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1. Executive summary

Despite the calls for action in the context of the climate emergency, fossil fuels continue to be the main energy source in the world (82%) and the EU (71%). The fossil fuel industry, in all its three main stages – upstream, midstream, and downstream –, is one of the most polluting industries worldwide. By producing environmental data and knowledge, Citizen Science might offer a unique opportunity to improve the industry operational practices and minimize the risks posed to the health of the people living in the vicinity of the fossil fuel infrastructure. This document summarises the best practices, lessons learnt and benefits of using citizen science for environmental monitoring of the fossil fuel industry, while at the same time highlights the obstacles that citizen science face that prevent the improvement of the environmental performance of the energy sector. To do so, this document examines environmental Citizen Science initiatives for the environmental monitoring of oil, gas and coal exploration, extraction and refining across (mainly) the EU.

The EU (and global) initiatives were selected using a three-step methodology collaboratively developed by all project partners. This process included a literature review involving a comprehensive search across academic databases, an exploration on the Environmental Justice Atlas (EJAtlas), and the use of snowball method for identifying environmental citizen science initiatives on the Fossil Fuel industry.

These citizen science initiatives demonstrate different levels of success in influencing the development of new environmental regulations and law enforcement mechanisms, and controlling the expansion of these industries. Notably, successful examples in Marseille and Sarroch led to the establishment of new emissions limits and policy changes through formal channels. While not all CS projects have directly impacted regulations, they have raised awareness, prompted further environmental and health studies, and advanced methodologies for pollution surveillance. For instance, several initiatives described underneath have linked specific pollutants to public health issues, such as increases in respiratory diseases and cancer. In the case of coal mining, participatory monitoring has empowered vulnerable communities by providing them with the skills and tools to confront environmental and health threats.

The effectiveness of CS data depends on factors such as accuracy, timeliness, and accessibility, which require adequate training, standardized protocols, centralized platforms, and targeted communication. Additionally, citizens participating in these programs need ongoing support and quality control measures to ensure data reliability. Technological tools, such as GPS-enabled devices

and automated sensors, enhance data accuracy, while real-time data collection and open data policies improve accessibility and usability.

The advantages of CS include increasing public awareness, enhancing community participation, and providing extensive geographic and temporal data coverage. However, challenges remain, such as ensuring data quality, institutional acceptance, participant support, and managing societal implications. Issues such as funding sources, participant retention, and tool certification can affect the reliability and legal acceptability of CS data. Preventive risk analysis and informed consent can mitigate negative social impacts and prepare communities for the implications of CS activities. In fact, while CS has significant potential to improve environmental monitoring and regulation, it faces obstacles that must be addressed to maximize its effectiveness and impact.

2. Introduction

This document compiles mainly EU fossil fuel projects where pollution from fossil industries has harmed the environment and public health, and where citizen responses have led to citizen science (CS) initiatives for controlling pollutants through participatory monitoring methods. It also outlines the initial phase of the 'Environmental Monitoring through Civic Engagement' project (ERICA). This Erasmus Plus initiative, co-funded by the European Union, involves the following academic and scientific institutions and environmental justice organizations: the University of Barcelona (UB), the International Institute of Social Studies (ISS), the Adama Mickiewicz University (AMU), the Environmental Volunteer Association Cova Contro, Source International ONLUS, and the European Association for Local Democracy (ALDA). The goal of this phase is to study reference cases to help create the ERICA E-booklet of Best Practices, an open-access online platform to promote and support citizen science initiatives for monitoring pollutants produced by fossil industries.

The cases described below illustrate how CS is an indispensable tool to enrich the scientific knowledge of society by providing more and better data while educating and empowering citizens. In the following description, the selected cases include examples where the population itself took the initiative to carry out environmental monitoring, as well as cases where other entities (researchers, private or public agencies) promoted citizen participation. By examining these examples, we will explore methodological approaches to implement CS, but also how CS has influenced society, contributing to the development of public policies aimed at improving industrial practices such as the investment in advanced technology and open-access monitoring systems. All this information will be integrated into an educational Website: The E-booklet of best practices that will be easily accessible to the public for implementing DIY monitoring initiatives based on previous experiences from other places in Europe and beyond.

As we consider that only a participatory and well-educated society can face the new challenges of the industrialized world in the context of climate change, we aim to assess whether CS initiatives can provide more and better data for science research and at the same time educate and empower civilian population.

Citizen science can be defined as the non-professional involvement of volunteers in the scientific process, including problem definition, data collection, data analysis and interpretation, and the dissemination of results (Cohn, 2008; Silvertown, 2009). Citizen science is a powerful tool for public engagement and empowerment in policy-making and for raising awareness of environmental or other

socially-relevant issues. The potentiality of collaborative science to produce crow-sourced data is also clear. However, there are underlying tensions at the basis of citizen science, since the term has been broadly used for public participation in science, frequently meaning free or cheap labour, in an exploitative way, providing data for scientists and entrepreneurs who have set up the system: "scientists using citizens as data collectors" rather than "citizens as scientists" (Lakshminarayanan, 2007). In most initiatives that claim to be citizen science projects, participation is circumscribed to data collection (crowdsourcing). This document does not cover these initiatives where citizen involvement is limited to their participation in data collection. In here, we use the normal acceptation of citizen science, i.e. science by and for the citizens, aiming at the empowerment of citizens and the democratisation of science. Citizen science as a bottom-up process that seeks political action and social transformation. This acceptation of citizen science has been also named "extreme citizen science" (Haklay, 2013).

3. Methodology

The CS initiatives presented below, related to petrochemical industries, coal mines and oil and gas exploration and extraction sites, were selected using a three-step methodology collaboratively developed by all project partners. This process included a literature review involving a comprehensive search across academic databases, an exploration on the Environmental Justice Atlas (EJAtlas), and the use of snowball method for identifying environmental citizen science initiatives on the Fossil Fuel industry. For each CS initiative, several attributes were collected (i.e. Country, Region, Geographical coordinates, Name and website of the citizen science initiative, Name and website of civil society organizations and stakeholders involved, Name of operating company, description of the Fossil Fuel project, Start date of operations, description of the socio-environmental conflict, description, history and start date of the Citizen science initiative, description of the monitoring system and number of people involved, parameters/pollutants and environmental matrices monitored, Sensors used and detections limits, achievements of the CS initiative, mechanism to secure actionable data and sources of information). The University of Barcelona (UB) collected data on CS initiatives on petrochemical industries, the International Institute of Social Studies (ISS) handled gas exploration and extraction, Cova Contro and Source International focused on oil extraction, and Adam Mickiewicz University (AMU) was responsible for collecting information on CS initiatives monitoring coal extraction.

To begin, a literature review was conducted following the "Guidelines for Systematic Review and Evidence Synthesis in Environmental Management" (CEE, 2013). This process started with defining a clear and focused research question using the PICO framework, which outlines the Population, Intervention, Comparator, and Outcome. This step ensured a well-defined and targeted scope for the review. A detailed protocol was developed by all partners before starting the review, including the research question, search strategy, inclusion/exclusion criteria, data extraction process, and analysis methods. Registering the protocol in a public database enhanced transparency and prevented duplication of efforts.

The review involved conducting a comprehensive search across academic databases using a combination of keywords and controlled vocabulary. For this case, the search phrase “citizen science" AND monitoring AND "INDUSTRY (i.e., oil extraction)" was used on Google Scholar for each of the four previously defined areas. After compiling an initial list of articles for each industry, a two-step relevance screening was performed: an initial screening based on titles and abstracts, followed by a detailed review of full texts applying the inclusion/exclusion criteria rigorously. Multiple reviewers participated to minimize bias and resolve disagreements through discussion. Data extraction was systematically conducted using a standardized form in Excel to ensure consistency and accuracy, and to identify the location of cases in European territory and the rest of the world. Extracted data included location, type of industry, CS initiatives, outcomes, and key findings. The quality and risk of bias of the included studies were critically appraised using standardized criteria, evaluating factors such as a full description of the CS initiative, monitoring methods, and potential conflicts.

After this initial screening, selected articles were examined for content based on keywords: “citizen science,” “type of industry (i.e. petrochemical industry)” and “monitoring.” This step turned out to be necessary because keywords often appear only in bibliographic references or specific parts of the text without being the main topic addressed by the research article. The articles selected from this keyword exploration within the complete text were then subjected to an exhaustive reading, including a review of their bibliographies. In this initial research phase, many relevant cases outside the European Union (EU) were identified.

The second phase of the case search involved exploring cases of environmental conflicts documented on the Environmental Justice Atlas (EJAtlas) website. This platform, developed in 2014 by the EJOLT project and coordinated by the Institute of Environmental Science and Technology (ICTA) at the Autonomous University of Barcelona (UAB), is an open-access tool supported by the European Commission. It is enriched by contributions from various environmental justice organizations, scientists, activists, and experts worldwide. The project aims to analyze and understand

environmental conflicts from an environmental justice perspective, integrating the knowledge of social movements with scientific research (EJOLT, 2015; Temper, Del Bene and Martinez-Alier, 2015; Del Bene, 2018; Temper *et al.*, 2018).

Similar to the first phase, the web exploration used filters to identify cases related to the four areas of fossil industries in Europe. The filters applied were "Conflict Type = *type of industry*" AND "Mobilizing form = Community-based participative research (popular epidemiology studies, etc)". The data obtained were integrated with the previous search results, refining the selection of cases to be described and filling in any missing information.

Finally, the snowball method was used with the purpose of uncovering new cases and a broader and more comprehensive set of information sources. After the initial search using Google Scholar and selecting the most suitable articles, a new list of items was created with the references cited in them. These new articles were reviewed, and the process was repeated again and again until their references were either repeating or becoming less relevant. Thanks to this method, the reliability of the information collected was improved and verified (Noy, 2008).

All methods were employed specifically to find CS initiatives in EU. However, it proved challenging to gather a relevant number of CS initiatives in EU. Therefore, it was necessary to incorporate experiences from countries outside EU, particularly for gas and coal exploration and extraction. The cases included from outside EU were selected based on the success of the CS initiatives and the reliable availability of the information needed for their description. Supplementary searches, like hand-searching reference lists and Focus Groups meetings, helped to identify additional relevant studies.

Alongside the progressive implementation of the methodology, information was also gathered from focus groups with local civil society organizations from the 3 pilot sites of the project, i.e., petrochemical complex in Tarragona (Catalonia), oil extraction in Basilicata Region (Italy) and coal mine in Turow (Poland). As focus groups are essential to various stages of ERICA, they were structured from the beginning and are detailed in the annexes of this document. Focus groups were conducted by UB in the case of the petrochemical complex in Tarragona, by Cova Contro in the case of oil extraction in Basilicata, and by AMU in the coal mine in Turow.

4. Citizen Science Initiatives

After conducting the initial search for articles in the bibliographic review using Google Scholar, the combination of keywords directed toward each of the four areas of study yielded a number of articles. These articles then underwent the phases described in the methodology. Based on the review of titles and abstracts, the articles were classified according to their relevance and location.

For the petrochemical industry, the Google Scholar search initially resulted in 200 articles, which were compiled into an Excel table by title. Of these 200 articles, 20 were discarded after the first review. Upon further review of those containing the three keywords as relevant content in the text, an additional 126 articles were discarded, along with 7 repeated titles. Moreover, 15 articles initially marked as possibly relevant were discarded after an exhaustive reading of the text. Finally, after thoroughly reading the full texts and searching for the necessary information for a complete case description, only 12 of the 54 articles initially marked as relevant were used for detailed case descriptions and as alternative references. The cases identified from this process were Tarragona, Val d'Agri, and Louisiana. The other five cases were selected through focus group meetings. Additionally, a search for environmental conflicts in Eastern, Central, and Western Europe through the EJAtlas website identified 11 cases related to "chemical industries," of which only 2 matched with the previously detected cases.

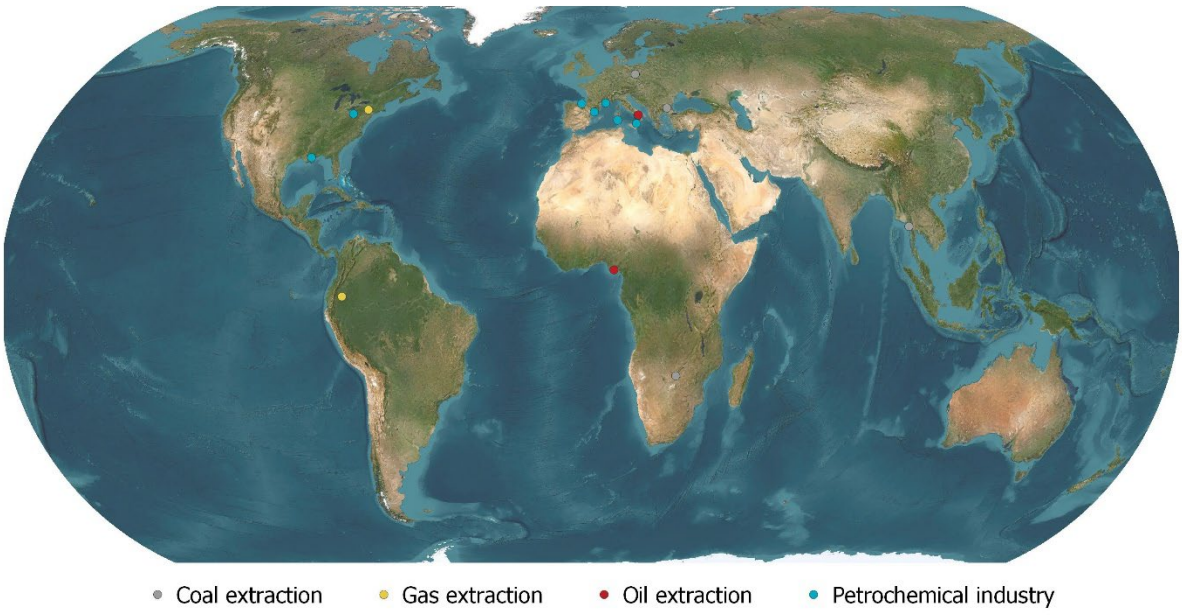

Figure 1. Citizen Science initiatives by fossil fuels industry typology

The literature review in Google Scholar on the topic of gas exploration and extraction yielded 545 articles. However, it was not possible to identify any CS initiatives for environmental monitoring in Europe with sufficient information for a detailed description. Nonetheless, relevant information was found for two cases in other parts of the world. For the Pennsylvania case alone, 171 of these articles were related in some way. The other case, from Ecuador, was selected using the snowball methodology. No environmental conflicts involving citizen participation initiatives were found in EJAtlas website for this industry in European territory

Regarding oil exploitation, 355 references were found in Google Scholar. Among these, 25 articles were linked to the 3 cases in Basilicata, Italy, and 26 were related to the Niger Delta in Nigeria. Leveraging Cova Contro's prior knowledge, it was necessary to describe three different CS initiatives within the Basilicata region. The Nigeria case was included due to its significance in terms of results and the amount of scientific information available. Both cases are also registered on the EJAtlas website, with the Basilicata case being one of the seven cases corresponding to community-based participatory research in Europe.

Regarding coal, the initial literature review conducted in Google Scholar yielded 61 articles. Among these, only the case related to Poland was referenced in 7 articles, while the other 4 had either one or no references. The search on EJAtlas resulted in 3 cases in European territory, but only Stara Zagora case in Bulgaria is described below according to the initially set parameters. Given that the CS initiatives identified out of Europe, in Myanmar and Zimbabwe through the snowball method proved relevant and well documented to the project's final objective, they were included in the following description.

4.1. Petrochemical industry

Regarding the petrochemical industry, six citizen science initiatives were identified within the EU: in Tarragona and Muskiz, Spain; Sarroch, Milazzo, and Val d'Agri, Italy; and Marseille, France. Additionally, two initiatives from the USA were included due to their relevance to citizen science, particularly in terms of monitoring systems, outcomes, and their well-documented available information.

4.1.1. Petrochemical complex of Tarragona, Spain

Fossil fuel Project

The petrochemical complex of Repsol in Tarragona has been in operation for more than 40 years. There are a set of facilities in which many petroleum products such as gasoline, diesel, jet fuel, and petrochemical feedstocks are produced. Currently the complex takes up more than 500 hectares. In Tarragona Repsol has four large areas: refining, chemistry, LPG and exploration. Through the refining process, LPG, gasoline, kerosene, diesel, fuel oil and asphalt are obtained. In butane only, 300 kilograms per minute- which would be sufficient for the annual consumption of an entire family – are produced

In the chemical area, materials such as polyethylene, polypropylene, polyol, glycol, butadiene or styrene are obtained. All these products are used to make plastic materials and a multitude of components used daily such in shower gel, shampoo, medicines, clothing, cosmetics, perfumes, computers, mobile phones, furniture, cars, mattresses, etc. (Repsol, 2024).

The complex began operating in 1971 when the construction of the first refinery was approved. It is now considered the most important of its kind in southern Europe.

Several companies are part of this extensive petrochemical and chemical network, including ASESA, BASF, BERTSCHI, CARBUROS METALICOS, CEPSA, CLARIANT, IQOXE, DOW, ERCROS, ELIX, GRACE, MESSER, TEPSA, KEMIRA, IQLIT, INOVYN, and SEKISUI.

Socio-environmental Conflict

The largest concentration of petrochemical industries in Southern Europe is located in Tarragona. The largest refinery is located in the northern part (La Pobla de Mafumet, El Morell, Perafort and Constatí). Local communities experience multiple impacts: atmospheric, acoustic, hydric and soil disturbances. Civic groups have highlighted landscape degradation and health risks generated by the petrochemical industries. Those risks include: cancer, allergies, asthma, other respiratory problems and poor quality of semen from Tarragona (Durán Castellanos, Felipe Pérez and Vilaseca Boixareu, 2018). Several epidemiological studies estimate a level of risk of lung cancer among the population of the area above the values recommended by the WHO (Ramírez, Marcé and Borrull, 2011; Ramírez *et al.*, 2012).

In 2008 residents living around the petrochemical complex created the platform Cell Net, which promoted independent studies to reveal what residents were breathing. The civic platform demanded new legislation for regulating the impacts of the local petrochemical industry.

Since the creation of the refinery, several episodes of ecological disasters were reported. In 2008, the discharge of 190 tons of liquid waste from a container carrying toxic products such as phenolic compounds were discharged to the Francolí river, killing thousands of fishes. More than 40 000 tones of naphtha were spilled in 2013, affecting the groundwater of surrounding fields. Oil spills were also located along the coast of Tarragona.

The main environmental conflict is linked to the bad odours associated with the activity of the petrochemical complex. It has been raised by the residents for years, yet the administration has always

stated that these odours are not related to any toxic product. People wanted to know what they smelled as well as what kind of products the odours were related to. Nowadays another concern is the presence of pellets on the beaches in Tarragona.

Citizen Science initiative

Organizations and campaigns

There are three civil society campaigns against the petrochemical industry in Tarragona. The campaigns "Something Smells Bad" and "Do You Know What You Breathe?" are spearheaded by Pataforma CelNet and supported by GEPEC-EdC (Study Group for the Protection of Catalan Ecosystems) and La Canonja3. Additionally, "There Is No Chemistry: Dismantling 10 Myths About the Petrochemical Industry in Camp de Tarragona" is led by Enginyeria Sense Fronteres. Other stakeholders involved include universities such as Universitat Politècnica de Catalunya-Laboratori del Centre de Medi Ambient (LCMA-UPC) and local governments, notably the Ajuntament del Morell.

Facing the latent lack of information on air quality, the civic organization Cel Net launched a campaign to state the urgent need to monitor emissions around the refinery. The association started a long negotiation with the municipalities of the norther areas, where the refinery is located. After two years of pressure, the municipalities of El Morell, Vilallonga del Camp, Constantí and Perafort-Puigdelfí got the Polytechnic University of Catalonia (UPC) to start an air monitoring project focusing identifying the pollutants in the North petrochemical area near the largest refinery. The project conducted a survey on local public health and measured air quality, determining the source of odours and emission values, producing maps for the prediction of impacts. The first results indicated the level of a carcinogenic compound, 1,3 butadiene, seven times higher than recommended (Berbís, 2017). Other carcinogenic and teratogenic compounds such as benzene and benzopyrene were detected, (Bertran, 2017). This was followed by a second, third and fourth study in 2016, 2017 and 2018. As reported by Enginyeria Sense Fronteres (Durán Castellanos, Felipe Pérez and Vilaseca Boixareu, 2018), despite the evidence collected by the studies, the Generalitat claimed that European and national regulations only demand them to control certain compounds found in the air, such as benzene, but not many others, such as 1,3 butadiene that in certain concentrations can result in health hazards, thus eluding public responsibilities.

Cel Net is a citizen organization created in 2008 by residents form the petrochemical complex of Tarragona. It seeks to promote public health and bring value back to the territory through citizen science initiatives.

Since 2014 Cel Net has launched several independent air quality studies, coordinated by the LCMA of the UPC and financed mainly by local councils. With these studies, Cel Net also launched the dissemination campaigns *'Something smells bad'', ''Do you know what you breathe?''* and *''You breathe it too''.* These initiatives seek to obtain data about the products breathed by people around the petrochemical industry, disseminate these data and ask for new regulation on all toxic petrochemical products. The studies have detected high rates of carcinogenic chemical products such as Benzene, 1-3 Butadiene, Benzo(a)pyrene or ethylene oxide.

Once these environmental studies were published, Cel net has achieved some actions and changes from both the industry and the government. In 2015 the Catalan Parliament unanimously approved

the creation of the Territorial Air Quality Board formed by citizen platforms, social agents, administrations, research centres and companies, with the joint objective of creating a new system of control, regulation, prevention and protection adapted to the industrial complexity of the area. Unfortunately, this system proved to be insufficient since many of the emitted products are not yet under legislation. In 2023 another motion, focused on the air quality of Tarragona, was approved in the Catalan Parliament. This motion proposed to increase the number of official monitoring points and to also include the analysis of 1,3 buthadiene in the surroundings of the petrochemical complex. Now the objective of Cel Net is to promote a new regulation that includes those carcinogenic pollutants produced by the industry which are not still regulated, such as 1,3-buthadiene or ethylene oxide.

Brief history

The first monitoring campaign started in 2009 and was motivated by the repeated presence of bad smells in towns around the petrochemical area. As a result, several social movements (GEPEC-ed, La Canonja 3, and Cel Net) asked a specialized laboratory (LCA-UPC) to carry out an environmental study of the air. This first study detected more than 200 VOCs in the air around the petrochemical area. After this study, other air quality studies have been financed by local governments in order to find out: a) which are the main VOCs present in Tarragona; b) which are the main VOCs related to the bad odours; c) which are the petrochemical or chemical companies responsible for this pollution? and d) which are the main toxic VOCs produced by the petrochemical industry that the current regulation do not consider.

In 2012 the municipalities of El Morell, Vilallonga del Camp, Constantí and Perafort-Puigdelfí commissioned a study on contamination focusing on pollutants present in the North petrochemical area to the Polytechnic University of Catalonia (UPC) and participating civic organisations. The surprising results triggered a series of further participatory studies in the area with dozens of people involved.

Monitoring system

Several studies were carried out by LCMA-UPC because of the social movements in Tarragona petrochemical area. The first ones, undertaken between 2013 and 2017 in twelve sampling points, focused on monitoring the maximum spectrum of VOCs present in the air (Gallego, Roca and Gadea, 2018). The last studies compared different methodologies to find the best one to monitor 1,3-buthadiene, during long low basal periods as well as during high short episodes (Gallego *et al.*, 2018) The first studies were developed thanks to the hospitality of those participants who installed the equipment from LCMA-UPC in their homes. The last studies were developed using different municipality installations. Most of the studies promoted by Cel Net have been financed by local municipalities and by an anonymous patron. The cost of the studies depends on the number of samples to analyse. Sample analysis could cost between 500€ and 700€ depending on the number of samples. The price of the analytical equipment of the thermal desorption coupled with GC-MSD is around 150-200000€.

The **parameters and pollutants monitored** in the Tarragona petrochemical industry include bad odours and their origins, 200 VOCs (with the most notorious being benzene, 1,3-butadiene, acetic acid, and ethylene oxide following the IQOXE chemical accident in 2020), PM10, and PAHs (notably

benzo(a)pyrene, benzo(a)anthracene, benzo(b+j)fluoranthene, benzo(k)fluoranthene, indenol(1,2,3-cd)pyrene, and dibenzo(a,h)anthracene). The primary environmental matrix monitored is air.

The studies performed by LCMA-UPC demonstrated that Radiello® **passive samplers** can be used for baseline 1,3-butadiene levels, while 24-hour active sampling by multi-sorbent bed tubes is advisable for relevant episodes. The **method detection limit** (MDL) for both sampling methodologies is 0.2 ng of 1,3-butadiene per sample (Gallego *et al.*, 2018; Gallego, Roca and Gadea, 2018).

Chemical control was carried out through the determination of volatile organic compound concentration levels using the following two methods: a) NTP 978: Volatile organic compounds captured by tubes; DT-CG-EM analysis; and b) EPA TO-17: Determination of volatile organic compounds in ambient air using active sampling in adsorbent tubes.

Chemical analysis was performed using a VOC capture system (screening) with tubes filled with solid adsorbents (multibed), operating at a sampling flow between 70-120 ml/min, and utilizing equipment sensors designed and manufactured in the Laboratory of the Environmental Center of the Polytechnic University of Catalonia.

Figure 2. VOC capture system. Source: UPC (2019)

The monitoring campaigns have been linked to several **achievements** 1)it has shown that the industry can regulate its production processes, as it has been done with the reductions in pollutants such as 1,3-buthadiene; 2) the regional administration has promised the installation of more air emission monitoring points in different areas 3) the industry is performing studies of air quality in towns near the petrochemical area; 4) air sampling sensors of VOCs have been installed in municipal facilities.

Civic actions led by Cel Net, and the series of study conducted have raised awareness, triggering a public demand for further studies. However, legislation has not changed yet. Following years of insistent demands by Cel Net and evidence of pollution over the recommended level, the government of the metropolitan area, the Generalitat, created a Territorial Table of the Air Quality of Camp de Tarragona. However, Cel Net claims that the Table does not meet with the required frequency, and asks the Generalitat to adopt norms on regulating emission levels, aligned with other countries of the EU. The series of study promoted by Cel Net, triggered other related initiative: In 2018 the NGO Mare Terra Fundació Mediterrània launched an independent study, which complex results that highlighted the need to improve the methodology. Furthermore, the civic initiative Colectivo Ronda, brought Repsol Petróleo S.A. to Court for causing cancer to a worker. The judge ruled that the plaintiff was right and assured that his illness was due to exposure to the chemical compounds present in the facility (Rodríguez, 2018).

Actionable data

Teaching material has also been produced to be distributed in schools. The educational project around the TV documentary ''ÉS A L'AIRE'' coproduced by Catalan television, where Cel Net is present, is a unique proposal to educate on air quality in Tarragona.

An important consequence of Cel Net initiatives has been the joint work of universities, local and regional governments and citizens.

Other useful information

During the first studies, retro-trajectory systems based on mathematical models were used to trace bad odours in the towns near the petrochemical area. Also, the VOCs associated to the bad odours were analysed in order to know the potential toxicity of the odours. Many volunteers were needed in order to 1) report all the bad odours (intensity, hour, site) https://www.celnet.cat/que-pots-fer-tu.html and 2) install in their homes the air pump active samplers because the volunteers start them each time that the bad odour appeared. The main difficulty in this initiative was to recruit a number of volunteers high enough (Cel Net, 2019).

4.1.2. Petrochemical complex of Muskiz, Spain

Fossil fuel Project

The Petronor refinery, also known as Petróleos del Norte S.A. and a subsidiary of Repsol, is the largest in Spain and is located in Muskiz. Specializing in the refining of heavy and ultra-heavy crude oils, the refinery covers an area of 220 hectares. It has a storage capacity of 894,000 m^3 of crude oil, 1,279,000 tonnes for raw materials, 922,000 m^3 of finished products, and 254,600 m^3 of intermediate products.

The complex comprises two traditional refineries, a delayed coking plant, and their corresponding product treatment units, which include two hydrogen production units and a vacuum gas oil desulfurization unit. The refinery is connected to a marine terminal via pipelines. This terminal features a 3 km jetty with three berths, a wharf with three additional berths, storage tanks for marine fuel (diesel, fuel oil), pumps for crude oil unloading from tankers, and a ballast water reception facility.

Since its commissioning in the 1970s, the Petronor refinery has undergone various expansions and now extends to within a few meters of residential areas. The latest expansion, a coking and cogeneration plant, has been operating since 2012. This plant required an investment of 800 million euros, funded by the European Investment Bank and the Spanish Ministry of Industry, Energy, and Tourism as part of the Reindustrialization Program. The coking plant transforms the heaviest components of crude oil, known as the "bottom of the barrel," typically used to manufacture fuel oil, into lighter and more in-demand products (Ekologistak Martxan, 2013).

Socio-environmental Conflict

In the municipalities of Muskiz, with 7,600 inhabitants, and Abanto-Zierbena, with 10,000 inhabitants, both near the city of Bilbao, residents have been fighting against the Petronor refinery for over 40

years. Their concerns include environmental impacts such as air pollution, noise, soil contamination, hazardous waste generation, and wastewater discharges, as well as the risk of serious chemical accidents, which have occurred periodically. Over the years, the complex has faced repeated complaints from environmentalists and local residents due to atmospheric emissions, discharges into the estuary, and especially because of expansion projects like the FCC catalytic unit (1982), the Integrated Gasification Combined Cycle (IGCC) thermal project (2001), and the coking plant since 2007. The IGCC project faces strong opposition from residents in the neighbouring municipalities. The Abanto-Zierbena City Council had announced the denial of the necessary zoning reclassification. The project was ultimately withdrawn in 2004, officially due to being "unfeasible." In 2007, the Coordinadora Anti-Coke was established, initially as a citizen platform and a meeting space for neighbourhood, social, labour, and political organizations opposed to the new project. It later evolved into a collective of individuals actively opposing the coking plant project. An important aspect that has been present in the conflict from the outset is the possibility of holding a popular consultation on the URF project. Despite the rejection of the consultation on multiple occasions due to a lack of majority in the town council, it was finally organized in March 2009, initiated by the Anti-Coke Coordinator itself. The consultation garnered varied support and included a Guarantees Commission, from which opposing municipal political forces abstained despite receiving explicit invitations. The residents of Muskiz municipality were posed the question, "Are you in favour of installing a Coke plant in Muskiz?" The results, with 1,204 participants (20.16% of the electoral roll), were as follows: 1,165 NO votes (96.76% of votes cast), 24 YES votes (1.99% of votes), 4 blank votes, and 11 null votes (Meatzalde Bizirik Ekologista Taldea, 2013; Barcena, 2014).

Citizen Science initiative

Organizations and campaigns

The "Citizen Movement Against the Petronor Coking Plant" in Muskiz, also known as Coordinadora Anti-Coke, comprises several associations working together to oppose the coking plant. These associations include Ekologistak Martxan, Greenpeace, Izate, Kima Berdea, Bizkaia Benetan Maite, Blog Ararteko, EBB/Indaz, M 15M, Plural Anitzak, Turruntero, Biltzen, Por Muskiz Bai, and Meatzaldea Bizirik. This movement involves between 200 to 500 persons actively participating in their campaigns.

Monitoring system

Since 2020, the Mehatzaldea Bizirik association has acquired a 2.5 particle detector (PM 2.5) for air monitoring, which was installed on the balcony of a resident in one of the most affected neighborhoods. Although they recognize the need for more sensors, they face challenges in finding suitable locations with electricity and internet connection on the street to collect additional samples. The sensor, manufactured by the citizen group Barakaldo Makers, is one of several distributed throughout the region. The results are published on the CanAirIO website (Ekologistak Martxan, 2013).

4.1.3. Petrochemical complex of Marseille, France

Fossil fuel Project

The industrial area hosts approximately 400 facilities, including four major refineries and two significant petrochemical plants. Notable companies operating in this area include LyondellBasell (LyondellBasell Services France SAS), Ineos (Ineos Manufacturing France SAS), PetroChina (Petroineos Manufacturing France SAS), ExxonMobil (Esso Raffinage SAF), and Total (Arkema, Total Raffinage France). The large steel plant ArcelorMittal is also located there.

The refinery LyondellBasell was bought in 2008 from Shell. Due to financial losses in 2014 LyondellBasell permanently closed the Raffinerie de Berre, but the company maintain petrochemical production there.

The Raffinerie de Lavéra was owned by BP until 2005, when it was sold to Ineos. Since 2011, the refinery is owned by Petroineos, the joint partnership between Ineos and PetroChina that also owns Grangemouth's refinery. The refinery provides inputs to the Ineos petrochemical plants, occupying together 650 hectares. The refinery has a capacity of 210,000 barrels per day (ICIS 2016). The petrochemical plants produce olefins (ethylene, propylene, butadiene) plus benzene, and with Oxochimie produces oxoalcohols (n-butanol, iso-butanol, and 2-ethyl hexanol). On site, polymers products include polyethylene and polypropylene as well as high performance chemicals such as ethylene oxide, glycol ethers, ethanol amines, acetates and ethylene glycol Indopol polybutene".

The Raffinerie de Fos, formerly owned by Esso and now ExxonMobil, began operations in 1956 and has a capacity of 140,000 barrels per day. The Plateforme de la Mède, owned by Total, started operations in 1935 and ceased production in 2016 to be converted into a biorefinery using vegetable oils, particularly palm oil, as raw materials. This biorefinery is projected to have a capacity of 500,000 tonnes per year.

Socio-environmental Conflict

Socio-environmental conflict description: Conflicts arose over the effects of pollution on health and the environment. In particular, the dispute focused on a Gaz de France liquid natural gas terminal and the construction of a large incinerator (Allen, 2018). Groups of citizens filed a criminal complaint in 2018 accusing the steel, oil and petrochemical companies in the region of putting their lives at risk, including 260 residents, seven citizens groups and several unions (The New York Times, 2020). In 2018 Greenpeace and the farmers' union blocked several oil deposits and refineries countrywide to protest Total's planned imports of palm oil. Since 2005 several workers' strikes took place around Total refineries over wages, planned restructuring (in 2010) and the reform of the labour market (2016, 2018). In 2019, workers at the Raffinerie de Lavéra halted production as part of protests over pension reform.

Citizen Science initiative

Organizations and campaigns

The VOCE (Volunteers for the Citizens' Observation of the Environment) initiative, alongside the community-based participatory health survey Fos EPSEAL, represents significant citizen science efforts aimed at monitoring environmental health. These initiatives are driven by civil society organizations such as the Association de Défense et de Protection du Littoral du Golfe de Fos and the Collectif Citoyen Santé Environnement. They collaborate closely with the Institut Écocitoyen pour la Connaissance des Pollutions to gather and analyse data, ensuring community involvement in environmental observation and health assessment.

After multiple environmental controversies that triggered citizens activism, a large study composed by two main initiatives started in 2014, with the community involvement both in the development of protocols and data collection:

1) A participatory study (Fos EPSEAL) funded by the National Science Foundation conducted by Social Scientist Barbara Allen and her team; it included a survey and 30 small focus groups, more than 60 workshops, and a community-based participatory health survey (Lees and Jeanjean, 2019; Lees, Jeanjean and Allen, 2023).
2) The creation of a citizen observatory of the environment (VOCE) to support on-going communication and co-learning between scientific activities and local communities. Its method, which effectively integrated the experience and knowledge of citizens, were certified by the French Ministry of Ecology, Sustainable Development and Energy (Allen, 2018). VOCE trained a network of volunteers dedicated to monitoring the environment (including flagging industry violation, biodiversity, etc.) and the dissemination of scientific knowledge in the community. Through their professional recreational activities (e.g. hiking) volunteers were collecting data on different compartment of the environment including air, soil, waters. Volunteers were collecting data on lichens, used as a bioindicator of air quality; members of a diving club were snorkeling to monitor the diversity of the benthic diversity of the fauna and flora of the gulf of Fos, and other hydrological parameters to monitor marine biodiversity; volunteer fishers chose sentinel species for biomonitoring contaminant in fish; volunteers were monitoring vegetables in gardening in order to investigated the transfer of industrial atmospheric and terrestrial contaminants.

A close attention to environmental exposure and a focus on environmental justice allowed to diversify the sources of pollution to be studied, as well as the methods to be implemented. This explored global forces (climate), local (physical and political) and individual forces (social and physical). This case is listed on the Global Petrochemical Map.

Brief history

In 2007, local communities collected over 4000 signatures requesting health data and occupying the terrace of the regional health service in Marseilles. The controversy was the debate over scientific knowledge, as there a lack of credible health science used for guiding policy, despite the high number of cancer (Allen, 2018). Over the two previous decades, an alliance of government agency conducted a study discussing "safe chemical thresholds" which didn't establish a link between pollution and illnesses in the area. Both VOCE and EPSEAL have been co-production processes with a high level of

residents' involvement – research questions were involved by local experiences and concerns. Some of the project partnership lasted 8 years, some are still ongoing. The project underlined deteriorated health indicators in the region, demonstrating tangible and positive contributions from the residents. It found high rate of illness associated to the local industries – association which previously wasn't reported also due a "normalization" of chronic illness (Allen *et al.*, 2018). VOCE campaign started in 2014 and Fos EPSEAL in 2015; both concluded the main work in 2018, but some monitoring is still ongoing.

This CS initiative engages various stakeholders in environmental monitoring and health assessment which include different groups of citizens such as: environmental organizations such as the Association de Défense et de Protection du Littoral du Golfe de Fos and the Collectif Citoyen Santé Environnement, and the Institut Écocitoyen pour la Connaissance des Pollutions, a publicly-funded independent research centre specializing in citizen science. Universities contributing to the initiative include the Department of Science, Technology and Society at Virginia Polytechnic & State University-National Capital Region, Laboratoire de Sciences Sociales Appliquees in Marseille, UMR-GEAU INRAE in Marseille, Centre Norbert Elias in Marseille, the Department of Sociology and Anthropology at Northeastern University in Boston, and the Department of Epidemiology & Biostatistics at the University of California San Francisco. In total, the initiative involves between 200 to 500 individuals dedicated to fostering community engagement in environmental and health issues in the Gulf of Fos region.

Monitoring system

The monitoring system employed in the VOCE (Volunteers for the Citizens' Observation of the Environment) initiative encompasses a variety of approaches tailored to different environmental matrices and parameters. These include soil, sea water, freshwater, biological samples, and air quality. Various sensors are utilized with specific detection limits:

- Petunias are employed for outdoor air quality assessment using air monitoring techniques.
- Lichen is utilized to monitor biodiversity and assess outdoor air quality.
- Hydrological parameters such as salinity and temperature are monitored to assess marine water quality in the Gulf of Fos.
- Numerous families of benthic fauna are observed to evaluate the quality of marine waters.
- Marine macro-invertebrates are used to assess river quality by monitoring river biodiversity.

This comprehensive approach enables the initiative to gather diverse data across multiple environmental domains, fostering a thorough understanding of environmental health in the Gulf of Fos region.

The project has started a long-term collaboration among different participants; it increased the public scrutiny on the industries of the area, producing new knowledge and triggering social transformation (Allen *et al.*, 2018)By triangulating qualitative and quantitative data collected through a community-based participatory health study, the project revealed the overexposure to pollutants, reporting the association with illnesses. It appears that the collaborative project might has pushed formal channels to pursue actions to substantial positive outcomes such as: policy, structural and behavioural change,

increasing self-efficacy among residents, new plans for actions and increased awareness (Davis and Ramírez-Andreotta, 2021). The advisory body of the French ministry of ecology stated the existence of substantial health risks in the region. Residents came up with a list of recommendations, including the creation of a regional cancer registry that was accepted by the state agencies. Collected data have resulted in catalysing local communities' legal battles. Residents of Fos-Mer engaged in several juridical proceedings, including bringing several industrial facilities (Arcerol-Mittal Mediterranée, Dépôts Pétroliers de Fos, Esso refinery and Kem one) to court for abnormal disturbances. In 2018 the state fined one of the largest industrial emitters of air pollution in the area, later sentenced by the juridical tribunal for 36 environmental infractions. The legal process isn't concluded yet at the moment of writing.

Actionable data

The study was conducted with the support of scientists from universities and from an independent institute of research on citizens sciences. It received public fundings by the National Science Foundation (NSF). Medical professional and local residents were making sense of the data, together, carrying out an interpretation through triangulation of qualitative and quantitative data. Measuring the prevalence of illness based on self- reporting and combining it with qualitative and quantitative data on the impacts of local industries on the environment, allowed to find associations between public health and specific industrial activities in the area.

A large final report with the empirical evidence was presented to a large and diversified audience in Marseille in 2017 and published online. It received a lot of attention, in a few months over 100 press entries were published, including radio and TV programs. The media buzz also generated numerous requests from other polluted towns in France, wanting a similar study. French health service stated the validity of the analysis structure and statistical results. It stated that that the hybridization of data, even though it made them uncomfortable, was the actual strength of the Fos EPSEAL study. Several professionals from the French health service enrolled in the workshop organised by the project and one of their lead epidemiologists asked to lead similar training at the institutional level.

4.1.4. Petrochemical complex of Sarroch, Italy

Fossil fuel Project

In Sardegna, Saras S.p.A., now 35% owned by Vitol since 2024, operates the Sarroch refinery, a key player processing approximately 15 million tons of oil annually, representing 15% of Italy's total refinery capacity. The refinery markets its products, including diesel, gasoline, heating diesel, liquefied petroleum gas, virgin naphtha, and aviation fuel, primarily in Italy and Spain through subsidiaries like Saras Energia SAU. In 2018 alone, Saras sold 2.12 million tonnes of petroleum products in Italy and 1.56 million tonnes in Spain. Since the early 2000s, the Saras Group has operated an Integrated Gasification Combined Cycle (IGCC) plant managed by Sarlux Srl, generating 575 MW of power annually from heavy refinery products. This plant supplies over 4 billion kWh of electricity annually,

meeting 45% of Sardinia's electricity demand (Saras, 2018). The Sarroch refinery has been operational since 1965, playing a pivotal role in the region's energy landscape.

Socio-environmental Conflict

Saras is the second biggest refinery in Europe. In the 1960s Milan-based Moratti family acquired land in Sarroch to open a refinery, which despites job promises, created a sense of discontent across some locals. That land had a high agricultural value and potential for tourist development. Its impacts on the surrounding environment are heavy – Saras emits a mixture of harmful substances such as benzene, aromatics, fine particles, hydrogen sulphide and mercaptans every day. Farmers have complaints about the pollution of soil and water. Fishermen have found fish that smell of gasoline 15Km offshore the refinery. The environmental and health risk for the 5.170 residents of Sarroch has been highlighted by environmentalists and several associations (Donne Ambiente, Società della cura, Sardegna Pulita, Wilpf Italia, Confederazione del sociale). In 2021its turnover was 10.397 billion euros with a net profit of 140 million and approximately 1800 employees (Mazzotta, 2009; Cagliari, 2021).

Citizen Science initiative

Organizations and campaigns

The **Environment and Health project in Sarroch**, is a CS initiative that engages the general population and refinery workers in collaborative studies. Spearheaded without direct involvement from specific civic organizations, this project aims to assess environmental and health impacts in the Sarroch region. Through crowd-sourced efforts, participants contribute to monitoring and understanding the local environment, fostering community involvement and scientific inquiry.

The implementation of this study was complex and represents the culmination of a dialogue and negotiations between researchers from different disciplines (epidemiology, social and environmental sciences) and different types of actors (local administrations, residents, industry owners). The study focused on air pollution, vulnerable subjects and short-term effects (sulphur dioxide and children's respiratory health). Its approach to epidemiology was both academic and popular. It targeted both workers and the general population.

The strategy of the Environment and Health project in Sarroch was therefore to provide proof of a cause-effect relationship between industrial pollution (sulphur dioxide from the petrochemical factory) and the respiratory distress of children residing in the town. To this end, the project put in place certain systems aimed at providing evidence of population exposure. A fixed air quality monitoring station was installed by the municipality; its results were associated with those of several sampling records by passive dosimeters to describe geographic variability. Following, several epidemiological studies (surveys and longitudinal studies by panel) were carried out. Finally, molecular epidemiology studies have provided individual data on the relationship between exposure and outcomes. The study aimed also at assessing the community's perception of risk, in particular on the relationship between health and environment (Bécot and Le Naour, 2023; De Marchi, Bertazzi and Biggeri, 2023).

The study was funded by Sarroch municipality, after the Region denied its financial support for the located epidemiological study. The interdisciplinary team included epidemiologists, environmental chemists and physicists, clinicians, biologists, sociologists and social sciences specialists. The project can be defined as an epidemiological surveillance program. Results confirmed an excess number of cases of respiratory diseases and lung cancers.

Brief history

In 1996 citizens highlighted an excess of Leukaemia, hence the regional government started a first study to analyse cancer-related mortality (1981-1988). This initial study didn't show any anomaly in Sarroch, but suggested monitoring. In 2000 the Ministry of Environment met local institutions and companies and commissioned a study on public health in Sarroch to the University of Cagliari, which previously signed a convention with Saras S.p.A. The results do not show cancer anomalies in Sarroch, compared to the rest of the region. In 2003, the regional assessor for Hygiene, health and social assistance commissioned a survey on the 'Environment and health in high-risk areas of Sardinia', funded by European Structural Fund; the town of Sarroch was grouped, with other municipalities, into a larger risk area of the study, which represented 52,000 inhabitants of the hinterland of Cagliari. Excess risks of respiratory diseases (in men and women), lung cancers, pleural tumours, liver cancers and lymphohematopoietic tumours were recorded. According to the conclusion of the report, "environmental pollution (non-professional) could partly explain the excess increase in certain diseases, observed in the industrial zones studied. Following, the mayor of Sarroch decided to finance a new monitoring project called "Environment and Health in Sarroch". The monitoring initiative in Sarroch ran from 2007 to 2009, engaging a variety of stakeholders including civil society (citizens), universities such as the University of Florence, University of Udine, and University of Cagliari, as well as the Municipality and Regional Health Agency. The initiative aimed to assess environmental and health impacts in the region, although specific numbers regarding the involvement of participants are not available.

Monitoring system

It consists of 4 monitoring units belonging to Saras; 6 monitoring units belonging to Polimeri Europa; 4 public monitoring unions; a mobile monitoring union created by the municipality to detect effective exposition of citizens, for 6 months.

The health state of students was monitored every week for 7 months, with doctors conducting spirometry and nitric oxide detection in local schools. Children's parents were engaged in a survey about the health state of their kids.

Air pollutants monitored in the Sarroch area include volatile organic compounds (VOCs) like benzene, ethylbenzene, methanal, xylenes, and toluene. Additionally, heavy metals such as cadmium, hexavalent chromium (CrVI), lead, and nickel compounds, as well as polycyclic aromatic hydrocarbons (PAHs) such as benzo[a]pyrene (B[a]P) are also monitored.

The environmental matrix for this monitoring is primarily air. Sensors used include spirometers and air monitoring units, each with specific detection limits tailored to their respective pollutants.

The results of this study have been useful in reducing the thresholds for exposure to sulphur dioxide in authorization procedures. During the process of renewing the factory's authorization, which took place at the Ministry of the Environment, the mayor, assisted by a consultant of his choice and an environmental chemist from the EP Company, succeeded in obtaining a reduction in the annual limit of sulphur dioxide emissions. Thus, in January 2009, a new regulatory emission limit of 6,400 tonnes was set in the region; the limit of SO2 was set at 500n/m3; new level of alert set at 100n/m3.

The project triggered another study that resulted from an agreement between the union and the refinery owners. It was carried out in 2011-2013 by an independent team of epidemiologists – The Labor Clinic (Clinica del Lavoro) of the University of Milan – subsidized by the owners of the refinery. More than 2,000 workers observed participated in the study from its conception, the definition of its objectives to the discussion of the epidemiological results and their meaning in terms of health or safety measures for people working at the refinery and living nearby. The study did not reveal excess risks from exposures to the refinery's pollutants. Harmful and even carcinogenic exposures were nevertheless present and were quantified. This led to a triple conclusion shared by the unions, the owners and the team of epidemiologists: 1) Exposure control measures adopted in the past appeared to be adequate. 2) Such monitoring had to be continued and updated. 3) A study was deemed necessary to assess the possible effects on the health of the local population since there were no measures to control their exposure. This project was terminated quite abruptly, and in a context of increased social tensions.

Actionable data

Data accuracy was ensured by the universities, and the level of independence of the study, supported by public funding. The possibility of carrying out an independent study and the usability of its results was enabled by a particular window of political opportunity, with the mayor commissioning the study. This mayor was not reappointed by his party, contrary to traditional practice in small towns. The local press has reported dissatisfaction with the management of the municipality's industrial policy during his administration. The new candidate, who was also the predecessor of the mayor who initiated this study, won the 2011 elections at the top of a civic list called 'Progetto Sarroch', with a clear reference to the experience of epidemiological research. However, once in place, the new administration showed no interest in continuing it even though we believe that support for the efforts of the previous coalition constituted a real reason for residents to vote.

4.1.5. Petrochemical complex of Milazzo, Italy

Fossil fuel Project

Located in Sicily, the RAM – Raffineria di Milazzo, operated jointly by ENI S.p.A. (50%) and Kuwait Petroleum Italia S.p.A. (50%), processes approximately 10 million tonnes of oil annually. This refinery has the capacity to handle a wide array of raw materials and produces various refined products such as diesel, gasoline, jet fuel, LPG, propylene, sulphur, and naphtha, all meeting stringent quality standards. Spanning an area of about 212 hectares, RAM plays a crucial role in the regional energy

landscape. Originally opened in 1961 under the name Raffineria Mediterranea, operations slowed during the international oil crisis of 1973 and ceased in 1979. It was subsequently acquired by Agip Petroli and reactivated in 1982, undergoing a name change to RAM – Raffineria di Milazzo.

Socio-environmental conflict

Following the pressure of the civic society, between 1990 and 2004 Milazzo (56.000 inhabitants) was declared as an area of high environmental risk, with the aim of starting a cleansing of the territory and protection of public health. Pollution of the air, soil and sea added on the labour crisis produced by automatization and subcontracting processes. Deformation in kids, as well as in fish, and excess of mortality increased the perception of risks since the 1990s on. Environmental groups have been demanding the regulation of emissions' limits, as well as questioning the petrochemical future of the territory.

Citizen Science initiative

Organizations and campaigns

The citizen science initiative "Epidemiological investigations of air pollution and asthma symptoms in children living in the Milazzo-Valle del Mela high-risk area," involved comprehensive epidemiological studies on the effects of air pollution on children residing in several municipalities. These municipalities include Condrò, Gualtieri Sicaminò, Milazzo, Pace del Mela, San Filippo del Mela, San Pier Niceto, and Santa Lucia del Mela. The initiative encompassed cross-sectional and panel studies, alongside a participative monitoring campaign aimed at understanding the correlation between air pollution levels and asthma symptoms among children in the region.

The aim was to clarify the role of air pollution in creating and exacerbating asthma symptoms. Its specific objectives were to quantify the prevalence of childhood respiratory disorders among the paediatric population residing in the Milazzo–Valle del Mela area; to quantify the prevalence of childhood respiratory disorders among the paediatric population residing in the Milazzo–Valle del Mela area; to characterize the air pollution level in the area; and to evaluate respiratory function among resident children affected by obstructive pulmonary diseases and evaluate its relationship to air pollution levels. The cross-sectional survey of the prevalence of respiratory disorders among all children (6-10 years old) surveyed 2506 children. A questionnaire was administered to the parents of the children.

Two panel studies – PANEL 120 and PANEL 50 – were then conducted on a subsample of children. The first panel study, PANEL 120, enrolled 154 children that scored positive for any asthmatic symptoms on the questionnaire completed by their parents. Every two weeks, respiratory function and bronchial inflammation were assessed, while parents recorded (in a diary) symptoms and drugs taken by their children during the follow-up. The second panel study, PANEL 50, enrolled 50 children. The subjects were followed up for a week with daily measurements of health status, respiratory function, bronchial inflammation and air pollutant level, performed with personal monitors. Epigenetic markers – that is, the study of pathways that develop heritable patterns of gene expression without changing the underlying DNA – were evaluated twice using samples of nasal cells. The 50 children were divided into

small groups of 5 children each. Several meetings with the parents of the population groups accompanied the subsequent studies (Biggeri *et al.*, 2014).

Ambient air quality was assessed by monitoring campaigns. Dosimeters measured gaseous pollutants, and a gravimetric device measured PM2.5. Each primary school of the study area had 21 passive dosimeters. Sampling was done every two weeks, and dosimeters were left in place for a week, monitoring gaseous pollutants (sulphur dioxide, nitrogen dioxide, and benzene, toluene and xylene) (Biggeri *et al.*, 2014).

A communication plan was developed, and the parents of the children attending the schools enrolled in the study participated in all investigatory phases through a series of public meetings and initiatives. (Biggeri *et al.*, 2014).

According to Irwan (2005) this study is a citizen science project of Level 1 in which citizens simply gather information as a form of crowdsourcing.

Brief history

The study was conducted following the pressure of civic society to tackle the little information of environmental pollution in the Milazzo–Valle del Mela area and its impacts on residents' health. Initial research on air pollution conducted by ARPA Sicily had shown values of sulphur dioxide above the EU-legislated alarm threshold of 500 µg/m3. Also, descriptive epidemiological data from the Sicilian Epidemiological Observatory documented a higher-than-expected occurrence of respiratory diseases. In 2002, the mayors of the Milazzo–Valle del Mela area requested the WHO Regional Office for Europe to work in the high-risk areas of Sicily. In 2005, the regional government in Sicily created a dedicated Office for Risk Areas and involved WHO in providing support for the rehabilitation plans of these areas (Mudu, Terracin and Martuzzi, 2014).

The monitoring initiative, conducted from 2007 to 2008, involved a broad array of stakeholders actively participating in various capacities. These included civil societies represented by children and parents, local schools, and institutional working groups. The initiative saw contributions from prominent organizations such as the Italian National Research Council, the French National Center for Scientific Research, the Italian National Institute of Health, the Sicilian Epidemiological Observatory, and universities including the University of Florence, University of Grenoble, and University of Messina. Overall, the initiative engaged a significant number of participants, specifically 2506 children attending primary schools, contributing to a comprehensive study on the impacts of air pollution and asthma symptoms in the Milazzo-Valle del Mela high-risk area.

Monitoring system

Ambient air quality was assessed by monitoring campaigns. Passive dosimeters were located at 21 sites in each schoolyard, measuring continuously for a week each month during the study period, from November 2007 to April 2008. A gravimetric device located at the secondary school of Pace del Mela measured PM2.5, and ARPA Tuscany analysed the particle filters collected. Personal passive dosimeters were also used for personal monitoring of exposure to gaseous air pollutants. Every day, at the witness's home a nurse collected and replaced the daily personal passive dosimeters and checked the PM2.5 instrument.

For the first panel study, PANEL 120, a team of two nurses and one or two pneumologists performed a spirometry. Children enrolled in the PANEL 50 study performed self-administered FEV1 measurements at home, using a pocket-size pulmonary function electronic monitoring device (Piko-1) twice a day – in the morning, when they got up for school, and in the evening (at 18:00), under the supervision of a nurse. Twice a week each child went to a dedicated outpatient clinic to undergo nasal brushing, to collect nasal cells for DNA methylation analysis.

The monitoring focused on air quality involved the assessment of various pollutants such as sulphur dioxide, nitrogen dioxide, benzene, toluene, xylene, and PM2.5. These parameters were monitored specifically within the environmental matrix of air using a range of sensors. Passive dosimeters and gravimetric devices were employed for accurate measurements, complemented by pocket-size pulmonary function electronic monitoring devices (Piko-1) to assess respiratory health impacts

The study did not have an immediate effect on the regulation of emissions levels. However it advanced methodological approaches and it increased awareness and opened the way for further studies, which produced impact in 2018, when the regional plan for the air quality applied a reduction of the allowed limits of emission for the most polluted industries – included Milazzo refinery. These limits will be fully implemented in 2027. Environmentalist said this was an historical victory; however, big local industries are planning legal manoeuvring for hindering the plan.

Actionable data

Right after the conclusion of the study, the results were "returned to the population" through presentations in public events, as well as reported by newspapers, and they were used by an electoral campaign. Later, in 2014 when an explosion at the refinery burnt an entire cistern full of naphta, the study was retaken to understand how the event had exacerbated air quality. With the support of volunteers' samples of dust were collected using absorbent paper, and analysed. The results were used in two criminal proceedings relating to pollution in the Milazzo area, one associated to the 2014 fire at the Milazzo refinery, the one relating to the results of the Milazzo study. Scientific fundings were attachments to the leading scientist's deposition in Court, where he took part as witness on behalf of some municipalities and civil parties.


L'incendio al serbatoio Ram e lo studio commissionato dai Comuni di Santa Lucia del Mela, San Pier Niceto e Monforte San Giorgio

Industrie, fiamme e veleni: è scontro sui dati

«Riscontrata un'eccedenza del 70% di inquinanti pericolosi nelle vicinanze dell'azienda dopo l'incidente»

La Raffineria smentisce: abbiamo altri risultati

L'impatto ambientale determinato dai fumi di combustione

Incontro Pubblico

INCENDIO SERBATOIO TK513:

LE ATTIVITÀ DI SORVEGLIANZA EPIDEMIOLOGICA E AMBIENTALE CON LA PARTECIPAZIONE DEI CITTADINI NELL'AREA DI MILAZZO E VALLE DEL MELA

18 Novembre 2015 Ore 11:00

Teatro Trifiletti Milazzo

LA CITTADINANZA È INVITATA A PARTECIPARE

Figure 3. Image on the left: "Industries, flames and poisons: clash over the data" on the newspaper La Repubblica, 2014. On the right: a poster of a public event in which the study's results were presented. Courtesy of prof. Annibale Biggeri.

4.1.6. Petrochemical plant in Val d'Agri, Italy

Fossil fuel Project

In Basilicata, Eni SpA (Ente Nazionale Idrocarburi), Shell, and Total operate within the region. The focal point of their activities is the "Centro Oli Val d'Agri" (COVA), Italy's largest oil pre-treatment plant. Located in Val d'Agri, this facility processes crude oil extracted from local wells, including those in Monte Alpi, Monte Enoc, and Cerro Falcone fields. The extracted oil undergoes hydrodesulfurization before being transported via over 500 km of pipelines to the COVA plant and subsequently to the Taranto refinery in Puglia. Operational since 2001, COVA plays a pivotal role in Italy's oil production landscape, although its anticipated economic benefits, such as increased employment and infrastructure development, have not significantly impacted the local community's quality of life (Demarinis Loiotile, de Gennaro and Petraccone, 2016; Di Gilio *et al.*, 2021; Selva, 2023).

Socio-environmental conflict

Val d'Agri is a clear example of the tension between the oil industry and local communities. Hydrocarbon exploitation has raised concerns about environmental pollution, public health, and ecosystem degradation. While inhabitants of Val d'Agri face negative impacts on their quality of life and health, oil companies and authorities minimize or ignore these effects. Under the justification of socioeconomic dependency on oil extraction by both the private sector and state agencies, citizens have been facing adverse health effects such as eye and upper airway irritation, difficulty in breathing, and others (Demarinis Loiotile, de Gennaro and Petraccone, 2016; De Gennaro *et al.*, 2017).

This conflict highlights the need for environmental justice and recognition of acceptable damage limits for affected communities. To achieve this goal, the lack of adequate monitoring and transparency that has generated concern and mistrust among residents must be addressed. The use of a network of sensors and citizen participation in data collection seeks to mitigate uncertainty by providing detailed information on air quality and promoting environmental justice through community participation (Demarinis Loiotile, de Gennaro and Petraccone, 2016; De Gennaro *et al.*, 2017; Di Gilio *et al.*, 2021).

Citizen science initiative

Organizations and campaigns

The initiative involved citizens from Viggiano and Grumento Nova, along with the Research group of Biology Department at the University of Bari (Aldo Moro) and the municipalities of Viggiano and Grumento Nova. Citizens actively participated in collecting data on fugitive emissions using portable sensors and mobile phones. They reported volatile organic compounds (VOCs) and real-time olfactory annoyances to the network. These citizen reports supplemented data gathered by fixed sensors, weather stations, and image recordings. The monitoring network was strategically positioned in the uninhabited areas surrounding the plant, providing high spatial and temporal resolution in data collection and reflecting community concerns and risk evaluations. Sensors employed included electrochemical, optical, MOS, and PID sensors for VOCs and ozone. This collaboration between scientists and the community validated citizen perceptions and quantified exposure to pollutants during short-duration events (Di Gilio *et al.*, 2021).

Brief history

Since the beginning of its operation, COVA has generated both expectations and uncertainty among the population, especially due to fugitive emissions perceived as bad odours and their possible risks to health and the environment. Consequently, given that data provided by the private sector and public entities were inaccessible or scarce, scientists and researchers, with the active collaboration of citizens, implemented the network of fixed and mobile sensors described in the previous section.

This initiative not only marked significant progress in environmental monitoring systems but also strengthened the relationship between researchers and citizens. Subsequent monitoring campaigns, initiated on February 16th and concluded on July 30th, 2017, were repeated, collectively serving as a foundation for decision-making and policy development aimed at enhancing industrial processes to safeguard the environment and public health.

Stakeholders involved in these efforts included administrative staff and plant operators, researchers, scientists, government and local regulators, citizens, and communication media outlets.

Monitoring system

The sensing monitoring network was located in the inhabited surroundings of COVA plant for detecting fugitive emissions. The monitoring system implemented in this case is a sensing network that mixes eight photoionization detectors (PIDs) for measuring volatile organic compounds VOCs , meteorological sensors, a video camera and a telephone system set up to systematize citizen alerts. The collected data is sent to digital platforms for storage and analysis, facilitating the visualization and exchange of information. This system allows e real-time representation of pollution events in maps, and the early evaluation of impacts on the population.

This participatory approach solves the limitations of conventional monitoring with respect to data accuracy in areas where short term fugitive emissions events occur and promotes community awareness of air quality.

The pollutants monitored where Total Volatile Organic Compounds (TVOCs), which can encompass a variety of volatile organic compounds, as well as other air pollutants associated with fugitive emissions. The sensors and other devises employed were:

- Air: Photoionization detectors (PIDs) (Corvus, Ion Science Ltd., UK) “zero calibration was determined with zero (VOC-free) air and the span calibration with a 10-ppmisobutylene standard gas. The uncertainty was ±3% at the 10-ppm calibration point”.

- Weather: Weather stations (Vantage Pro2™wireless - Davis Instruments Corporation) – “Integrated Sensor Suite including a rain collector, an anemometer and sensors for temperature, humidity, UV and solar radiation detection”.

- Image: Infrared Wi-Fi video camera (Mobotix M26). It included an “HD telelens (up to 320 mm) and new image sensor technology able to provide excellent images of up to 3072 × 2048 pixels.”

The most significant achievements of the monitoring network initiative in Val d’Agri were: a) the integration of data allowed detailed and real-time visualization of fugitive emissions, resulting in higher spatial and temporal resolution of the collected data; b) citizen participation strengthened the

knowledge and collaboration between scientists and the community; c) the implementation of the telephone communication system enabled residents to quickly report odour perceptions, reaffirming their knowledge and facilitating a faster and more effective response to their concerns; and c) the use of wind direction and speed data, along with residents' observations, made it possible to identify the sources of odour emissions and pollution.

In summary, the monitoring network improved the understanding and response to fugitive emissions from the petroleum pre-treatment plant by increasing data resolution, involving the local community, and enhancing communication about environmental issues.

Actionable data:

The Val d'Agri monitoring network constitutes an important contribution in terms of methodological innovation since it managed to successfully integrate data from various sources. It is an example cited to demonstrate the effectiveness of community monitoring networks in cases of identification and management of contaminants from the petrochemical industry.

Regarding citizen science, this case has shown how the active participation of the population has a lot to contribute to scientific knowledge and complement it, at the same time as it is a source of empowerment of local communities in terms of surveillance and care of the environment.

Taken together, this case has highlighted the importance of the integration of advanced monitoring technologies and community participation in environmental management, contributing to the enrichment and development of literature that supports citizen science as a valuable tool for addressing complex environmental problems (Bertollini *et al.*, 2018).

This study was carried out thanks to a collaboration agreement between the Department of Biology of the University of Bari and the municipality of Viggiano and Grumento Nova (Italy) within the framework of a larger project aimed at evaluating the impact of the oil industry on health carried out in collaboration with “The Institute of Atmospheric Sciences and Climate (CNR-ISAC)” (Wu *et al.*, 2023; Mauro and Borghesi, 2024).

4.1.7. Petrochemical complex in Louisiana, USA

Fossil fuel Project

The ExxonMobil refinery in Chalmette, Louisiana, was a significant industrial site until its sale in 2015 to PBF Energy. Originally owned by ExxonMobil and PDVSA (Petróleos de Venezuela S.A.), the refinery has a processing capacity of around 185,000 barrels of crude oil per day and includes various processing units such as atmospheric crude distillation, vacuum distillation, fluid catalytic cracking, hydrotreating, and catalytic reforming. The associated logistics assets include pipelines, crude and product storage facilities, and a maritime terminal.

The Chalmette refinery was built in 1915 and occupies around 2 km² on the banks of the Mississippi River. It can produce a range of products, including gasoline, distillate, petroleum coke, benzene, and xylene (Energy, 2021).

Socio-environmental conflict

The origin of the conflict is related to the health and environmental impacts of the refinery's operations over its area of influence. The community's concerns are directly related to air pollution and its health effects, which include respiratory problems and other serious health conditions linked to chemical contaminants. Furthermore, there is a clear disparity in power between the industrial facility and the local residents. The refinery's approach to addressing community concerns often involves complex technical data and regulatory compliance measures that can be difficult for non-experts to understand or challenge effectively. This dynamic tends to disregard community voices and can undermine grassroots environmental justice efforts.

Given that residents' concerns about access to air quality monitoring and transparent reporting were underestimated, in 2005 community members associated with the nonprofit environmental health and justice organization "The Bucket Brigade." In this initiative, residents could collect their own air samples to test for pollutants, playing a crucial role in raising awareness and pushing for regulatory changes. These grassroots actions highlighted the community's resilience and their proactive stance in advocating for a healthier environment (Louisiana Bucket Brigade, 2005b, 2005a; Ottinger, 2010, 2020).

Citizen science initiative

Organizations and campaigns

The Chalmette Air Monitoring Project was a collaborative citizen science initiative involving several key stakeholders: St. Bernard Citizens for Environmental Quality (SBCEQ), The Louisiana Bucket Brigade (LABB), the Louisiana Department of Environmental Quality (LDEQ), the Environmental Protection Agency (EPA), researchers and academics studying the impacts of petrochemical pollution and public health, and the citizens of Chalmette. The exact number of people involved in the project is unknown.

This initiative started with the collaboration of the Louisiana Bucket Brigade and St. Bernard Citizens for Environmental Quality). This community-based approach to air quality monitoring utilized a primary tool known as the "bucket," a simple and cost-effective device designed to capture air samples for subsequent analysis. These samples were tested for pollutants such as benzene, sulphur dioxide, and toluene. The resulting data provided concrete evidence of air quality issues, raising awareness and driving regulatory changes. Fenceline communities participating in the campaign collected air samples, which were analysed using the same techniques as Summa canister samples used by state agencies (Louisiana Bucket Brigade, 2005b).

Brief History

In 2004 Fenceline monitoring was implemented in Chalmette by the community group St. Bernard Citizens for Environmental Quality (SBCEQ). The next year, with the assistance of the New Orleans-based environmental health and justice non-profit organization “The Louisiana Bucket Brigade (LABB)” community members began collecting their own air samples to monitor pollutants emitted by the refinery. This grassroots effort was driven by the residents' concerns about air pollution and its associated health risk (Chalmette Air Monitoring Project Newsletter, 2006; Bera and Hrybyk, 2013).

Monitoring system

The Bucket System consisted of a modified five-gallon plastic container equipped with a vacuum pump and a sampling bag inside. It was designed to be user-friendly and inexpensive, making it accessible for community use. When residents detected a suspicious odour or air quality issue, they used the bucket to collect an air sample and then the vacuum pumped air into the sampling bag over a few minutes(Ottinger, 2009; Bera and Hrybyk, 2013).

Once the air sample was collected, it was sent to a certified laboratory for analysing different volatile organic compounds (VOCs).

CHAMP’s air monitor detects five critical chemicals emitted by ExxonMobil, known as the Foul Five: benzene, carbon disulfide, sulphur dioxide, toluene, and xylene. These chemicals, which have significant health impacts, have been consistently detected in air samples collected by local residents over the past three years. CHAMP’s system provides real-time monitoring, updating the website every minute with current air quality data. Whenever one of the Foul Five chemicals exceeds safety levels, an alert is issued with details on the location, time, and specific chemical detected.

The Bucket System employs EPA Method TO-15. This procedure involves analysing air samples collected through canister sampling, such as Summa canisters or the Bucket. The name 'TO' stands for 'toxic organics,' and the method can measure up to 97 volatile organic compounds (VOCs). In the case of CHAMP, particular concern was focused on benzene, carbon disulfide, sulphur dioxide, toluene, and xylene, as they represent serious health risks for the population.

The Bucket Brigade's efforts highlighted the disparity in power between the industrial facility and the local community, particularly regarding access to transparent and accurate environmental information. By taking matters into their own hands, residents were able to hold the refinery accountable and advocate for a healthier environment. In 2004, the Chalmette Health Assessment Project, conducted in collaboration between CHAMP and the St. Bernard Citizens for Environmental Quality, identified elevated levels of respiratory illness in the neighbourhood nearest ExxonMobil’s Chalmette Refining. In 2005, in response to legislation developed by the St. Bernard Citizens for Environmental Quality and the Louisiana Bucket Brigade, the Louisiana Department of Environmental Quality installed an air monitor across the street from ExxonMobil’s Chalmette Refining. Finally, after a five-year campaign, in 2007, the Environmental Protection Agency (EPA) filed a federal consent decree against ExxonMobil in Chalmette, requiring the refinery to remediate the environment in accordance with federal guidelines(Ottinger, 2009, 2010).

Actionable data

The findings of the Chalmette Air Monitoring Project have been cited in numerous academic studies and scientific reports, significantly contributing to the body of knowledge on the effects of petrochemical pollution on human health and the environment. This research has underscored the risks associated with air pollution in communities near refineries and other industrial facilities. Furthermore, the success of the project has served as a model for other citizen science initiatives worldwide, demonstrating the feasibility and importance of involving citizens in environmental monitoring and efforts to combat pollution.

4.1.8. Petrochemical complex in Pittsburgh (Pennsylvania), USA

Fossil fuel Project

The Shell Pennsylvania Petrochemicals Complex is an ethylene cracker plant located in Potter Township, Pennsylvania, United States, owned and operated by Shell Oil Company, the American subsidiary of supermajor oil company Royal Dutch Shell. Operations began in November 2022 and produce over a million tons per year of plastic pellets.

Citizen science initiative

Organizations and campaigns

1. **Air quality monitoring throughout cylinders that collect data on PM and VOCs**

In this region that has long suffered from poor air quality, some people installed monitors in 2016 to analyse the emissions from the new petrochemical plant (ethane cracker) in order to compare air quality of the region before and after the plant operation.

The monitors, which are not much bigger than a soda can, have the shape of small white cylinders and they are fixed under the eve of a garage roof. The cylinders collect data on particulates and volatile organic compounds (VOCs). There have installed 14 monitors within about five miles of the plant; they aim to add six more before the Shell plant opens. The devices cost $200 to $300 each. They automatically upload the information to two websites — Purple Air[1] and Airviz — that contain maps showing air quality at specific locations in near real-time.

The initiative was funded by the Mountain Watershed Associations's Direct Support Fund[2], a local group that provides small grants to grassroots organizations and advocates working on environmental justice, fracking, and pollution created by petrochemical plants, from Pittsburgh (Hurdle, 2021).

[1] https://www.purpleair.com/
[2] https://mtwatershed.com/direct-support-fund/

2. Breathe Project

The Breathe Project is a clearinghouse for information on air quality in Pittsburgh. They use the best available science and technology to better understand the quality of the air we breathe and provide opportunities for citizens to engage and take action.

The Breathe Collaborative is a coalition of citizens, environmental advocates, public health professionals and academics working to improve air quality, eliminate climate pollution and make our region a healthy and prosperous place to live. The Collaborative powers the Breathe Project[3] through science-based work and a community outreach platform. Their website provides different tools:

- Smell App produced by Carnegie Mellon University CREATE Lab for mobile device to monitor and report toxic air.
- Plume Pittsburgh, produced by Carnegie Mellon University CREATE Lab, which shows that air pollution has effects beyond the immediate surroundings of emitters. Pollution is one part of our air-shed that has the potential to spread throughout the entire region as weather and wind direction change.
- Watch Air Quality in Real-Time with live panoramic cameras at four high points located in and around Pittsburgh.
- Compare Your Air See Pittsburgh's air quality compared with other cities around the country.

3. Protect PT: monitors for noise around the natural gas fracking wells that will supply the Shell plant[4]

Protect PT (Penn-Trafford), based in Harrison City, Pennsylvania, and was established in 2014 as a grassroots community-based nonprofit organization. Its mission is to protect the communities of Allegheny and Westmoreland Counties from the harmful environmental impacts of fossil fuel activity, with a focus on residents' safety, security, and quality of life. The organization provides information about fracking, oil and gas waste, legal advocacy, environmental monitoring, and environmental reporting apps.

4. Mountain Watershed Association: monitoring microplastics[5]

The Ohio River valley, residents have been collecting fragments of plastic to compare with any leakage of nurdles from the new plant when it opened. The Mountain Watershed Association has been using fine nets to trap plastic debris in the river near the Shell plant.

5. Communities for a Better Environment[6]

Communities for a Better Environment, a California nonprofit, was a leader in this field starting in the 1990s when it helped local residents sample air in the San Francisco Bay area.

[3] https://breatheproject.org/
[4] https://www.protectpt.org/
[5] https://mtwatershed.com/
[6] https://www.cbecal.org/

In Charleston, South Carolina, where a water-quality nonprofit found that the same kind of tiny plastic pellets that will be produced by the Pennsylvania Shell plant had leaked onto beaches and into waterways from a local shipping facility.

4.2. Gas exploration and extraction

Since no CS initiatives related to the environmental monitoring of gas exploration and extraction were found in Europe, two notable non-European cases are presented below: one from the USA and other from the Ecuadorian Amazon.

4.2.1. Gas extraction in Yasuní Biosphere Reserve, Ecuador

Fossil fuel Project

Chevron-Texaco has been conducting oil extraction implementing gas flaring in this area. Gas flaring consists in burning waste natural gas on site emitted during fossil fuel extraction; companies flare gas in the atmosphere, instead of store it and process it – operation which requires investment in infrastructure. Chevron-Texaco (Texaco before 2001) has been conducting oil extraction in Ecuador from 1964 to 1992 using techniques that allegedly produced severe and lethal environmental degradation. In 1993 attorneys on behalf of 30,000 Ecuadorian citizens living in Oriente region filed a class lawsuit against Texaco for environmental damages. By 2007, the surviving company Chevron-Texaco was forced to pay for cleanup and compensation costs; eventually the cleanup was not conducted properly due to corruption (Buccina, Chene and Gramlich, 2012). The Texaco/Chevron lawsuit, which started in November 1993 and is still being litigated in 2020, is a prominent example of the process of judicialization of environmental conflict (Pellegrini *et al.*, 2020). However, the company is still extracting gas form the Yasuní Biosphere Reserve, and gas flaring is still an operation implemented by the company. Yasuní Biosphere Reserve is located in the provinces of Orellana and Sucumbíos.

Socio-environmental conflict

Impacts of gas flaring have materialized through acid rain, soil acidification, atmospheric pollution, putting in danger the health of local communities and ecosystems. Emissions include NO, which may cause lung irritation; CO which may cause headache nausea; other chemical substances like Volatile Organic Compounds, heavy metals and Polycyclic Aromatic Hydrocarbons are associated to cancer and diseases such as asthma, cough, eye and skin irritation. Acid rains caused from nitrates and sulphates produced during the gas flaring, may cause skin cancers, and stomach ulcers. Finally, alteration of microclimatic conditions can impact agroecosystems decreasing crop's productivity, affecting the self-sustainment capacity of local communities (Odjugo and Osemwenkhae, 2009). Damages cause by Texaco could be measured in cancer deaths, miscarriages, birth defects, dead

livestock, sick fish, and the near-extinction of several tribes; Texaco's legacy in the region amounted to a "rain-forest Chernobyl." (Radden Keefe, 2012).

Citizen science initiative

Organizations and campaigns

The AMAZONYA project - Mapping Gas Flaring from Below is a CS initiative aimed at mapping and estimating the potential impacts of gas flaring in and around the Yasuní Biosphere Reserve, one of the most biodiverse areas in the Amazon Rainforest and likely in the world. The objectives of the CS initiative were: 1) To map all the gas flaring sites in the Ecuadorian provinces of Orellana and Sucumbíos, combining remote sensing analysis and participatory mapping on the ground; 2) To empower local people in environmental decision making, by developing a participatory mapping process to create data above gas flaring activities; 3) To obtain data on temperature and humidity in order to assess areal impacts of the gas flaring flame on the microclimate.

The initiative involves several stakeholders, including the research group Climate Change, Territories, Diversities from the ICEA Department at the University of Padova, the Unión de Afectados y Afectadas por las Operaciones Petroleras de Texaco, and the Fundación Alejandro Labaka, an NGO dedicated to research, cultural promotion, and support for indigenous communities in the northern Amazon. The number of people involved in the project ranges from 10 to 100.

Brief history

Gas flaring has been a diffused practice in the area for several decades, but the volumes of flared gas had not been investigated before this project. The only estimative of gas flaring conducted previously, was done by Durango-Cordero et al. (2019), consisting in a spatial inventory built from publicly disclosed reports (2003-2012), compared with satellite observation and historical energy statistics from the UN. Generally, information and data about gas flaring (position, volumes and chemical composition, burning efficiency) are critical. They are mainly provided only by fossil fuel companies, with lack of direct measurements, standardized procedures and third-party control.

The Amazonya project was the first attempt to monitor gas flaring activities by combining remote sensing-based methods with a participatory, citizen science approach to develop a ground validated dataset on a regional Amazonian scale. The project was born in the frame of the campaign "¡Apaguen Los Mecheros, Enciendan La Vida!" an initiative for defending communities and their ecosystem from gas flaring. The project combined remote sensing-based methods with a participatory, citizen science approach to develop a ground validated dataset on a regional Amazonian scale. The AMAZONYA project was conducted from 2012 to 2018.

Monitoring system

The monitoring project processed National Oceanic and Atmospheric Administration (NOAA) Nightfire annual dataset, based on the elaboration of imagery from the Visible Infrared Imaging Radiometer Suite (VIIRS) and developed a GIS-based novel simple method to identify new flaring sites from daily detections. Drones and satellite were implemented for the survey on the ground, allowing a cross validation and finding non-officially mapped gas flaring sites.

Cross validation was carried out using high-resolution satellite imagery and ground truth GPS surveys to check additional gas flaring sites. A ground spatial validation campaign was performed in the months of May and June 2019. For each site, GPS points and geo-referenced photos were collected. Alternatively, in cases with a lack of accessibility, Unmanned Aerial Vehicles were used to take georeferenced photos of the ongoing gas flaring activities and GPS position. To ensure long-term sustainability of the mapping project, were employed only open access data and open-source applications and software. Spatial data from the participatory mapping process were used to conduct ground truth validation of existing datasets, including: (a) the annual dataset produced by the NOAA Nightfire algorithm for 2019; (b) daily detections from 1 January 2019 to 11 May 2020; and (c) the official data from the EME. Data collected include photo, coordinates and table data. Data were collected from geophotographs, spatial data, and ancillary information (number and status of stacks).

The monitoring project collected data on the impacts on microclimates within a 200-meter radius at 10 sites. The study also documented other impacts, such as the tons of insects burned by gas flaring, black carbon deposits in the rainwater tanks of local people, and the contamination of a river (Facchinelli *et al.*, 2022). The parameters and pollutants monitored included the geolocation of gas flaring points. The environmental matrices studied were soil, seawater, freshwater, and air. The sensors used in the project included those from the National Oceanic and Atmospheric Administration (NOAA), drones, and GPS.

Data and cartographies created were included in the demand for a Protection Action presented by nine children and supported from the campaign Apaguen Los Mecheros, Enciendan La Vida! In February 2020, the campaign 'Apaguen los mecheros' presented a 'protection action' to the Court of Nueva Loja to demand the end of gas flaring activity. The request was initially rejected in May 2020, then appealed and accepted in January 2021 (El Universo 2019). The decision gave oil companies 18 months to close all gas flaring sites near populated centres and until 2030 to close all other sites. After more than one year the Court of Sucumbíos, issued an historical order to ban gas flaring activities in the Ecuadorian Amazon on January 26, 2021 (El Comercio 2021). A sentence issued by the Provincial Court of Sucumbíos ordered to remove 443 flaring points. The sentence established that gas flaring violates the environmental and health rights of kids and the local population in general. The sentence stated that the government must eliminate gas flaring site in two stages: the closest to populated centers must be removed within 18 months since the sentence; the others before 2030. It also indicates that the Ministry of Energy will no longer be able to issue permits for opening new gas flaring points, unless they have technology that prevents pollution, and that the Ministry of Health should analyze the possibility of building a cancer hospital in Sucumbíos. (El Universo, 31/7/2021).

Actionable data

The reported data highlighted for the first time the true extension of gas flaring activities in Ecuador, showing 198 sites more the Universal Ministry of Environment and 223 more than the ones detected by the Nightfire algorithm through the elaboration of imagery from the Suomi-NPP imagery. Of the identified sites, 75 were in the UNESCO Biosphere Reserve and 3 in its Core Area (Facchinelli *et al.*, 2020, 2022). Data also shows gas flaring sites otherwise 'invisible' to satellite sensors, as well as sites of gas venting (which is not detectable from the satellite and can easily be confused with inactive stacks during data collection). The involvement of a university ensured accuracy of data.

The map of gas flaring has been used for supporting communities' legal battles, which led the Court of Nueva Loja to issue an order to remove gas flaring. This legal victory underscores how citizen science projects can support the struggle of local communities, when research goals remain linked to the real needs of communities. It shows that citizens' sciences can foster policy changes in the respect of human and nature's rights, toward a more climatic just world. Notably, the Court of Nueva Loja's decision has inspired other communities to take action in similar ways.

This participatory mapping was based entirely on free and open-source Geographical Information Systems (GIS) technologies for ensuring the implementation of low-cost environmental monitoring that is economically sustainable for NGOs and researchers.

4.2.2. Gas extraction and fracking in Pennsylvania, USA

Fossil fuel Project

The Marcellus Shale region, which extends across the Appalachian Mountains and spans New York, Pennsylvania, West Virginia, and Ohio, is a significant area for fossil fuel extraction. Several companies, including leading producers such as Range Resources, EQT, Rice Energy, Chevron, and CONSOL Energy, are involved in this region. The Marcellus Shale is composed of a sedimentary rock formation, millions of years old, containing gas created from decomposing organic material. Since 2008, gas extraction through the controversial method of hydraulic fracturing has been steadily increasing. By 2015, there were approximately 7,800 active wells in operation in Pennsylvania alone (Frazier, McDevitt and Phillips, 2015). The fracking infrastructure consists of a horizontal network of pipelines, wells, and water treatment points. This infrastructure continues to grow, with some estimates suggesting the total number of wells could reach up to 100,000 in Pennsylvania over the next several decades (Griswold, 2011).

Socio-environmental conflict

Fracking is unfolding as an experiment where earthquakes, untested and proprietary chemicals, groundwater contamination and air pollution are among the emerging material- political and environmental configurations and inhabitations that are generated through this mode of energy extraction (Gabrys, 2017). To date, there have also been over 4000 recorded environmental violations at well sites, with fines for a total of US$6.1 million. Violations include everything from failing to dispose of residual waste correctly to discharge of wastewater to poor construction of pits and tanks, to not adopting Pennsylvania Department of Environmental Protection (DEP) pollution prevention measures (Frazier, McDevitt and Phillips, 2015). Rural communities, with a prior history of extraction and few income sources, are bearing the costs of fracking development in exchange of a boost of local economies. People living nearby fracking sites, compressor sites, waste pits, roads and more, m multiple environmental disturbances and health effects, being exposed to VOC, and developing asthma, cardiac, pulmonary diseases, and cancer (Gabrys, 2017).

Citizen science initiative

Organizations and campaigns

The Citizen Sense – