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Urban flooding and the resultant pollution: What French-speaking scientists make of it?

(Original research article)

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ABSTRACT

Flood damage has increased worldwide in recent decades with a concomitant increased risk of flood-induced pollution. From the perspective of urban political ecology, we ask whether scientists acknowledge flood-induced pollution as a problem and if so how they address it. Using a mixed-methods approach, we analyse 30 semi-structured interviews with researchers in France and Quebec. Our results show that flood pollution can be framed not only in terms of its impact on the environment and our societies, but also as a social representation that varies with the spatial context. The diversity of flood-induced pollution, whether in terms of materiality, visibility, or causation, highlights the undefined contours of flood pollution for the scientific community. We identify obstacles to the emergence of this problem in the scientific arena explained by the structuring of this arena, the vagueness of the term pollution, regulation, and individual and collective approaches to resilience. We argue that these obstacles can be overcome by considering pollution as a social construct and viewing cities in a metabolic framework.

KEYWORDS

Discourse analysis, representation, risk management, urban political ecology, urban metabolism.

ACKNOWLEDGEMENTS

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1. Introduction

Although flooding is a normal part of the functioning of a hydrosystem and is beneficial to the environment, urban floods leave behind visible waste after rivers rise and fall or stormwater drainage systems overflow. Floodwaters also carry pollutants while ever expanding urban populations and infrastructure are vulnerable to flooding. Indeed, global flood damage has increased in recent decades, primarily because of the steady growth of urban populations and economic activities in flood-prone areas (Winsemius et al. 2016). Floods disrupt the urban infrastructure network – both its physical

infrastructure (energy, transport, communications, sanitation, and solid waste management) and its social, economic, and political components (including disaster risk management services) – thereby exacerbating the consequences of floods (IPCC, 2022). A large body of literature has worked on the metaphor of “urban metabolism” (Cousins and Newell, 2015). First, industrial ecology focuses on quantifying the flow of material and energy into, out of, and through cities (Wolman, 1965; Fischer-Kowalski, 1998). This functional approach, which is sometimes criticized for its lack of spatiality (Cousins and Newell, 2015), views nature abstractly as a source of supply of natural resources. Second, urban ecology emphasizes the interactions between the biotic and abiotic entities that make up the urban ecosystem. The focus is on the complexity of the urban ecosystem, not on the flows that traverse the city (Pickett et al., 2001). However, as with the first approach, this second conceptualization of urban metabolism is somewhat apolitical (Cousins and Newell, 2015). Third, urban political ecology emphasizes the power relations that constitute uneven social-ecological production (Gandy, 2004). This Marxist-inspired approach focuses on the study of infrastructure and flows driven by power dynamics that shape urban space and resource accessibility. Urban metabolism is understood here as the embedding of societies in their environment via the extraction of resources, their transformation, their circulation, as well as the disposal of materials (Heynen et al., 2006).

The more functional first and second approaches are most widely taken in the environmental sciences to examine how pollution impacts ecosystems (Garcier, 2010). However, we argue here that the third approach involving urban metabolism, marked by power relations, is a legitimate way to apprehend what pollution is and what makes pollution. We draw on Mary Douglas’s (1966) constructivist definition of pollution as matter that is “out of place”. Her definition enables us to go beyond the chemical nature of the matter, its origin, or its concentration in defining the pollutant, the dirt, and the filth. Flooding can displace materials outside the metabolic network, which may then be recognized and experienced by societies as pollution, which was not the case before. Pollution, then, cannot be understood without reference to a social ordering framework that assigns legitimate places to matter.

Various actors, including the media and activist groups, highlight the problems of pollution during floods. The IPCC report (2022) also mentions this pollution risk, emphasizing the vulnerability to flooding of some urban infrastructures, such as sewerage systems or reservoirs, due to faecal sludge and other hazardous materials that pollute waterbodies and expose humans to health risks. Where pollution is concerned, urban flood modelling focuses primarily on the chemical analysis of water samples collected from sewer overflow to the streets. Raw sewage contains many pathogens that can cause a variety of health problems (Addison-Atkinson, 2022). Ten Veldhuis et al. (2010) assessed the risk associated with three combined sewer floods in the Netherlands and reported significant concentrations of *Escherichia coli*, which is a classical indicator of water contaminated by faeces. Fewtrell et al. (2011) concluded that a considerable number of people are at risk of contracting viral gastroenteritis when cleaning up after flooding. But otherwise there is a shortage of studies on the dispersal of other waste and pollution during floods (Mignot and Dewals, 2022).

Because of this shortage, we focus on how pollution during floods is represented by scientists. Political ecology attaches great importance to the analysis of dominant discourses, as they produce knowledge about the environment and establish truths that can be naturalized (Liboiron and Lepawsky, 2022) to justify political action. Such is the case with scientific discourse (Forsyth, 2003). Scientists “select some categories as relevant, create new ones, and ignore others, in relation with current social and political issues” (Bouleau, 2014). Scientists thus shape the material and conceptual boundaries of pollution, conditioning its recognition as a social problem in the public arena.

Our goal is to ascertain to what extent scientists recognize flood pollution as a “social problem”, that is “a putative condition or situation that is labelled a problem in the arenas

of public discourse and action” (Hilgartner and Bosk, 1988). An arena is a network of actors who exchange ideas and shape the definition of a problem in relation to other arenas. The scientific arena here refers to a set of actors attached to research institutions and using scientific protocols to validate their evidence-based hypotheses. However, the capacity of the public arena to accommodate problems is limited. Selection is therefore involved with different problems and their various definitions vying to capture public attention (Hilgartner and Bosk, 1988). Scientists shape the representations of what pollution is, conditioning its recognition as a social problem by different stakeholders such as decision-makers, managers and also citizens. They can play a role of whistleblowers or primary definers (Comby et al., 2014).

Pollution as a system of values, interests and representations influences scientists. Science and Technology Studies (STS) theorists, such as Latour (2009), explain that the separation between the social and physical worlds did not exist in nature. Thus, pollution can be endowed with an agency for conceptualizing urban space as a relational set of socioecological configurations (Gandy, 2022). Research that addresses the politics of objects is crucial because materials of unprecedented tonnage, toxicity, and heterogeneity threaten to disrupt the survival of the human species (Liboiron, 2015). Thus, we wish to give importance to how and why knowledge has been produced (or not), as well as to the knowledge itself. We want to examine i) how scientific knowledge is built by considering the context in which knowledge is produced or not, ii) how pollution is understood by different types of scientists, iii) how pollution during floods reveals and recomposes the relationship between humans and nonhumans in more-than-human assemblages (Jørgensen et al., 2013).

