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Thesis:

Exploring environmental justice issues in drinking water contaminant exposure

A Scoping Review in Europe and a Case Study in Ille et Vilaine, France

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"La medicina es una ciencia social y la política no es más que medicina a gran escala"
R. Virchow

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List of acronyms

ANSES: French Agency for Food, Environmental and Occupational Health & Safety

ARS: Health Regional Agency

BrTHM: Brominated trihalomethanes, summary of bromodichloromethane, chlorodibromomethane, tribromomethane (bromoform)

CépiDc: Center for Epidemiology of Medical Causes of Death

CMU: Universal health coverage in France

DBP: Disinfection by Products

ECHA: European Chemicals Agency

EDI: European Deprivation Index

EJ: Environmental Justice

ELFE: French Longitudinal Study since Childhood

EU: European Union

EU-SILC: European Union Statistics on Income and Living Conditions

FDep: French Deprivation Index

HAA: Halo Acetic Acids

HiWATE: Health impacts on long-term exposure to disinfection by-products in drinking water

IEV: Ille et Vilaine

INERIS: National Institute of Industrial Environmental Risks

INSEE: National Institute of Statistics and Economic Studies

INSERM: National Institute of Health and Medical Studies

IRIS: Aggregated Units for Statistical Information Blocks

LERES: Laboratory of study and research of Environment and Health

PFAAs: Per and Polyfluoroalkyl Acids

PFBS: Perfluorobutane Sulfonic Acid

PFHxS: Perfluorohexane Sulfonic Acid

PUCA: Urbanism Constructure and Architectural Plan

ScR: Scoping Review

UK: United Kindom

US: United States

TMF: Technical, Managerial and Financial capacity

THM: Trihalomethanes

4THM: Trihalomethanes summary of bromodichloromethane, chlorodibromomethane, tribromomethane (bromoform) and trichloromethane (chloroform)

WDF: Water Framework Directive

ABSTRACT (EN)

Introduction: This thesis investigates the environmental justice (EJ) issues related to exposure to drinking water contaminants (DWC) in Europe. In North America, different studies rooted in civil rights and social movements have highlighted the racialized and socioeconomic disparities in environmental hazards exposure in DWC. This research aims to assess similar EJ issues in Europe, identifying contaminants and potential drivers. Then, through a specific case study in France, we illustrate it.

Methods: A Scoping Review (ScR) was conducted, exploring the existing European studies from 1990 to 2022. The review encompasses types of DWC studied in relation to EJ, research designs employed, and potential drivers contributing to inequalities in exposure to specific DWC.

In addition, a case study was conducted in Ille et Vilaine, France. It incorporated contaminants identified as part of the ScR. Inequalities in DWC were assessed using a composite deprivation index, FDep15, applied to the census tract level (IRIS), the smallest aggregated information system in France.

Results and Discussion: The findings indicate a limited number of primary studies focusing on EJ and DWC exposure as compared to North America. Nevertheless, various contaminants such as nitrates, trihalomethanes, heavy metals (lead, manganese, arsenic…) and pesticides have been assessed in the available studies. Case study findings suggest some association between EJ and DWC, with a different level of correlation depending on the contaminant, consistent with what has been identified in the literature. For instance, trihalomethanes show a negative correlation with deprivation, while lead displays a positive correlation related to the FDep15.

Therefore, the results emphasize the need for comprehensive studies on environmental justice and DWC exposure on a larger scale. As EJ disparities are multifaceted, understanding complex interactions between contaminants distribution, socioeconomic factors, and exposure is essential for addressing EJ in drinking water.

Keywords: drinking water quality, environmental justice, inequality, water and health, Europe

1. Introduction

1.1. Water scarcity and quality

Increasing water scarcity and its quality degradation have become pressing global issues, with significant implications for human health, ecosystem services, and ecological cycles (1,2). Although water covers around 70% of the Earth's surface, freshwater constitutes approximately 2% of this vast resource (3,4). Anthropogenic activities such as industrial processes, intensive agriculture and farming deteriorate water quality contaminating its source, and introducing harmful substances such as pesticides, fertilizers, and antibiotics (5-7).

Access to safe drinking water is recognized as a fundamental human right under binding international law by the United Nations (8). In Europe, the recast Drinking Water Directive (2020/2184) has included this aspect (9-10). France integrated this new directive into law (Nº 2022-1721 Decree of December 2022), aiming to enhance access to water intended for human consumption (11). However, this directive addresses primarily accessibility issues rather than equally prioritizing both accessibility and water quality (11).

Ensuring safe drinking water is essential for public health. Microbiological contamination is a prevalent risk worldwide, controlled through continuous disinfection. Disinfectants like chlorine and ozone are potent oxidants that can react with organic matter, anthropogenic contaminants and other halogens (bromide/iodide) to form disinfection byproducts (DBPs) (12). Trihalomethanes (THM) and halo acetic acids (HAA) are common DBPs found in drinking water (12,13). Long-term exposure to THM may be linked to cytotoxic, mutagenic and cancerogenic effects like bladder cancer, reported in the European project about the "health impacts of long-term exposure to disinfection by-products in drinking water" (HiWATE) (13). Additionally, the specific risk posed by THMs may vary depending on their exposure route and the predominant compound fraction (14,15). For instance, brominated THM (BrTHM) is associated with reproductive health issues and bladder cancer (14,15). Global assessment of THM in Drinking water highlights the gap in a THM uniform regulation worldwide to ensure the safety and equal exposure to safe drinking water (16).

Lead was once a common component of various constructions, including pipes, faucets and fixtures, until its ban in 1995 (17,18). Consequently, controlling lead levels in drinking water is of significant concern for public health. While the 98/83/CE norm has reduced the limits of lead in drinking water to 10 µg/L, approximately 1.2 million pipeline branches still required replacement in France as of 2013 (17). To mitigate lead release into drinking water, water corrosivity is monitored and controlled by adjusting the calcium-carbonate balance (18). In adults, lead produces renal and cardiovascular pathologies representing the most concerning effect, whereas fatigue, muscular pain, and digestive symptoms are less specific (19). In infants, lead exposure causes significant cognitive and developmental impairments (19,20).

Other heavy metals present in drinking water, such as arsenic pose significant health risks to vulnerable populations. Studies conducted in Clermont-Ferrand, France, have linked exposure to arsenic with congenital anomalies and gestational diabetes (21,22). Manganese is another heavy metal of concern, with high doses potentially leading to neurological impairments affecting motor skills, as well as psychological or behavioral problems (23). In addition, Manganese faces challenges in establishing its water safety threshold levels due to limited studies, thus, its limits are based on food consumption.

Manganese and fluoride are essential for proper human body function in low doses. They play vital roles in numerous enzymatic and metabolic processes, including cellular stress oxidation, coenzyme function and bone formation (24,25). For instance, fluoride has been added to the general water distribution in many countries as a preventive measure against dental caries and a contributor to healthy bone metabolism (26). However, the implementation of fluoride as a public health measure remains a topic of debate, as high concentrations of fluoride could lead to neurotoxicity, disturbances in bone homeostasis, dental anomalies and kidney disease (25). In the context of emerging research, investigations into the impact of exposure to mixed pollutants such as lead and manganese, are revealing synergistic associations that contribute to neurodevelopmental issues and cardiovascular diseases (27-29).

While water is not the primary source of nitrates contaminants in human health (30), it particularly impacts infants. Increased levels of nitrates in water have the potential to induce the onset of methemoglobinemia, commonly referred to as "blue baby syndrome" and may contribute to neural tube effect in fetal development (30, 31). Additionally, its effect has been extensively reviewed concerning its risk of colorectal cancer and thyroid disease (30). Regarding its environmental cycle, nitrates in drinking water are mainly issued from agriculture and farming practices, which are also a significant cause of microbiological contaminants in water, a source of antibiotic resistance and a high-water footprint contributor (32).

Pesticides represent a significant group of agrochemical contaminants frequently detected in drinking water (33); therefore, it constitutes a public health concern. France, one of Europe´s leading pesticide importers from 1990 to 2020 (34), faces the ongoing challenge regarding potential pesticide leakage into water sources despite implementing policies for proper use. For instance, pesticides like atrazine have already been associated with adverse birth outcomes, including fetal growth restriction and urogenital malformation (35). Glyphosate, another concerning pesticide, has undergone two evaluations by the European Chemicals Agency (ECHA) due to its toxicity and suspected carcinogenic properties (36). The impact of these contaminants extends beyond occupational exposure, with rural communities facing an elevated risk of glyphosate exposure through groundwater (37,38). Additionally, S-metolachlor, an herbicidal compound, has been approved for withdrawal from the market following a negative evaluation due to groundwater contamination and subsequent pollution of drinking water sources (39).

Other contaminants, including plasticizers like PFAAs (per and poly-fluoroalkyl acids) and pharmaceutical compounds, also present risks to human health (33). Nevertheless, the effective detection and regulation of these substances still lack established methods (40). It is noteworthy that even bottled water, which is regulated separately from tap water, can potentially contain plasticizers depending on factors such as the source, processing method, and storage material (41). This raises concerns about the safety of bottled water as an alternative. Additionally, the production of bottled water is estimated to be 100 times more expensive than drinking tap water (42), exacerbating issues of inequity and emphasizing the importance of improving tap water quality.

Water surveillance aims to address potential risks and ensure water quality. For this purpose, water analyses must be conducted at legally mandated minimum frequencies (10). However, small water providers (in terms of people supplied and volume of water distributed) could perform less frequent sampling and analyses, leading to disparities in contaminant surveillance and potential spatial and temporal variations in drinking water quality. This discrepancy, often referred to as "low TMF" (technical, managerial, and financial capacity), highlights the challenges faced by small waterworks and private wells in delivering safe, high-quality drinking water (43). Other important external factors are seasonality, extreme weather conditions, and the distance between distribution pipelines and waterworks' size and capacity (44-46), which complexifies the water analysis, amplifying inherent variability. As a consequence, it represents a huge public health issue where policy institutions often struggle to effectively respond to pollution incidents, as evidenced by past examples such as the PFAAs contamination in Sweden (47-48) and the aluminum water pollution incident in Camelfort, United Kingdom (UK), leading to a mass poisoning events (49).

This global perspective highlights two fundamental problems: the quality of potable water and its impact on the population´s health. Consequently, it arises the question of the existence of an unequal distribution of health risks related to differential exposure.

1.2. Environmental justice concept

Environmental Justice (EJ) is a conceptual framework that aims to address the disproportionate burden of environmental pollution and degradation faced by vulnerable communities (50). It has evolved from conceptualization and acknowledgment to a more dynamic framework that accentuates how various factors coalesce to have adverse effects on specific communities, shifting away from assigning inherent attributes to these communities (51). It recognized that certain characteristics such as race/ethnicity/racialized population[1], income and education level are more vulnerable to environmental inequities (52,53). The origins of EJ have deep roots in African American communities and can be traced back to two significant historical events in the US. In the '70s, Dr. Luther King Jr. advocated for improved working conditions for Memphis garbage workers (51). In the '80s, the Bean v. Southwestern Waste Management lawsuit highlighted the siting of waste facilities near African American Communities in Texas (51).

EJ encompasses four dimensions, including epistemic justice, recognition justice, procedural justice, and distributive justice (55-57). Epistemic justice refers to the ability to lead a fulfilling life based on knowledge. This knowledge is valued differently based on an unequal balance of power due to social or economic characteristics which leads to recognitional justice (55,56,58). Constructed upon the notion of recognition, procedural justice allows communities to legitimately participate in local or national decision-making (55,56,59). Lastly, distributive justice relates to the uneven allocation of resources or pollutants, with examples including toxic waste disposal, the location of polluting industries, or socioeconomic differences in access to clean air, water, and greenspace that may affect health outcomes (43,60,61).

