they have only recently raised concern (Richardson and Ternes 2011). Micropollutants have been termed "known unknowns" or "unknown unknowns" (Müller 2011), which refers to a class of substances that cannot be categorized into known molecules or identified by standard evaluation methods (Cleven et al. 2013). Additionally, virtually no limits exist concerning the types of possible chemicals—quite the contrary, new chemicals are introduced to commerce continuously, while the multiple modes of

action are rarely fully understood (Daughton 2004). If risk assessment must stay up to date with each single newly engineered substances in use, evidence-based water policies will remain a resource-intensive challenge. Considering the high number of substances in use, together with the ongoing development of new compounds and potential interaction effects of substances and their metabolites, it seems unlikely that the associated risks can be fully assessed for each compound (Schwarzenbach et al. 2006). Decision-making will most likely always face some degree of uncertainty when it comes to micropollutants. A consequence of inherent uncertainties of the issue, policy action is not only a means of improving knowledge about micropollutants in water bodies, but also depends on a commitment toward the precautionary principle. When the burden of scientific proof is costly to the point of becoming insuperable, precautionary action is regarded as the most logical form of state intervention available to policymakers (Vogel 2004).

Precautionary measures related to micropollutants

When it comes to precautionary measures for the reduction of micropollutants in water bodies, one can broadly distinguish source-directed measures from end-of-pipe policy strategies (Metz and Ingold 2014). We introduce this distinction here for two reasons: first, in order to understand whether actors favor certain types of precautionary approaches over others, and secondly, to differentiate between two types of target groups in the context of our hypothesis 4. Source-directed measures refer to policies that address the origin of the problem by reducing the use of potentially harmful substances in production or consumption in order to prevent their release into water. Source-directed policy approaches include various types of policy instruments, which impose, incentivize, or encourage reducing the use of chemicals. For example, restrictions on the application of pesticides in specific buffer zones around a water body can prevent input into water; substance charges can incentivize chemical-free or chemical-reduced production processes, while product charges can incentivize environmentally conscious consumption behavior. Target groups of such measures include consumers as well as industrial and agricultural producers. In contrast to source-directed policy approaches, end-of-pipe measures focus on removing or eliminating micropollutants after their use or release into water. End-of-pipe policies involve various types of instruments that impose, incentivize, or encourage improved wastewater treatment or waste disposal. Conventional municipal wastewater treatment plants have not been designed to remove many micropollutants that are resistant to biological degradation. Hence, new wastewater treatment technologies must be implemented that are able to eliminate emerging micropollutants. One end-of-pipe policy option is to provide incentives for the upgrade of wastewater treatment plants with new removal technologies. Another end-of-pipe option involves improvement of waste disposal where products containing micropollutants have been used by consumers, but their release into water is prevented by waste disposal requirements. Target groups of end-of-pipe measures typically include wastewater treatment plants and municipalities, or cities responsible for waste and wastewater treatment.

The Swiss case

In Switzerland, the issue of micropollutants entered the political agenda after several research projects (Projekt Fischnetz[2] on declining fish populations; NFP 50 on endocrine

[2] http://www.fischnetz.ch/index_e.htm (last access on August 21, 2017).

disruptors[3]) indicated that even small concentrations of certain pollutants can negatively impact the aquatic environment (Burkhardt-Holm et al. 2002). In 2007, the Swiss Federal Office for the Environment (FOEN) launched a project entitled "Strategy Micropoll for the Optimization of Sewage Treatment." Several working groups, bringing together the FOEN, sub-national jurisdictions (cantons), operators of treatment plants, professional water associations, science, and industry, were established to prompt further policy action. As of 2009, a revised Waters Protection Ordinance (WPO) was drafted, which proposed a technical standard according to which wastewater treatment plants must eliminate 80% of organic micropollutants from sewage (WPO Appendix 3.1 Numeral 2 Nr 8). This proposed technical standard only applied to the biggest sewage plants,[4] or to smaller plants[5] if they drained into sensitive rivers, e.g., water used for drinking water purposes. With these selection criteria, about 100 out of the 700 existing sewage plants in Switzerland would have to upgrade with a further treatment step and a new filtering technology. According to the FOEN, the estimated cost of about 1.2 Billion Swiss Francs (approx. 1.3 Billion USD) was to be paid by those 100 treatment plants that were upgraded. Costs would be passed on to households connected to the treatment plants that must upgrade their filtering technologies, while those plants that do not meet the selection criteria, along with their connected households, would not be required to contribute payments. The draft ordinance was then submitted for a public hearing, in which the majority of the respondents expressed a need to act politically in order to reduce aquatic micropollutants. However, they criticized the unequal distribution of costs and argued for a financing solution that involves all Swiss households (not just those connected to the 100 selected plants), since they all contribute to the pollution problem. In August of 2010, this argument was taken up by the parliament (Motion 10.3635). Consequently, the FOEN proposed the introduction of a Swiss-wide wastewater fee earmarked for the upgrade of sewage plants. By contrast to the previous solution, all Swiss households were to pay this fee, up to a maximum of 9 CHF per year (approx. 10 USD). The revenue raised from the fee was to be used to reimburse up to 75% of the costs that sewage plant operators pay for the upgrade.

