RESEARCH

"The toxic substance has killed all ducks": framing of chemical risks related to the 2021 summer flood in German news media

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Abstract

Background The public understanding of environmental issues, such as chemical pollution due to flooding, is reflected and shaped by media representations and how these issues are framed. This study aims to identify how local, regional, and national German newspapers pick up and frame the issue of chemical pollution and related environmental and health risks regarding the 2021 summer flood using content analysis.

Results The analysis shows that chemical pollution is rarely addressed compared to other flood-related topics. We identified 189 newspaper articles published in the months following the flood, which specifically mention chemical emissions. Of these articles, 50 report only marginally on chemical pollution, while 36 focus on the factual description of chemical emissions without addressing the consequences of pollution. The remaining 103 articles address impacts of certain pollutants such as oil, pesticides, heavy metals, or dioxins. Using content analysis, we identified four narratives that were common in their broad storylines and used to create a problem frame: (i) Highlighting severe contamination of the environment with chemical pollutants causing serious environmental damage (31 articles), (ii) describing possible contamination but with uncertainty about the extent and consequences (39 articles), (iii) tending to give the all-clear and emphasizing that there is no severe long-term contamination (25 articles), and (iv) indicating continuous contamination that does not allow the all-clear to be given (8 articles).

Conclusions The results suggest that flood-related chemical pollution does not receive much media attention. Where it does, coverage focuses primarily on the description of the "tangible parts" of pollution, and thus contamination by oil, depicted by both smell and oil streaks, is frequently addressed Articles indicating severe contamination suggest threats to human and environmental health as likely consequences. However, most articles only report the results of chemical monitoring in the contaminated regions, which are evaluated by experts. This contrasts with other topics of controversy related to the flood, such as climate change as a potential cause. In light of our study, we propose that media and science communication need to pay more attention to chemical pollution—in general and as a result of flood events.

Keywords Media analysis, Narrative, Uncertainty, Risk communication, Flood, Chemical pollution, Problem frame

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Background

The frequency and intensity of flooding are increasing globally, with severe consequences for individual and community well-being [1, 2], loss of life, damage to infrastructure, and private and commercial property [3, 4]. In addition to these widely recognized direct impacts, flood events also have less visible indirect impacts, including the (re)mobilization and (re)distribution of pollutants

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due to damaged wastewater infrastructure or oil tanks, but also sediment-bound pollutants resulting from historical discharges [5]. Within the research community investigating flood-related pollution, some voices have emphasized that the associated environmental and health risks are underrepresented in public discourse (e.g., [5, 6]).

The news media are an important vehicle for communicating environmental risks, reflecting, and shaping public discourse and responses, and for framing whether and how these risks become social issues affecting a broader public [7–10]. Media frames structure complex problems, make them more salient and emphasize moral evaluations or recommendations for action [11]. Gray [12] summarizes that frames "(i) define issues, (ii) shape what action should be taken and by whom, (iii) protect oneself, (iv) justify a stance we are taking on an issue, and (v) mobilize people to take or refrain from action on issues." Concerning media frames of flood events, Escobar and Demeritt [8] showed that reporting has traditionally focused on descriptive coverage of the flood event and its impacts. However, in their analysis of British news media reports covering a 25-year period, they found that media attention on flood events has generally increased and transformed from an agricultural problem of land drainage to contemporary concerns about urban impacts that, among other aspects of flood hazard management, are now topics of political debates. Devitt and O'Neill [13] further point out that flooding has evolved from an environmental issue to a contentious political issue in media coverage by linking flooding to climate change and thus shifting responsibilities, which can be used to justify limitations of federal flood policies. Further studies have shown that public discourse on flood events controversially discusses climate change as a potential cause of catastrophic events [14, 15]. Although chemical pollution is commonly discussed in the media as another global environmental problem [10, 16–19], there have been no studies that have addressed media coverage of flood-related chemical pollution.

In the course of the July flood of 2021 in Western Germany, industrially used areas and contaminated sites in the catchment area of the German rivers Inde and Vicht (federal state of North Rhine-Westphalia) were flooded in addition to the widespread destruction of infrastructure and buildings. This area was characterized by mining activities and is further highly contaminated due to historical large-scale soda ash production [20]. As a result, the region is considered among the most contaminated sites in Germany with heavy metals, dioxins, and other persistent organic pollutants [20–22]. Sediments in particular play an often underestimated role in flooding, acting as a sink and source for pollutants. In addition,

high flow velocities can remobilize bound pollutants, re-entering the water phase [5, 23, 24], where they pose a potential hazard to aquatic organisms. In this context, deposition can occur on agricultural land, in floodplain areas, homes and gardens, so that grazing livestock and humans can also be directly affected by such a chemical load and the associated health risks [20, 25].

Given this specific problem and the lack of existing studies on media coverage of flood-related chemical pollution, this study aims to understand how the risk of chemical pollution related to the German summer flood of 2021 is picked up and framed in the media. We analyzed local, regional, and national German newspapers quantitatively and qualitatively and addressed the following question: *How are the impacts of flood-related chemical pollution addressed and framed in media reports?*

The media analysis was conducted as part of an interdisciplinary project covering various aspects of the flood event and also included an ecotoxicological hazard assessment of water and sediment samples. For the media analysis, we rely on the concept of frames and framing by Entman [11] and concentrate on contents that create problem frames of the environmental risk of chemical pollution caused by the flood event.

Methods

Case study

In July 2021, Western Europe was hit by a severe summer flood, causing widespread destruction and casualties. Due to several days of heavy rainfall, severe flooding occurred in the uplands of the Eifel-Ardennes region in Germany, Belgium, and the Netherlands as well as in their forelands. The scale and intensity of the flood were unprecedented, with some areas experiencing rainfall equivalent to 2 months in just 2 days.

In the course of the so-called "flood of the century", German regions particularly in the catchments of the rivers Ahr, Erft, Inde, and Rur in the federal states of Rhineland-Palatinate (RLP) and North Rhine-Westphalia (NRW) were affected [26]. More than 180 people died in the floods, most of them in the district of Ahrweiler (RLP), which was particularly hard hit. The flooding also severely affected the Eifel region and the city of Trier in RLP as well as the district of Euskirchen, the Rhine-Sieg district, and parts of the Bergisches Land in NRW [27]. In addition to the deaths and many hundreds of injuries, the flood caused massive destruction to entire villages and small to medium-sized towns, e.g., on buildings and infrastructure. For many thousands of people in the region, this meant enormous economic damage [26, 28, 29]. The flood additionally led to the discharge of pollutants into the environment, for example fuels, contaminated water from partially destroyed wastewater

treatment plants, private homes, or damaged industrial facilities [30].

The flooding was caused by Storm "Bernd," which brought more than 200 mm of precipitation in places from 13 to 15 July 2021, exceeding historically observed precipitation records many times [30, 31]. Results of the World Weather Attribution (WWA) study show that this severe flooding was caused primarily by heavy rainfall over 2 days, wet conditions already before the event, and local hydrological factors. Thus, the 3 weeks before the flood were already characterized by recurrent rainfall, resulting in nearly saturated soils: in RLP soils had less than 10 mm free soil water storage in some cases, while soils in the south-west of NRW still had over 75 mm free soil water storage. The area is an elevated plain (200 to 500 m, individual mountain ranges of 700 m), in which the river network runs through locally very narrow and steep valleys, which sometimes leads to funnel-like effects during floods. At the Altenahr gauge, a peak discharge of about 1000 to 1300 m3/s was estimated [32].

In the subsequent reappraisal by local, regional, and national media, questions such as the appropriateness of official action, the reaction of citizens and responsible municipal offices, the technical aspects, and the identification of causes and possible solutions for prevention were addressed. In addition, the event is also scientifically analyzed and discussed across various disciplines, including, for example, studies on appropriate flood risk management (e.g., [33]), flood risk assessment (e.g. [34]), flood-related pollution (e.g., [6]), climatic causes (e.g., [35]), or public discourses (e.g., [14]).

Approach
For the media analysis, we draw on the concept of "frames" and "framing" in communication and media studies [11]. Entman [11] defines framing as "to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described". Thus, framing involves selection and salience; that is, framing highlights certain aspects of a situation to make them more prominent. According to Snow and Benford [36], there are three core framing tasks: (i) Diagnostic framing, which identifies problems and attributes responsibility, (ii) prognostic framing, which identifies proposed actions, solutions, or policy alternatives, and (iii) motivational framing, which develops consensus, mobilizes action, and constructs "vocabularies of motive".

Research in psychology and communication has shown that framing can significantly impact people's attitudes, beliefs, and behaviors [37–41]. For example, studies have found that gain-framed health messages were more likely to encourage prevention behaviors than loss-framed health messages [42], and that framing an issue in terms of a threat can be more persuasive than framing it in terms of an opportunity [38]. The concept of framing is particularly relevant in political and media contexts, where the way information is presented can shape public opinion and decision-making [43]. Understanding how framing works can help to better evaluate the biases and assumptions that underlie different perspectives on an issue or topic, and to make more informed decisions based on a complete understanding of the available information.

Frames are constructed by specific framing devices, which define problems and causes and can contain moral valuations as well as possible solutions [11]. A wide range of framing devices can be found in the literature. For the analysis of frames and frame elements, discursive structures and content formats must be identified that integrate the words and images of a story into a frame [44]. This study concentrates on contents that create "problem frames" of the issue of flood-related chemical pollution ("diagnostic framing" according to Snow and Benford [36]). By problem frames, we understand how news stories or topics are problematized and discussed in the media, including the way they are framed, emphasized, or presented with a certain perspective, which can influence how people perceive and understand these issues. To examine the problem frames of newspaper articles, we focus on narratives as framing devices. Narratives are representations of events [45] that consist of a specific meaningful storyline. Thus, they give a particular meaning to things and processes, providing a plausible way to understand a story or events in a particular way and are an import element in how people make sense of their environment [46].

For the analysis, we rely on the concept of environmental risk. Here, we do not refer to the specific expert understanding and guiding paradigm of (eco)toxicology that exposure of a chemical substance must be compared with its inherent hazard to conclude an environmental risk. Rather, we have chosen a broader concept of risk that deals with the anticipation or likelihood of events with negative outcomes, as is often addressed in risk research [47, 48].

Mixed methods combining quantitative and qualitative analyses
For the media analysis, 28 German newspapers with different geographic scales and a broad political spectrum were selected (Table 1). National newspapers cover a large readership and are available and noticed nationwide. In contrast, regional and local newspapers originate

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Table 1 National, regional, and local newspapers selected for the media analysis

Geographic scale	Newspapers
National	FAZ.NET
	Frankfurter Neue Presse
	Frankfurter Rundschau
	DER SPIEGEL online
	Süddeutsche Zeitung online
	taz.de
	Welt online
	ZEIT online
Regional	Aachener Zeitung
	Allgemeine Zeitung Mainz
	Bonner General-Anzeiger
	Eifel-Mosel-Zeitung
	Kölner Stadt-Anzeiger
	Kölnische Rundschau
	Neue Ruhr Zeitung/Neue Rhein Zeitung
	Neue Westfälische
	Rhein Zeitung
	Rheinische Anzeigenblätter
	Rheinische Post
	Ruhr Nachrichten
	Trierischer Volksfreund
	Westdeutsche Allgemeine Zeitung
	Westdeutsche Zeitung
	Westfalenpost
	Westfälische Rundschau
Local	Blick Aktuell
	Stadtzeitung Bad Neuenahr-Ahrweiler
	Wochenspiegel

from the affected regions and are largely read locally. Regional newspapers are published only in a specific area or region and are also location based. Local newspapers operate on an even smaller scale, such as in individual cities.

For our analysis, we picked regional and local newspapers with publicly readable online content from the

affected areas for which our research provided results. Concerning the national newspapers, we selected the most prominent ones with publicly readable online content. We searched the WISO database, Google Advanced, and the online search masks of each of the newspapers for freely available articles. The WISO database [49] offers the largest German-language compilation of literature references and full texts on economics and social sciences. The database also contains daily and weekly press articles. We selected media articles from the 3.5-month period immediately following the flood (14 July to 31 October 2021), which we considered as critical discourse period.

First, to get an overview of the general reporting on flood events, a quick Google search was performed on all websites of the selected 28 newspapers based on the key words or combinations of the key words "flood", "climate change", and "pollutant". We used the term "pollutant" (German: Schadstoff) instead of "pollution" (German: Verschmutzung) for the search, since the latter is less common in German reporting about chemical pollution. In addition to our study period following the flood, we also searched for the 3.5-month period following the one-year anniversary of the event. Since the first search only aimed at a rough comparison of the number of article hits and the question of whether climate change or environmental pollution play a role in the reporting in general, no in-depth investigation of the content was carried out.