This dynamic framework seeks to destigmatize populations often linked to inherent attributes (52). It empowers communities to address their health needs through sustainable, environmentally-conscious solutions that transcend mere correction, catalyzing transformative shifts in perspective (62). In the context of drinking water pollutants, it can identify underlying drivers and establish collaborative structures addressing complex structural challenges of EJ in public health. Using a transdisciplinary approach, it focuses on integrative solutions and empowers all stakeholders, enhancing its effectiveness (50). These four justice dimensions form. a robust framework for transformative research, policy development and promote fairness and equity in environmental decision-making for public health.

This framework becomes particularly relevant when we consider the complexities of water pollution and its impact on public health, as it affects communities differently along an inequity gradient. Water pollution intersects with various economic or political conflicts, such as poverty, the agrarian or urban movement, feminism, indigenous rights, the working class and public health (52). It is a global challenge resulting from unsustainable production and lifestyles, which give rise to environmental and health externalities (52,53). For instance, Canada´s First Nation population has faced adverse environmental consequences from water-related economic activities such as dam constructions (55,56,63). In South America, the "environmentalism of the poor" movement emerged

[1] We are refering from here on as “racialized population” to emphasize its nature as a social construction of external categorization of individuals based on some observable characteristics such as skin color or country of origin in contrast to inherent attribute. This term is intended to highglight the historical and systemic processes of assigning individuals to social groups, which has implications for access to resources and opportunities and has a lack of equity perspective (54).

in response to the Amazon River contamination by the oil industry activities, a vital water source for indigenous communities (53). Arsenic contamination in water due to the textile industry has also been reported in India, and access to public drinking water sparked one of the largest political movements in Bolivia (64,65).

In Europe, the “environmental inequality” concept emerged in the 90s in the context of the European EJ movement in the UK by the association “Friends of the Earth” (56). European EJ movement brought forward two different spheres of EJ: the Ecological Debt, that the European Union (EU) has accumulated since the industrial revolution due to resource and waste disposals allocation towards the impoverished countries (55); and then, the difference within European communities such as the Roma communities, who have been denied equal opportunities in their environment, such as potable water, sewage or sanitation (57,66).

In France, the awareness of Environmental Justice (EJ) issues emerged in 2004 with the implementation of the Plan Urbanisme Construction Architecture (PUCA), closely aligned with sustainable development principles (56). The inequitable distribution of environmental risks is influenced by various factors, including historical patterns of industrial and urban growth, dynamics within the land market, the absence of robust social networks, and selective residential mobility (67). Consequently, marginalized communities often face what is known as the "double or triple jeopardy" phenomenon, experiencing compounded challenges and vulnerabilities arising from multiple sources of disadvantage and environmental injustice (68,69). Moreover, the level of urbanization significantly influences the dynamics of the studied populations. In France, rural areas are characterized by more homogeneous populations, indicating higher social cohesion and uniformity (70,71), while urban areas, with their dense concentration of population and infrastructure, show greater socioeconomic variation within their population (70,71). Recognizing this distinction is pivotal when conducting territorial analyses and understanding the complexities of EJ in water contaminants exposure. To effectively address EJ, it is essential to recognize that distribution conflicts lie at the heart of the global movement.

1.3. Measuring inequality: assessing environmental justice

To expose EJ issues in drinking water contaminants exposure worldwide, inequality has been assessed through various lenses including racialized categorization, income, home ownership, small rural area, employment or socioeconomic status (69, 72, 73). In addition, the likelihood of identifying significant associations with EJ factors strongly depends on the unit of analysis and spatial distribution (74). Employing smaller area units within a larger context increases the likelihood of revealing significant relationships while capturing variations with reduced variance. This approach avoids assumptions about variable stationarity over distance, which is the assumption of the statistical properties of a variable, such as mean and variance, that remain constant as one moves across space (74). Shrinking the spatial scale may increase variance due to underlying variation

being masked by larger scales, and conversely, scaling down and increasing areal units can reduce variance leading to closely grouped observations around the mean.
In Europe and particularly in France, deprivation is measured heterogeneously depending on the study´s objective. Some studies use a single indicator such as salary or preceptor of the universal health coverage (69,75,76). Others employ a composite index like the Townsend index, which incorporates the following dimensions: car ownership, dwelling ownership, overcrowding and unemployment rate (69,75,77). See a summary of the most relevant index in ANNEX. Table I.
In France, there are different standardized validated indexes for measuring deprivation (75,78). The European Deprivation Index (EDI) and the French Deprivation Index (FDep) are specially designed for the whole French territory and both are available at the IRIS scale (Ilôts de regroupement d´information statistique) (79), the smallest aggregated units for statistical information, which is composed approximately by 2.000 habitants by area.

The European Deprivation Index (EDI) was created in 2007 to provide a unified measurement that allows comparisons between countries. Currently validated in England, North Ireland, France, Spain, Portugal (75,80,81) and Slovenia (ANNEX. Table II) (82). It is composed of weighted variables of material, social and residential dimensions coming from census data, which provides population-level indicators; merged with the European Union Statistics on Income and Living Conditions (EU-SILC survey) which provides individual indicators of deprivation. Still, it presents its challenges, as the variables are not uniform across countries within Europe (75,81). What is more, this index seems to be a good proxy for individual observations and that is why, almost all of the health research publications are based on the EDI (75,83). In addition, some indicators may not accurately reflect levels of deprivation; for instance, the contrast in owning a car between urban and rural area are not comparable. In cities with good public transport networks, cars might not be an essential element (also applicable for other deprivation indexes such as Townsend or Carstain). Another subjective notion is the definition of “monoparental family” and the burden it represents between households (77,84). The most recent update of French EDI is based on the survey EU-SILC 2017 with the 2019 IRIS geography limits (85).
The French Deprivation Index (FDep), used since 1999 in France, offers a comprehensive assessment of neighborhood deprivation (86) and it encompasses indicators for employment, income, occupation and education level. Calculated at the municipal and IRIS scale, its last update was made from the census of 2015 and geographic IRIS limits of 2017 (87). It has been used in prior environmental studies, proving its robustness, reliability and suitability. For instance, in a French geographic ecological study, which explored the connexion between bladder cancer and exposure to trihalomethane (THM), FDep was employed to measure socioeconomic (SES) status as a confounding variable (75,88).

For identifying disparities in exposure to drinking water contaminants, researchers have also examined the concentration or frequency of violation of water quality standards or the level of law enforcement mostly in the United States (US) and Canada. The most relevant drinking water pollutants studied were related to nitrates (89,90), arsenic (91-93), lead (94), or THM (95) exposure in indigenous communities, poorly served areas and rural regions in the context of preexisting conditions as geographic or water source characteristics (89,91). However, few studies on EJ related to DWC in Europe were conducted (96) and no comprehensive assessment of these studies was conducted.

Disparities in the accessibility and quality of drinking water are influenced by various factors, converging natural, sociopolitical, and historical elements (38,89,90). For instance, the association between arsenic contamination in drinking water and EJ dynamics has a contextual variability, with the association shifting from positive to none depending on the specific EJ considerations and geographical context. Therefore, each scenario needs a personalized evaluation. In California, high arsenic levels in drinking water have raised EJ concerns, as evidenced by the presence of compliance and higher levels of arsenic concentrations in more socioeconomically disadvantaged communities (97). In contrast, the situation in Arizona presents an absence of EJ implications related to law enforcement of arsenic exposure (92).

The Drinking Water Disparities Framework emphasizes that racialized communities and class do not have a direct causal association with uneven exposure to contaminants. They are intertwined with a multilevel and composite burden influenced by environmental factors (such as built environment characteristics and nearby industries), natural factors (hydrogeology and climate), and sociopolitical context (urbanism and planning policies including the Technical, Managerial, and Financial (TMF) capacity) (43). In many cases, the coping strategies implemented in vulnerable communities and policies are short-term and partial solutions (e.g., reliance on bottled water or point-of-use filters) that fail to address the underlying uneven exposure (43).

1.4. Drinking water quality and management in France

The Water Framework Directive (WFD) primarily regulates water bodies in France, aiming to protect sustainably the use of rivers, lakes, groundwater, and coastal water (98). However, source water quality has been degraded by agriculture, domestic and industrial activities leading to the abandoning of some catchments due to high concentrations of nitrates and microbiological issues (99). Groundwater constitutes about 70% of the total collected water supplies for human consumption in France (100). In the department of Ille et Vilaine (IEV), France, surface water serves as the main drinking water source, accounting for 75% of its total water supply (33). This surface water source is particularly susceptible to both point and diffuse pollution. The quality of drinking water is of paramount importance, with 66% of the population relying on tap water in 2017 (42).

The microbiological properties of the drinking water in IEV consistently meet the standards, ensuring that 98,5% of the population consumes microbiologically safe water (100). Another secondary parameter to assess the organic content in drinking water is the level of THM, as higher THM formation indicates lower-quality water. In 2021, only 0,2% of the population in the region was temporarily exposed to concentrations above the threshold limits (100). While nitrate concentrations did not exceed the threshold limit of >50mg/l in 2021 (100), concerns remain as the classification of the water quality is based on the WFD. It classifies IEV in 2021 as "medium quality", between [10-25mg/l] levels, highlighting the distinction between safe and high-quality water (101).

In IEV, the prevalence of nitrates, pesticides and various pharmacological compounds is a significant challenge, primarily due to the region´s predominant agriculture and farming activities (39,101). Since April 2021, pesticide regulations have expanded to include metabolites, resulting in the monitoring of a broader spectrum of molecules in water (100). Atrazine, as a banned pesticide, remains still detectable in urine samples in the PELAGIE cohort in Brittany (77), underscoring the need for monitoring. Additionally, emerging contaminants have been identified, including plasticizers from pre-1980 PVC and pharmaceutical compounds of veterinary and human origin (33).

Furthermore, the region´s industrial activities account for 35% of water usage and it contributes to potential water source pollution (102). For instance, arsenic, naturally occurring in drinking water due to sediments, can also be found in industrial effluents. This is particularly notable in industries like leather production and the manufacturing of fungicides for vineyards and orchards, both of which are present in the region (103,104).

The challenges regarding drinking water quality and management in France, particularly in IEV, highlight that while regulatory standards are met, ensuring high-quality drinking water remains a public health concern. This raises concerns about EJ issues related to water contaminants and their potential to exacerbate social and environmental inequalities. Addressing these challenges requires a comprehensive review of current knowledge.

2. Aim and Rationale

This thesis aims to investigate the extent of EJ issues related to exposure to drinking water contaminants in Europe. It will explore the types of drinking water contaminants that have been studied concerning EJ in Europe, the designs used to study the link between EJ and drinking water in Europe, and the drivers that could explain inequalities in exposure to the specific contaminants.
In a subsequent step, the aim is to determine whether EJ issues, measured by deprivation index FDep15, are present in drinking water contaminants in IEV, France. This analysis will test whether the contaminants from the ScR are applicable in this context, to offer a local perspective on the existence of disparities in drinking water related to EJ issues.

3. Methods

This scientific analysis includes two steps, firstly the scoping review and secondly, an ecological case study based on the drinking water contaminants results of the scoping review.

3.1. Scoping review

The research was conducted in a scoping review (ScR) study format as it is a broad question to be mapped in a systematic synthesis of the scientific literature identifying "the main concepts, theories, sources and knowledge gaps" (105). It followed the PRISMA-ScR guidelines and reported checklist methods (ANNEX. Table III) (106) and the Joanna Briggs Institute guidance document for ScR (107).

3.1.1. Eligibility criteria

The framework applied was Population-Concept-Context (PCC), as recommended in PRISMA_ScR guidelines (106). None specific population was referred so it was not applicable in our study context.

3.1.1.1. Concept

The main concepts are drinking water, drinking water contaminants, environmental justice and geographic Europe. For this purpose, drinking water is considered globally since its source, treatment, storage, quality indicators and regulation violation. For contaminants of drinking water, we included in the wording along with generic terms such as « contaminants », some priority contaminants for public health such as microbiological contaminants, nitrates, THM, some pesticides and heavy metal. For the environmental justice, the two of the four dimensions of justice of J. Rawls (55,56) were taken into account to delimit EJ which are procedural and distributive justice. (ANNEX Table IV).

3.1.1.2. Context

Environmental justice is a relatively recent concept that emerged in the 90s in Europe. As the review is focused on the European region, the period covered was from 1990 to 2022.

3.1.1.3. Selection criteria

The following inclusion exclusion criteria were used to select the articles:

Table I: Inclusion and exclusion criteria

Items	Inclusion	Exclusion
Type of publication	Quantitative approach of observational studies: cohort, cross-sectional, ecological, case study, community- based study Qualitative: phenomenological, case study, grounded theory ethnographical, historical or narrative Books and chapiter	Letters, newspaper or other special articles (Editorials, commentaries, …) review articles, systematic review, meta-analyses Reports Grey literature: Thesis, Dissertations and official documents
Year of publication	From 1990 to 2022 (included)	Before 1990 or from 2023
Geographic location	Europe (including Eastern Europe, Alpine region, the Mediterranean region, Scandinavia and Nordic countries and Western Russia)	Countries outside European continent
Population of interest	Individuals, household, communities	Studies focused on non-human animals and their environment
Language	English, French, Spanish	Other than the 3 languages mentioned before

Research area specifics	Studies target both issues: treated or untreated drinking water quality for human consumption and its contaminants related to environmental justice in all its form: distributional, procedural, recognitional and epistemic. Studies link tap drinking water and its supply services with inequalities or inequities of access or alteration of its quality due to at least one of the several aspects of environmental justice. Studies that treat one or several specific contaminants related to water quality (nitrate, bacteria, heavy metals…) in drinking water are linked with environmental justice. Challenges related to water quality or their management, lead to inequities in potable water distribution.	Engineering processes of water systems-based only (e.g., design and/or construction of water treatment plant and/or distribution systems). Contamination of water not intended for human consumption. Studies not linking drinking water with environmental justice concepts. Politics and governance including engagement about drinking water or environmental justice but not both. Environmental justice issues related to other types of environmental contamination (air soil) than drinking water.

3.1.2. Information sources

The authors (Delpla and Chen) conducted a preliminary search on PubMed and Scopus between the 30th of January and the 15th of February, 2023, to gain an understanding and refine the search terms of the topic and determine the necessary keywords. After an agreement between the two authors on the final search strategy, the search was conducted on PubMed, Ovid-Embase, Web of Science and Scopus between the 28th of February and the 8th of March 2023. An example of the wording and query construction is specified in the ANNEX. Table V.

3.1.3. Data extraction and analysis plan

Information was extracted to answer the objective of the scoping review agreed upon by the two reviewers through discussion and consensus through a standardized three-step screening procedure. Initially, duplicate articles were removed using Zotero software. Subsequently, articles were screened by title/abstract to apply exclusion criteria. The final step involved skimming the entire article to select studies meeting inclusion criteria. A reference list check was conducted for additional studies before data analysis. Quality assessment of the selected articles is not required for ScR (106), consequently, it was not conducted.

The collected data was structured to include Title, first author, publication year, contaminant type and measurement method, type of injustice and its measurement. A narrative synthesis approach was then employed to organize and summarize the extracted data. This approach helped to create a thematic framework identifying key themes, patterns and gaps in the literature.

3.2. Case Study

To test the hypothesis, an ecological case study was conducted in the IEV department, in France. In 2019, IEV had a population of 1.079.498 inhabitants and covered an area of 6.774.7 km². (108). Unlike the prevailing water source in the rest of the country, IEV predominantly relies on surface water, constituting around 75% of its total water supply (100). This setting was specifically chosen as surface water is generally more susceptible to contamination from anthropogenic activities (agriculture, industries, wastewaters…) and climate events such as rainfalls and droughts than groundwaters (7,44).

This study used the French Deprivation Index 2015 (FDep 2015) as a comprehensive measure of socioeconomic status (SES). The index integrates four key indicators: the unemployment rate, the proportion of blue-collar workers, the proportion of high school graduates > 15 years and the median household income (84). FDep15, established by CépiDc (Center for Epidemiology of Medical Causes of Death) of INSERM (National Institute of Health and Medical Studies), is based on population data from the 2015 census (86), which is published annually and covers 5 years (109). The geographic areas to construct the FDep 2015 used the cartographic information and limits from the municipality's geography of 2017. The index was calculated at both municipality and IRIS scales (105). An IRIS includes an area of 2000 individuals with relatively homogeneous social characteristics (79) and it was chosen as the geographic unit for our study. As previous literature analyzed deprivation by a unique indicator, we incorporated an external analysis of the level of education of FDep15 by itself, with N=528 observations (110).

The FDep 2015 reunites 345 municipalities and 526 IRIS in IEV. The index was divided into quartiles, categorizing Q1 as less deprived areas and Q4 as the most deprived areas.

Regarding IRIS categorization into different urban development zones, due to the limited study area, the approach was to regroup them into three main areas: urban, periurban and rural. Urban areas had over 50.000 inhabitants, periurban are influenced by an urban area and the rural area are out of the influence of a city or an area of less than 50.000 inhabitants.

This dataset comes from the INSEE (National Institute of Statistics and Economic Studies) of the 2017 census, published in 2020 after redefining French territory, aiming to break with the dichotomic conception of rural versus urban areas (69,70).

3.2.1. Water quality data

Water analysis data was extracted from the database of the Laboratory of Research and Studies in Environment and Health (LERES), which is the responsible organism for drinking water regulatory monitoring. It englobes sampling and analysis in IEV department (111). The database includes a set of chemical parameters tested from 2015 to 2023, following a prior request to the sanitary authority (ARS). The period of study was selected to match the FDep data collection period. The final database covered the period 2016 to 2020, after evaluating the missing data and the inaccurate locations and considering annual monitoring site changes after 2020.

Contaminants were measured according to the established normative limits as the initial value and then, they were divided and aligned with the regulation limits and quality recommendations as shown in ANNEX. Table VI. A total of 654 stable geolocation points representing distinct geographic surveillance points (PSV) were selected from the drinking water surveillance dataset. These points were matched with geographic IRIS areas, obtaining 430 geographic areas where 81.7% of IRIS has included a surveillance point for drinking water quality analysis (PSV) (ANNEX. Figure I).

The dataset encompasses two types of PSV: production points and distribution points. Production PSV corresponds to sampling points located in the water treatment plant or water towers, controlling the water after treatment. Whereas the distribution PSV points are providing information about the water quality for population consumption, these points are located mainly in public buildings (town halls, schools…).

The study selected specific contaminants, including nitrate, lead, THM4 (chloroform and brominated THMs) from distribution points; and arsenic, fluoride, and manganese from production points. Production point data helps estimate contaminants not analyzed at distribution PSV. Median levels from production PSVs were linked to distribution points using the management unit code (UGE), approximating the final water quality for these pollutants.

To ensure data accuracy, observations from different geographic locations registered as the same PSVs were excluded. Each contaminant had a systematic analysis considering factors such as the proportion of limits of detection (LOD), the consistency of data across the studied years and the distribution skewness of the variable. Median values were used to group pollutants by each PSV and then by IRIS; ensuring each IRIS has a median derived from different PSV points. Additionally, it is worth noting that the LOD/2 equation was applied to handle LOD.

3.2.2. Database construction

In summary, the following datasets were merged:

- Water contaminants database (N=13.209 samples) collected from the LERES with respective geolocation performed by our team. It included the following contaminants: arsenic, fluoride, manganese, lead, nitrate, THM4 and the brominated THMs (BrTHM).
- FDep15 of IEV (N=526) representing the deprivation index or the SES, sourced from the INSERM, and the proportion of high school graduates > 15 years (N=528).
- The geographic division coordinates of IRIS 2017 (N=528) were obtained from the statal Géoservice.

3.2.3. Descriptive statistics

The final database encompasses 430 IRIS areas and a total of 11.761 water samples (Table II).

Table II: Water chemical contaminants database

		Total	Lead	Nitrate	THM4	BrTHM	Manganese	Fluoride	Arsenic
	IRIS (N)	430	381	425	376	369	269	255	267
	PSV (N)	654	502	592	497	484	347	329	344
Observations (N)	Total	11761	1583	10923	1505	1542	1303	423	421
	Production	1483	42	1401	449	469	1265	423	421
	Distribution	10278	1541	9522	1056	1005	38	-	-

3.2.4. Database analysis

Spatial analysis was conducted using Quantum Geographic Information System (QGIS) software version 3.22 to merge the data of the IRIS area with the PSV point and to do a database validation. Geographically, Lambert conic projection using French Geodetic Network (RGF93) was applied to the data as it is the one used for Metropolitan France.

Given the non-normal distribution of contaminants, we used Spearman´s rank correlation coefficient for assessing potential linear association, determining correlation strength and direction. The

analysis was performed using R Studio version 4.2.2 to explore the association between the FDep 2015 index, the urbanization degree and the variable of study levels in population with each water contaminant. The correlation coefficients underwent statistical significance testing, meaning $p < 0.05$. For visualization and enhanced analysis, we designed stacked bar charts for each contaminant. Initially, we grouped pollutants based on the number of IRIS within each FDep15 quartile and then extended the analysis to include population subdivisions by urban development degree.
As previously mentioned, to categorize contaminant levels, we researched the regulatory limits as well as established toxicological benchmarks such as the no observed adverse effect level (NOAEL) or lowest observed adverse effect level (LOAEL) from the literature (ANNEX. Table VI).

3.2.5. Sensitivity analysis

To analyze the robustness of our study´s findings, a sensitivity analysis was assessed, examining the impact of various methodological choices on our results.
The stratification by IRIS instead of the original PSV resulted in the loss of some granular information, but it allowed us to compare both data in the same geographic unit. Despite the merging of two sources of data, over 80% of the PSV data was retained within the IRIS.

The measurement of pollutants from production PSV introduces considerable variability when merging data by UGE codes. This is due to the presence of multiple waterworks within each UGE, and their output water may or may not be mixed in the distribution network. As a result, certain final water points may have lower levels of these contaminants, which we are not currently accounting for in our analysis. However, it is important to note that we did not have access to that type of data at the time of the study.

3.2.6. Ethical Considerations

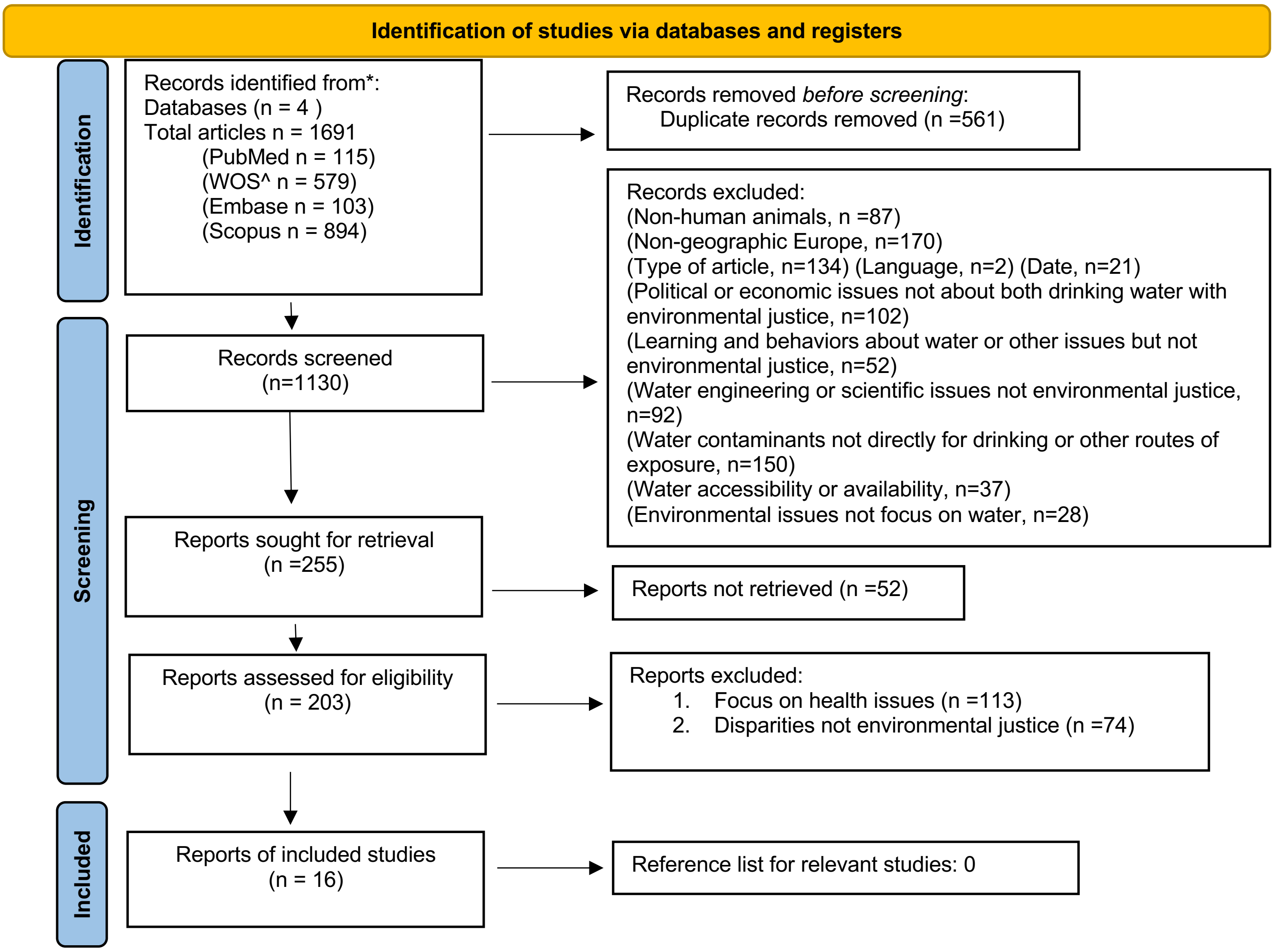
For this study, ethical approval was obtained from the Agence Régionale de Santé (ARS) due to the sensitive nature of the data, which contains geolocalized information about water quality at the household level. To protect privacy and confidentiality, sensitive data was removed for the analysis.

4. Results

4.1. Scoping review

Based on the four chosen research engines, 1.691 articles were initially identified. After removing duplicates, applying exclusion criteria resulted in 203 studies to screen whether they met the inclusion criteria. Finally, 16 articles were included in the analysis. No additional articles were found in the reference lists of the selected articles.

Table III: Adapted from: PRISMA 2020 flow diagram for new systematic reviews (112, 113)



^WOS= Web of Science

Figure I: Number of articles by country from our ScR which as EJ issues related to drinking water contaminants

Table IV: Articles included in the scoping review

Title	First Author, Year	City, country	Study design	Water Sample (N)	Type of pollutant	Population (N)	Social stratification related to EJ	Type of EJ
Anthropogenic gadolinium as a microcontaminant in tap water used as drinking water in urban areas and megacities (114)	Kulaksiz, S. 2011	Berlin, Germany	Cross-Sectional Ecological	Tap water samples (N=23)	Gadolinium	East and West Berlin before reunification in 1990 (N=2)	Geohistorical division of Easter and Western Berlin before reunification in 1990	Distributive
Blood lead levels and risk factors in young children in France, 2008-2009 (76)	Etchevers, A. 2014	France	Cross-Sectional Ecological	Presence of lead branch pipelines (N=3831)	Lead	French children 6 months to 6 years (N=3.831)	Complementary French free health insurance Age of dwelling pipeline	Distributive
Does area deprivation modify the association between exposure to a nitrate and low-dose atrazine metabolite mixture in drinking water and small for gestational age? A historic cohort study (77)	Limousi, F. 2014	Deux-Sèvres, France	Historic cohort	Community water systems withdrawals (N=10784)	Atrazine metabolites Nitrate	Coupled woman-neonate (N=10.784)	Townsend Index regrouped by IRIS	Distributive
Environmental inequity in England: Small area associations between socio-economic status and environmental pollution (115)	Briggs, D. 2008	England, United Kindom	Analytical Ecological Cross-Sectional	Mean samples of water zone[2]: N=11,2; 6,3 and 4,5 respectively per year	4THM[3]	SOAs[4] (N=32.482) Ward and district scale	IMD 2004 (Index of Multiple Deprivation)	Distributive
Fluoride intake through consumption of water from municipal network in the INMA-Gipuzkoa cohort (116)	Jiménez-Zabala, A. 2018	Gipuzkoa, Spain	Prospective Cohort	Before and after, mean concentration of 4 years (N=328 and N=366)	Fluoride	Pregnant women (N=431) and children (N=372)	Water suppliers for more than 30.000 inhabitants	Procedural Distributive
Influence of contaminated drinking water on perfluoroalkyl acid levels in human serum - A case study from Uppsala, Sweden (48)	Gyllenhammar, I. 2015	Uppsala, Sweden	Case study	Ground water (N=172), well water (N=10), drinking water (N=30)	PFAAs (PFBS and PFHxS)[5]	Serum level in women (N=297)	Geographic	Distributive
Private wells as potential sources of heavy metal exposure: a pilot study in northwest Slovakia (117)	Sovicova, M. 2021	Korňa, Raková and Zákopčie; Slovakia	Cross sectional ecological	Water samples from private wells (N=69)	Chromium Cadmium Copper Manganese Lead	Private well owners (N=69)	Private well stewardship	Epistemic Procedural Distributive
Regional disparities of microbiological drinking water quality: assessment of spatial pattern and potential sociodemographic determinants (118)	Karthe, D. 2017	Germany	Cross sectional ecological	Noncompliance of microbiological standards (N=5471)	Microbiological contaminants	Water Supply Zone (WSZ) (N=2.416)	Degrowing populations areas	Distributive
Relation of trihalomethane concentrations in public water supplies to stillbirth and birth weight in three water regions in England (119)	Toledano, M.B. 2005	Great Britain, United Kindom	Retrospective ecological	Mean samples of water zone: N=11,2; 6,3 and 4,5 respectively per year	4THM	Newborns of three water region (N=975.304)	Carstain Index by SAHSU [6]	Distributive
Socioeconomic status and exposure to disinfection by-products in drinking water in Spain (95)	Castaño-Vinyals G. 2011	[7]Spain	Cross sectional ecological	Tap water samples (N=113)	4THM	Control patients from another study(N=1.271)	Education level Household income	Distributive

[2] United Utilities Water, Severn Trent Water and Northumbrian Water
[3] 4THM: Trihalomethanes summary of bromodichloromethane, chlorodibromomethane, tribromomethane (bromoform) and trichloromthane (chloroform)
4 SOAs: (super output areas, average of 150 people)
5 PFAAs: Perfluoroalkyl acids; PFBS: perfluorobutane sulfonic acid PFHxS: perfluorohexane sulfonic acid
6 SAHSU: Small Area Health Statistic Unit, 400 people
7 Barcelona, Vallès/Bages, Alicante, Tenerife and Asturias

Socioeconomic status and exposure to multiple environmental pollutants during pregnancy: evidence for environmental inequity? (120)	Vrijheld, M 2012	Gipuzkoa, Sabadell, Valencia; Spain	Prospective Cohort	Tap water (N=753)	4THM	INMA cohort (N=2.081)	Mother: Education level Country of birth Occupation classified by Spanish Epidemiological Society (SCI)	Distributive
Spatial and seasonal variability of urinary trihalomethanes concentrations in urban settings (121)	Andrianou, X.D. 2014	Cyprus	Cross-sectional	Urinary THM concentration in two seasons (N=310)	4THM, TCM, BDCM[8]	Two district metered areas (DMA) clusters from the same water plant (N=310)	Historical spatial pipelines network distribution	Distributive
The effect of water fluoridation and social inequalities a dental caries in 5-year-old children (122)	Riley, J.C. 1999	UK[i9]	Ecological descriptive cross-sectional	Pair of fluoridated and non-fluoridated districts (N =14)	Fluoride	5 years old children (N=41.879)	Townsend Index	Distributive
Trihalomethane and haloacetic acid concentrations in drinking water and their estimated intake during pregnancy in the INMA cohort (Guipúzcoa, Spain) (123)	Santa Marina, L. 2010	Gipuzkoa, Spain	Prospective Cohort	Before and after treatment water samples (N=33)	4THM HAA[10]	INMA cohort (N=590)	Geographic	Distributive
Trihalomethane concentrations in tap water as determinant of bottled water use in the city of Barcelona (124)	Font-Ribera, L. 2017	Sabadell, Spain	Cross sectional	Point of distribution water (N=16) Bottled water (N=15)	4THM	School children 9-12 years (N=2.037)	Parental education	Epistemic Distributive
Water fluoridation, dentition status and bone health of older people in Ireland (125)	O'Sullivan, V. 2015	Ireland	Cross sectional ecological	Proportion of household in electoral distric with fluoridated water (N > 3.500)	Fluoride	(TILDA) The Irish Longitudinal Study on Ageing (N=4.977)	Urbanization degree	Procedural Distributive

Table V: Summary of number of studies by contaminants and by type of EJ

Type of contaminant	Number of articles	Type of EJ	Number of articles
DBP[11]	7	Distributive	16
Fluoride	3	Procedural	3
Microbiological contaminants	1	Epistemic	2
Nitrate	1	Recognition	-
Pesticides (Atrazine)	1		
Plastizised (PFAAs)	1		
Heavy metals: Lead, copper, manganese, cadmium, chromium	2		
Medical diagnostic compound (Gadolinium)	1		

[8] BDCM: Bromodichloromethane

[9] Solihull, Bromsgrove, Redditch, W. & E Brimingham, N. Warwickshire, Sandwell, Shropshire, Chester, Liverpool, Trafford, Warrington, Sheffield, St Helens, Knowsley.

[10] HAA: Halo acetic acids,

[11] DBP: Disinfection by products either 4THM or HAA

4.1.1. Type of relation between EJ and drinking water contaminants

The majority of studies can be categorized under distributive justice (121-123), and they are geographically diverse across Europe (Figure I). These studies cover a wide range of chemical and microbiological contaminants, including disinfection byproducts (such as trihalomethanes and halo acetic acids) (115,119,120), fluoride (116,122,125), nitrate (77), atrazine (77), perfluoroalkyl acids (PFAAs) (48), heavy metals (117) and gadolinium (as a medical diagnostic compound) (114).

In the context of distributive justice, several determinants were used to assess unequal exposures. These include measures of deprivation or socioeconomic class, assessed through composite indices such as Townsend (77,122), Carstain (119), or IMD 2004 (115), as well as individual indicators like education level (95,120,124), household income (95), birth country (120), occupation (120), or eligibility for universal healthcare coverage (such as CMU in France) (76). Other determinants that increase exposure risks include residing in areas with declining populations (118), being located downstream of a contaminant source (48), or being affected by geohistorical and spatial divisions that influence water sources and network types (76,114,116).

Three articles also address procedural justice, which creates distributive injustice and uneven exposure too. In the Spanish Basque Country, a decree mandated the compulsory fluoridation of water suppliers serving more than 30,000 inhabitants (116). Similarly, in less urbanized and rural areas of Ireland, private suppliers contribute to fluoridation-related disparities (122).

Epistemic injustice, for instance, is reflected in disparities in education levels, which can influence the intake of trihalomethanes (THMs) based on whether individuals consume tap or bottled water (124). Another study emphasizes the importance of knowledge and awareness of water surveillance and analysis to reduce heavy metal concentrations, such as chromium, cadmium, copper, manganese, or lead, in drinking water (117).

4.1.2. Types of water contaminants involved

The majority of the studies focused on disinfection by-products (DBPs), particularly THMs (119-121), Table V. Their increasing levels indicate the high level of organic material in the distribution network. Unlike other contaminants that could remain stable or degrade over time, THMs can potentially increase in concentration in the distribution system, as they can continue to be formed as long as there remain free chlorine residual in the network, particularly when water is at high temperatures and contains residual organic matter (95,125). Investigations into THMs indicate that the relationship between these contaminants and environmental exposure through drinking water may be more complex as stated in the Drinking Water Disparities Framework (43).

Water fluoridation emerged as a controversial topic, with regulations dependent on each country's policy. For example, the study conducted in Spain demonstrated differential exposure to fluoridated drinking water based on the population size of a municipality, as compulsory fluoridation was enforced selectively (116). Another study revealed a direct ecological relationship between deprivation, measured by the Townsend Index, and the benefits of water fluoridation (122). Additionally, a study highlighted the historical benefits of being connected through a public network where fluoridation was compulsory, which explains the contrast with the patchy fluoridation practices in rural areas of Ireland non-connected to this network (125). Currently, French policy does not mandate the fluoridation of water for human consumption. Instead, fluoridation is promoted through the fluoridation of table salt (126).

Heavy metals in water such as lead, have been associated with lead line connections (76), which has been banned in 1995 (17,18). Another study has acknowledged mainly the excess of manganese and lead in small private wells in rural areas, validating low TMF capacities in small waterworks, as financial cost, as the main reason that discourages regular private well stewardship (117).

The combined effect of nitrates and atrazine exposure is studied in pregnant women focusing on small gestational age outcomes from a district in France characterized by high agricultural activity (77). The correlation between nitrate exposure does not appear to follow a linear pattern. This observation suggests the presence of competing risk factors, particularly in more deprived districts, which are known to experience "social stress", interacts with other factors creating a complex interplay of risks; whereas in the most advantaged population, not been exposed to other factors seems made them more vulnerable to the exposure of this single pollutant (77). In such multidimensional contexts, the composite Townsend index alone may not fully capture the complexity of the environment and its influence on health outcomes. In this specific case, socioeconomic factors seem to act not merely as confounding factors but rather as effect modifier factors (77).

Microbiological contamination (Clostridium perfringens and Escherichia coli in this case) in drinking water seems to be also related to the previous low TMF capacity, in this case, due to the reduced water flow in distribution systems due to low quantity of users and also the reduced investment due to the low economic power of the demographic shrinkage area in Germany (118).

In the context of exposure to Perfluoroalkyl substances (PFAAs), they have been detected in aquifers near a military airport in Uppsala, Sweden, leading to their dissemination over the surrounding area through water flow (48). The cumulation of PFAAs along the water flow is not equally distributed, resulting in inequitable exposure levels among different populations.

Finally, Berlin had a historical division that made it possible in West Berlin to mix groundwater with surface water by bank filtration. This process, made possible higher concentrations of Gadolinium contrast in the West area of Berlin, affecting unequally population sitting in this area (114).

4.1.3. Types of studies and population involved

The scoping review mainly includes ecological studies designs (117-119), which allow for data aggregation at the group or population level, aligning with the primary objective of investigating drinking water contaminants and their association with EJ. While some studies primarily aimed at biomonitoring or water source analysis, they also explored, to a lesser extent, the relationship between EJ and drinking water contaminants.

The review includes a diverse range of populations, including large environmental cohorts like INMA or TILDA (N=590 and N=4977, respectively) (120,125). The studies are categorized based on various geospatial divisions, such as Super Output Areas (SOAs with an average of 125 households or 300 people) (115), District Metering Areas (DMA, a section of the water distribution network) (121), and Small Area Health Statistic Unit (SAHSU, which includes approximately 400 people) (119). Special attention is given to vulnerable populations, particularly pregnant women and children (76,77,117), to comprehensively assess the implications of drinking water contaminants on environmental justice.

4.2. Case Study

In this ecological case study, we conducted a comprehensive assessment of chemical drinking water contaminants and their potential implications for environmental justice in the IEV department, France for the period 2016 to 2020.

Table VI: Summary of descriptive statistical analysis of each pollutant

Drinking water quality	Lead (µg/L)	Nitrate (mg/L NO3)	4THM[12] (µg/L)	BrTHM[13] (µg/L)	Manganese (µg/L)	Fluoride (mg/L)	Arsenic (µg/L)
Median	0.5[14]	17.4	39.1	32.6	2.5[7]	0.1	0.1[7]
Percentiles 25-75	0.5-0.5	10-24.6	27.7-51.1	23.9-43.5	2.5-2.5	0.08-0.10	0.1-0.3
Percentiles 5-95	0.5-2.2	3.1-37.2	9.15-73.6	8.7-64.5	2.5-25	0.03-0.18	0.1-0.4
LOD[15]	<1	<0.5	<0.2	<0.5	<5	<0.02	<0.2
N values <LOD (%)	1254 (87,9%)	141 (1,5%)	3 (0.3%)	73 (6.8%)	1016 (80.3%)	11 (2.6%)	258 (61.3%)

4.2.1. Descriptive analysis of data

The database included 11.761 water samples distributed in 654 different PSV points in 430 IRIS areas, focusing on six different chemical drinking water contaminants, Table II.

When comparing the results of each contaminant data with the reference value in their 95 percentiles, none of the pollutants reaches the maximum safety regulation values, Table VI. In addition, concentrations lower than the levels of detection are commonly found for the three heavy

[12] 4THM: bromodichloromethane, chlorodibromomethane, tribromomethane (bromoform) and trichloromthane (chloroform)

[13] BrTHM: sum of brominated THM

[14] Values under the limit of detection, used the LOD/2 equation

[15] LOD: Limit of detection.

metals (lead, manganese and arsenic), for which policy “as low as reasonably achievable” levels are recommended to ensure safe water quality (127).

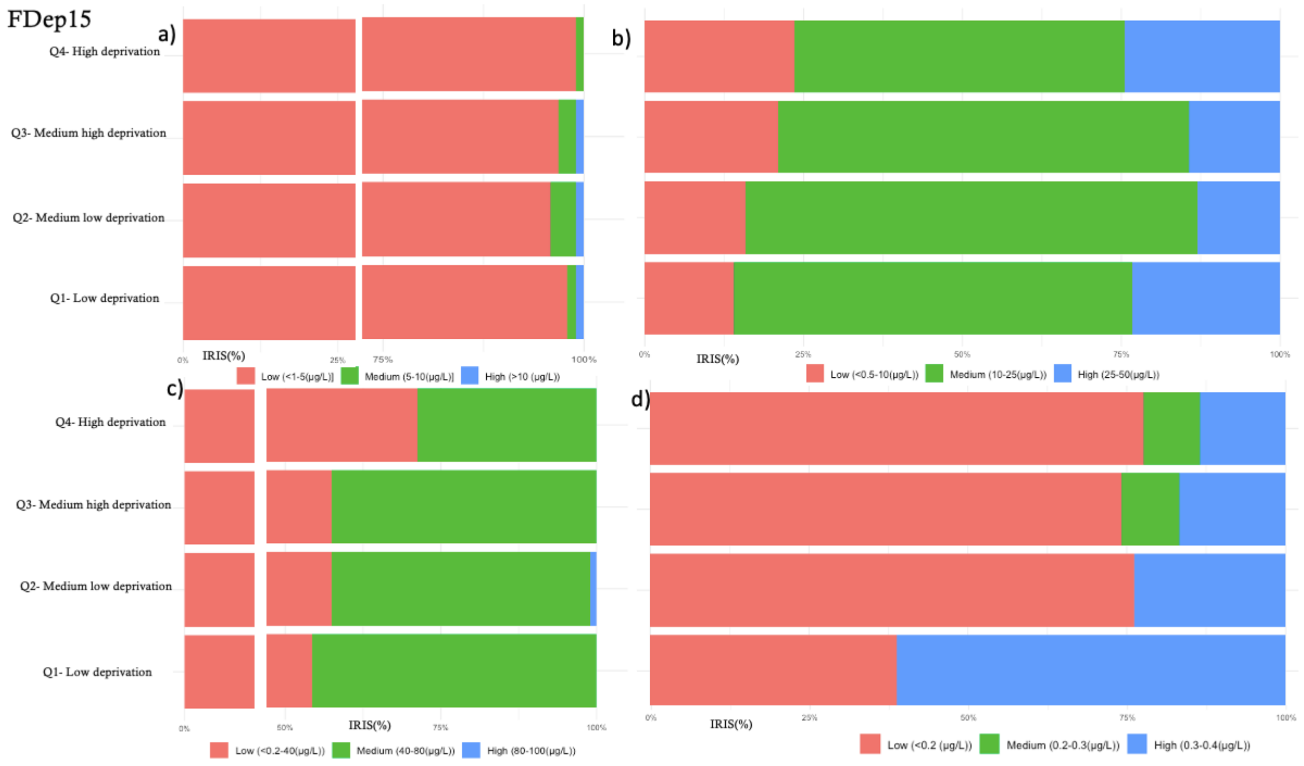


Figure II: Contaminants (a) Lead (b) Nitrate (c) 4THM (d) Arsenic by IRIS

Graphical representation of contaminant distribution reveals their patterns. All contaminants display a low deprivation high concentration of contaminants except nitrate (b) which seems to be more an inverse U-shape. Other contaminants are in ANNEX. Figure II.

4.2.2. Correlation analysis

Correlation analysis was conducted to have a better understanding of the relation between chemical drinking water contaminants with FDep15, acknowledging the direction and the strength of the pattern, results are presented in Table VII.

Overall, each contaminant shows a significant linear correlation with both FDep15 and the level of education. Comparing FDep15 and education level, it becomes evident that they are inversely related, as higher levels of education are associated with lower levels of deprivation (FDep15). Most of the contaminants show a negative correlation with the deprivation index consistent with the expected findings from the visual analysis. However, lead and manganese have a discordance between the graphical representation and the correlation analysis. Although, lead distribution displays some high outlier values, the non-parametric correlation analysis (Spearman) is robust to outliers. This suggests that the observed pattern is not solely attributable to the data points of lead and manganese. These results align with the concept of “triple jeopardy” for the less privileged population.

Additionally, some contaminants, like nitrates, show a non-monotonic relationship, which in the visual analysis seems as an inverse U shape and, in the correlation, has an apparent significant weak inverse correlation even in the urban strata.

Regarding other specific contaminants, such as THM (total and brominated), fluoride and arsenic, they all show a significant inverse correlation with the FDep15. These results suggest that in the less deprived areas, there are higher concentrations of these pollutants in water. This trend is particularly pronounced in the periurban strata for all pollutants. In addition, in urban areas, fluoride and arsenic also display significant inverse correlations with deprivation. Notably, fluoride shows the strongest correlation coefficient (Coefficient > /0.5/) indicating a strong negative association between FDep and this pollutant. These results are consistent with previous studies in the literature for THM (95), nitrates (89,90) and arsenic (91,93).

