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Original article

Interdisciplinary community-based participatory health research across the industrial region of the Étang de Berre : The EPSEAL Fos Crau study

Étude participative en santé environnement ancrée localement dans la région industrielle de l'Étang de Berre, une approche interdisciplinaire : le projet Fos Crau EPSEAL

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ABSTRACT

Background. – We conducted a community-based participatory environmental health study in three towns: two in the heart of Marseille's industrial zone (Fos-sur-Mer and Port-Saint-Louis-du-Rhône), and one on the periphery located about 30 km away (Saint-Martin-de-Crau).
Methods. – We first conducted a cross-sectional survey of a random sample of residents in each of the three towns. We asked study participants to self-report a wide variety of health issues (Port-Saint-Louis: n = 272, Fos-sur-Mer: n = 543, Saint-Martin-de-Crau: n = 439). We then conducted focus groups with residents and other stakeholders to share preliminary data in order to propose areas of reflection and collaboratively produce contextually-situated knowledge of their health and environment. We directly standardized the prevalences (by age and gender) to the French metropolitan population to make our results more comparable.
Results. – Study participants who lived closer to the core industrial zone (residents of Fos-sur-Mer and Port-Saint-Louis-du-Rhone) had higher prevalences of eye irritation, nose and throat problems, chronic skin problems and headaches than people who lived further away (residents of Saint-Martin-de-Crau). Residents also offered diverse qualitative insights about their environment and health experiences.
Discussion. – We observed elevated prevalences of diseases that affected residents across the industrial zone (Fos-sur-Mer and Port-Saint-Louis-du-Rhône) compared to those living outside (Saint-Martin-de-Crau), and qualitative evidence of how residents made sense of their health experiences strengthening an understanding of their own empirical observations which helps to produce knowledge about health in an industrial context. The results of the workshops show an important benefit from the co-production of local knowledge.
Conclusion. – We encourage future researchers to do in-depth, community-based research to comprehensively describe the health of residents in other heavily polluted zones, product local knowledge and to help identify policy solutions, engender trust among the local people, and identify opportunities for intervention.
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R É S U M É

Contexte. – Une étude participative en santé environnement ancrée localement (EPSEAL) a été menée dans trois villes de la région industrielle de l'étang de Berre, à proximité de Marseille : deux d'entre elles étaient localisées au cœur de la zone industrielle (Fos-sur-Mer et Port-Saint-Louis-du-Rhône), la troisième se situait plus en périphérie, à environ 30 km (Saint-Martin-de-Crau).
Méthodes. – Dans un premier temps, une étude transversale a été réalisée sur un échantillon aléatoire de personnes résidant dans chaque ville. Un questionnaire de santé déclaratif a été complété par les participants (Port-Saint-Louis : n = 272, Fos-sur-Mer : n = 543, Saint-Martin-de-Crau : n = 439). Des ateliers collaboratifs ont ensuite été menés avec les habitants de la zone industrielle, les professionnels de santé, membres d'associations, syndicats et élus locaux pour partager les résultats afin de proposer des pistes de réflexion et de produire de la connaissance au sujet de leur environnement. Les prévalences standardisées (sur le sexe et l'âge) ont été calculées par une méthode de standardisation directe en prenant comme référence la France métropolitaine.
Résultats. – Les habitants de la zone industrielle (Fos-sur-Mer et Port-Saint-Louis-du-Rhône) présentaient des prévalences pour les irritations des yeux, problèmes nez-gorge, problèmes de peau chroniques, et maux de tête plus importantes que pour ceux résidant à l'écart de la zone (Saint-Martin-de-Crau). Les citoyens ont également décrit de nombreuses expériences au sujet de leur environnement et de leur santé.
Discussion. – Nos résultats suggèrent un état de santé des habitants de la zone industrielle (Fos-sur-Mer et Port-Saint-Louis-du-Rhône) plus dégradé que celui des personnes résidant à l'écart de cette zone (Saint-Martin-de-Crau) et témoignent d'une bonne appropriation des résultats de santé ainsi qu'un renforcement de la compréhension des déterminants et savoirs environnementaux locaux dans un contexte industriel. Les résultats issus des ateliers montrent un réel apport bénéfique dans la co-production de savoir local.
Conclusion. – Nous encourageons les futures recherches à approfondir l'approche participative en santé environnement ancrée localement afin de saisir de manière compréhensible et pertinente la santé des habitants dans un contexte industriel. Cette démarche permet, en articulant aux savoirs scientifiques les savoirs locaux, de produire de la connaissance et formuler des recommandations à destination des pouvoirs publics afin de consolider la cohésion entre habitants, d'orienter les décisions politiques et de proposer des opportunités d'intervention.
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1. Introduction

Understanding the health implications of complex environmental exposures is challenging and requires inductively braiding together insights from diverse disciplines and study types. Many lab-based studies of both animals and humans have documented the "cocktail" effects of multiple sources and types of pollution on health [1,2]. Notwithstanding a more and more complex methodology, these studies still often oversimplify the potential accumulation and diversity of pollution sources. There are also place-based health studies of locations experiencing high amounts of environmental pollution, which seek to fully characterize health consequences [3–5]. Within this latter group of studies, few have systematically compared health issues in places

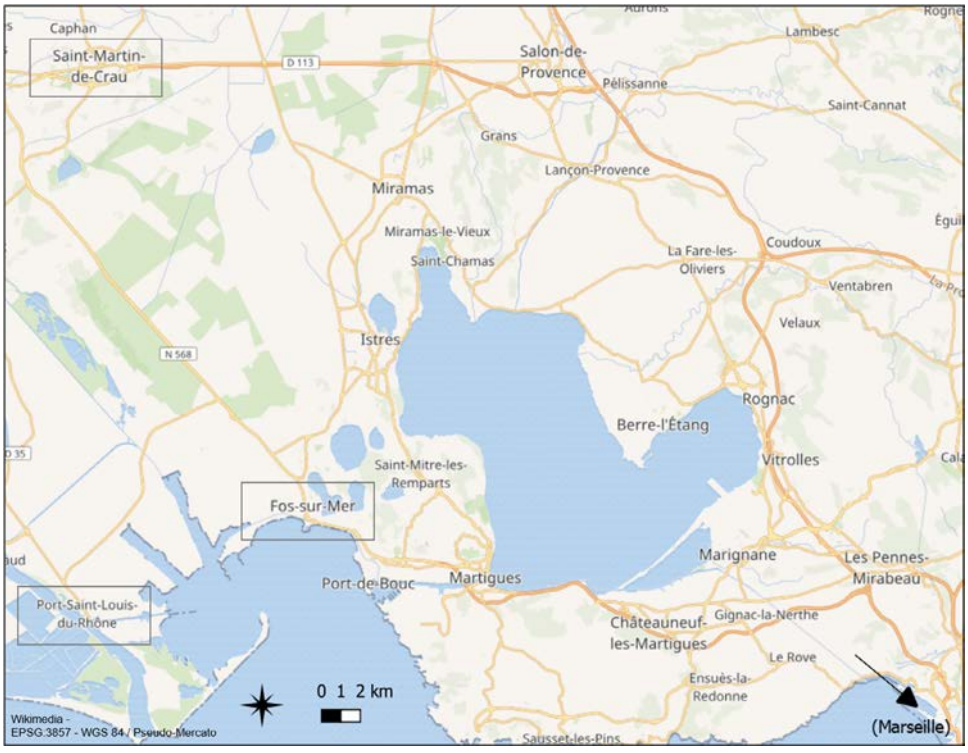


Figure 1. Map of the region of the Étang de Berre.

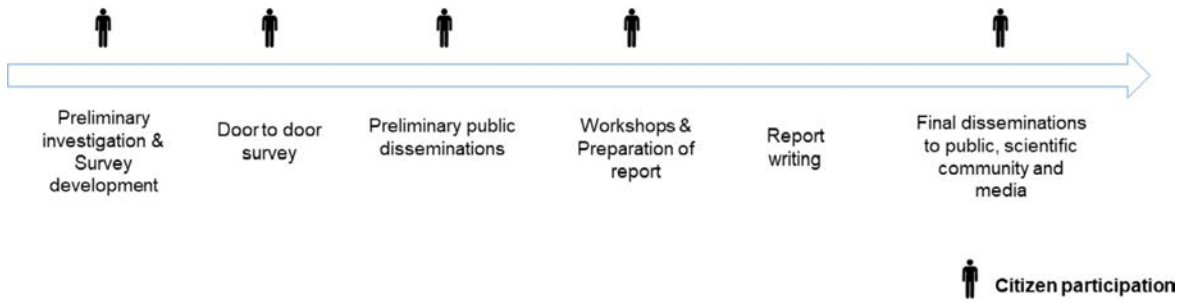


Figure 2. Citizen participation in the study process.

near each other but with different levels of pollution. One study did have a comparison group, but was focused on exposure assessment rather than health assessment [6].

In the context of our study, there were co-occurring industrial, occupational, transportation/logistics, and (in the less industrial area) agricultural exposures in the region. Specifically, the EPSEAL Fos Crau project took place in the industrial area of the Etang de Berre region in the south of France, which includes about 30 towns and has a population of approximately 400,000 people. Our research focused on three towns within this region : two in the center of the industrial zone (Fos-sur-Mer and Port-Saint-Louis-du-Rhone) and one on the periphery of the industrial zone (Saint-Martin-de-Crau), nearer to agricultural activity (Figure 1). This region, located about fifty kilometers from Marseille, is at the center of one of the most important industrial zones of France and Europe. The industrialization of the territory began over one hundred years ago and today has more than 430 industrial or agricultural facilities, including oil refineries, oil and shipping container depots, gas storage, organic chemistry industries, steel industry, and aeronautics. Over 60 % of these facilities are classified SEVESO II (accidental risk "high threshold"), according to the European directive SEVESO, including around 50 facilities classified as IED (Industrial Emission Directive), which indicates a chronic hazard. The General Council for the Environment and Sustainable Development concluded that the industrial sector is the major contributor to air pollution in the region, including the heavy metal particulates, carbon monoxide, particulate matter and greenhouse gases. The road, air and sea transportation sector also contributed a substantial amount of pollution to the air [7].

Given the : (i) presence of numerous industrial sites in the area of the Etang de Berre ; (ii) emissions of associated pollutants ; (iii) existing local health studies on several specific illnesses [8,9] ; and(iv) international scientific literature on the links between environmental pollution and health [10] residents and other stakeholders have had many questions about health in their region. To respond to these questions, we designed the EPSEAL Fos Crau study, in which we worked with three towns that were illustrative of the Etang de Berre experience. In our first phase, we studied just the health of residents in towns close to (and highly exposed to) industrial facilities and related pollution [11], and found high levels of health problems among residents. In our second phase, in response to residents' interest in comparing their health to others', we surveyed residents in a town further away from the center of the industrial activity, but still somewhat exposed : Saint-Martin-de-Crau. We considered Saint-Martin-de-Crau to be not a control or an unexposed town, but rather a town that was differently exposed to pollution (both industrial and agricultural). The town of Saint-Martin-de-Crau is located at about thirty kilometers from the core industrial area of the Étang de Berre ; thus, it had a lower exposure to industrial activity than the other two towns, but was on the same major roads and had the same Mediterranean climate (e.g., temperature, humidity, atmospheric pressure).

Because of the wind patterns, all of the towns are subject to industrial pollutants dispersed in the air. A recent bioimpregnation study of 138 residents in the area, the INDEX study [12], documented the presence of industrial pollutants (in fine particulates and lichen) in Fos-sur-Mer and, to a lesser extent, in Saint-Martin-de-Crau. The latter has a small industrial area (approximately 4 hectares) that includes construction, transportation, facility maintenance, product manufacturing, and chemical industry.[1] Agricultural lands represent 97 % of Saint-Martin-de-Crau's surface, and are mostly used for conventional farming. Additionally, in 2009, the area had a pipeline spill of > 4000 m^3 of hydrocarbons that contaminated 46,000 ton of land and made the region's groundwater temporarily non-potable.

The populations of Fos-sur-Mer, Port-Saint-Louis and Saint-Martin-de-Crau share some similarities regarding environmental exposure. Some of the people who work in the industries in Fos-sur-Mer and Port-Saint-Louis live in Saint-Martin-de-Crau. Also, the towns of Fos-sur-Mer and Saint-Martin-de-Crau are exposed to traffic pollution as they are both located on national highways that are heavily used by industrial freight. In fact, Saint-Martin-de-Crau is a major axis of industrial freight, since it has a 4-halogistics platform nearby that employs about 2000 people.

1.1. Study objectives

This article reports on quantitative and qualitative findings from a community-based participatory environmental health study we conducted in all three towns, to understand health issues in this environmentally polluted region and to build upon previous studies of the region [8,9,11,13–15] that were focused on specific illnesses at the center of the industrial zone. The goal of our multi-method approach was to triangulate quantitative and qualitative data to present a more comprehensive perspective of health in the region.

2. Methods

2.1. Research approach

We used a community-based participatory research (CBPR) approach [16] to conduct a cross-sectional epidemiology survey. We followed the same methodology as described in previous research [11], including the residents of the three towns and other local stakeholders throughout the study process (Figure 2). In fact, the three towns included in the study were chosen based on conversations with residents and other local stakeholders. Specifically, there were opportunities for any residents, local practitioners, environmental and/or health associations and experts or other stakeholders to participate and interact with each other in different stages of the research, from framing and expanding on research questions, to suggesting topics for inclusion in the survey, to offering hypotheses and perspectives on the analysis through collaborative workshops, to reflecting on

[1] For a detail of the presence of industries in the industrial area of the Leuze Wood, see https : //www.saintmartindecrau.fr/Zone-industrielle.html, accessed le 01/25/18 and its appendix https : //www.saintmartindecrau.fr/IMG/pdf/Entreprises_Bois_de_Leuze.pdf accessed 01/26/18.

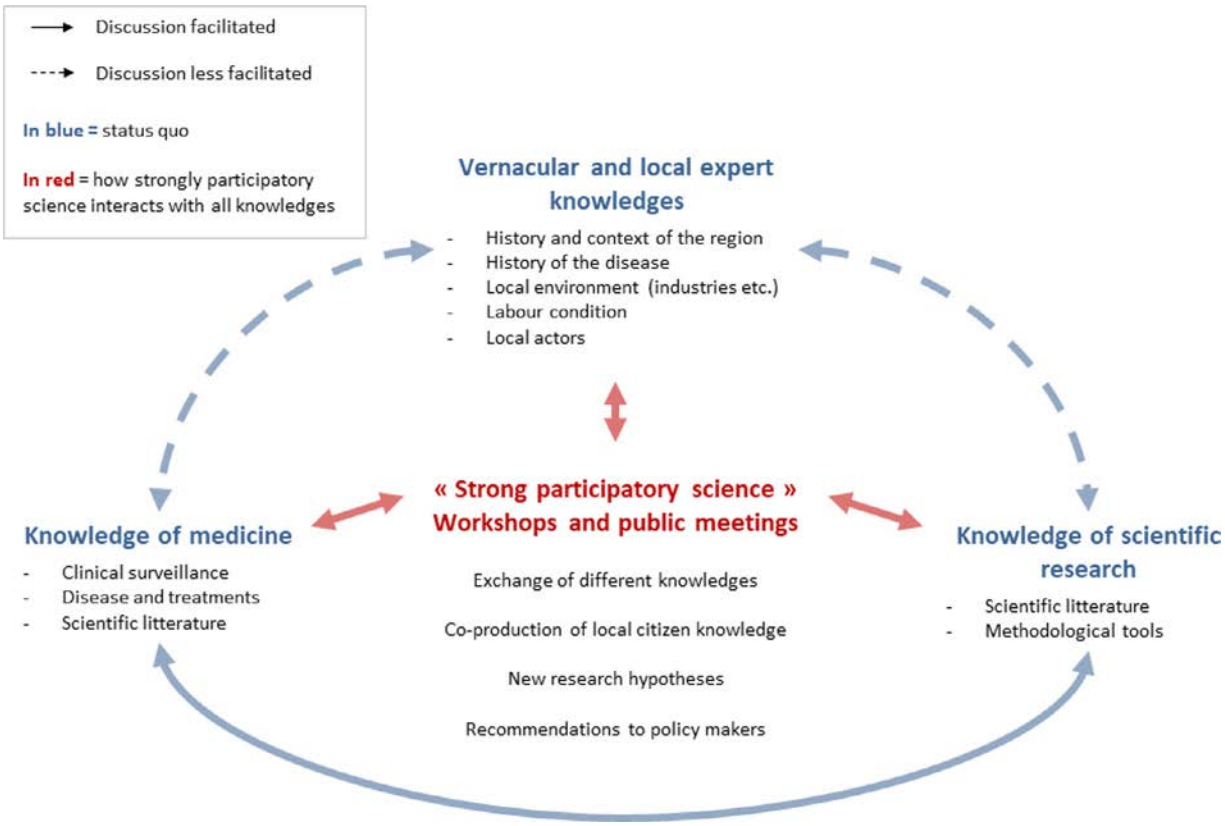


Figure 3. Conceptual framework of community-based knowledge co-production.

dissemination goals and possible recommendations (Figure 3). All of these stages facilitated the exchange of information. More details about our participatory approach are outlined elsewhere [17]

Briefly (see [11] for more details), two surveyors systematically randomly sampled households by knocking on the door of every fifth residential unit (i.e., freestanding house or flat within a multi-unit building) covering every street of the town, on different days and times in order to maximize our chances of reaching participants while they were home. We held public meetings in advance of collecting data and also circulated flyers and messages through associations and municipal bulletins and regional media outlets to increase knowledge among residents that our survey was occurring and that surveyors may knock on their door. The surveyors were in Fos-sur-Mer (FSM) and Port-Saint-Louis-du-Rhone (PSL) from June to December 2015 and in Saint-Martin-de-Crau (SMC) from September to mid-December 2018. Whoever answered the door (over 18 years of age) was invited to participate by completing the survey in-person at that time, or to schedule a time to complete the survey by phone at a later date, or to complete the survey online at their leisure. It took participants 15–90 min to complete the survey. All data (qualitative and quantitative) were entered through the Qualtrics survey platform using digital tablets.

We also conducted collaborative workshops and public meetings (see [18] for more details) : 28 workshops in FSM and PSL between June and December 2016, and 19 workshops in all three towns between February and April 2019. Anyone who had provided contact information (some survey participants, other interested people, key informants, members of local associations) were invited by email to participate in the workshops, which were also advertised to anyone in the area on our project's website. Workshops and public meetings took place in different locations in all three towns, in locations made available free of charge by the municipal governments and/or local associations.

2.2. Research ethics

The Virginia Tech University's Institutional Review Board (IRB) approved the survey. The survey was strictly anonymous—no identifying personal data were collected ; thus the study was not covered by Chapter 1, Article 4 of the EU General Data Protection Regulation [19]. Additionally, the IRB stated that no consent forms were needed. Instead, consent was given by agreeing to a statement read to the prospective participant about the study and the informant's right to participate or not, and their right to end the survey at any point. A copy of the statement was given to all participants. The survey only asks that the respondent be at least 18 years of age ; no names, birthdates, addresses, medical records, or other personal identifying information was collected.

2.3. Data collection tools

We constructed the survey using several sources including both local and expert knowledge. We drew heavily on a survey conducted in Richmond, California, that described the population's health status in a similar industrial context [3,20] but we also considered the specifics of the French context [17]. The questionnaire covered a broad thematic spectrum, including residential history and household information, demographic features, health outcomes, health care access, residential and occupational exposure, pollution concerns and civic involvements. The data reported here concerned health conditions (e.g., chronic diseases and symptoms), demographics (e.g., sex, age), and socioeconomic (e.g., education) characteristics.