A larger number of search terms were used to identify as many articles as possible that focus on flood-related chemical pollution to address chemical pollution in more detail. The search was performed in the respective databases, either by manually entering individual search terms and in combination or by Boolean search using a search string (Table 2). The search strategy resulted in 244 articles from the 28 different newspapers that were evaluated using the software MAXQDA Analytics Pro 2022 (VERBI GmbH, Berlin, Germany).

While we used a deductive approach with specific search terms for the article search, we took an inductive approach to group the articles into different categories

Table 2 Key search terms and search string used to identify articles in the respective databases

Key search terms	flood; heavy rain; catastrophe; Eifel; Ahr*; load; pollution, polluted; contamination, contaminated; sewage sludge, wastewater treatment plant; wastewater; pollutant(s); epidemic, epidemic danger; poison; tox, toxic, toxicological; fecal, fecal matter; chemical; oil; fuel(s); harmful; (un)healthy; hygiene, (un)hygienic; dirt, dirty
Search string for the Boolean Search, where applicable	((flood*) AND (load*) OR (poll*) OR (polluted*) OR (contaminated*) OR (wastewater*) OR (pollutant*) OR (epidemic*) OR (poison*) OR (fecal*) OR (chemi*) AND (tox*) OR (oil*) OR (fuel*) OR (harmful*) OR (healthy*) OR (hygien*) OR (dirt*))

Note that the search was performed in German. Thus, terms represent only a translation and do not reflect the exact search. We define pollutants/contaminants as chemical substances of anthropogenic origin, i.e., caused or released by humans. By pollution/contamination we mean exposure of the environment to anthropogenic substances

and to identify specific pollutant terms and narratives used. Articles were first categorized into different groups to distinguish articles (i) which deal only marginally with pollutants (issue mentioned with one word or sentence without detailed description), (ii) which focus on the factual description of chemical emissions without addressing the consequences, and (iii) which address and frame consequences and risks of chemical pollution in more detail. This differentiation was made because articles that only hint marginally at pollutants or focus on descriptive reporting of emissions provide too little material for a framing analysis. In addition, we quantified which pollutants or paraphrases for pollutants were mentioned in the articles. Finally, using content analysis based on the assumptions of grounded theory [50], we identified several narratives that are similar in their broad storylines and are used to create a problem frame in the articles dealing with the consequences of chemical pollution. For identification, we considered the context of the corresponding text passages and the general style of the article. We further analyzed the frame elements (i) problem definition, (ii) causes, (iii) moral evaluation, and (iv) treatment recommendation [11, 16]. In addition, we analyzed the temporal distribution of the various identified narratives over the 3.5-month reporting period. Data documentation and descriptive statistics were prepared using the software Microsoft Excel (Redmond, WA, USA) and GraphPadPrism (GraphPad Software, La Jolla, CA, USA).

Results

The following sections first provide an overview of the general media coverage of the flood and then explore in more detail the articles that address chemical pollution and use narratives to frame the environmental risk of these pollutants.

Media coverage of the flood

Looking at the 3.5-month period following the flood, the quick Google search using the term "flood" on all URLs of the selected 28 newspapers revealed 8360 hits. Adding the term "climate change" as an associated cause of flooding generated 2250 hits. In contrast, the query using the terms "flood" and "pollutant", to cover chemical pollution as an associated impact of the flood, only resulted in a number of 108 hits (Table 3). At first glance, this shows a stronger framing of the disaster in terms of its causes. However, this overview only presents a very limited picture. As will be shown in more detail below, the newspaper articles examined refer to pollution in many instances, for example, in relation to hygiene concerns, waste issues, and epidemic risks.

We further compared the quick search results of the 3.5-month period following the flood with the 3.5-month period following its one-year anniversary. Search hits related to "flood" are very similar (8244 hits), while "flood" and "climate change" were mentioned about half as often as in the period immediately following the flood (1442 hits). The terms "flood" and "pollutant" were only mentioned 24 times.

Overview of articles dealing with chemical pollution

Of the articles selected from the detailed search, 189 out of 244 mention chemical pollutants, while the remaining 55 articles mainly address hygiene issues and epidemic risks. Most of the articles come from regional newspapers (Table 4). While national newspapers frequently report on flooding in general (see Table 3), coverage of flood-related chemical pollution is lower than in regional newspapers. However, the geographical scale of newspapers does not reveal any trend in the type of reporting.

Articles dealing with chemical pollution were grouped into three different categories depending on how they address the issue (Table 4). In many cases (50 articles), the main focus is on other topics than chemical pollution, which is only reported on marginally. Another part of the articles (36) focuses on the factual description of chemical emissions without addressing the consequences of pollution. The majority of articles (103) address these consequences and use four main narratives to frame the problem. We identified these in the 103 articles as: (i)

Table 3 Search hits on the websites of the 28 evaluated German newspapers at different times

Period	Search terms	Geographic scale			Total
		Local	Regional	National	
3.5-month period following the flood	"flood"	754	5203	2403	8360
	"flood" and "climate change"	11	834	1405	2250
	"flood" and "pollutant"	3	81	24	108
3.5-month period after the one-year anniversary of the flood	"flood"	913	5738	1593	8244
	"flood" and "climate change"	30	698	714	1442
	"flood" and "pollutant"	2	18	4	24

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Table 4 Type, number, and geographic scale of articles dealing with flood-related chemical pollution

Article type	Number of articles	Geographic scale		
		Local	Regional	National
Minor reporting	50	6	35	9
Descriptive reporting	36	6	22	8
Narratives	103	12	75	16
	Severe contamination (31)	*1*	*22*	*8*
	Uncertainty about contamination (39)	*4*	*33*	*2*
	No severe long-term contamination (25)	*5*	*17*	*3*
	Continuous contamination (8)	*2*	*3*	*3*
Total	189	24	132	33

Highlighting severe contamination of the environment with chemical pollutants causing serious environmental damage (31 articles), (ii) describing possible contamination but with uncertainty about the extent and consequences (39 articles), (iii) tending to give the all-clear and emphasizing that there is no severe long-term contamination (25 articles), and (iv) indicating continuous contamination that does not allow the all-clear to be given (8 articles). The narratives are described in detail in the next section.

We further analyzed which specific pollutants or umbrella terms for pollutants are mentioned in the articles (Fig. 1). This analysis revealed a difference between articles that provide minor or descriptive coverage of the topic and the articles that use narratives. While articles with minor and descriptive reporting mainly focus on oil as contaminant (79.1% of articles), articles using narratives as problem frames list many different pollutants in addition to oil, with the umbrella term pollutants/chemicals being mentioned most frequently (78.6%). It should be noted that "oil" was the only term also used in the search, while the other chemical substances were not searched for, but were found in the newspaper articles using the umbrella term "pollutants/chemicals". The descriptive reporting about oil contamination focuses on visible oil streaks and the smell of oil. It primarily addresses the problems associated with the disposal of oil-contaminated sludge, water, or soil. However, since the media analysis focuses on the framing of environmental risks of chemical pollution, the share of articles with descriptive or minor reporting was not further analyzed.
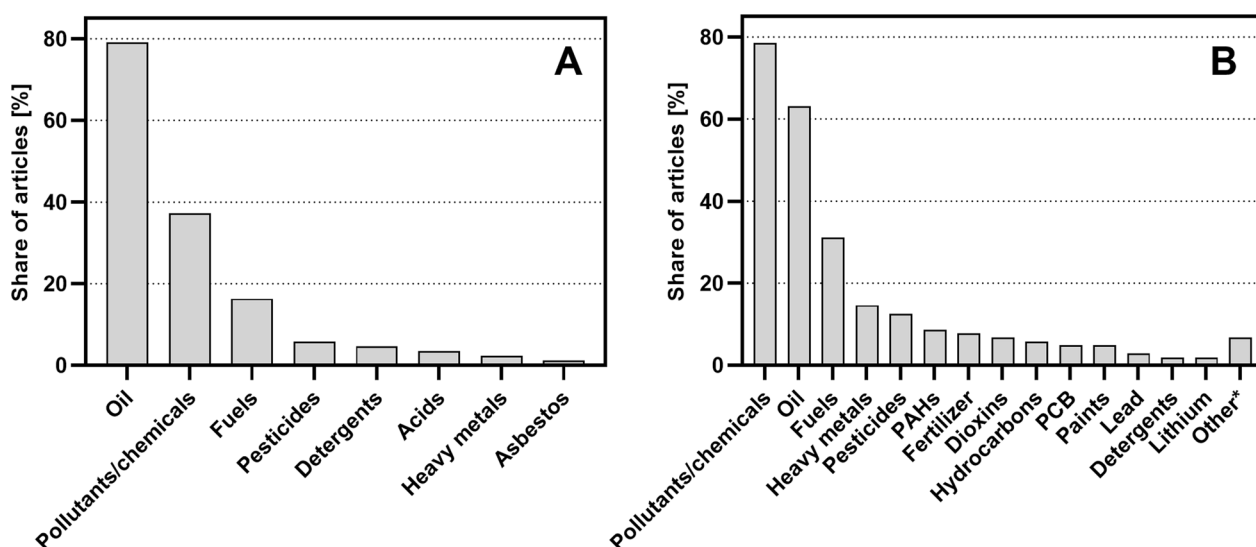

Fig. 1 Pollutant terms used in chemical pollution articles [% of articles]. **A** Articles with minor and descriptive reporting (*n* = 86), **B** articles using narratives (*n* = 103). *"Other" includes terms only used in one article at a time: Arsenic, lye, phosphate, pharmaceuticals, perfluorinated surfactants, benzpyrene, and asbestos

Narratives as problem frames

Figure 2 shows the main lines of argument from each of the four identified narratives, sample quotes are given in the supplementary information (Additional file 1: Table S1−S4). In all articles, these narratives are conveyed through direct or indirect statements by politicians, authorities, experts, or affected parties and do not reflect independent framing by journalists. Notably, external experts and scientists mostly convey the first narrative, while statements by politicians and authorities are more likely to be found in the other articles.

Narrative 1: Severe contamination

The first narrative highlights severe contamination of the environment with chemical pollutants causing serious environmental damage (Fig. 2, Additional file 1: Table S1). The articles are often structured in such a way that an "endangerment of the public by environmental pollution" (Eifel-Mosel-Zeitung, 30 July 2021) is formulated by the crisis team. Within the problem definition, serious ecological and health impacts are indicated by describing concrete effects on single organisms, e.g.,: "[…] the toxic substance had reached the middle and last pond at the castle and had killed all ducks there." (Bonner Generalanzeiger, 27 August 2021). In addition, effects on human health are speculated by listing specific effects of different pollutants, including, for example, "carcinogenic" or "liver damage" (Kölner Stadt-Anzeiger, 31 August 2021). Articles also use descriptions such as "toxic," "chemical time bombs," "fears,"

Narratives

	„Severe contamination"	„Uncertainty about contamination"	„No severe long-term contamination"	„Continuous contamination"
Problem definition	Description of ecological/health impacts of pollutants/ contaminated sites Contamination of human food chain including drinking water	Authorities cannot yet assess environmental hazard	All-clear based on chemical monitoring results	Slight increase of pollutants
Causes	Damaged infrastructure Historical pollution/remobilization of pollutants	Lack of knowledge and ignorance about contamination	Dilution effect of the flood wave Self-cleaning power of ecosystems	Rising wastewater volumes that cannot be adequately treated
Moral evaluation	Indication of incorrectly stored hazardous substances	Lack of information and fear among the public, accusation of authorities Accusation of the federal government by the political opposition	Emphasis on successful measures taken by governing political party	Emphasis on the importance of measures taken by governing political party
Treatment recommendation	Communication of protective measures by authorities	Political action, chemical monitoring of various sites to provide security Special attention to vulnerable groups and hotspots	Safe use of drinking water Complete replacement of soils not necessary	Political action, continuation of chemical monitoring