The proposal of the amended Waters Protection Act (WPA) was discussed in the Swiss Government on April 25, 2012 and, subsequently, was sent for a public consultation (April–August 2012). The respondents still criticized the financing solution for not respecting the polluter pays principle. Some actors preferred a product charge, which would address the problem at the source. At the end of 2013, the Swiss Government sent the finalized draft to the Parliament, where both chambers adopted the legal revision, which includes the above-described technical standard and fee.

In summary, the Swiss regulation of micropollutants adopted the precautionary principle, and policy measures were taken despite remaining uncertainties about the underlying policy problem. Moreover, Swiss policy action followed an end-of-pipe approach. Nevertheless, some stakeholders clearly considered reducing micropollutants at the source of the problem during the above outlined process, while others were opposed to any sort of policy action, thereby rejecting the precautionary principle.

[3] http://www.snf.ch/en/researchinFocus/nrp/nrp50-endocrine-disruptors-relevance-to-humans-animals-andecosystems/Pages/default.aspx (last access on August 21, 2017).

[4] Population equivalent of more than 100,000.

[5] Population equivalent of 10,000 to 100,000.

Data and methods

We surveyed policy actors who participated in the above-mentioned policy process on micropollutants. We assessed actors' preferences toward precautionary and reactive action, and the factors that shape preferences. Policy actors are defined as state and non-state *collective* actors who have a stake in water quality policy and represent governmental bodies, science, political parties, as well as water, environmental, and economic associations. To identify the key actors involved in the elaboration of the legal revisions, the well-approved decisional, positional, and reputational approaches were applied as follows (Laumann et al. 1983; Knoke et al. 1996; Knoke 1994). In line with the decisional approach, the policy process was retraced and split into several phases (agenda setting phase, concept phase, preparation of the legal drafts, consultations, finalization of the draft, parliamentary phase, and implementation). Out of the approximately 170 actors participating in this process, only those who participated at least twice in the same phase or in at least two different phases were retained. The resulting list of 50 actors was then complemented, according to the positional approach, by actors who are qualified to decide on, and implement, micropollutants regulation. These were typically federal agencies involved in internal consultations of legal revisions, sub-national associations assigned with implementation tasks, or political parties in parliamentary commissions. Finally, this extensive list was presented to two senior officials of the FOEN, and one from the Swiss Water Association, who, through applying the reputational approach, indicated the most crucial actors, while also adding missing actors to our list. The combination of decisional, positional, and reputational approaches resulted in a list of 62 actors in total.

Data gathering took place between April and July 2013 through a mixed-mode survey based on standardized questionnaires. We mail-surveyed 50 actors and interviewed another 12 actors, who were identified as particularly crucial in the decision-making process by experts. During the interviews, the same standardized survey questions were asked as were included in the postal survey and, additionally, open questions were discussed in order to complement the quantitative data with some qualitative information. A total of 41 actors[6] answered the relevant questions for the present analysis and are therefore considered here (see "Appendix" for an actor list). The sample provides an accurate and complete overview of the key actors in the field of micropollutants.

We surveyed actors' *preferences* toward precautionary and reactive policy measures in two steps. First, we wanted to know whether actors favor (or reject) the precautionary principle for the reduction of micropollutants. We asked respondents about their level of agreement on a four-point Likert scale (from "strongly agree" to "strongly disagree") with the following approaches:

- As long as the consequences of micropollutants are not fully understood, precautionary measures for the reduction of micropollutants should be adopted (precautionary principle).
- As long as the consequences of micropollutants are not fully understood, no measures for the reduction of micropollutants should be adopted (reactive principle).

[6] A total of 12 actors reported having a common position or not having participated enough to respond to the survey questions; another six actors (i.e., federal agencies who must formally partake in consultations internal to the government, but who do not necessarily have a stake in the issue of aquatic micropollutants) only partly responded to the survey; three actors did not reply.

Secondly, we wanted to know whether actors generally oppose precautionary measures in addressing the problem of micropollutants, or whether they favored certain types of precautionary approaches over others, be they end-of-pipe or source-directed. Again, we asked survey participants about their level of agreement on a four-point Likert scale (from "strongly agree" to "strongly disagree") with the following statements:

- Measures should address the source of the problem.
- Measures should address the end-of-the-pipe (sewage treatment).

Moreover, we gathered data on explanatory factors of policy preferences. With hypothesis 1, we analyze the effect of collaboration on actors' preferences toward precautionary measures and thereby adopt a network approach. We assess interconnectedness here through the maintenance of collaboration ties in the policy process on micropollutants. We asked survey respondents about their collaboration ties as follows: Please check all the actors (from the following list) with whom your organization has closely collaborated during the policy process on pharmaceutical micropollution (2007–present). Close collaboration is defined as: discussing new findings, developing policy options, exchanging positions, and evaluating alternatives. Responses were coded as a dummy variable (0, 1) in an actor × actor matrix and symmetrized, because collaboration can be regarded as a mutual relationship. We employ the resulting collaboration network to better understand the social processes behind preference formation. We distinguish between two types of social processes in our operationalization of hypothesis 1. First, we seek to capture the tendency of actors to be more aware and to learn about the adequacy of the precautionary principle, as they collaborate in the policymaking process. We calculated actors' *degree centralities*, i.e., the number of ties each node maintains toward others. Centrality provides information on the extent to which an actor collaborates with others on the topic of micropollutants policies. We expect that actors with comparably high degrees (number of ties) tend to prefer precautionary action due to learning processes. Secondly, we test whether an actor's preferences depend on the preferences of others' with whom the actor maintains collaboration ties. We capture these *social dependencies* by analyzing the autocorrelation inherent in the network, i.e., the tendency of an actor to approve of the precautionary principle because others, with whom the actor maintains collaboration ties, also approve of the precautionary principle.

We surveyed actors' *involvement in international arenas* by asking respondents about their organization's memberships in international water commissions and other forms of international collaborations, including those with foreign municipalities, regions, countries, associations, or research institutes. For the present analysis, we coded this variable as a dummy, "1" indicating membership in international water commissions or collaboration with international partners, or "0" indicating the absence of memberships or international collaborators.

As a proxy for the *agenda priority* actors attribute to micropollutants, we surveyed actors' perception regarding the severity of the micropollutants problem. We asked respondents to rate the reduction of micropollution as a higher, equal, or lower priority compared to 10 other water policy issues, such as aquatic ecology, renaturation, *macro*pollutants, hydroelectricity, floods, or the like. We coded the responses so as to range from −1 to 1, where "−1" indicates a comparably low priority to micropollutants, "0" denotes equal priority to micropollutants compared to other water-related policy issues, and "1" signifies comparably high priority to micropollutants.

As precautionary measures involve both source-directed and end-of-pipe measures, we also differentiated between two types of *target groups*: First, actors who are responsible for

implementing end-of-pipe measures, which include wastewater associations and sub-national jurisdictions (cantons representing the municipalities in charge of sewage treatment); secondly, actors who are responsible for implementing source-directed measures. The latter includes agricultural, industrial, economic, and trade associations.

We use descriptive statistics to illustrate actors' policy preferences toward both the precautionary and the reactive principle. We then focus on the precautionary principle and seek to understand which factors influence actors' preferences toward precautionary policy measures. To this end, we employ the Temporal Network Autocorrelation Model (TNAM, version 1.6.2), developed by Leifeld and Cranmer (2016), in the statistical computing environment R (version 3.1.0, R Development Core Team 2014). While standard regression models assume independence of observation, preferences of actors may strongly depend on other's preferences. TNAM is a model that can specifically account for interdependencies of relational data. TNAMs employ the Bayesian information criterion (BIC) to evaluate model fit. With each added parameter, models potentially improve while eventually resulting in overfitting. To avoid such overfitting, BIC penalize for the number of model parameters.

Analysis

The analysis first shows our results on actors' preferences regarding precautionary and reactive measures, and secondly, it highlights the factors that influence political actors in favoring precautionary action.

Support for precautionary action

Figure 1 illustrates that most Swiss policy actors reported to prefer precautionary measures in the case of micropollutants policy. A total of 32 actors either strongly agree or somewhat agree to the precautionary principle. Eight respondents either strongly disagreed or somewhat disagreed with adopting precautionary measures and, instead, advocated for a reactive strategy based on withholding measures as long as uncertainties remain.

Next, we illustrate what type of precautionary measures—end-of-pipe or source-directed approaches—policy actors prefer. Figure 2 displays consensus among policy actors regarding the adequacy of source-directed measures for the reduction of micropollutants in water bodies. In principle, actors agree on addressing the source of the pollution problem, and thereby avoiding the input of pollutants into water bodies, as an appropriate way of dealing with micropollutants. Nevertheless, actors remain divided when it comes to end-of-pipe measures. While 24 actors agree on pursuing such an approach, 15 actors are persuaded otherwise.

In order to analyze whether actors who oppose (or support) the precautionary principle are particularly reluctant (or favorable) toward certain measures, we correlated preferences for source-directed or end-of-pipe measures with preferences for precautionary approaches (Fig. 3). We found that actors who oppose the precautionary principle tend to oppose any sort of policy approach, but are less reluctant toward end-of-pipe than source-directed measures (see Fig. 3). Such results indicate that target groups disfavor policies that blame them as causes of pollution and induce potentially costly behavioral changes. Meanwhile, those who support precautionary action tend to agree on the adequacy of source-directed and end-of-pipe measures, but are less supportive of solutions that address the "end of the

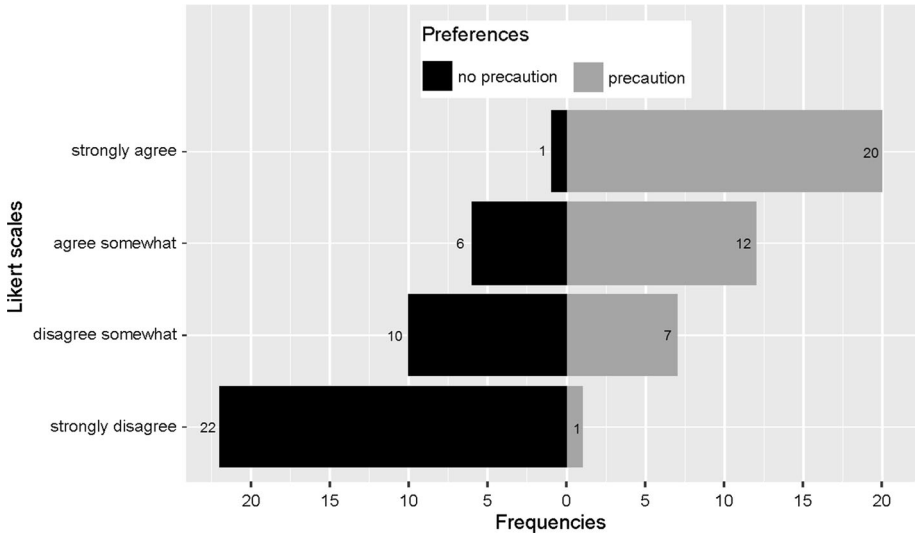

Fig. 1 Actors' preferences for precautionary measures versus no precautionary measures ($N = 41$, missing items = 4); graphic created in R (Version 3.1.2)

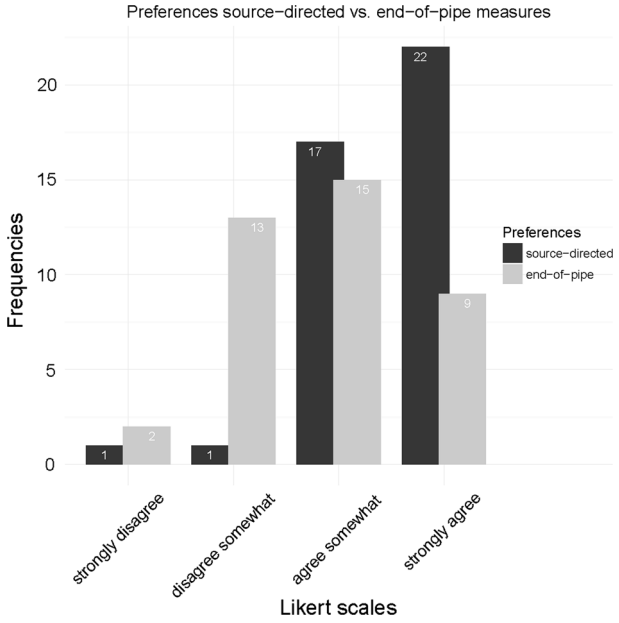

Fig. 2 Actors' preferences for and against source-directed and end-of-pipe measures ($N = 41$, missing items = 2); graphic created in R (Version 3.1.2)

pipe" through wastewater treatment. Results also confirm that one can classify both end-of-pipe and source-directed as precautionary measures (see "Precautionary measures related to micropollutants" section).

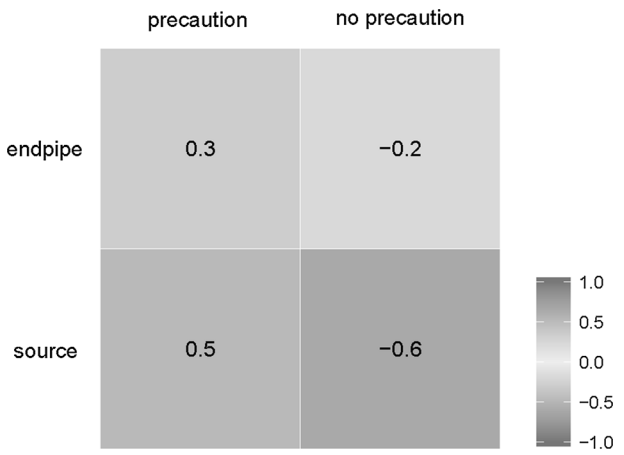

Fig. 3 Correlations between preferences [−1; 1]; graphic created in R (Version 3.1.2)

Explaining precautionary policy intervention

Table 1 displays the results of the TNAM we calculated in order to understand which factors are associated with actors' preferences for precautionary measures. We calculated three models: The first considers only exogenous network effects in the form of attributes of actors (covariates); it serves us as a reference for evaluating the explanatory value of our two main models with network effects. The Bayesian information criterion (BIC) scores indicate model fit, where smaller values signify better explanatory value. As BIC scores closely resemble one another for all three models, the explanatory values are approximately equal. We additionally calculated the R squared, for which results indicate that we can explain 32 and 41% of the variance of our data.

Our first hypothesis seeks to understand the social processes that lead to preference formation. In Model 3, we assessed whether actors who exhibit comparably many collaboration ties tend to prefer precautionary measures. Results indicate that the estimate for degree centrality is significant and relates positively to precautionary measures. With one additional collaboration tie, preferences for preventive measures increase on average by 0.16 units on the index ranging from −2 to 2. These results show that exchanges with other actors have a positive effect on precautionary preferences. The "social dependency" term in Model 2 is our second operationalization of the effect of collaboration on actors' preferences toward precautionary measures (hypothesis 1). Social dependency tests whether actors tend to exhibit similar preferences toward precautionary measures to their collaboration partners. Results indicate that this effect is not significant. To further assess whether degree centrality alone holds significance, i.e., independently of the preferences of an actor's collaborators, we also controlled for an interaction effect between degree centrality and collaborators' preferences in a subsequent model. As this interaction term was not significant and explanatory strength of the model did not improve, we can conclude that these effects work independently of one another, and we therefore refrain from displaying the results here.

The coefficients for involvement in international arenas (H2) are insignificant throughout all models. Results for agenda priority, i.e., the importance actors attribute to the issue of micropollutants compared to other water-related policy problems (H3), exhibit

Table 1 Regression table ($N = 41$)

	Hypothesis	Model 1	Model 2	Model 3
Exogenous controls				
(Intercept)	Control	1.97**	1.83**	1.93**
		(0.48)	(0.55)	(0.52)
State actor	Control	−1.02°	−1.07°	−1.54*
		(0.56)	(0.58)	(0.59)
Scientific actor	Control	−0.59	−0.52	−0.34
		(0.65)	(0.67)	(0.64)
Main hypotheses				
Degree centrality	H1			0.16*
				(0.08)
Social dependencies	H1		0.02	−0.08
			(0.04)	(0.06)
International arena	H2	0.00	−0.11	−0.34
		(0.17)	(0.27)	(0.28)
Agenda priority	H3	0.83°	0.94°	0.93°
		(0.45)	(0.51)	(0.48)
Target group source	H4	−2.23**	−2.10**	−2.66**
		(0.64)	(0.69)	(0.71)
Target group end of pipe	H4	−0.56	−0.68	−0.97
		(0.60)	(0.64)	(0.62)
BIC		144.26	147.63	145.87
R^2		0.32	0.32	0.41
Num. obs.		41	41	41

Statistical models

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ° $p < 0.1$

a modest positive relation toward preferences for precautionary measures in all models. We controlled for an interaction between agenda priority and actors' degree centrality, since actors who attribute a higher priority to an issue may also be more active in the network. Likewise, we controlled for an interaction effect between agenda priority and actors' involvement in international arenas, because actors' prioritization could be driven by whom they meet and exchange within international arenas. In other words, an actor may attribute importance to an issue because others whom the actor meets, or with whom the actor collaborates, in international arenas assign importance to it. Both interaction terms did not yield any further significance, and therefore, we did not display them here. We conclude that agenda priority is not an intermediate factor, where respondents' prioritizations are driven by their collaboration patterns in the policymaking process or in international arenas, but instead impact policy preferences independently. We also looked at the actor types that prioritize the issue of micropollutants in particular. We found that there is no single actor group that prioritizes the issue more than others. Instead, a handful of actors exist in each group that attributes high importance to the issue of micropollutants.

Both parameters capturing membership of the target group for precautionary measures relate negatively to preferences for precautionary action (H4). Those who would have to

implement precautionary measures to reduce micropollutants in water bodies tend to oppose precautionary policy action. This target group effect is highly significant for actors targeted by source-directed measures, which includes agriculture and industry associations, but insignificant for target groups of end-of-pipe measures. The latter involve wastewater associations and sub-national jurisdictions in charge of sewage treatment. Finally, we controlled for state actors, as we suspected that they may have more opportunities for collaboration or participation in international arenas, or they may attribute a higher priority to the issue of micropollutants due to their role as civil servants. The estimate produces a negative result and is significant only in model 3, suggesting that identifying as a state actor negatively impacts (if at all) favoring preventive measures. Likewise, we controlled for scientific actors, which did not yield a significant effect.

Discussion

A first insight from our study is the positive correlation between an actors' level of collaboration with others (degree centrality model term) on the issue of micropollutants and the probability that this actor prefers precautionary action. Results that support our first hypothesis can be interpreted such that actors who socially interact, also exchange ideas and raise their awareness about the risks related to a policy issue such as micropollutants in water bodies, which may urge them to act toward the prevention of micropollutants' potential negative impacts. Since the social dependency term is not significant in our case, results suggest that more than a social influence effect is at work. Actors do not simply depend on their collaborators' preferences for precautionary action. Rather, the intensity of collaboration toward others, independently of the preferences of those collaborators, seems to trigger a process of raising awareness about the adequacy of the precautionary principle in addressing the issue of micropollutants. Results support the idea according to which cooperative behavior among political actors induces mutual understanding of an issue, as well as social capital, thereby increasing capacities for collective action in environmental protection (Innes and Booher 2003).

Our second hypothesis predicted that actors involved in international arenas would prefer precautionary action; however, our results do not support this claim. One reason for this unexpected finding might be the strong degree to which national interests determine policy preferences. In line with national interests, actors who both favor and oppose precautionary action participate in international arenas. As we dispose of "snapshot data" only, we cannot make conclusions about the possibility of policy preferences changing over time through their involvement in the international arena. For the observed "snapshot," we must conclude that international involvement does not relate to preferences for precautionary action.

Results provide modest support for our third hypothesis, according to which actors who attribute high significance to the issue of micropollutants tend to favor precautionary measures. Although actors who attribute high agenda priority to micropollutants tend to favor state intervention following the precautionary principle, other factors appear to act as a stronger predictor. We also found that issue prioritization impacts preferences independently of involvement in international arenas. These results together suggest that exchanges with others in international arenas may likely raise awareness about the appropriateness of the precautionary principle, but that this process of learning happens independently (i.e., in parallel or consecutively) from setting agenda priorities. A possible

interpretation of the findings could be the different time dynamics of issue prioritization and the exchanges in international arenas: Agenda priorities tend to build on actors' pre-formulated mission statements, existing beliefs, or resource restrictions. Exchanges with others and learning, by contrast, evolve throughout the policy process.

Another insight from this study supporting hypothesis 4 is that target groups of precautionary measures, which typically include representatives from agriculture and industry, tend to oppose precautionary measures. This result highlights the relevance of integrating target groups into the policy process in order to work toward precautionary measures that they deem acceptable. While the obligation to comply with further regulations seems to deter target groups from supporting precautionary measures, alternative policy designs may still encourage support, e.g., through compensations or low administrative burdens.

Overall, precautionary action is facilitated in the present case by collaboration among network members and, to some degree, by actors' agenda priorities relating to micropollutants. Nonetheless, precautionary measures are impeded by target groups of precautionary measures, especially in the case of actors representing the agricultural and industry sectors.

Conclusion

This paper investigates the ways in which policy actors position themselves toward precautionary measures in water protection and seeks to identify factors that enhance actors' support of precautionary action. The precautionary principle is tailored for issue areas with considerable uncertainties about problem properties and potential effects on humans and the environment. The case of micropollutants represents an example of an issue where many open questions remain regarding risks for human and ecological health. As political concern is emerging, policymakers face the challenge of deciding whether or not to take precautionary measures. In the case investigated here, most of the actors supported precautionary action as an appropriate policy strategy for dealing with remaining uncertainties. Our combination of network and policy design variables has proven to represent a powerful explanation for actors' support of the precautionary principle.

Our results show that social interactions in the form of collaboration ties among actors involved in policymaking matter for precautionary action. Actors with higher degrees of collaboration ties are more supportive of the precautionary principle. We interpret our results such that policy actors seem to gain a further understanding of the complexities and inherent uncertainties of micropollutants thanks to their collaborative ties. In accordance with Weible and Sabatiers' (2009) work on collaborative subsystems, we find that establishing and maintaining collaborative relations provides a context for learning about the issue, and lead to the approval of precautionary action as an adequate means for handling existing uncertainties related to water pollution. Our findings parallel work by Scott (2015) who finds that collaborative environmental governance promotes the achievement of environmental outcomes. Our case suggests that, already during early stages of the policy process, collaboration can lay the groundwork for environmental protection, namely through fostering preference in favor of the precautionary principle in water protection.

A drawback of the present study, however, is that we were unable to unfold the exact mechanism behind the network effect. As we do not have longitudinal data, we cannot assess the ways in which policy preferences change over time based on the preference of actors that comprise one's network. In their longitudinal study, Weible and Sabatier (2009)

find that actors develop increased concern for water quality degradation over time in a collaborative subsystem. When actors exchange intensively on a policy issue, they create a context conducive to building trust, empathy for others' rationales, as well as learning from one another. In the context of our case, collaboration among actors could have promoted convergence toward precautionary preferences in order to deal with inherent uncertainties of micropollutants in water.

While most of the actors supported precautionary action, we also find that target groups representing agriculture and industry, which would be required to implement future precautionary measures, most strongly oppose such an approach. It is worth mentioning that other water polluters, such as wastewater treatment plants or households, prioritize protection over the use of waters and support the precautionary principle. These divergent attitudes of polluters prove puzzling in that agriculture uses water resources as a sink for their emissions, as do households, and at the same time, depend on clean water (for irrigation or drinking water purposes). Yet, the dependency on clean water does not induce support for precautionary water protection measures on behalf of agricultural actors in the same manner than on behalf of households. In conclusion, processes of cost and blame avoidance may be at work here. While simply stating that polluters generally oppose environmental protection may seem an overly simplistic explanation for policy preferences, it is vital to design policies such that target groups are not blamed, and instead that their positive efforts toward environmental protection are stressed. In order to promote precautionary policies, policy design questions play a decisive role, i.e., whether or not a policy is designed such that the target group can provide its support.

Water protection represents a matter of "quiet politics" (Culpepper 2011), because water pollution, especially that from micropollutants, is invisible to the naked eye, and hence it is less likely to attract attention from the political realm (Prakash and Potoski 2013). Switzerland having already addressed the issue through politically binding decisions indicates that the forerunner country represents an anomaly rather than a "typical" case. In fact, research on environmental attitudes suggests that, within an international scope, Switzerland ranks particularly high on indices that measure environmental concern (Franzen and Vogl 2013). Hence, the generalizability of the results presented here must be regarded with caution. Nevertheless, the present case provides us with insight into the drivers of political action in a context where environmental concern is comparably high, which is also the case for many western European countries and Canada, for example Franzen and Vogl (2013).

Finally, the analysis indicates that precautionary political action can be promoted in cases where actors attribute high priority to an agenda item, and perceive the issue of micropollutants as an urgent issue within the realm of water protection policy. Research has already pointed to the critical role public perceptions play in the study of environmental policy (Bickerstaff and Walker 2001). With our research presented here, we expand this insight to political elites (as opposed to the general public), and illustrate that agenda priorities can act as a driver for political action in the form of precautionary policy preferences. The underlying study suggests that agenda priorities are not irrelevant for political action in quiet politics, such as water protection policy. We can conclude that, in order to promote the precautionary principle, quiet politics must take the forefront of political actors' priorities. Such a development can be promoted through collaborative settings which contribute to raising policy actors' awareness of the severity of a policy issue.

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Appendix: Actor list

Full name	Type of actor
Swiss Association for Agricultural Development and Rural Areas	Science, laboratories, consulting
Western Swiss Association for Water and Air Protection	Environmental association
Federal Office for the Environment, Department of Air Protection and Chemicals	National-level state actor
Federal Office for the Environment, Department for Water	National-level state actor
Federal Office for Health	National-level state actor
Federal Office for Agriculture	National-level state actor
BMG Engineering AG	Science, laboratories, consulting
Conference of Cantonal Directors of Construction, Planning and Environmental Protection	Cantonal-level state actor
Cercl'eau	Cantonal-level state actor
Christian Democratic People's Party	Political party
Swiss Federal Institute of Aquatic Science and Technology	Science, laboratories, consulting
Economiesuisse	Trade association
Sewage Treatment Plants in Large Cities Initiative	Municipalities, cities, water or wastewater association
Free Democratic Party. The Liberals	Political party
University of Applied Sciences of North-West Switzerland	Science, laboratories, consulting
Swiss Fishery Association	Environmental association
Swiss Green Party	Political party
Western Swiss Group of Sewage Treatment Plants Operators	Municipalities, cities, water or wastewater association.
Basel Chamber of Commerce	Trade association
Hunziker-Betatech	Science, laboratories, consulting
Scienceindustries	Trade association
Consumer Forum	Consumer association
Communal Infrastructure	Municipalities, cities, water or wastewater association
Conference of Heads of Cantonal Offices for Environmental Protection	Cantonal-level state actor
Competence Network of Cantonal Laboratories for Water and Environmental Protection	Cantonal-level state actor
Ecotox Centre	Science, laboratories, consulting
Pro Natura	Environmental association
Swiss Farmers' Association	Trade association
Swiss Trade Association	Trade association
Swiss Cosmetics and Detergent Association	Trade association
Swiss Mechanical and Electrical Engineering Industry Association	Trade association
Swiss Social Democratic Party	Political party

Full name	Type of actor
Swiss Gas and Water Industry Association	Municipalities, cities, water or wastewater association
Swiss People's Party	Political party
University of Basel	Science, laboratories, consulting
University of Lausanne	Science, laboratories, consulting
National Council's Committee on the Environment, Spatial Planning and Energy	Legislature
Council of State's Committee on the Environment, Spatial Planning and Energy	Legislature
Association of Cantonal Chemists of Switzerland	Cantonal-level state actor
Swiss Water Association	Municipalities, cities, water or wastewater association
World Wide Fund For Nature Switzerland	Environmental association

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