We used a semi-structured focus group protocol to conduct the collaborative workshops [18]. Briefly, the protocol began with a presentation of our quantitative findings (either a general overview of all of the findings, or a more extensive subset of the findings,

depending on the workshop group) and then led to a discussion. At each workshop (sessions typically lasted 1–2 h), there were two research team members present : one was the lead facilitator and the other the lead notetaker in charge of collecting transcribed verbatims, provided elsewhere [21]. A thorough explanation of the collaborative workshop process, participant demographics, and outcomes have been reported elsewhere [18].

2.4. Analytic approach

Survey data were downloaded from Qualtrics platform and prepared for descriptive and analytic statistics using R software [22]. We chose to directly standardize the prevalences by age and gender to make our results comparable to France as a whole ; the population of metropolitan France (which only includes continental/mainland France, and not its small islands elsewhere) was used as the reference population (Insee, RP2015 exploitation principale, géographie au 01/01/2017).

We analyzed the qualitative data from the focus groups using a grounded theory approach [23], identifying themes and illustrative quotes.

3. Results

3.1. Study sample

We collected 1254 questionnaires from all the study areas (PSL : n = 272, FSM : n = 543, SMC : n = 439) with similar participation rates on solicited doors (22–23 %). Among people who were home when we knocked on their door, the response rate was approximately 45–46 %. In the industrial zone, reasons for non-participation included health reasons (e.g., being too sick). The average participant age ranged from 51–55 across the three towns (Table 1). Almost fifty people participated in the 19 workshops in all three towns. Workshop size ranged from 1 to 13 participants ; workshop participants included survey participants, invited experts (medical specialists, physicians, air pollution measurement engineers), as well as people from local unions, civic associations and local activists. Most participants came once (66 %) ; others came two or three times (24 %), and a few even more frequently (10 %).

There were some differences between our survey participants and the demographics of the towns. Women and people aged 65–79 were over-represented (Table 1). People without any diploma were under represented and people with a high school degree were over-represented. However, these imbalances were consistent across the three towns, such that it did not affect our comparisons across the towns, and we took into account gender and age imbalances when we conducted direct age- and gender-standardized prevalences. Additionally, the number of persons per household and the time spent at the current address were very close to those of the town census [24].

3.2. Exposures to environmental pollution

3.2.1. Quantitative findings

The proportion of current smokers in the three towns (SMC : 25.5 % ; PSL : 27.2 % ; FSM : 31.5 %) was slightly lower than the French national average (34.1 %) [25]. We also documented workplace exposures. In our SMC sample, 26.7 % of workers reported working or having worked in the industrial area of Fos/Etang de Berre. In addition, 32.3 % of SMC workers reported working or having worked in the agricultural sector. Of these, about half (46.9 %) reported being exposed to pesticides and 16.8 % did not know if they had been.

Residents had expressed concern about exposure to pollution through consuming local fish. PSL residents were the largest consumers of local fish (58.5 %), compared to the inhabitants of FSM (44.3 %) and SMC (17.5 %). Among those who consumed local fish, most of the fish consumed (by residents from all three towns) came from the Golf de Fos (more than 78 %). It should also be noted that the Port-Saint-Louisiens also consume fish from the Rhône (17.2 %).

3.2.2. Qualitative findings

In general, during the collaborative workshops, the participants identified different sources of pollution that could affect health in the three towns.

First, there was air pollution. The participants recalled that, while the towns of PSL and FSM are directly exposed to industrial pollution in the air, the town of SMC is also exposed to a lesser extent, due to the dispersion of volatile pollutants in the industrial area of the Étang de Berre. Some participants discussed how the wind pattern is balanced throughout the year. This information was partly corroborated by a local study that investigated the influence of meteorological conditionson bioaccumulation of atmospheric pollutants in lichens [43]. The cumulative east and south winds would account for one third of the winds, the northern winds another third, and it would seem that the other days are days without wind. The authors reported that the winds were balanced during the study period (2016) between the northwestly predominant winds (called “Mistral”, 48%), and the southeast and northeast winds thar regularly occur (18% and 22%, respectively), partly through sea breeze events. Precisely, the days reached by the winds of the south-east are days where the pollution related to the industrial activity are widespread in SMC. In addition to the air pollution from stationary sources like industrial facilities, there was also concern about air pollution from mobile sources. Focus group participants noted that SMC has substantial road traffic, directly related to the industrial activity and the important logistics platform near the town. Road traffic is observed in proportions comparable to those of PSL and FSM.

Participants reported concerned regarding their exposure to polychlorinated biphenyls (PCBs), dibenzo-*p*-dioxins (PCDDs) and dibenzofurans (PCDFs), through seafood consumption. Indeed, participants reported the results from a local associative research center, the Institut Écocitoyen pour la Connaissance des Pollutions, which recently showed that the frequent consumption of seafood (e.g., fish, shellfish) of a local origin (Gulf of Fos – Berre Lagoon) increased the impregnation of pollutants [1] [12]. These results were corroborated by another local study which reported important levels in congers' muscle tissues [26].

Collaborative workshop participants also noted that some residents of SMC had occupational and/or prior residential exposure to FSM and PSL. Some of the inhabitants of SMC reported working or having worked in the industrial area of the Etang de Berre (26.6 % of participants). Additionally, some of the inhabitants of SMC also reported having lived in the industrial zone.

3.3. Health issues in the region

3.3.1. Quantitative findings

We surveyed participants about many health issues. We asked participants about a variety of chronic health issues, including asthma, respiratory diseases other than asthma, respiratory allergies other than hay fever, chronic skin problems, diabetes, endocrine disorders, autoimmune disorders, and cancers (Table 2).

The prevalence of having any chronic disease was not different between FSM and PSL (63.5 % ; 95 %CI : 60.1, 66.9) and SMC (56.5 % ; 95 %CI : 51.6, 63.3). There was not a statistically significant difference in the prevalence of cancer in the two areas : 10.6 % (95 %CI : 8.6, 12.7) of survey participants in FSM and PSL and 9.6 % (95 % CI : 7.0, 12.2) of participants in SMC report having been diagnosed with at least one cancer during their lifetime (French national cancer prevalence = 6 % in 2008 [27]). The prevalence of diabetes in

Table 1
Demographics of the study population and towns of Port-Saint-Louis-du-Rhône, Fos-sur-Mer and Saint-Martin-De-Crau.