Our study draws on recent work (e.g. Bouleau, 2014) combining political ecologies of water and social studies of science to analyse the construction of scientific discourse and knowledge about water pollution during floods. We interviewed 30 scientists about how the scientific community contributes to recognizing, legitimizing, and constructing flood pollution as a social issue. We used a mixed-methods research approach to identify criteria that define pollution associated with urban flooding for scientists and to explain the scientific community’s failure to see such pollution as a problem.

2. Materials and methods

2.1. A comparison between France and Quebec

As pollution is a profoundly contextual system rather than a “natural” characteristic inherent to humans, it prompts us to pay attention to cultural, material, political, and regional differences in what constitutes (or not) dirt (Liboiron and Lepawsky, 2022). Following Robinson (2014), our comparative investigation between France and Quebec has three main advantages: i) understanding shared features by composing a comparison, ii) tracing connections between scientific stakeholders confronted with the risks of urban flooding and pollutions, iii) studying specific contexts within broader theoretical frameworks.

The comparison between France and Quebec is recurrent in the scientific literature on risk management, and more specifically on flood risk (e.g. Heinzl et al., 2020). These two political entities have recently experienced large-scale urban floods, such as in 2017 and 2019, in the Montreal region, or in 2016 and 2018, in the Paris region. France and Quebec are also two developed countries that are part of the Global North and of two wider jurisdictions (Canada and the European Union). These relationships can be understood because France and Quebec are two francophone regions that share certain historical and cultural roots (Rousseau et al., 2015). By focusing on French-speaking regions, we limit certain translation biases or difficulties, since our main material is discourse. The inter-knowledge and pre-existing scientific and managerial exchanges enabled us to quickly identify some common points.

These two regions were also chosen for their contrasts. There are differences in urban design (in buildings and urban planning), institutions (unitary centralized state in France

versus provincial federalist system in Quebec), insurance arrangements, and natural hazards. Quebec's hydrographic network exceeds France's in size and power. Floods of varying types occur in Quebec and France. Spring floods prevail in Quebec, when melting snow cover (especially during sudden increases in temperature) combines with heavy rainfall (Buffin-Bélanger et al., 2022). This is not the case in France, where floods are mainly the result of heavy precipitation. Ice jam floods are very common in Quebec. In France, torrential floods and urban runoff floods (linked to the saturation and then the backup of sewage networks) are well identified. These also occur in Quebec.

Finally, on both sides of the Atlantic Ocean, there are floods due to the failure of structures, floods related to marine submersion, and floods due to the rise of the water table. This diversity sometimes conceals similarities in terms of duration, seasonality, or media coverage.

2.2. A corpus of 30 semi-structured interviews

Two exploratory interviews were conducted with researchers in France and Quebec. We then selected participants by snowball sampling, where one subject gives the researcher the name of another subject (Vogt, 1999). This method also relies on a gatekeeper who is inclined to promote the interest of this research, thus reinforcing a bond of trust between the interviewee and the "co-opted" investigator (Atkinson and Flint, 2001). This approach was easier to implement in Quebec, given the visibility of water-related networks such as RIISQ (Réseau Inondations InterSectoriel du Québec), of which 10 of the Quebec scientists interviewed are members, or Centr'Eau (Centre québécois de recherche sur la gestion de l'eau), of which 6 of the Quebec scientists surveyed are members. Nevertheless, in an attempt to interview scientists who are not connected to any network, we performed a literature search to understand the state of progress of the community on these issues.

We conducted 30 semi-structured interviews with 12 Quebecer (or Québécois because French speakers) and 18 French researchers in 2022. We ended the survey because of information saturation (Guest et al., 2006). We selected the researchers for interview based on their research topics (flood risk), to cover the two study areas (France and Quebec), and on the basis of the flood-causing phenomena they were studying in particular. 18 scientists study river flooding, 10 rainwater runoff, 5 marine submersions, 2 torrential flooding, 1 ice jam flooding. 21 teaching and research establishments in 14 cities in France and Quebec are represented in the sample. We surveyed 10 disciplines divided into three categories: engineering sciences (9 respondents), social sciences (18 respondents) and natural sciences (3 respondents). By focusing on floods (and not pollution), we sought to question the extent to which pollution is included in studies of flooding.

The interview guide was designed to characterize the main floods that occurred in the city after 2000, in terms of location, temporality, and physical processes. The respondents also mentioned the subject of their studies with their objectives and methods. Starting the interview with the question of flooding rather than pollution was preferred so as to assess the level of concern with flood pollution. Where pollution was recognized to be an issue, respondents were first asked to characterize it in terms of origin, materiality, impact, hazard, and opportunity. To reduce the impact of the survey, although some scientists asked for the definition of pollution to be clarified, the interviewer endeavored to do so while remaining as inclusive as possible, in order to collect as many disturbances as possible considered to be pollution. They were then asked about the recognition and management of pollution in terms of risk anticipation and post-crisis management. They also specified how they, and other actors in the area, had become aware of these risks. Finally, they assessed whether this issue was of concern, emerging or, on the contrary, absent within their scientific community.

2.3. A mixed methods study

We conducted a content analysis combining qualitative and quantitative approaches (Berelson, 1952). Our categorization of the discourses allowed us to identify a range of topics by adopting a deductive and inductive approach. We stabilized a coding grid with 183 variables distributed under three headings (Table 1). To avoid inter-coder variability, a single analyst read and coded all the texts (Comby et al., 2019).

For textual data analysis and textometry, the interviews were formatted for two open-access software packages (Lebart et al., 2019): IRaMuTeQ (Ratinaud and Marchand, 2012) and the TXM platform (Heiden, 2010). IRaMuTeQ divides the corpus into text segments (of approximately 40 words); performs lemmatization; creates a contingency table between lemma, metadata, and text segments; and performs a top-down hierarchical classification as developed by Reinert (1983) to analyse the lexical structure of the corpus by presenting the degree of association between each class and the different text segments (Cottet et al., 2015; Flaminio et al., 2021). It produces a dendrogram displaying several clusters and indicating the percentage of text segments in each cluster (Boyer et al., 2021). This output enables us to visualize (i) the lexical forms frequently occurring within a cluster, (ii) the association of lexical forms that form clusters, which can then be thematized, and (iii) the links between the different clusters.

By analysing the textual data on the TXM platform it is possible to identify the under- and over-represented words (with the occurrence and specificity tools). We also use lexical specificity (Lafon, 1980) which identify the most (and the least) representative words in a given interview, based on the hypergeometric distribution and a comparison of our interview corpora (Lebart et al. 1998). The concordance tool replaces each term in its context and allows a return to the text, to go further than a simple statistical abstraction of the text, and to propose qualitative interpretations, notably with the help of excerpts.

3. Results

3.1. Defining the subjective concept of pollution

In all the interviews conducted with the 30 scientists, we counted 164 references to pollution caused by floods, immediately classified into eight types of pollution. The scientists mainly associated flood pollution with water (18% of 164 classified occurrences of pollution), micropollutants (17%), debris (16%), and sewage discharges (16%) (Figure 1).

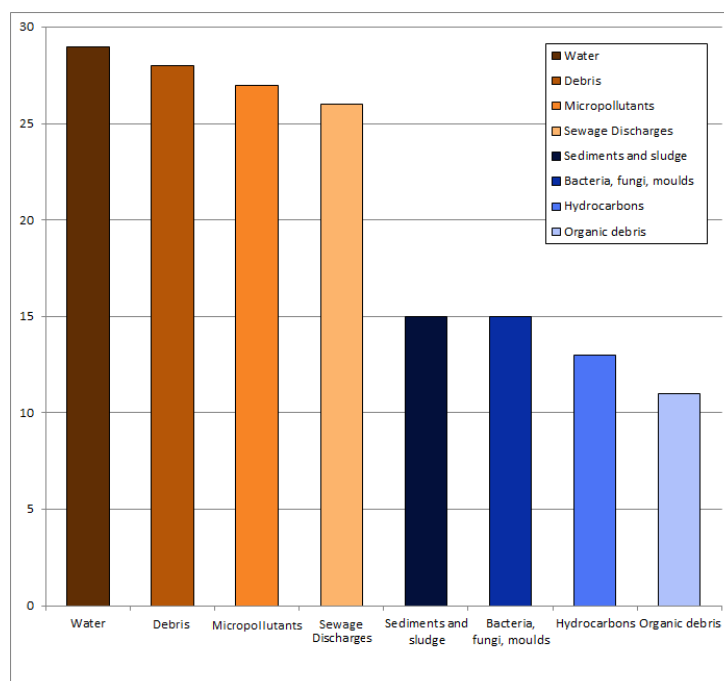


Figure 1: Distribution of types of pollution associated with urban flooding (n=164) by respondents (n=30)

Water causes material damage and mental trauma. “It’s dirty water, it’s muddy water, it’s smelly water, it’s water that carries waste, so rubbish, dead bodies of small animals, materials, it’s water that’s noisy” (Respondent 17). The category of debris covers material damage caused by floods, from household rubbish to construction rubble, including soiled household appliances and macroplastics. Micropollutants include heavy metals such as mercury or zinc, as well as chemical residues from cleaning products, and microplastics. Hydrocarbons are put in a separate category because they are cited separately by many scientists. The “sewage overflow” category refers to untreated water due to sewerage system saturation, preventive overflows to avoid malfunctions of sewage treatment plants, and discharge from flooded sewage treatment plants. The diversity of the pollution cited, in terms of materiality, visibility, and sources, for example, reflects the absence of any clear definition of flood-induced pollution among the scientific community. In point of fact, half of the respondents asked for clarification as to the definition of pollution during the interview. This diversity and imprecision can be observed within the different scientific communities working on floods (Figure 2).

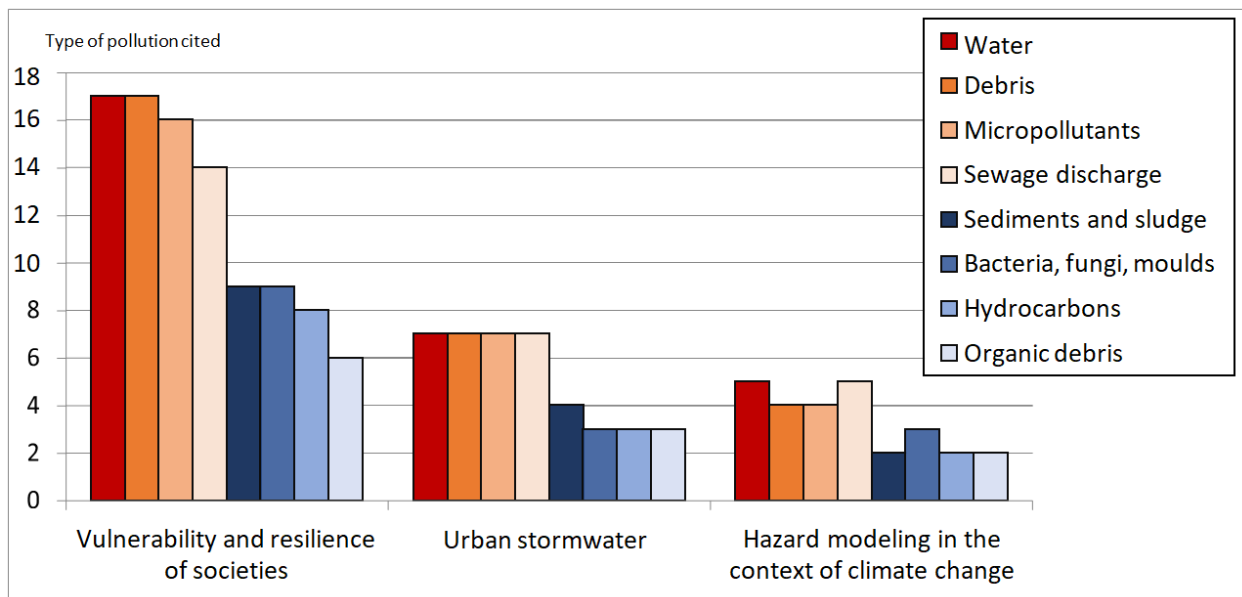


Figure 2: Distribution of pollution types associated with urban flooding (n=164), classified according to three fields studied by the scientists surveyed (n=30)

Water, micropollutants, and sewerage system discharges are also the forms of pollution most cited by scientists working on risk modelling in the context of climate change (5 respondents), on urban stormwater (7 respondents), and on the vulnerability and resilience of societies with regard to floods (18 respondents). This observation can also be made with regard to disciplinary affiliation, which is not a structuring criterion for understanding the identification, definition and recognition as a problem of a particular type of pollution.