Table VII: Correlation analysis between water chemical pollutants and FDep15

Spearman Correlation		**FDep 15 by IRIS 17**				**% High school graduated > 15yo**
		Total	**Stratification urban degree**			
			Urban	**Periurban**	**Rural**	
Lead	Coefficient	0.188	0.062	0.129	0.058	-0.177
	Significance	<0.001***	0.504	0.071	0.672	<0.001***
	N	381	118	196	55	381
Nitrate	Coefficient	-0.105	-0.251	-0.097	0.076	0.118
	Significance	0.030*	0.005**	0.152	0.547	0.015*
	N	425	126	221	66	425
THM4	Coefficient	-0.170	-0.136	-0.226	-0.239	0.147
	Significance	<0.001***	0.144	0.002**	0.084	0.004**
	N	376	117	194	53	376
BrTHM	Coefficient	-0.212	-0.120	-0.265	-0.305	0.198
	Significance	<0.001***	0.202	<0.001***	0.030*	<0.001***
	N	369	114	192	51	369
Manganese	Coefficient	0.220	0.188	0.278	-0.174	-0.259
	Significance	<0.001***	0.095	<0.001***	0.278	<0.001***
	N	269	80	141	41	269
Fluoride	Coefficient	-0.594	-0.336	-0.576	-0.081	0.636
	Significance	<0.001***	0.002**	<0.001***	0.620	<0.001***
	N	255	79	130	39	255
Arsenic	Coefficient	-0.379	-0.322	-0.035	-0.023	0.417
	Significance	<0.001***	0.003**	0.035*	0.890	<0.001***
	N	344	79	141	40	344

*p<0.05,**p<0.01,***p<0.001

5. Discussion

5.1. Main drivers of differential exposure to drinking water contaminants in Europe

The ScR shows that most of the studies conducted in the European region relating drinking water contaminants to EJ are ecological studies and that the main focus is on distributive justice, in line with other studies conducted in different areas (97). However, this view is also limited as we included two of the four key concepts of EJ from J. Rawl. The main parameter studied in the European context is DBP and in particular, THM (119-121), whereas studies conducted in North America are focussed on different parameters such as nitrates, arsenic or lead (89-94).

The different drivers that influence the differential exposure to drinking water contaminants highlight the multifaceted nature of environmental justice (43). Several key dimensions were identified in the scoping review:

- Socioeconomic status (SES): SES is measured using a composite deprivation index (e.g., Carstain, Townsend, IMD) (77,115,119). Although, this parameter is normally included as a covariate to control its effect as a confounder (77,88), due to its relation to exposure and outcome and the distortion it produces, citing the nitrate study, where the most disadvantages IRIS was the one most exposed to nitrates studying embryonic malformation (77). It seems in this same study that SES acts as an effect modification factor, having no consistency or been not uniform across different levels of SES (77).
- Geographic location: The location of a community could modify its exposure to different water contaminants. Factors such as the size or degrowth areas, the degree of urbanization and proximity or location downstream of industrial activities (e.g., military airport) can affect contaminant levels (48, 118, 125).
- Seasonality also affects the concentration patterns of certain contaminants such as the THM (121).
- Infrastructure disparities: Aging water pipes and historical legislative context contribute to disparities in water contamination. For instance, the use of heavy metals (lead) in the water distribution lines during certain periods could lead to contamination incidents (76).
- Regulatory enforcement: Inconsistent or insufficient enforcement of regulations contributes to enhancing the gap of disparities in exposure to water contaminants. Policies regarding lead pipes underscore the importance of continued efforts even after implementing laws (76,117).
- Capability, information and awareness: the capability of a community, including their water literacy and access to resources for water testing and treatment, could help to identify and address water contamination issues in private water supply systems (117,124).

Despite the increasing number of recent articles investigating EJ in the past decade (50), there remains a research gap in comprehensively addressing the diverse array of factors influencing water quality, as previously discussed. Moreover, our study, while focusing on two of the four dimensions of EJ, highlights the need to encompass all dimensions when examining drinking water contaminants in Europe (96). This approach should involve a transdisciplinary team to ensure an integrative evaluation and would engage the population in a participatory research project that empowers the community while fostering a culturally sensitive perspective for each personalized study.

5.2. Understanding the drivers behind the drinking water disparities at the local scale

This case study assesses drinking water contaminants distribution in the IEV, France and its implications for EJ based on deprivation levels (FDep15). The study finds that overall water quality adheres to safety regulations with heavy metals like lead, manganese and arsenic mostly below detection limits (33,100) as recommended by the European directive and WHO: “as low as reasonably achievable” levels (10,128).

For instance, in literature, THM in rural areas shows an inverse correlation with FDep15 whereas lead shows the contrary pattern (126). Our study, the overall THM and FDep15 confirm this direct association, although, rural strata show no significant correlation, mostly due to the limited sample size. THMs levels variations depend on the source water quality and seasonality, the disinfectant dose and type, the complexity of the water treatment (presence of a clarification step, membranes, etc…) as well as the presence of storage and rechlorination points (44,121,123). Additionally, the distance or water-residence time are other factors for THM levels (126). Unfortunately, none of these variables were accounted for in our analysis due to limited data access.

Nitrate values show a direct correlation in Hispanic populations (89,90), while Black Americans appear to have an inverse correlation in the US (90). In the European literature, from the ScR, further research is needed to understand the pattern (77), and we confirm this need, observing a possible non-linear pattern, with an inverse U shape primarily seen in urban areas. IEV is based on agricultural activity and 35% of its water is used for this purpose (129), then it was expected to have higher nitrates in rural areas. However, an explanatory factor could be that major urban areas that are less deprived, such as Rennes and Saint Malo, source partly their water from agricultural land catchment areas where nitrates levels tend to be higher (33,130). Conversely, municipalities in rural areas, often more deprived, rely on groundwater sources, which in Brittany typically have lower nitrate levels (130). Unfortunately, the rural/urban areas´ nitrate concentrations hypothesis could not be verified in this study due to the lack of information connecting the end water with the sources.

Certain IEV areas require control measures for lead, cadmium and nickel associated with agriculture and industrial activities (131,132). Our study shows a positive correlation of lead and manganese with FDep15, while fluoride and arsenic exhibit the inverse pattern. These findings are in alignment with earlier research on lead associations (126). This underscores the urgency of implementing strategies to mitigate but also correct lead-induced corrosiveness in water systems (94), implementing measures to manage aging pipelines (76), and investigating the potential interplay between lead and manganese exposure, given their overlapping clinical manifestations (27,28). Nonetheless, our study is limited by its modest sample size and the incomplete coverage of various geographical units in the primary urban centers of the department. There is an added degree of uncertainty, as public network pipes have been replaced due to lead regulations law enforcement; however, private owners' pipelines at the end of the distribution network are not subject to compulsory replacement laws (17,18). This potentially gives rise to an additional hypothesis that more deprived neighborhoods might harbor older infrastructure.

In the case of arsenic, earlier studies failed to observe the presence of procedural injustice (92), although distributive injustice was evidenced (93). Both pollutants, fluoride and arsenic, are influenced by groundwater (92,116) which lies outside the primary scope of our current case study. Fluoride shows the strongest negative correlation with FDep15, also evidenced in the periurban strata. Nevertheless, its maximum values are lower than the regulatory limits. Still, we observe an inverse correlation phenomenon that requires further investigations, particularly in the context of urban development and specific methodologies employed in water treatment processes.

Individual and socioeconomic behaviors, such as the use of home water filtration systems or bottled water, contribute to variability in exposure (124). A more comprehensive understanding of uneven exposure to chemical contaminants in drinking water would require multilevel analysis, considering individual-level characteristics alongside group-level phenomena.

Given the particularities of IEV and Brittany, the use of the FDep 2015 index presents some limitations. While this composite index is validated in France, it focuses solely on four dimensions related to deprivation. However, it is essential to recognize that there are additional drivers contributing to environmental injustice that extends beyond the scope of this index. For instance, the exposure of racialized populations to contaminants differentially, note this exploration is constrained in the French context. Other factors, historical, cultural, resource-related aspects or regional policies in Brittany, could play pivotal roles in influencing environmental inequities. Consequently, the FDep 2015 lacks the specificity required to effectively address the unique dynamics of the department as it is context-dependent. In contrast, alternatives such as the municipal index of deprivation (Lalloué) offer a more contextually adapted approach, however, it is not available for IEV (69).
Additionally, there is a missing population that has to be considered from the environmental justice perspective, such as homeless individuals and undocumented migrants which are not accounted for due to the lack of a fixed dwelling or reflected in the statistics about their professional activities and SES due to their irregular situation (133,134).

In our current study, we have focused on the most pertinent variables related to the ScR results, considering their relevance in public health and availability at the time of the research. However, it is essential to recognize that there is a wide array of drinking water contaminants that are already being monitored and analyzed for safety purposes that could be studied through the EJ lens. Furthermore, the increasing pressure of pharmaceutical compounds in wastewater demands an evaluation of their ecological and public health risk (114). Therefore, an effective and dynamic EJ framework becomes essential for assessing this aspect of drinking water sources and distribution networks.

Future research efforts should encompass a broader spectrum of variables within drinking water contaminants. A multilevel analysis approach incorporating factors such as seasonality, distribution infrastructure and land use at the population level is essential. By clustering the population by these variables, researchers could explore potential patterns specific to the department of IEV. Additionally, exploring the socio-spatial relation between urban development and EJ could serve as an influential driver within the context of IEV. Employing a more specific deprivation index that integrates this measure along with other dimensions of deprivation, including demographics, cultural or different types of discriminations could enhance our understanding of EJ, and help to disassociate it from the stereotype of being linked to inherent characteristics of specific populations. This comprehensive approach could extend its significance beyond the local scope, enlightening the potential implications for drinking water contaminant-related EJ across Europe to construct a specific framework for participatory research and inform policies in public health.

6. Conclusion

This study sheds light on the main drivers influencing the exposure to drinking water contaminants in Europe related to EJ, with a special scope on chemical water contaminants in IEV, Brittany, France. The most relevant finding in the scoping review reveals that there is a lack of studies in this field (96). Additionally, the most studied type of EJ, as all of them are related, is the distributive justice (120-122), THM being the prominent pollutant of interest due to its variation in concentration along the distribution network and the uncertain effects on health (115,119,120). The main drivers of this unequal exposure to water contaminants are the geographic location, seasonality, infrastructure disparities, regulatory enforcement and the adaptation capacity and awareness of the communities (43).

The ecological case study conducted in the IEV department revealed an inverse correlation between THM, arsenic and nitrates levels and deprivation measured by FDep15, in line with the existing literature (89-93,95). Nevertheless, the suspected non-linearity pattern observed in nitrate highlights the need for further research (77). Conversely, a positive correlation was established between lead and manganese concentration and FDep15, while fluoride displayed the strongest negative correlation. Nonetheless, the constrained accessibility to supplementary data impedes our ability to comprehensively elucidate the underlying patterns of analysis. Addition insights regarding the quality of water sources, disinfection methodologies, temporal variations, characteristics of the distribution network (such as pipe composition, length and rechlorination points…) and building construction dates could potentially provide insights into the driving factors behind the observed correlations (43,76,126). Finally, it is essential to tailor the deprivation index to the local context to accurately capture the measure of deprivation, as well as to recognize the limits of most studies as it overlooks the official statistics of vulnerable populations such as undocumented or homeless population.

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Appendixes

ANNEX. Table I: Inequality index. Adapted mainly from Inserm CépiDc (87), Palka E. Disertation (69, 84)

Index (Place)	Data source	Production years	Division scale	Variables	Methods
Carstain (UK)	Census	Every 10 years : 1981, 1991, 2001, 2011	Postcode sector level	Car ownership Occpational social class Household overcrowded Male unemployent	Z-Score
Townsend (UK)	Census	1981, 1991, 2001	IRIS[16], Municipality	Rate of households: non owners of a car, non owners of their dwelling, where there is more than a person per room. And rate of unemployment in active population	Log-Transformation Z-Score
FDep (France mainland)	Census	1990, 1999, 2008, 2013, 2015	IRIS, Municipality, Canton, Department	% unemployed % non skilled workers % Bachelor´s degree Household mean income	Population-weighted principal component analysis (PCA)
French EDI (France mainland)	Individual : EU-SILC survey 2006 Ecological : Census	2007, 2015, 2017	IRIS	% Foreigners Household conditions: % without sanitary facilities, % Single parent, % House not in property, % not car %, unemployment, %non-superior studies % unskilled workers	Score=0.11×"Overcrowding"+0.34×"No access to a system of central or electric heating"+0.55×"Non-owner"+0.47×"Unemployment"+0.23×"Foreign nationality "+0.52×"No access to a car"+0.37×"Unskilled worker-farm worker"+0.45×"Household with 6+persons"+0.19×"Low level of education"+0.41×"Single-parent household"
Lalloué (Lille, Lyon, Marseille)	Census	1999	IRIS	15 variables divided by: Employment, housing, family and dwelling, income, level of studies and migration status	Multiple PCA[17]
IMD [18]	Census	2000, 2004, 2007 Actual : IoD 2019	SOA (Super Output Areas), ward, district, county and primary care trust	Weighted domains: Income 22,5%, Employment 22,5%, Education 13,5%, Health 13,5, Crime 9,3%, Barriers to housing and services 9,3% Living environment 9,3%	Seven step method of generating domains scores ranked and exponentially transform and wights it in the SOA[19] level.

[16] IRIS: regrouped area which has 2000 population
[17] PCA: Principal component analysis
[18] IMD: Index of Multiple Deprivation
[19] SOA: Super Output Area is divided into Low (>=1000people, 400 household) and Middle layer (>= 5000people and 2000 household)

ANNEX. Table II EDI across countries comparison (81,82)

	Total population	Year of Census	Smallest geographical unit	Average population per unit	Number of units
France	58 500 000	1999	IRIS	2000	50 000
Italy	57 000 000	2001	Census tract	170	352 205
Portugal	10 500 000	2001	Census tract block groups	640	16 090
Spain	40 850 000	2001	Census tract	1000	34 300
England	59 950 000	2001	SOA[20]	1500	34 400
Slovenia	2 000 000	2011	Municipalities	600	3 104

ANNEX. Table III. PRISMA-ScR Checklist (105)

SECTION		ITEM	PRISMA-ScR Checklist Item	Reported on Page
TITLE		1	Identify the report as a scoping review.	Front page
ABSTRACT	Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	4
Introduction	Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	12
	Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	13
Methods	Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	None
	Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	13
	Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	14
	Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	ANNEX- Table IV and V

[20] SOA: Super Output Area

	Selection of sources of evidence	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	13
	Data charting process	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	14
	Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	13
	Critical appraisal of individual sources of evidence	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	None
	Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	18
	Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	18
	Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	18
	Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	None
	Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	19
	Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	19
Discussion	Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key	21

			groups.	
	Limitations	20	Discuss the limitations of the scoping review process.	26
	Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	26
Funding	Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	None

ANNEX. Table IV: Concept words

Concept	
Drinking water (DW)	**Water:** Tap water, potable water, drinking water, bottle* water*
Drinking water related concept	**DW Surveillance:** Water quality, water surveillance, water test*, water monitor*, water management **DW Source:** Water source*, water resource*, water security, water safe*, groundwater, surface water, water well*, water suppl* **DW Access:** Water access*, water scarcit*, water deprivation, water insecurity **DW Treatment, storage and pipelines:** Water infrastructure*, water purification, water softening, water treatment, water filtration, water distribution, water storage, water pipeline*, chlorination **DW quality:** turbidity, water microbiology, Escherichia Coli, Enterococcus, virus*, parasite*, nitrate*, nitrite*, heavy metal, copper, chromium, lead, iron, arsenic, cadmium, mercury, nickel, pesticide*, glyphosate, disinfection by-product*, chlorination by-product, trihalomethane*, Halo acetic acid*, chemical water pollutant, radioactive water pollutant*, water pollut*, water contamination, water contaminant, water index*, water indicator* Agrochemical **DW safety:** Water borne disease*
Environmental justice	**Environmental justice:** Environmental justice, environmental racism, environmental injustice **Procedural justice:** Public opinion, community integration, community based participatory research*, community Network*, community participation, social perception, public non-discrimination polic*, vulnerable population **Distributional justice:** Social justice: health disparit*, deprivation ind* income, depriv*, wealth, economic factor*, economic status, poverty, education unskilled work*, employment, unemployment, socioeconomic factor*, social justice, social class, sociodemographic, social planning, discrimination, gender, gender equity, pregnancy, migration, foreign nationality, indigenous communit*, racism, ethnic*, roma/gipsy, minorit*, isolation, homeless*, equity, unequal, inequal*, inequit*, disadvantage, household overcrowding
Geographic	Europe, Andorra, Austria, Balkan, Belgium, Eastern Europe, Albania, Baltic, Estonia, Latvia, Lithuania, Bosnia, Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Kosovo, Moldova, Montenegro, Poland, Belarus, North Macedonia, Romania, Russia, Serbia, Slovakia, Slovenia, Ukraine, European Alpine Region, France, Germany, Gibraltar, Greece, Ireland, Italy, Liechtenstein,

	Luxembourg, Mediterranean Region, Mediterranean Islands, Cyprus, Malta, Monaco, Netherlands, Portugal, San Marino, Scandinavian and Nordic Countries, Denmark, Finland, Iceland, Norway, Sweden, Spain, Switzerland, Transcaucasia, Armenia, Azerbaijan, Georgia, United Kingdom, UK, England, Northern Ireland, Scotland, Wales ,USSR, Armenia, Moldova, Ukraine, Vatican City)

ANNEX. Table V. Query string of each database construction

PubMed

(((("Tap water"[Title/Abstract] OR "Potable water"[Title/Abstract]) OR "Drinking Water"[MeSH Terms]) OR "Bottle water"[Title/Abstract]) AND ("Water surveillance"[Title/Abstract] OR "water test*"[Title/Abstract] OR "water monitor*"[Title/Abstract] OR "Water management"[Title/Abstract] OR "Water Quality"[MeSH Terms] OR "water source*"[Title/Abstract] OR "Water Resources"[MeSH Terms] OR "water safe*"[Title/Abstract] OR "Groundwater"[MeSH Terms] OR "Surface water"[Title/Abstract] OR "Water Supply"[MeSH Terms] OR "Water Wells"[MeSH Terms] OR "water access*"[Title/Abstract] OR "water scarcit*"[Title/Abstract] OR "Water Insecurity"[MeSH Terms] OR "Water Deprivation"[MeSH Terms] OR "Water security"[Title/Abstract] OR "water infrastructure*"[Title/Abstract] OR "Water Purification"[MeSH Terms] OR "Water Softening"[MeSH Terms] OR "Water treatment"[Title/Abstract] OR "Water filtration"[Title/Abstract] OR "Water distribution"[Title/Abstract] OR "Water Storage"[Title/Abstract] OR "water pipeline*"[Title/Abstract] OR "Chlorination"[Title/Abstract] OR "Water Pollution"[MeSH Terms] OR "Water Pollutants"[MeSH Terms] OR "water contamina*"[Title/Abstract] OR "Water index"[Title/Abstract] OR "water indicator*"[Title/Abstract] OR "Water turbidity"[Title/Abstract] OR "drinking water/microbiology"[MeSH Terms] OR "Escherichia coli"[MeSH Terms] OR "Enterococcus"[MeSH Terms] OR "Viruses"[MeSH Terms] OR "Parasites"[MeSH Terms] OR "Nitrates"[MeSH Terms] OR "Nitrites"[MeSH Terms] OR "metals, heavy"[MeSH Terms] OR "Copper"[MeSH Terms] OR "Chromium"[MeSH Terms:noexp] OR "Lead"[MeSH Terms] OR "Iron"[MeSH Terms:noexp] OR "Arsenic Poisoning"[MeSH Terms] OR "Arsenic"[MeSH Terms] OR "Cadmium"[MeSH Terms] OR "Cadmium Poisoning"[MeSH Terms] OR "Mercury"[MeSH Terms:noexp] OR "Mercury Poisoning"[MeSH Terms] OR "Nickel"[MeSH Terms] OR "Pesticides"[MeSH Terms] OR "Agrochemicals"[MeSH Terms] OR "glyphosate"[Supplementary Concept] OR "Trihalomethanes"[MeSH Terms:noexp] OR "haloacetic acid*"[Title/Abstract] OR "disinfection by product*"[Title/Abstract] OR "chlorination by product*"[Title/Abstract] OR "water pollutants, chemical"[MeSH Terms] OR "water pollutants, radioactive"[MeSH Terms] OR "Waterborne Diseases"[MeSH Terms]) AND ("Environmental Justice"[MeSH Terms] OR "Environmental injustice"[Title/Abstract] OR "Environmental racism"[Title/Abstract] OR "Community Integration"[MeSH Terms] OR "Community-Based Participatory Research"[MeSH Terms] OR "Community Networks"[MeSH Terms] OR "Community Participation"[MeSH Terms] OR "Public Opinion"[MeSH Terms] OR "Social Perception"[MeSH Terms] OR "Public Nondiscrimination Policies"[MeSH Terms] OR "Vulnerable Populations"[MeSH Terms] OR "Health Disparities"[Title/Abstract] OR "deprivation

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ANNEX. Table VI: Directives leves and literature review of different levels

	Tap water					Bottled water		Literature
	Dir 98	Dir 20	OMS (4 ed)	IEV (LQ)[21]	(RQ)[22]	Dir 2003/40/EC19	Dir 2009/54/EC	
Lead	10 µg/l	5 µg/l	0.01 mg/l	5 µg/l	-	0,01mg/l	-	Lead exceeding 5 µg/L in drinking water exhibited a positive correlation with 75th and 90^{th} percentiles of blood lead levels among children who consume such water (135).
Nitrate	50 mg/l	50 mg/l	50 mg/l	≤ 50 mg/L	-	50 mg/l	-	Among individuals who consumed private well water wth nitrate levels less than 10 mg/L NO3-N, an association was identified between the quantity of nitrate ingestion and the methemoglobin levels in the blood (30). → Used the classification of water quality from WFD (97).
4THM	100 µg/l	100 µg/l	100 µg/l	≤ 100 µg/L	-	-	-	In epidemiological studies NOAEL (Non-Adverse Effect Level) was settled in 40 µg/L (126).
Arsenic	10 µg/l	10 µg/l	0.01 mg/l	≤ 10 µg/L	.	0.01 mg/l	-	Since 2006 and 2017 in New Jersey and Denmark, respectively, has stablished 5 µg/L as the maximum level. And in The Netherlands the water companies adopted a policy of reducing it below 1 µg/L (136). →Absence of values above 1 µg/L, so divided the values in 3 equal breaks from the LOD.
Manganese	50 µg/l	50 µg/l	Not of Health concern	-	≤ 50 µg/L	0.5mg/l	-	The World Health Organization (WHO) reduced the guideline values from 500 to 400 µg/L. This update in water is based on the food NOAEL" (137). "However, studies involving 4–18-month-old children in UK indicated that exposure from tap water is negligible ranging from 2 to 15 µg/L" (138). →Therefore, we used the median of the range which is 8 µg/L.
Fluoride	1.5 mg/l	1.5 mg/l	1.5 mg/l	≤ 1.5 mg/L	-	5mg/l	1mg/l	Fluoride guidelines recommend 0.6 mg/ F Lfor children under 6-8 years (and lower for the first two years of life), and 1.0 mg/ F L for older children and adults. Dental fluorosis can occur with fluoride levels of 0.9–1.2 mg/ F L, while concentrations over 1.5 mg/F L are more linked to it. Skeletal fluorosis is generally associated with water concentrations of 3-6 mg/FL, with severe cases above 10 mg/FL (139). → Absence of high values, therefore, 3 breaks divisions from the LOD were made.

[21] LQ: Quality limits

[22] RQ: Reference Limits

ANNEX. Figure I: Scope of IRIS with water quality analysis data by PSV

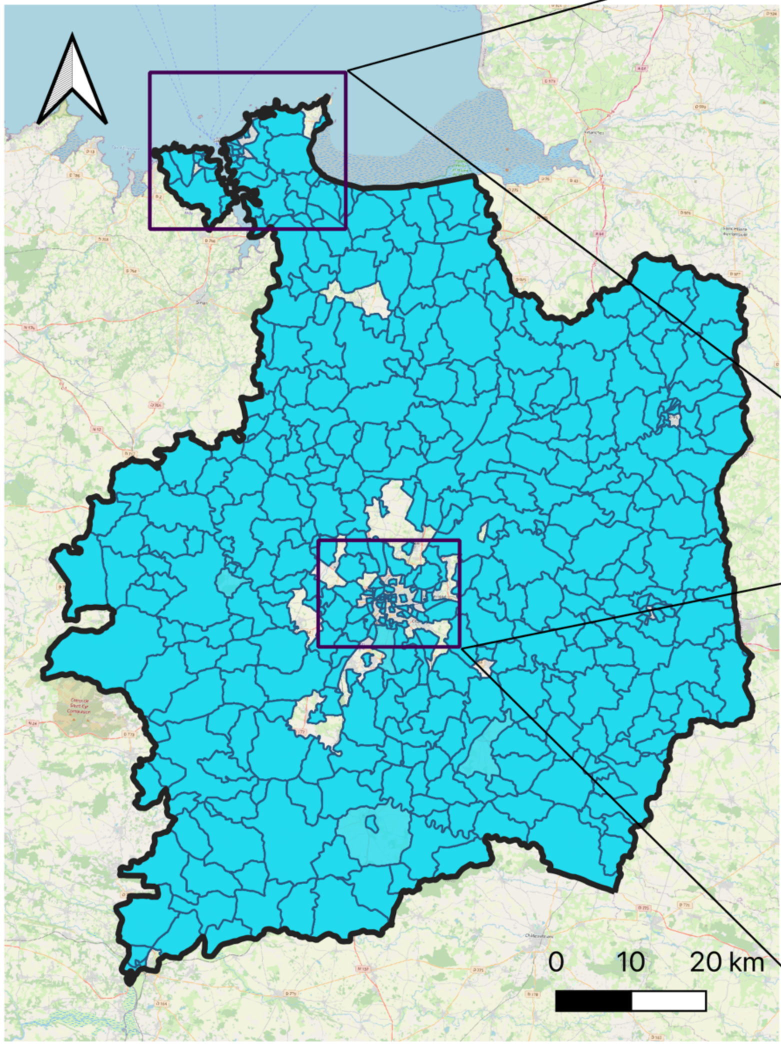


Figure a. Ille et Vilaine- IRIS with PSV data

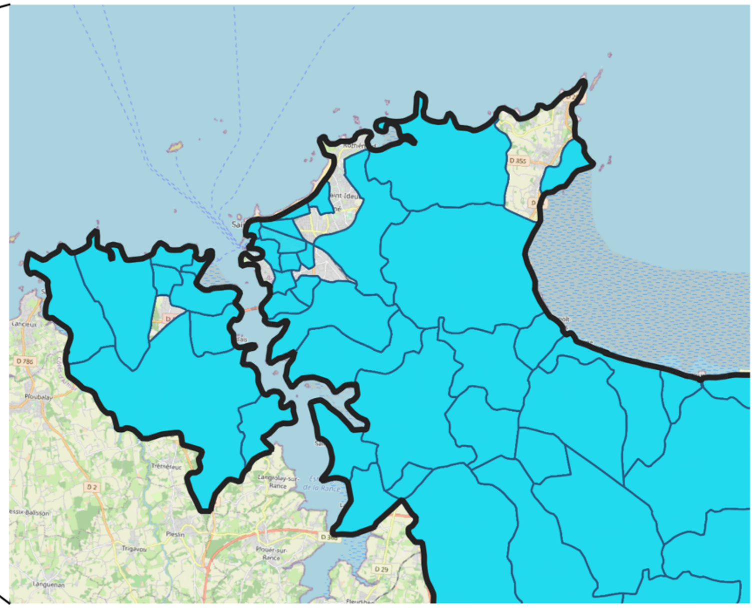


Figure b. Saint Malo area- IRIS with PSV data

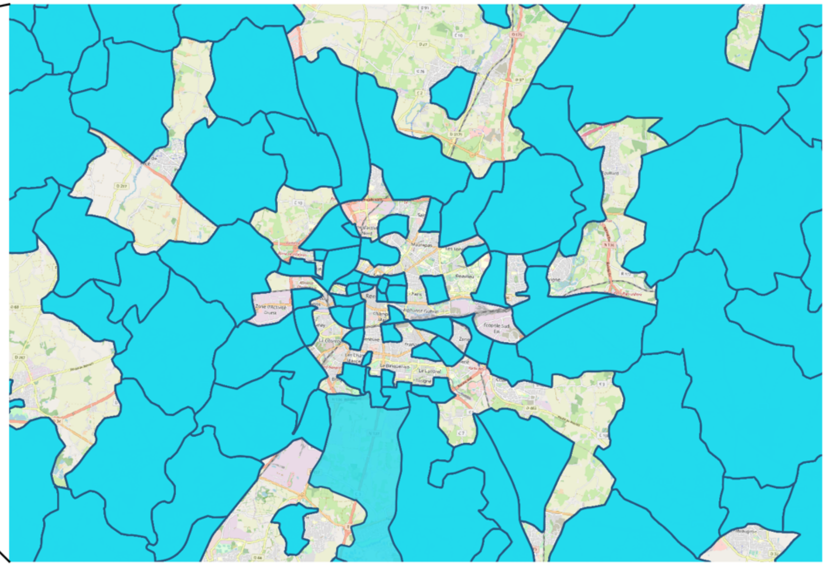
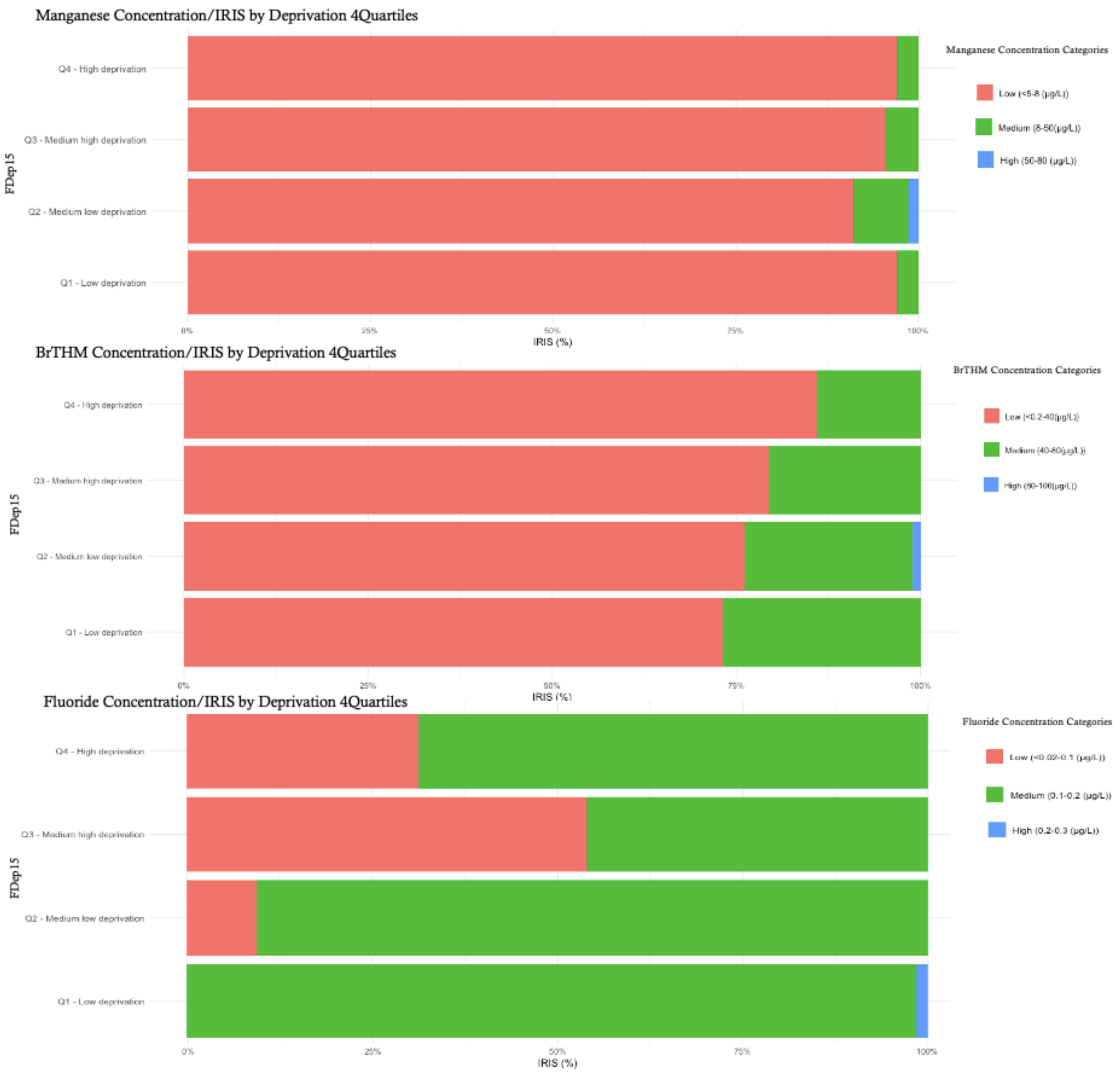


Figure c. Rennes area- IRIS with PSV data

Data from Geoservice,Cépidec and LERES.

ANNEX. Figure II: Other pollutants (Manganese, BrTHM, Fluoride)



ABSTRACT (FRENCH)

Contexte : Cette recherche examine la problématique de justice environnementale (JE) liée à l´exposition aux contaminants de l´eau potable (CEP) en Europe. En Amérique du Nord, différentes études fondées sur les droits civiques et des mouvements sociaux ont souligné les disparités racialisées et socio-economiques et dans l´exposition aux CEP. Cette étude vise à déterminer si des problématiques de JE existent en Europe et l´illustrer avec un cas étude en France.

Méthodes : Un examen de la portée (EP) a été réalisé explorant les études européennes parues entre 1990 et 2022. La revue englobe : les types de CEP étudiés en lien avec la JE, les méthodes de recherche utlisées, et les facteurs potentiels contribuant aux inégalités dans l´exposition à des CEP spécifiques.
Apres, une étude de cas a été menée en Ille et Vilaine, France, où l´eau de surface, plus vulnérable à la pollution, constitue la principale source. L´étude a intégré les CEP identifiés dans EP. La JE a été mesuré par un indice de défavorisation composite, FDep15, qui a été appliqué dans les divisions geographiques IRIS, l´échelle de regroupement la plus petite en France.

Résultats et Discussion : Un nombre limité d´études primaires sur la JE liée à l´exposition aux CEP ont été menées. Néanmoins, des contaminants tels que les nitrates, les trihalométhanes, les métaux lourds (plomb, manganèse, arsenic…) et les pesticides ont été évalués dans les études disponibles. Les résultats suggèrent une certaine association entre la JE et les CEP, la corrélation variant selon le contaminant. Par example, les THM montrent une corrélation négative avec la défavorisation tandis que le plomb présente une relation inverse.
Par conséquent, les résultats soulignent la nécessité d´études approfondies sur la JE et l´exposition aux CEP à plus grande échelle. Étant donné que les disparités en JE sont multicomposant, comprendre les interactions complexes entre les contaminants, les facteurs socio-économique et les expositions est essentiel pour aborder la JE face à l´exposition aux CEP.

Mots-Clés : qualité de l´eau potable, justice environnementale, inégalité, eau et santé, Europe