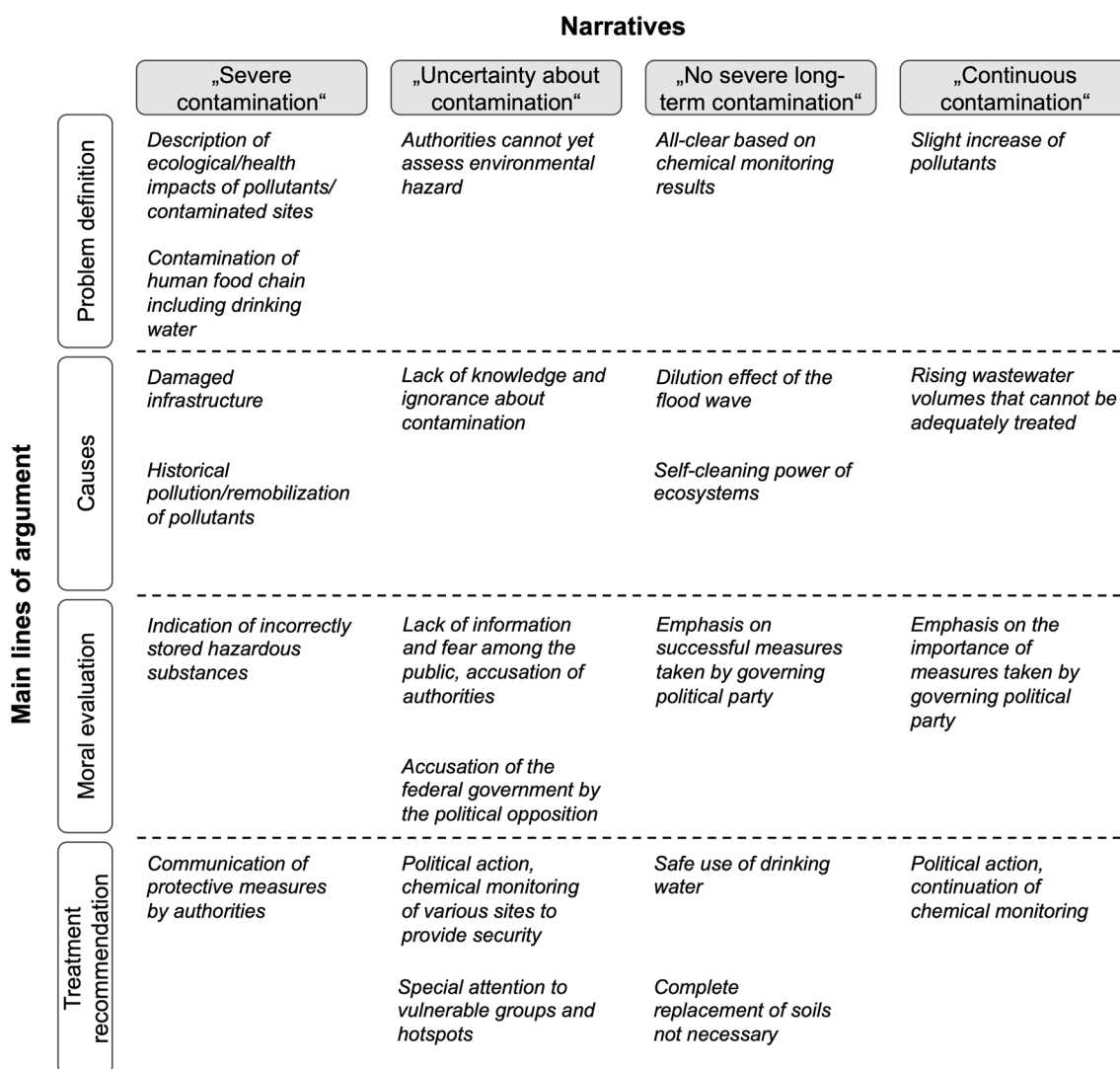*Main lines of argument* (row label spanning all rows on the left)

Fig. 2 Main lines of argument from articles on flood-related chemical pollution using different narratives. Severe contamination ($n=31$), uncertainty about contamination ($n=39$), no severe long-term contamination ($n=25$), continuous contamination ($n=8$)

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or "underestimated danger" (Frankfurter Neue Presse, 09 August 2021) that suggest endangerment, without specifying the danger more precisely. The consequences of pollution are further illustrated by providing a link to human foods that may be contaminated by chemical substances from soils or waters: "In addition, fears are spreading among people that fruit and vegetables from the fields around the farm have been contaminated or at least rendered inedible by the Ahr floodwater, which is contaminated with pollutants." (Rhein-Zeitung, 05 August 2021). The articles mention the causes and refer to the damaged infrastructure, which includes wastewater treatment plants and industrial plants, and therefore "incredibly many different substances" (FAZ.NET, 01 August 2021) must have been released into the environment. In addition, a link is made to historically polluted sites impacted by flooding, as evidenced by scientific studies conducted in other regions of the world (Welt Online, 30 July 2021). Moral evaluations hardly appear in the articles; in some cases, reference is made to incorrect storage of hazardous substances. As treatment recommendations, many articles also include advice on health protection measures, such as wearing protective clothing and gloves and avoiding contact with contaminated river water.

Narrative 2: Uncertainty about contamination

The second narrative describes possible contamination but with uncertainty about the extent and consequences (Fig. 2, Additional file 1: Table S2). Therefore, the problem cannot really be defined and articles emphasize uncertainty and a missing hazard assessment by experts. Uncertainty regarding contamination is caused by a general lack of knowledge and ignorance about the substances released into the environment: "No one can ultimately tell what ended up in the reservoir, but it will certainly have included hazardous materials such as gasoline, oil, paints and varnishes, as well as household cleaners and similar substances." (Kölnische Rundschau, 10 August 2021). Many of the articles also contain moral evaluations by highlighting public perceptions of the consequences of pollution, which are characterized by feelings of fear, insecurity, and lack of information: "'No one tells us what's going on with the soils. My potatoes could be contaminated,' says Linden." (Kölner Stadt-Anzeiger, 31 August 2021). In this quote resonates an accusation of the local authorities, which did not provide information to the affected persons. In this way, the existing uncertainty is also exploited by the political opposition, which highlights "dangerous uncertainty" in which people "still have to live for weeks or even months" (Rheinische Post, 18 August 2021) and thus accuses the ruling parties of not paying enough attention to the issue. In contrast, as

a treatment recommendation, the Minister of the Environment emphasizes specific actions and chemical monitoring campaigns designed to obtain certainty about the possible environmental impact. In most cases, particularly vulnerable groups and sensitive areas such as children's playgrounds are highlighted.

Narrative 3: No severe long-term contamination

The third narrative tends to give the all-clear and emphasizes that there is no severe long-term contamination (Fig. 2, Additional file 1: Table S3). The problem definition is closely linked to the results of the chemical monitoring, which showed that pollutant levels are back within the normal range. The causes given for the relatively low pollution are ecological factors, including the dilution effect brought by the flood wave and the self-cleaning power of ecosystems: "The high water volumes and flow velocities apparently quickly diluted wash-off from vineyards, ruptured oil and gasoline tanks, or destroyed wastewater facilities and washed them away with the flood wave." (Bonner General-Anzeiger, 07 September 2021); "Soil organisms break down the organic components, so that the soil can regenerate over time." (Stadtzeitung Bad Neuenahr-Ahrweiler, 15 September 2021). Concerning moral evaluations, low pollution levels are emphasized by the governing parties, and attributed to "the success of the emergency measures taken on site," which included installation of "mobile wastewater treatment plants" or "mobile toilet cabins." (Allgemeine Zeitung Mainz, 02 September 2021). The articles emphasize that measures (treatment recommendations) are not necessary by addressing human foods such as drinking water, emphasizing that they are not at risk, or certain protective measures such as soil replacement, which do not have to be performed.

Narrative 4: Continuous contamination

The fourth narrative indicates continuous contamination that does not allow the all-clear to be given (Fig. 2, Additional file 1: Table S4). This narrative shapes relatively few articles (8 in total). The articles are mainly characterized by statements of the Minister of Environment, who defines the problem and describes the environmental load of pollutants as "consistent […] even with a slight increase." (Bonner General-Anzeiger, 17 September 2021). Returning residents and increasing wastewater volumes, as well as the still-damaged wastewater infrastructure and work on the riverbed, are named as causes of the constant pollution levels. Concerning moral evaluation, the minister's statements do not give the all-clear, but they are formulated in a calming way: "The current measurement results are within expectations. They underline the importance of the special measuring

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program and show that we cannot give the all-clear. We must keep a close eye on the situation in the waterways. That is why the special measuring program is being carried out in parallel with the remediation measures at the wastewater treatment plants." (Eifel-Mosel Zeitung, 17 September 2021). As a treatment recommendation, the continuation of the chemical monitoring is mentioned.

Temporal distribution of narratives

Since the narratives partly build on each other and are interrelated, especially via the chemical monitoring mentioned, we analyzed the chronological progression of the narratives within the study period in the last step. Figure 3 indicates that there were more articles on chemical pollution shortly after the flood (July) than at the end of the study period in October. It is evident that articles using the narrative "severe contamination" appear most frequently at the beginning of the study period and are scarce toward the end. From September onwards, articles that highlight either "uncertainty" or "no severe long-term contamination" predominate. Few articles emphasizing "continuous contamination" are found only from late August to early October with a peak at the end of September.

Discussion

Overall, our analysis on media coverage of flood-related chemical pollution has shown that the topic tends to be treated on the margins, while other issues related to the flood, such as responsibility or causes like climate change, are discussed more prominently in the media [13, 15]. This is also reflected in social media, as an analysis of Twitter (Germany) data related to the flood event in Germany in 2021 has shown [51]. Public discourse

during and after the event mainly revolved around topics such as protection and warning systems, damage to people, buildings and infrastructure, criticism of politicians, and prevention measures including climate change [51]. That the immediate consequences of the flood dominate the news media and public discourse is an understandable consequence of the flood disaster and the extent of the destruction of buildings and infrastructure. Attention to related environmental issues is focused primarily on climate change as a cause. Djerf-Pierre [52] who studied issue dynamics in news media, showed that coverage of one environmental issue does not crowd out other environmental problems in the media, but rather generates attention for those issues. She also showed that this is particularly the case for related subjects, such as biocides and industrial pollution, and that global crises events fuel national attention dynamics. In this regard, climate change shows the strongest correlation with other related environmental issues [52]. Considering the issue dynamics in our study, climate change is frequently reported in conjunction with the flood event, suggesting that climate change is perceived as a catalyst of extreme weather events. Chemical pollution as a consequence of flood events, in contrast, is less present in the media as a topic. The flood event did not lead to increased media attention, suggesting that this topic is not perceived in conjunction with extreme weather events.

Newspaper articles discussing pollutant emissions focus primarily on the "tangible parts" of pollution. Thus, many articles describe vividly and in sensory terms the destruction of infrastructures and buildings, leaking oil tanks, or flooded sewage treatment plants. These emissions are often depicted in terms of both smell and visible oil streaks on soils and water bodies, while destroyed
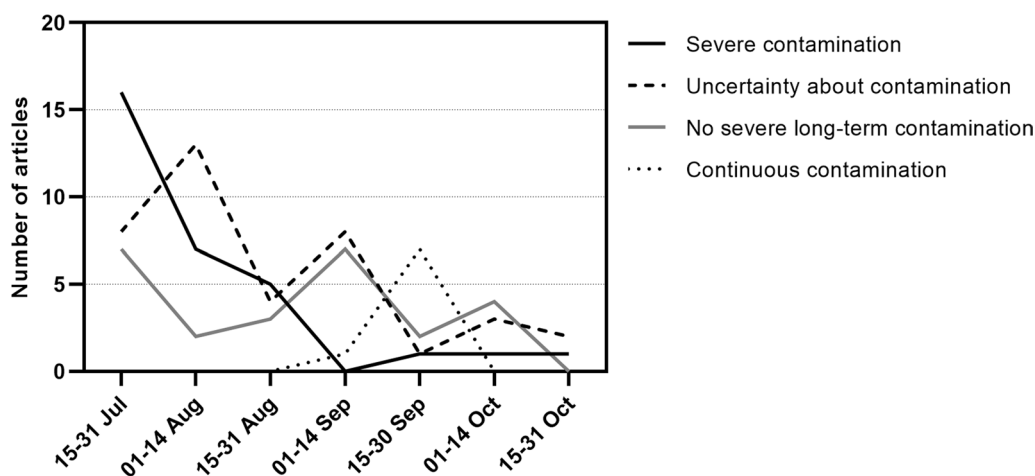

Fig. 3 Temporal distribution of 103 articles on flood-related chemical pollution using different narratives. Severe contamination ($n = 31$), uncertainty about contamination ($n = 39$), no severe long-term contamination ($n = 25$), continuous contamination ($n = 8$)

sewage treatment plants are mostly portrayed as entry points for microorganisms and the risk of epidemics. The "invisible" part of environmental pollution—i.e., synthetic chemicals that are only visible through chemical analysis methods—is considered an expert concern for which the public must be sensitized [16, 53]. It is further evident that water contamination by pollutants tends to be reported in regional or local editions of the respective media, reflecting the concern of the regions, since water is a regional product [16, 17]. In general, our search also indicates that reporting on flood-related chemical pollution is more prominent in the regional newspapers studied (Table 4).

Schulte-Römer and Söding [16] have analyzed the German media coverage on micropollutants (contaminants in low concentrations that are persistent and biologically active) in general and also found that the topic attracted only minor attention. In addition, the analysis shows that reporting articles usually have a neutral, fact-based tone and do not dramatize or alarm [16, 17]. With a few exceptions speculating about harmful effects on the environment and health, the articles in our study also generally report factually. However, articles that speculate about harmful effects list specific substances (e.g., polychlorinated biphenyls (PCBs)) and the associated health effects such as cancer or liver damage (see Additional file 1: Table S1). This suggests a threat to human health as a likely consequence, even though it is not clear whether these effects will actually occur in the affected regions. This assumption is strengthened by the statement that chemical substances may contaminate human food, resulting in ubiquitous exposure. Interestingly, articles that are rather alarmist about pollutants mostly refer to experts and scientists who have studied the issue. In their statements, these experts mostly emphasize the need for greater public awareness of the problem of chemical pollution.

Articles that discuss and frame the environmental risk of the discharged substances in terms of potential negative effects focus to a large extent on the chemical-analytical measurement campaign that was carried out by local authorities. As Schulte-Römer and Söding [16] suggest for media framing of micropollutants, there are generally two ways in which journalists report on an issue. First of all, journalists might frame issues independently, draw attention to specific problems or even dramatize specific aspects to highlight the newsworthiness of a story. Frequent criticism is that environmental issues, for example, are presented in an oversimplified or alarmist rather than constructive manner [54]. The other journalistic strategy includes adopting frames that are communicated by others, e.g., official bodies or authorities, which is criticized because it might uncritically reproduce the

risk evaluation of experts [55]. From our analysis, it is evident that for reporting on flood-related chemical pollution, the last strategy is followed. Thus, many of the articles focus on the statements of environment ministers, employees of official authorities, experts, or the appointed crisis team, which frame the problem accordingly. Moral judgments or blaming of political actors also occurs by referencing statements of the political opposition or affected groups of people. However, blaming of officials is rather the exception.

Generally, the topic is not reported very controversially, but as a reflection of the chemical monitoring results, which are evaluated by experts. Also, formulated uncertainties about the extent of exposure are mostly not addressed via speculative statements about toxic effects, but rather as a device to demonstrate the importance of the special measurement campaign set up. In contrast, other studies have found that flood-related issues are controversial. In their analysis of Australian news media, Bohensky and Leitch [15] showed that floods are generally framed as a blame game and political opportunity, and issues such as climate change are controversial. Considering the German flood event of 2021, the causes of the flood are also controversially discussed in public, with confirmation versus denial of climate change being the main lines of argumentation [14].

Considered as an environmental risk according to the ecotoxicological paradigm, which results from exposure (i.e., the concentration of a substance in the environment) and negative effects of the substance, the risk of flood-related chemical pollution is mainly discussed as a matter of exposure in the media. Thus, negative environmental consequences, all-clear signals, or uncertainties about the extent of exposure are mainly justified by emissions or measurement results for individual substances and not by adverse effects in the environment; in a few exceptions, observed negative effects on organisms or humans are used as a rationale. This contrasts with risk analysis claims presented by scientists. Environmental studies that address the environmental risks of flood-associated pollutants often emphasize the importance of effect-based assessments that evaluate the actual effects of exposure rather than relying solely on estimates of exposure levels. These assessments also include the mixture effects of different substances, which always occur in the environment in combination and not in isolation [5]. Focusing on exposure levels is a common pattern seen in media reports on environmental risks of chemical substances. For example, an analysis on risk framing of microplastic pollution, tiny plastic particles that are ubiquitous in the environment, has shown that media articles primarily frame the environmental risk as a matter of exposure, i.e., the abundance of microplastics in the

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environment, wildlife, and human food [10]. In contrast to the study of media coverage of microplastics, in the case of our study the time window of analysis is critical because effect-based tests were not available at the time of reporting. In addition, some articles also point out that potential effects on the environment only become visible over time.

The question of different risk perception patterns also relates to the research field of social risk research and the well-studied phenomenon of the discrepancy between risk perception of experts and laypersons [56, 57]. People's perceptions of risks are influenced by several factors, including the perception of the risk itself, the perspective on the risk, the response to the risk, and the communication of the risk [58]. For the latter, science communication and the media play a significant role. Scientists commonly refer to media reports as biased, in which risks are portrayed as more dangerous or less dangerous than mathematical estimates would justify [59]. However, while experts focus on equating impacts and environmental concentrations, the public understands the term risk differently and not in the sense of its (eco-)toxicological meaning. In risk perception research, it is common to refer to risk as a situation or development that may lead to a negative outcome [60], or as an event whose outcome is uncertain [61]. In contrast, risk in environmental sciences means that negative consequences occur with a known or estimated probability. This discrepancy between expert and lay perceptions of risk highlights the critical role of risk communication [58]. Risks should be communicated in a manner that takes into account the physical nature of the risks, including the perceived likelihood of contamination, the likelihood of impacts occurring, and the severity of catastrophic consequences. Inadequate communication can lead to high levels of public alarm and risk perception.

A second point that stands out when comparing media coverage with scientific analysis of the issue is the focus on pollutant emissions from destroyed infrastructure and buildings (media) versus the emphasis on effects of historical pollutants bound to sediments and remobilized by flood events (science). In fluvial systems, suspended particles bind various chemicals including metals and lipophilic organic substances, which are thereby removed from the water phase and deposited alongside the suspended particles in the sediment bed over time. Historical sediment layers, therefore, reflect historical pollutant emissions. These pollutants can be released during events that disturb the sediment, such as flooding [5]. In our analysis, only a small set of media articles covers the historical aspect of pollution. However, most of these articles refer to the press release on a newly published scientific study on the topic of flood-related

remobilization of pollutants, which was thematically linked to the 2021 summer flood in the reporting. This indicates that the topic of remobilization and redistribution of pollutants by flood events does not seem to play a major role in public perception, as claimed by scientists studying the issue [5, 6].

In addition to limited media attention, the scientific database on the topic of pollutant (re)mobilization is also rather limited. Crawford et al. [5] reviewed the role of contaminant remobilization during flood events and emphasize that ecotoxicological effects on aquatic organisms in particular have been poorly studied. Also, to our knowledge, no comprehensive scientific risk assessment exists in the present case study. However, there are individual studies that have examined different aspects of chemical pollution related to the flood disaster. Weber et al. [6] studied the concentrations of trace metal(loid)s in flood sediments in an affected town in Western Germany. In their assessment, they found high concentrations of lead in the sediments that exceed the tolerable daily intake when ingested (directly or indirectly via food grown on these sediments) or when dried sediments are inhaled by humans. They conclude that lead concentrations are of concern for human health and suggest raising awareness for the health risks of polluted sediments, in addition to other measures such as improved flood maps and extended warning mechanisms. Another study assessed the ecotoxicological effects of chemical mixtures present in the flood sediments of the affected regions using native sediments and applying whole-sediment exposure in bioassays. They found a strong ecotoxicological potential concerning dioxin-like and anti-androgenic activity. In addition, clear embryotoxic and teratogenic effects on zebrafish embryos were observed, mainly affecting the cardiovascular system [62]. Comparable effects have already been observed in other regions affected by floods [63, 64]. Specifically, the teratogenic and cardiovascular effects are attributed to dioxin-like substances like polycyclic aromatic hydrocarbons [65, 66]. It is difficult to estimate the impact on the environment based on these results, but negative effects on aquatic organisms and ecosystems cannot be excluded.

All scientific assessments have in common that they point to the high toxic potential of flood sediments and do not exclude long-term effects. This assessment contrasts with the narrative of "no severe long-term contamination" identified in our media analysis (Fig. 2, Additional file 1: Table S3), which tends to give the all-clear based on the results of a chemical monitoring set up by authorities. As mentioned above, statements about pollutants in media articles mainly focus on emissions from destroyed infrastructure (e.g., wastewater treatment plants) and the respective pollutant concentrations in rivers and soils. In

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contrast, scientific studies on flood-related chemical pollution concentrate on fine sediments, which also reflect historical pollutants bound to these sediments. Nevertheless, scientific studies also always point to uncertainties in their estimates and the limited understanding of ecosystem effects. Here, statements overlap with the narrative "uncertainty about contamination" (Fig. 2, Additional file 1: Table S2) transported by the media. In general, many scientists are calling for greater attention to the issue of flood-related chemical pollution, both in public perception and in the scientific community.

Although our analysis has shown that chemical pollution is only a minor topic in media reports about flood events, our study has some limitations. First of all, we have focused on newspapers as a particular type of media and, therefore, may not have captured the full range of relevant media content to understand the issue. Second, media analyses are constrained by time and resources and trade-offs had to be made in terms of the scope and timeframe of the analysis. It is, therefore, possible that more in-depth reporting on chemical pollution occurred at a later point in time.

Conclusions

This study investigates how the (re)mobilization and (re)distribution of pollutants resulting from the flood event in summer 2021 and associated human and environmental health risk are framed in media reports.

Compared to other flood-related aspects, e.g., the role of climate change, which is controversially discussed as potential cause, health and ecological impacts of chemical pollution play a minor role in public discourse. The analysis shows that articles in daily newspapers reporting on chemical pollution focus on directly visible impacts, such as infrastructure destruction and visible oil streaks. Pollution that is not "tangible", such as from synthetic chemicals, is less reported.

In the newspaper articles dealing with flood-related chemical pollution, we identified four main narratives that depict the issue: (i) Severe contamination of the environment with chemical pollutants implying serious environmental damage, (ii) possible contamination but with uncertainty about the extent and consequences, (iii) tendency to give the all-clear and emphasizing that there is no severe long-term contamination, and (iv) indicating continuous contamination that does not allow the all-clear to be given. Overall, the topic of chemical pollution is not reported very controversially, but as a reflection of chemical measurement results in the contaminated regions, which are evaluated by experts. The first narrative of severe contamination was most common in newspaper articles shortly after the flood event, when chemical measurements were not yet available,

while the other narratives gained importance later. In contrast to ecotoxicological research, which focuses on assessing the effects of pollutants, pollution in the media is mainly described in terms of the presence of chemical substances in the environment (i.e., exposure rather than hazard).

The work was carried out by an interdisciplinary team combining different fields of expertise and, therefore, contains valuable information for the broader discourse on flood-related chemical pollution, providing a nuanced contribution to media coverage and public understanding that has not yet been considered in the current debate. The question of cause, blame, and responsibility is a very important one to discuss in the context of social-ecological disasters such as the flood disaster in Germany in 2021, so that precautions can be taken to mitigate, if not prevent, such disasters in the future.

Similar to global climate change, chemical pollution needs to be better connected and contextualized with other environmental issues. Extreme flood events represent one pathway of chemical substances into the environment resulting in acute exposure to high pollutant concentrations. However, chemical substances are continuously emitted into the environment and, even under "normal conditions", pose a risk that needs higher attention. Increased risk awareness associated with chemical pollution would lead to a higher level of attention, especially against the background of disasters, as pollutants can be remobilized by flood events. As our analysis shows, however, media reports focus predominantly on the perceptible (catastrophic) consequences and the possible causes. Hardly any attention is paid to the invisible consequences of such events.

Against the background of our study, we therefore propose to (i) strengthen scientific research about the impacts of flood related chemical pollution, (ii) better inform the public about the ubiquity, diversity, and quantity of pollutants, as well as their pathways into the environment and their ecological impacts, and (iii) to communicate chemical pollution more strongly in the context of other environmental issues to raise awareness among the general public. Regarding the latter two points, the media and science communication play a crucial role.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12302-023-00789-2.

Additional file 1: Table S1. Main lines of argument from articles that use the narrative "severe contamination" (31 articles). **Table S2.** Main lines of argument from articles that use the narrative "uncertainty about contamination" (39 articles). **Table S3.** Main lines of argument from articles that use the narrative "no severe long-term contamination" (25 articles).

Table S4. Main lines of argument from articles that use the narrative "continuous contamination" (8 articles).

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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