Two common characteristics emerge to define pollution in the scientists’ discourse. The first characteristic of flood pollution concerns its negative impacts, observable on the dendrogram generated by IRaMuTeQ (Figure 3).

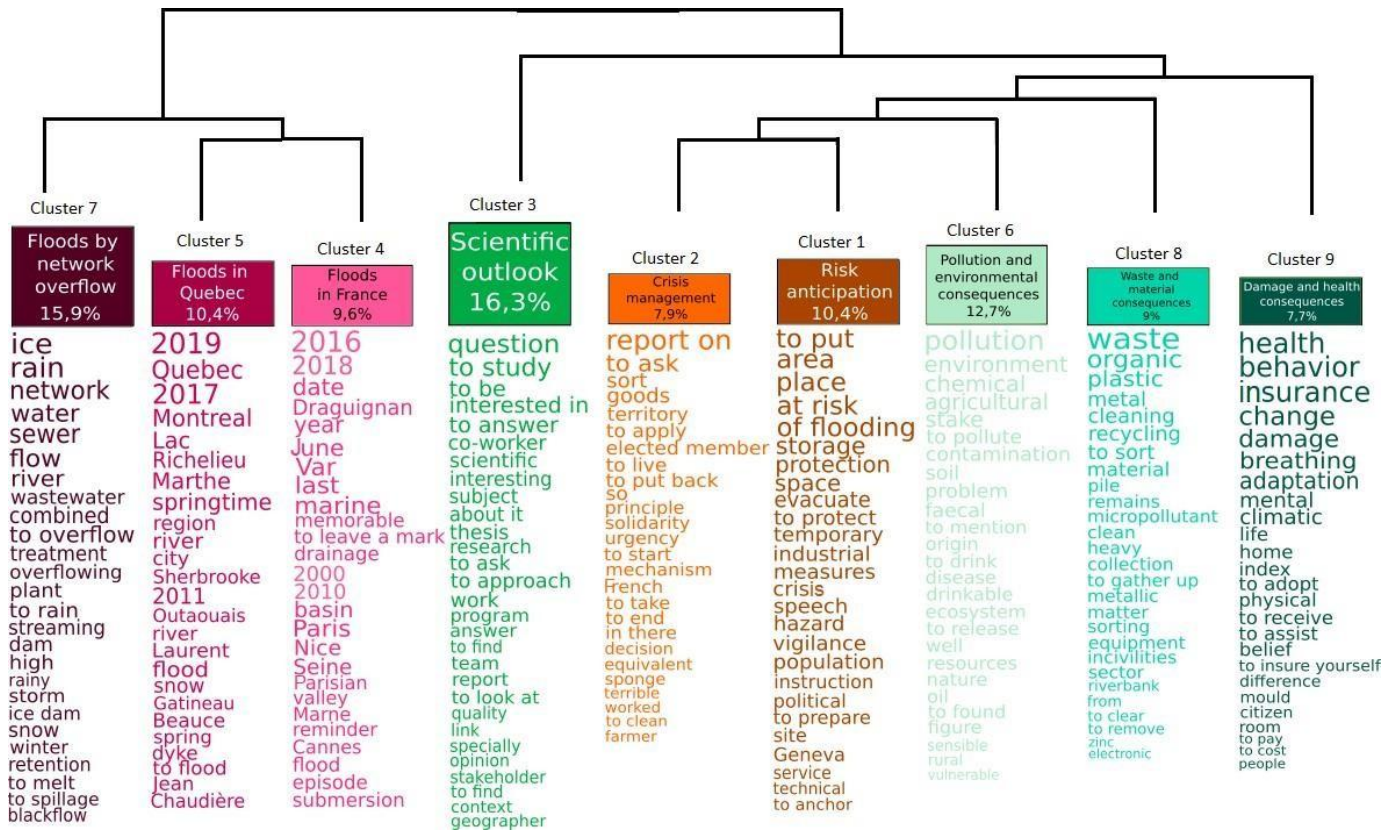


Figure 3: Clustering tree after top-down hierarchical clustering performed with IRaMuTeQ (Reinert, 1983) on the transcribed corpus of thirty interviews. Percentages correspond to the proportion of text segments contributing to form each cluster. Words are ranked by their Chi2 from the highest scores (at the top of the list) to the lowest.

The top-down hierarchical classification shows how three main branches structure the cluster tree: (i) the different flood events (Clusters 7; 5; 4); (ii) the anticipation and then the management of pollution (Clusters 2 and 1); (iii) the three types of pollution (Clusters 8; 6; 9) and their understanding by scientists (Cluster 3). Cluster 9 corresponds to pollution with adverse effects for victims’ *“mental”* and *“physical”* health. For example, *“mould”* is associated with this cluster. Cluster 6 refers to pollution as a source of *“contamination”*, particularly for *“soils”*, *“ecosystems”*, and *“drinking”* water. It is described as *“chemical”*. There is also mention of *“faecal”* matter, *“discharges”* from sewerage systems, and *“nuclear”* pollution. Finally, we find the category of *“waste”* in cluster 8. This work highlights the categorization of pollution in terms of its health, ecological, and material impacts. Indeed, in the 164 classified occurrences of pollution, scientists mentioned health impacts (27%); material damage (18%); pollution-induced malfunctions e.g. in terms of interruption of services (17%); and environmental impacts (15%). Seven scientists are uneasy about defining pollution in terms of negative effects, but believe that pollution is necessarily negative for the environment. Accordingly, substances producing other effects could not be classified as pollution since they do not degrade the environment: “I don’t know how to characterize it, but it’s certain [...] that having walls that are in the water, all that, there could be a development of bacteria in there, of fungi, of mould. So it’s a potential health hazard, but I don’t know if we can talk about pollution” (Respondent 15).

The second characteristic of flood pollution is dirt, which is mentioned in the discourse of 13 scientists. First of all, dirtiness concerns debris. It is soiled, even described as *“dross”* (Respondent 24), and can no longer be recycled or repaired. This soiled waste degrades the urban landscape, which in turn is made unsightly by its presence, especially in crowded spaces. Secondly, the water is also described as *“very dirty, smelly water”* (Respondent 8), contaminated with all kinds of *“muck”* (Respondent 23). The water spreads this dirt by establishing a link between the source of the pollution that has contaminated it and the vulnerable object or person. The origin of this dirt concerns

deposits washed away and displaced, especially by water: “What produces pollution are all the deposits that have accumulated on surfaces and that will be washed away by the rain. It’s the materials that make up the city too” (Respondent 27). These deposits leave traces: “Floods leave traces, at least with the people we interviewed, and their concern is to erase the traces and marks of the flood” (Respondent 11). Even if impurities, especially in contaminated water, are not always visible, dirt becomes particularly visible during floods: “The flood is precisely the moment when the water is cloudy. It is already full of floating waste. It smells bad” (Respondent 14).

It is the negative value attributed to an externality that makes it pollution, and this value depends on social or individual recognition. For instance, in 30% of cases, the pollution mentioned is also a resource. For example, researchers use the high-water marks to study the health of rivers. Thus, pollution is designated as such according to the context: “I spoke about wood earlier, which is not normally considered to be pollution, and yet precisely during the recent phenomena, there was such a quantity of it that it became pollution” (Respondent 2).

3.2. Spatial context and different identifications of pollution

We argue that pollution depends on the spatial context. The region studied is a first element of the spatial context that can explain the differences. The pollutants most frequently cited by French and Quebecer scientists are different (Figure 4). French scientists are more likely to mention micropollutants, as shown by a lexical specificity analysis. Quebecer scientists more commonly mentioned sewage discharge and bacteria as a source of pollution.

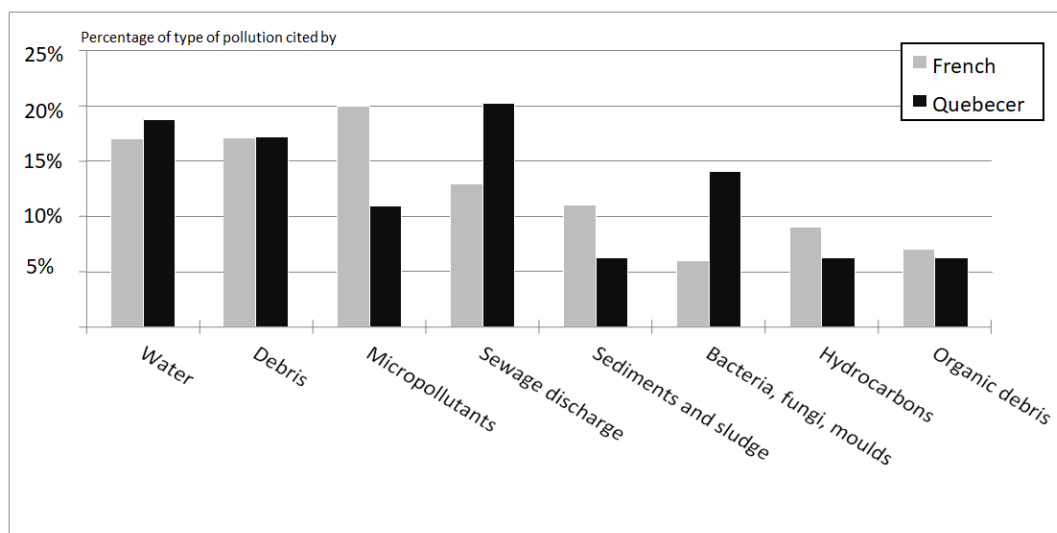


Figure 4: Percentage distribution, within each country (n_{french}= 100 and n_{quebecers}=64), of types of pollution associated with urban flooding by the scientific community

The second contextual element that explains the different representations of pollution is the nature of the event and the city in which it took place. Of the geographically accurately located pollution events, i.e. 63% of the 164 classified occurrences of pollution, 19% concerned the Montreal region and 15% affected the Paris region. The predominance of these two regions is also shown in the dendrogram (Figure 3). The first cluster of this classification corresponds to floods. Cluster 5 refers to floods in Quebec, and more specifically to spring floods in the Montreal region in 2019 and 2017. “*Marthe*” and “*Lac*” refer to the town of Sainte-Marthe-sur-le-Lac, which was particularly affected in 2019, due to the failure of its “*dike*”. Cluster 4 refers to French locations and the floods of 2016 and 2018 in the Ile-de-France region, when the Seine and its tributaries overflowed. If we associate the location of pollution with its type, we see that the Montreal region and the Paris region are mainly mentioned for waste, water, and sewage discharges. However, in the Paris region, micropollution is mentioned more

often. This feature, previously highlighted by the specificity index, therefore seems to be a French and more especially Parisian specificity.

However, the role played by the city and the event can be qualified, as many scientists imagine pollution without being able to refer to specific, real or localized floods. Of the 164 mentioned pollution referred to, 37% are not precisely located or are potential but not actual occurrences. Some 41% of potential pollution is micropollution and 24% involves hydrocarbons. This is the fear of flooding of technological infrastructures, particularly factories and service stations. The scientists cite the storage of hazardous materials and the leaching of soil as the main causes (Figure 5). According to 11 scientists, this concern about micropollution is not based on concrete examples. Of all the ways in which scientists became aware of the risk of pollution, 21% were based on intuition.

The third contextual element, which explains the differences in pollution representations, is to be found on a more local scale. This is the diversity of urban morphology and building architecture. 20% of imprecisely situated pollution concerns bacteria. In the same time, the main causes of bacterial growth are stagnant water and the design specificities of urban buildings according to the scientists (Figure 5). Spring floods in large river systems can last several weeks. In Quebec, water stagnates and seeps into basements: “In Quebec unlike in Europe, a lot of people build basements, have bedrooms and playrooms, and [...] when water gets into the basement, it damages the houses quite a bit” (Respondent 5). Thus, the specific design of the buildings in the region increases the vulnerability of the population to bacterial growth during floods. In other words, the nature of the risks (particularly in terms of duration) and the vulnerability of the design of the typical Quebec building (with many basements) make the development of bacteria more likely at a micro-local scale, which explains the difficulties for scientists to spatialize it in a precise urban area in Quebec. Accordingly, pollution can be analysed as a social representation that varies with the spatial context.

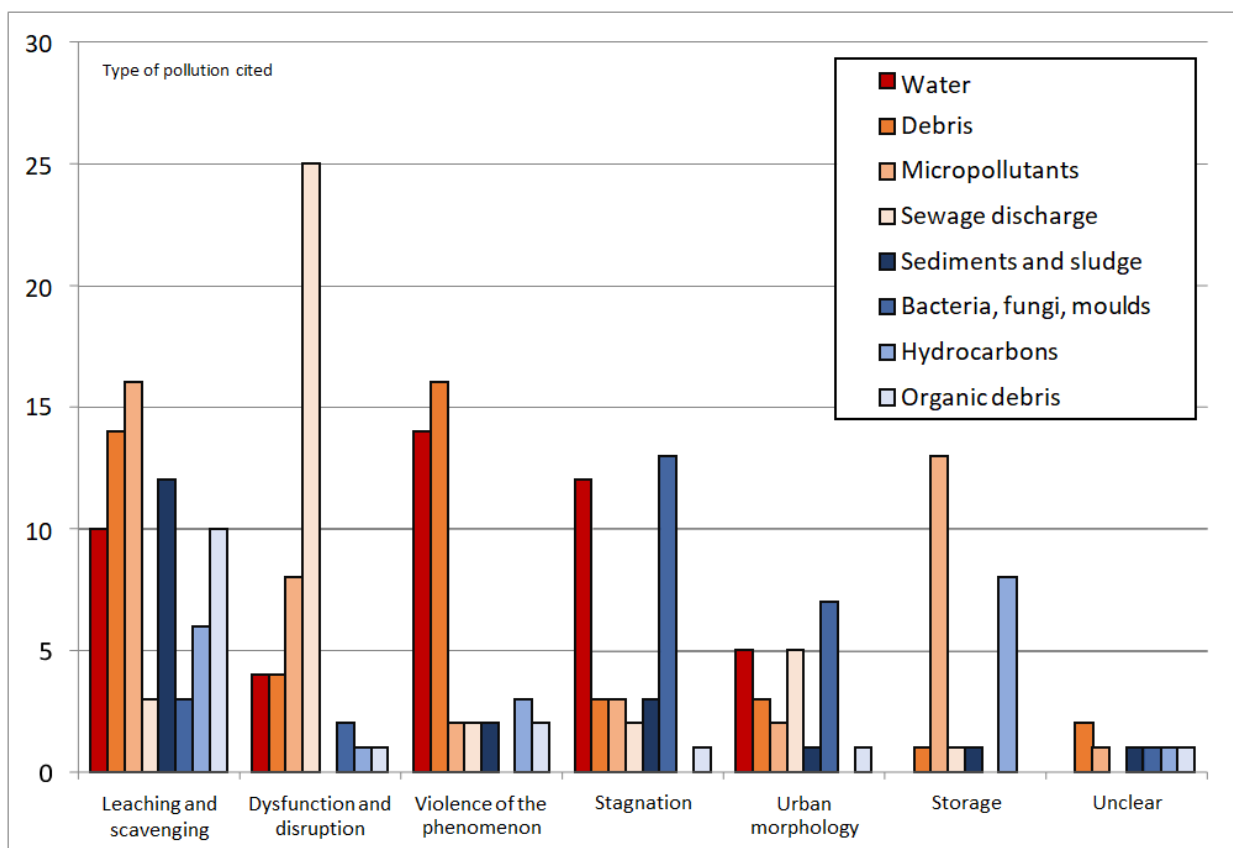


Figure 5: Distribution of types of pollution by their causes (n=252) by the scientific community

3.3. Is pollution a problem for the scientific community?

In all, 65% of the pollution identified by respondents is not viewed as a social problem within the scientific community. First, 28% of the occurrences of pollution mentioned are not considered a problem within the scientific community because of the lack of exchanges between the different research fields: “In the scientific community, there are two communities: there’s a community that works a little more on water quality, on the ‘water resource’ let’s say, and then another community that works on ‘water risk’... And these two communities don’t talk to each other much after all” (Respondent 7). Second, 23% of the classified occurrences of pollution mentioned were not considered to be problematic because the scientists felt that they did not know enough about the subject to answer this question. Indeed, 24 researchers expressed doubts about their legitimacy to answer our questions. Third, 15% of the pollution mentioned were not considered problematic because scientists considered them complex to study because of technical difficulties for example. Fourth, 15% of the pollution mentioned was not considered problematic because it is considered secondary to the immediate protection of goods and people. The qualitative study of the corpus provided two additional arguments for why scientists do not consider urban flood pollution to be a problem. According to 10 scientists, pollution in the flooding context is highly diluted due to the overflow of water. Besides, some types of pollution are invisible, particularly micropollutants, making it difficult to be aware of a risk and therefore of the need to study it: “Visually it is degraded, and that is why we talk a lot about plastics because we see them [...]. But that is not the case for micropollutants such as PCBs, [...] micropollutants that are invisible but have an impact that is currently, a priori, even greater than what we imagine” (Respondent 24).

According to scientists, pollution due to flooding is not considered a problem for the other actors in the arena. Some 52% of the pollution mentioned is not problematic for managers. This figure rises to 60% for inhabitants, and 63% for local authorities. However, closer scrutiny of the dendrogram (Figure 3) allows us to qualify this observation for managers and local authorities. First of all, it is in cluster 6, referring to “pollution” with environmental consequences, that we find the terms “*problem*” and “*problematic*”. This indicates a closer connection between this form of pollution and their assigned concern by the researchers. Secondly, study of the dendrogram (Figure 3) reveals a link between clusters 1 and 2, concerning the management and the anticipation of pollution, respectively, and cluster 6, which refers to “pollution” with environmental consequences. In other words, the types of pollution that are more likely to be perceived as an issue by managers and local authorities are also, according to scientists, those that are better managed in terms of risk and crisis, once they have occurred. Clusters 1 and 2 are, in a second step, also associated with cluster 8, which is related to “waste”. If we look at the lexical forms, and in particular the verbs frequently occurring in each cluster, we see that the lexical field of prevention and adaptation belongs rather to cluster 6 (“*evoke*”, “*perceive*”, “*become*”, “*worry*”, “*evaluate*”, “*anticipate*”, “*examine*”, “*filter*”, “*sensitize*”, “*document*”), while the verbs of cluster 8 are more related to management (“*sort*”, “*collect*”, “*remove*”, “*recover*”, “*burn*”, “*recycle*”, “*clean*”).

The qualitative analysis of the corpus supports the idea that at the local level, according to the scientists, managers and local authorities are aware of and take into account the risks of industrial pollution (included in cluster 6). For example, 14 scientists mention anticipating pollution via restrictions on locating production infrastructure in areas at risk of flooding. Of the 45% of the pollution that scientists believe is managed, 19% is waste. After water, it is the second most carefully managed form of pollution. So, there is local and technical knowledge about pollution caused by flooding but it is not systematized and characterized as a priority. Furthermore, seven scientists claim that managers and local authorities voluntarily refuse to make it a central issue within the public arena. They might be said to be in a state of political denial.

The problem of pollution is particularly acute for drinking water and wastewater systems. If we look at the instances of pollution identified as a problem by the

scientific community, 42% concern water and 33% concern sewerage systems. In 29% of the cases of pollution related to excess water, the consequences correspond to malfunctions that affect “electrical networks, drinking water, sanitation, transportation networks, and in recent years we have been talking a lot more about waste” (Respondent 12). Thus, water pollution generated by floods causes malfunctions engendering pollution that sometimes leads to further malfunctions. The surplus of water leads to the saturation of artificial hydrographic networks, which overflow, but also to the failure of purification plants, which then discharge untreated water. According to scientists, 66% of the pollution linked to discharge from sewerage systems is caused by malfunctions. The surplus of water also jeopardizes waste management, for example, with waste continuing to accumulate while the collection networks are inoperative, and at the same time the flood generates other waste. Furthermore, pollution, especially of soils, is often an unthought-of aspect of policies for storage in temporary landfills. In addition to this series of pollution events and malfunctions, there are, for example, health risks for workers in the waste sector. Drinking water supply systems can also be disrupted by flooding, leading to the contamination of “clean” water by excess water and “unclean” water. This consequence was mentioned by seven scientists, as the quality of drinking water, and particularly the networks through which it passes, is closely monitored and studied. Scientists then emphasize the determination of managers and communities to return to normal operations. Clusters 1 and 8 evoke the restoration of soiled areas after the crisis. Clusters 2 and 6, by mobilizing the lexical field of anticipation, also allow us to envisage this “return to normalcy” (Respondent 20) as quickly as possible, by avoiding further disturbances, and by taking preventive measures to keep the network functioning. According to scientists, anticipatory measures have been taken for 37% of the pollution incidents mentioned. Among the anticipated pollution events, a majority of devices concern water (38%), in particular rainwater. While urban development has increased the quantity of water due to soil sealing, there are also qualitative issues related to leaching. Infiltration or storage devices anticipate these two dimensions. For example, three scientists mention green infrastructure based on the “sponge city” model that manages stormwater and pollution at the source through infiltration. Seven scientists also mention retention basins to store excess water, but also contaminated sediments.

4. Discussion

4.1. Pollution as a disturbance of urban metabolism

Modern representations of water emphasize its purity (Bachelard, 1942; Linton, 2010). However, in the context of flooding, excess water can be thought of as a form of pollution, crossing “some line which should not have been crossed and this displacement unleashes danger for someone” (Douglas, 1966). Water flows out of its channel and/or overflows from the sewerage system. Water is displaced from metabolic networks, creating danger, damage, trauma, and dirt.

In the context of flooding, water itself is displaced, but it also displaces other elements. First, displaced water displaces pollution that was previously under control because it incorporates dirt and disease. Like Ten Veldhuis et al. (2010), who are interested in faecal matter, scientists tend to be interested in things that bring death and disorder upon us. Flooding disrupts the urban metabolism, leading to a series of malfunctions, displacements, and therefore pollution. For example, excess water saturates sewers and treatment plants from which contaminated water spills over. Wastewater pollution, monitored by scientists and controlled by networks for treatment (Moatty and Rhegezza-Zitt, 2018), is not an unpleasant incident; it is an intrinsic condition for the functioning of urban metabolism (Swyngedouw, 2006). However, in the context of flooding, this pollution is displaced, and “dirt offends against the order”, which was previously based on “a systematic ordering and classification of matter” (Douglas, 1966) by means of sewerage and treatment networks. Secondly, water displaces materials that, once

displaced, are newly perceived as pollution.

The framework of metabolism enables us to better define pollution and also to talk about resilience to pollution. Douglas (1966) lists several ways of dealing with pollution by developing a new order of things in which to insert the anomaly resulting from the metabolic system. First, “the existence of anomaly can be physically controlled” and eliminated to make the matter “undifferentiated” (Douglas, 1966), during cleaning operations, after the crisis, for example. Pollution can also be integrated “into a single, grand, unifying pattern” (Douglas, 1966), that of resilience in particular (UNISDR, 2015). Reactively, to increase their resilience, networks must be designed to absorb the disturbance while continuing to adjust and function so as to shorten the time taken to resolve the crisis (Moatty and Rhegezza-Zitt, 2018). Proactively, they must be able to adapt, i.e., transform after recovering from the damage to reduce the risks and impacts of future crises. Resilience refers, then, to the capacity, in this case of networks, to integrate disruption into their functioning so as to reduce their vulnerability (Folke et al., 2002). This anticipation of pollution, in the context of flooding, concerns displaced water. For example, storage ponds are designed to store water to avoid saturating sewerage systems. They also filter out water-borne pollution.

4.2 Scientific context and the lack of interest of the scientific community in flood pollution

Our results show that pollution in the context of urban flooding has not been raised to the status of a problem in the scientific arena because of the organization of scientific stakeholders. The definition of pollution, in this specific context of flooding and urbanization, has posed difficulties for researchers working in different thematic networks (stormwater, flood risk modelling and forecasting, risk assessment, etc.) within the scientific community. Because the network of actors, which is supposed to position itself and define the problem (Hilgartner and Bosk, 1987), is highly fragmented, a wide range of materials, processes, and consequences have been cited to explain pollution. Respondents do not make it a priority and view it as an issue in its own right within their network. The difficulty of characterizing pollution in the context of floods is compounded by competition among the different scientific issues raised by flooding, but also between different potentially problematic contaminants within an arena, in this case, the scientific community, to get into the spotlight (Hilgartner and Bosk, 1987).

Since pollution is a system (rather than a “natural” characteristic inherent in humans) which is profoundly contextual (Liboiron et Lepawsky, 2022), studying it would provide an opportunity to examine the relationships between societies and the activities that generate pollution and the relationships between societies and the environments affected by that pollution (Garcier, 2010). Emerging research into these issues (on water treatment and discharges, post-disaster waste management, the health impact of flooding, etc.) is therefore an object of study in its own right.

One of the fruitful arguments of Douglas (1966) is to consider pollution as a source of power. In other words, “dirt, or matter out of place, rarely describes waste or pollution. Instead, dirt describes a dominant system of order and threats against that order” (Liboiron and Lepawsky, 2022). Discard studies encourage us not only to denaturalize pollution, but also to decentralize it in order to question discarding, i.e. the fact of identifying and considering pollution as problematic (and therefore of wanting to control or annihilate it), as a technique for conserving power (Liboiron and Lepawsky, 2022). By focusing on the processes that create the need to be resilient, in this case the functioning of urban metabolic networks (March and Swyngedouw, 2022), we can analyse how discourses on resilience are precisely value laden, so as not to depoliticize environmental problems, in this case pollution caused by floods, by reducing them to technical issues that affect societies indifferently. Pollution, then, can be used as a political argument to promote alternative solutions to existing vulnerable metabolic networks. Thus, pollution caused by urban flooding can be mobilized as a new lexicon

to question (i) the forms of channelling of metabolic pathways that are anchored in the cities they cross; (ii) the risks that weigh on their malfunctioning; (iii) the political responses provided via the critique of resilience requirements. Thus, it is an opportunity to ask the question “who gains and who loses” to delegitimize (or not) the current mechanisms of water circulation, which are based on political and social compromises (Swyngedouw, 2006).

4.3. The scientific arena at the interface with other arenas

Downs (1972) recommends analysing social problems in five phases to highlight their importance in the sphere of public discourse and the actors involved. In the phase 1, some actors play a role of whistle-blowers without the issue generating any real awareness. Phase 2 is marked by the discovery of the problem, an enthusiasm for its rapid resolution, and massive social mobilization (Comby et al., 2014). We argue that we are in phase 1 concerning pollution due to floods.

Scientists consider that managers and local authorities have technical knowledge about flood pollution. Technical knowledge, especially on temporary storage areas or sorting methods, can be found in practical guides, such as the CEREMA (2019) guide on the “Prevention and management of waste from natural disasters” in France. The CEREMA stands for Centre for Studies and Expertise on Risks, the Environment, Mobility and Urban Planning and is a French public agency. Scientists claim that managers and local authorities are aware of this pollution but do not consider it to be their most pressing problem. In the absence of proactive regulation on these issues, managers and scientists turn away from them in favour of more burning issues in a context of austerity preferring instead to fund short, targeted projects on specific topics.

The risks to which people are exposed when cleaning their homes seem to be largely ignored. During disasters, media show residents cleaning up using their own equipment (broom, squeegee, mop, bucket, etc.) but not wearing any protective equipment. Besides, because of the time it takes for insurance procedures and refurbishment work, some flood victims have to live in housing where fungi, bacteria, hydrocarbons, or heavy metals may still be present. We hope that this survey will raise questions, and even sensitize scientists (who have not asked any questions here) to this issue, which has been left in the hands of managers. Further studies would provide a better understanding of the potential dangerousness of these flood marks, particularly during clean-up, and perhaps challenge the generally prevailing individual approach to resilience, all from a perspective of environmental justice.

The scientific arena is not yet involved in the rise of flood pollution as a social problem, at the interface with other arenas (Hilgartner and Bosk, 1987), such as that of the inhabitants or risk managers.

Conclusion

The contours of the definition of urban flood pollution are not clear for the scientists interviewed. However, two characteristic features emerge: danger and dirtiness, echoing Douglas’s (1966) constructivist definition. The designation of pollution depends on the spatial context, at different scales, according to the region and city studied. They can also be explained by the nature of the floods and the vulnerability of the inhabitants, linked, for example, to urban morphology and building architecture. Even so, flood pollution does not emerge as a social problem within the scientific community, either in France or in Quebec. This lack of visibility can be explained by the difficulty scientists encounter in defining what flood pollution is, given the fragmentation of their community. Nevertheless, scientists claim that managers and local authorities are aware of these problems. Finally, Douglas’s (1966) definition of pollution allows us to go beyond a purely impact-based approach to flood pollution and to consider what it says about the relationship of societies to their environment, particularly in terms of the resilience of urban metabolism while cities are particularly sensitive to network

malfunctions, for example, in terms of pollution.

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Tables	Coded elements
Metadata and interviewee	<ul style="list-style-type: none"> • Sense of legitimacy and requests for clarification of the topic (e.g., definitions). • Off-topic (flooding pollution in a rural context; pollution without talking about flooding; pollution that occurred before 2000)
Urban floods since 2000	<ul style="list-style-type: none"> • Places and scales impacted • Temporality of events • Water bodies concerned • Type of flooding • Explanatory factors • Floods studied (or not) by researchers (with what objectives and methods)
Pollution caused by urban floods	<ul style="list-style-type: none"> • Link or not with a mentioned flood • Type of pollution, its causes, the environments affected, and its impacts • How these forms of pollution are recognized • If these forms of pollution are identified as a problem by inhabitants, associations, local authorities, practitioners, central government, and the scientific community • Actors and resources involved in the anticipation and post-crisis management Of pollution • If the management of pollution has generated further pollution

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