Demographics	Port-Saint-Louis-du-Rhône Participants (n = 272)	Town[a] (n = 8,588)	Fos-sur-Mer Participants (n = 543)	Town[a] (n = 15,831)	Saint Martin de Crau Participants (n = 439)	Town[a] (n = 13,673)
Gender						
Women	160 (59 %)	4502 (52 %)	311 (57 %)	8067 (51 %)	257 (58.5 %)	7160 (52 %)
Men	109 (40 %)	4086 (48 %)	231 (43 %)	7764 (49 %)	182 (41.5 %)	6513 (48 %)
Gender ratio	1.5	1.1	1.3	1.0	1.4	1.1
Missing data	NA's = 3		NA's = 1		NA's = 0	
Age[b]						
20–34 years	45 (17.0 %)	1448 (22.1 %)	97 (18.7 %)	2436 (21.0 %)	75 (17.3 %)	2150 (20.7 %)
35–49 years	62 (23.4 %)	1583 (24.1 %)	129 (24.9 %)	3431 (29.6 %)	109 (25.1 %)	2765 (26.6 %)
50–64 years	68 (25.7 %)	1782 (27.1 %)	138 (26.6 %)	3255 (28.0 %)	107 (24.7 %)	2455 (23.6 %)
65–79 years	70 (26.4 %)	1212 (18.5 %)	129 (24.9 %)	1967 (17.0 %)	122 (28.1 %)	2237 (21.5 %)
80 or more years	20 (7.5 %)	539 (8.2 %)	26 (5.0 %)	510 (4.4 %)	21 (4.8 %)	784 (7.6 %)
Missing data	-		-		NA's = 2	
	Range : 18–98 years Mean : 54.2 (± 18.2) years		Range : 18–98 years Mean : 51.83 (± 18.1) years		Range : 19–97 Mean : 53.28 (± 17.8) years	
Household size	N = 619 Mean = 2.28	Mean [c] = 2.24	N = 1426 Mean = 2.63	Mean = 2.5	N =1082 Mean = 2.48	Mean = 2.25
How long at current address (in years)	Mean = 16.4 years	Mean = 15.6 years	Mean = 14.6 years	Mean = 14.5 years	Mean = 16.19 years	Mean = 15.8 years
How long in town (in years)	Mean = 33.2 years	-	Mean = 23.0 years	-	Mean = 24.7 years	
Education level [d]						
No diploma (or at least BEPC, DNB etc.)	37 (13.6 %)	40.4 %	25 (4.6 %)	27.7 %	51 (11.6 %)	30.9 %
High school degree (BEPC or CAP)	117 (43.0 %)	30.3 %	235 (43.3 %)	32.7 %	154 (35.1 %)	28.1 %
Baccalaureate diploma program	46 (16.9 %)	16.8 %	108 (19.9 %)	19.4 %	92 (21.0 %)	17.7 %
Any higher education degree	38 (14.0 %)	12.6 %	119 (21.9 %)	20.2 %	83 (18.9 %)	23.3 %
Other	12 (4.4 %)	-	11 (2.0 %)	-	1 (0.2 %)	–
Missing data	22 (8.1 %)	-	45 (8.3 %)	-	58 (13.2 %)	–

Sources : data for Fos-sur-Mer, Port-Saint-Louis-du-Rhône and Saint Martin de Crau is « Insee, RP2015 exploitation principale, géographie au 01/01/2017 » - INSEE (2015)[19].Source is INSEE (2012) because source INSEE (2015) was not available.

[a] Sources : data for Fos-sur-Mer, Port-Saint-Louis-du-Rhône and Saint Martin de Crau is « Insee, RP2015 exploitation principale, géographie au 01/01/2017 » - INSEE (2015)[19].

[b] Respondents aged [18–19] years are not represented for SMC, FSM and PSL for comparison reasons with Insee age categories available only by 5-year cuts.

[c] Source is INSEE (2012) because source INSEE (2015) was not available.

[d] Towns total inhabitants effective are slightly different for education level compared to the other variables (N_{PSL} = 6531 ; N_{FSM} = 11,478 ; N_{SMC} = 10,308).

Notes : NA's = missing data.

Table 2
Standardized prevalencesof health issues of respondents in Port-Saint-Louis-du-Rhône, Fos-sur-Mer and Saint-Martin de Crau, using Metropolitan French population

	Saint-Martin-de-CrauRespondents *N* = 439 (%, 95 %CI)	Fos-sur-Mer and Port-Saint-LouisRespondents *N* = 816 (%, 95 %CI)
Chronic conditions		
All respiratory diseases	37.5 (32.8, 42.3)	40.2 (36.7, 43.7)
Asthma	16.3 (12.6, 20.0)	15.8 (13.2, 18.4)
Other respiratory issues than asthma	11.4 (8.3, 14.4)	13.3 (10.9, 15.6)
Hay fever (pollen)	43.2 (38.4, 48.1)	42.3 (38.7, 45.8)
Other respiratory allergies (mold, cockroach etc.)	23.5 (19.2, 27.7)	25.6 (22.5, 28.7)
Cancers	9.6 (7.0, 12.2)	10.6 (8.6, 12.7)
All diabetes	7.9 (5.6, 10.2)	11.9 (9.7, 14.0)
Type I	0.8 (0.1, 1.4)	1.0 (0.4, 1.7)
Type II	5.8 (3.8, 7.8)	9.3 (7.3, 11.2)
Endocrine disease other than diabetes	10.1 (7.5, 12.7)	11.6 (9.5, 13.6)
Autoimmune diseases	10.4 (7.5, 13.4)	8.8 (6.9, 10.7)
Chronic symptoms		
Eye irritation	32.1 (27.6, 36.6)	42.9 (39.4, 46.5)
Nose and throat problems	29.8 (25.4, 34.2)	38.7 (35.2, 42.3)
Skin problems	20.2 (16.4, 24.0)	26.7 (23.5, 29.8)
Severe fatigue for at Least one month	29.4 (25.4, 33.4)	33.2 (29.9, 36.5)
Frequent headache	14.6 (11.0, 18.1)	38.6 (35.2, 42.0)

FSM and PSL (11.9 % ; 95 % CI : 9.7, 14.0) was higher than the prevalence of diabetes in SMC (7.9 % ; 95 %CI : 5.6, 10.2).

We also asked about acute symptoms that occurred multiple times and/or over an extended period of time. For some symptoms (eye irritation, nose and throat problems, skin problems, and frequent headaches), the prevalence was statistically significantly higher in FSM and PSL than SMC (Table 2).

3.3.2. *Qualitative findings*

The quantitative results for chronic diseases in FSM and PSL did not surprise collaborative workshop participants. They found it logical that, in a territory highly exposed to industrial pollution, the population could be suffering from chronic health issues, and that this would also be true for SMC on the periphery of the industrial zone and not just FSM and PSL. The available national indicator that suggests a significant gap between the three towns studied and the French population further supports participants' hypotheses of elevated chronic diseases in industrial territories.

Focus group participants identified stress as another important explanatory factor for chronic diseases in the industrial zone. They described stress as frequently present, especially for people who work in industry. They recall that physical and psychological stress can weaken the immune system potentially leading to chronic diseases.

In the focus groups, participants noted that air pollution is more concentrated and pollution peaks are more frequent on the industrial front, which could explain the higher prevalence of these symptoms in FSM and PSL, compared to SMC, if these symptoms reflect people's immediate physical responses to pollution episodes. For the participants, the elevated chronic symptoms seem to corroborate the hypothesis of a greater air pollution in the towns of FSM and PSL than of SMC. According to them, the symptoms illustrate the almost immediate reaction of the human body exposed to pollution. In one focus group in SMC, someone who had lived in FSM and Martigues (another town in the region) (and works in Martigues) and then settled for a year in SMC explains their comparative observations about living in the two towns : "Children no longer have eye irritation, coughs and runny noses all the time since we moved to St. Martin."

4. Discussion

In general, study participants who lived closer to the core industrial zone (residents of FSM and PSL) had higher prevalences of health issues than people who lived further away (residents of SMC). Nevertheless, our results suggest that the SMC population also experiences health problems that are elevated in comparison to French health statistics (which were calculated using different, but comparable enough, methods) [11]. By triangulating across our quantitative and qualitative data, and reaching similar conclusions from the findings, we increased understanding of and trust in our findings as accurately reflecting the health of this region.

We found several statistically significant differences, where FSM and PSL had a higher prevalence of illnesses than SMC, including chronic symptoms (e.g., nose and throat irritation, eye irritation, chronic skin problems, headaches, and extended fatigue). Based on the demographic data available, we assume that the towns of the industrial core and Saint-Martin-de-Crau are demographically and socioeconomically similar enough to be compared, especially for the direct standardized prevalences. There are also elevated health issues (e.g., cancer) in both communities in comparison to the general French population [11]. These health issues are complex and multifactorial, and likely involve interactions between genes and environmental and social determinants over the long term. In the collaborative workshops, participants shared qualitative data illustrating links between their exposure to environmental pollution and the health issues that they and other residents experienced. Given our study's documentation of elevated health issues across this region (some of which are particularly pronounced closer to the center of the industrial zone), and given the extensive body of research documenting the health hazards of industrial pollution, it is likely that industrial pollution has affected the health status of people in this region.

Our study had several strengths. Collecting both quantitative and qualitative data in three different towns, with different types of exposures to pollution, was novel. Our study was also relatively large for a community-based participatory health study, which allowed us to have the statistical power to detect statistically significant differences in many instances (although some analyses remained underpowered). Our community-based participatory research approach, useful for working with heterogeneous data, helped increase the scientific rigor, public relevance, and policy reach of our study [3,28,29]. Our random sample of residents increased the generalizability of our findings. Getting both quantitative and qualitative insights about residents' health experiences through a strongly participatory process (Figures 2 and 3) increased the richness of our understanding of the past history, environment and health issues in the Étang de Berre. Specifically, when epidemiologic participatory health studies are produced with the community, asking their questions and including their analyses, the findings can be reported in conversation with local observations. This empirical alignment between what residents have observed and the health report can lead to both trust in science and

hermeneutical clarity on the part of citizens [38]. This robustness of civically enhanced science produces what has been termed "knowledge justice knowledge about health from the perspective of the people for whom the science matters and can have impacts" [29]. This scientific knowledge both relevant to, and firmly grasped by, the local population was utilized to vociferously advocate for policy change in the press and to policy makers [30]. We found extensive media coverage of our study, in comparison to little media coverage of previous, non-participatory studies in the region [31]. While it is still too early to fully gauge the political significance of this approach, we plan to investigate this in the future.

We relied on self-reported data about health issues, rather than medical records or administrative health data. However, some scholars have shown that self-reported health data is equally complete or more complete than administrative health data [32,33]. Self-reported data can be useful for documenting symptoms, as an early warning signal [34], that may not have otherwise led to medical attention, but can also be less comprehensive than medical record data for specific diagnoses [35]. However, our survey questions were worded specifically asking as to whether participants had health issues that had been diagnosed by a doctor or other health professional. We do not assume that our self-reported data has the same level of precision as medical records, but we were also more likely to capture a broader view of population health in the region as well as ascertain other health experiences (like chronic skin irritation or headaches) that people may have not necessarily contacted a health professional to discuss. Therefore, we argue that this survey provides useful insights about the population's health that can be complementary to those documented in medical records as we have argued elsewhere [14]. Finally, we contributed to the body of literature of self-reported health data in industrial zones in France [36,37].

People chose to participate in collaborative workshops for many reasons. We did not record collaborative workshop attendance for phase 1 in FSM and PSL, but we observed at phase 2 in SMC that most collaborative workshops attendees came once (> 60 %) but some came up to 5 times. Most participants had at least some interest in environmental health in the region, but others came for social reasons. We noted that, like FSM and PSL collaborative workshop participants, many attendees in SMC had a strong personal connection with the industrial port zone, including working there and/or knowing someone who worked there, and/or having a health issue that they link with the surrounding occupational and/or residential environment. The experts, local union members and association members came to the workshops for professional (and sometimes also personal) reasons. Among the survey participants who also participated in collaborative workshops, many chose to increase their engagement in our study out of interest in environmental and/or occupational exposures and/or interest in the health of future generations. Finally, the attendees were generally older ; fewer young people participated. In the future, it could be worth identifying strategies to more deeply engage with young people to make sure their perspectives are heard. Further details about the collaborative workshop process and participants are published elsewhere [16].

We offer several recommendations for future research, drawing from our research findings and collaborative workshop participants' specific ideas on this topic. First, there needs to be more regional health data available to researchers. The existing cancer observatory, REVELA13, which opened in 2011, follows three types of cancers (kidney tumors, bladder tumors, and acute leukaemia) [38] ; it is an important first step, but is insufficient. The workshop participants recommended creating new secondary datasets that include medical records and can track all cases and types of cancers and other environment-related diseases, such as Type I diabetes and other autoimmune and neurological diseases ; we agree that this would be useful for more comprehensively understanding the health of this region. This would be particularly useful for capturing quick-onset and rapidly deadly diseases, which are less likely to be detected in a prevalence study like ours. Second, we identify areas for further research, including the health impacts of noise. Noise seems to be a daily problem for the inhabitants of the three towns in our study (e.g., hail guns used in agriculture, air and road traffic), and has also been documented as an emerging, underacknowledged issue elsewhere [20]. We did not collect any data on auditory health issues, or decibel levels in the environment, and encourage future researchers to do so. Additionally, fertility issues were mentioned by numerous residents, and merits further, more detailed exploration by future researchers.

Finally, the insights of residents and other community stakeholders enriched our study in many ways, from the data collection through the data interpretation phases, and even including recommendation for "next steps" to address the problems. This increased the relevance of the study to the local population, and we encourage future researchers to do similarly participatory research [39] or develop civic expertise in environmental health [40].

Again triangulating between our findings and specific ideas from workshop participants, we also have recommendations for future policy and practice. First, in order to more immediately address the health issues, we recommend providing additional health services to residents of this and other industrial zones, which may also require modifying clinical guidelines to account for this higher-risk population (for example, beginning cancer screenings at an earlier age). Second, residents recommended environmental policy changes to help reduce the health consequences of the pollution burden that residents experience. Such changes could include regulations that reduce both stationary (e.g., traditional industrial facilities) and mobile sources of pollution. This could include reducing road traffic and/or improving/modifying vehicle exhaust systems, increasing train freight as a transportation approach (over truck transport), and pursuing electrification of cargo ships (which currently emit nitrogen oxides, sulphur oxides and particulate matter) alongside the quays. Policies could also be enacted to require and share more and more comprehensive pollution data. For example, pollution regulations could be revised to better account for the cocktail of myriad pollution sources in the region. And, while the burden should not be placed entirely on individuals, residents could benefit from having access to clear information about daily emissions levels or industrial incidents so that they could plan activities accordingly to best protect their family's health.

This study shows the need to pay particular attention to the state of health of the inhabitants of an industrial zone, including those living on the periphery of the zone. The quantitative results, which have been reinforced and made contextually relevant with the collaborative workshop findings, highlighted the desire of many community members to be included in the full scientific enterprise. Combining both quantitative and qualitative approaches produced a final public report that included the perspectives of the local population within the study's bounds [21]. It is also an opportunity to demonstrate the importance and the richness of participatory science for better understanding health outcomes and potential solutions from the perspective and knowledge of those who live in distressed environments [5,41]. This locally-anchored approach, which is currently rarely used in France, would be particularly interesting to deploy in other regions of France, as well as around the world. This approach is also a way to engender trust among local citizens in the particular French context. In closing, we find that conducting epidemiological studies closely with local people, who live and experience environmental pollution on a daily basis, is a robust and rigorous approach to produce new, useful, and relevant public and environmental health knowledge [42].

5. Conclusion

We encourage future researchers to do in-depth, community-based epidemiology research to comprehensively describe the health of residents in other heavily polluted zones, product local knowledge

and to help identify policy solutions, suggest opportunities for intervention and engender trust among the local people.

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References

[1] Wu X, Cobbina SJ, Mao G, Xu H, Zhang Z, Yang L. A review of toxicity and mechanisms of individual and mixtures of heavy metals in the environment. Environ Sci Pollut Res 2016;23(9):8244-59.
[2] Svingen T, Vinggaard AM. The risk of chemical cocktail effects and how to deal with the issue. J Epidemiol Community Health 2016;70(4):322-3.
[3] Cohen A, Lopez A, Malloy N, Morello-Frosch R. Our environment, our health: a community-based participatory environmental health survey in Richmond, California. Health Educ Behav 2012;39(2):198-209.
[4] Shamasunder B, Collier-Oxandale A, Blickley J, Sadd J, Chan M, Navarro S, et al. Community-based health and exposure study around urban oil developments in South Los Angeles. Int J Environ Res Public Health 2018;15(1):138.
[5] Davis LF, Ramírez-Andreotta MD. Participatory research for environmental justice: acritical interpretive synthesis. Environ Health Perspect 2021;129(2):26001.
[6] Brody JG, Morello-Frosch R, Zota A, Brown P, Pérez C, Rudel RA. Linking exposure assessment science with policy objectives for environmental justice and breast cancer advocacy: the northern California household exposure study. Am J Public Health 2009;99(Suppl 3):S600–9.
[7] CGEDD. In: Legrand H, Mir C, editors. La pollution de l'air dans le secteur de l'étang de Berre. ConseilGénéral de l'Environnement et du Développement Durable; 2018. p. 80..
[8] OREP. EnquêtePanoxy-Berre. 1996.
[9] Pascal-Bensa L, Stempfelet M, GoriaS, Lasalle JL, Pascal M, Declercq C https://www.em-consulte.com/en/article/694141
[10] Bazyar J, Pourvakhshoori N, Khankeh H, Farrokhi M, Delshad V, Rajabi E. A comprehensive evaluation of the association between ambient air pollution and adverse health outcomes of major organ systems: a systematic review with a worldwide approach. Environ Sci Pollut Res Int 2019;26(13):12648-61.
[11] Cohen AK, Richards T, Allen BL, Ferrier Y, Lees J, Smith LH. Health issues in the industrial port zone of Marseille, France: the Fos EPSEAL community-based cross-sectional survey. J Public Health 2018;26(2):235-43.
[12] Goix S, Periot M, Douib K. Etude INDEX. Etude d'imprégnation de la population aux polluantsatmosphériques de la zone industrialo-portuaire de Fos-sur-Mer. Institut Ecocitoyen pour la Connaissance des Pollutions (IECP); 2018.
[13] Dab W, Ségala C, Dor F, Festy B, Lameloise P, Moullec YL, et al. Pollution Atmosphériqueet Santé: CorrélationouCausalité? Le Cas de la Relation entre l'Exposition aux Particules et la Mortalité Cardio-pulmonaire. J Air Waste Manag Assoc 1995 2001;51(2):203-19.
[14] Dotson MP, Allen BL, Cohen AK. "Allergic to the Region": apopulation-based study of the diversity of health experiences in the industrial zone of Marseille, France. Environ Justice 2020 [cité 20 nov 2020]; Disponible sur: https://www.liebertpub.com/doi/abs/10.1089/env.2020.0023.
[15] Perez S. Étude AIR-SANTE en Pays de Martigues : apports de l'IntelligenceArtificielle aux questions de santé environnementale. Nice, France: Université Côte d'Azur; 2019. [cité 22 févr 2021] p. 255. Disponible sur: https://hal.archives-ouvertes.fr/hal-03031201.
[16] Minkler M. Linking science and policy through community-based participatory research to study and address health disparities. Am J Public Health 2010;100 (Suppl 1):S81–7.
[17] Allen BL, Cohen AK, Ferrier Y, Lees J, Richards T. Redesigning a participatory health study for a French industrial context. NewSolut J Environ Occup Health Policy 2016;26(3):458-74.
[18] Allen BL, Lees J, Cohen AK, Jeanjean M. Collaborative workshops for community meaning-making and data analyses: how focus groups strengthen data by enhancing understanding and promoting use. Int J Environ Res Public Health 2019;16(18) [cité 3 févr 2020]Disponible sur: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6765948/.
[19] GDPR. Disponible sur: https://gdpr-info.eu/art-4-gdpr/
[20] Cohen AK, Lopez A, Malloy N, Morello-Frosch R. Surveying for environmental health justice: community organizing applications of community-based participatory research. Environmental Justice 2016;9(5):129–36.
[21] Lees J, Jeanjean M. FOS EPSEAL - Rapport citoyen - Étude participative en santé environnement ancrée localement sur : Le front industriel de Fos-sur-Mer et Port-Saint-Louis-du-Rhône (volet 1), La commune de Saint-Martin-de-Crau (volet 2). 2019.
[22] R core Team. R : alanguage and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2014. Disponible sur: www.R-project.org.
[23] Corbin J, Strauss A. Basics of qualitative research: Techniques and procedures for developing grounded theory. SAGE, 2014. SAGE; 2014.
[24] INSEE. Dossiers complets, communes de Fos-sur-Mer et de Port-Saint-Louis-du-Rhône et Saint-Martin-De-Crau (issus des Recensementsgénéraux de la population 2007 et 2012). Disponible sur: https://www.insee.fr/fr/accueil.
[25] Guignard R, Beck F, Wilquin JL, Andler R, Nguyen-Thanh V, Richard JB, et al. La consommation de tabac en France et son évolution : résultats du Baromètre santé 2014. Bull Epidémiol Hebd. 2015;(17-18):281-8. http://www.invs.sante.fr/beh/2015/17-18/2015_17-18_1.html
[26] Dron J, Revenko G, Chamaret P, Chaspoul F, Wafo E, Harmelin-Vivien M. Contaminant signatures and stable isotope values qualify European conger (Conger conger) as a pertinent bioindicator to identify marine contaminant sources and pathways. Ecol Indic 2019;107:105562.
[27] Colonna M, Mitton N, Grosclaude P. Estimation de la prévalence (partielle et totale) du cancer en France métropolitaine chez les 15 ans et plus en 2008 - Étude à partir des registres des cancers du réseauFrancim - Boulogne-Billancourt. [cité 14 juin 2019]. Disponible sur: https://www.e-cancer.fr/Expertises-et-publications/Catalogue-des-publications/Estimation-de-la-prevalence-partielle-et-totale-du-cancer-en-France-metropolitaine-chez-les-15-ans-et-plus-en-2008.
[28] Balazs CL, Morello-Frosch R. The three Rs: how community-based participatory research strengthens the rigor, relevance, and reach ofscience. Environ Justice 2013;6(1):9-16.
[29] Allen BL. A successful experiment in participatory science for promoting change in a French industrial region. Engag Sci Technol Soc 2017;3(0):375-81.
[30] Nossiter A. One of Europe's most polluted towns stages:a noisy revolt. Disponible sur https://www.nytimes.com/2020/04/01/world/europe/france-pollution-fos-sur-mer.html.
[31] Duarte CdP, Cohen AK, Allen BL. Community-based participatory research in the news: aqualitative case study of the online media characterization of a French health study. Science Communication. Science Communication 2020. [cité 19 mars 2020]Disponible sur; https://journals.sagepub.com/doi/10.1177/1075547020909463.
[32] Fortin M, Haggerty J, Sanche S, Almirall J. Self-reported versus health administrative data: implications for assessing chronic illness burden in populations. A cross-sectional study. CMAJ Open 2017;5(3):E729-33.
[33] Lujic S, Watson DE, Randall DA, Simpson JM, Jorm LR. Variation in the recording of common health conditions in routine hospital data: study using linked survey and administrative data in New South Wales, Australia. BMJ Open 2014;4(9):e005768.
[34] Spurgeon A, Gompertz D, Harrington JM. Modifiers of non-specific symptoms in occupational and environmental syndromes. Occup Environ Med 1996;53(6):361-6.
[35] Jiang L, Zhang B, Smith ML, Lorden AL, Radcliff TA, Lorig K, et al. Concordance between self-reports and Medicare claims among participants in a national study of chronic disease self-management program. Front Public Health 2015;3 [cité 20 nov 2020]. Disponible sur: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4597005/.
[36] Daniau C. Surveillance épidémiologiquefondée sur des indicateurs de santé déclarée : pertinence et faisabilité d'un dispositif à l'échelle locale en santé environnement. Paris: CNAM; 2014. Thesis[cité 29 janv 2020]. Disponible sur: http://www.theses.fr/2014CNAM0923.
[37] Daniau C, Wagner V, Salvio C, Kermarec F, Bérat B, Stempfelet M, et al. État de santé perçue de la population riveraine d'une plateforme industrielle chimique : Salindres. Environ Risques Santé 2018;17(6):583-95.
[38] Mantey K, Pascal L, Cortaredona S. Observatoire des cancers du rein, de la vessie et des leucémiesaiguës chez l'adulte dans le département des Bouches-du-Rhône (REVELA13). Analyses spatiales, 2013–2016. Saint-Maurice : Santé publique France; 2019. p. .80.www.santepubliquefrance.fr.
[39] Allen BL. Strongly participatory science and knowledge justice in an environmentally contested region: Sci Technol Hum Values. [cité 2 mars 2020]Disponible sur: https://journals.sagepub.com/doi/10.1177/0162243918758380.
[40] Calvez M. What is civic expertise in environmental health? Queries about the Ambassad'Air experiment in Rennes. Environ Risques Santé 2018;17(5):498-504.
[41] Cacari-Stone L, Wallerstein N, Garcia AP, Minkler M. The promise of community-based participatory research for health equity: aconceptual model for bridging evidence with policy. Am J Public Health 2014;104(9):1615-23.
[42] Bach M, Jordan S, Hartung S, Santos-Hövener C, Wright MT. Participatory epidemiology: the contribution of participatory research to epidemiology. Emerg Themes Epidemiol 2017;14(1):2.
[43] Dron J, Ratier A, Austruy A, Revenko G, Chaspoul F, et Wafo E. 2021. « Effects of Meteorological Conditions and Topography on the Bioaccumulation of PAHs and Metal Elements by Native Lichen (Xanthoria Parietina) ». Journal of Environmental Sciences 109 (novembre): 193-205. https://doi.org/10.1016/j.jes.2021.03.045.

[1] Jeanjean M, Goix S, Periot M, Douib K, Dron J, Etienne MP, et al. https://doi.org/10.1007/s12403-021-00395-8.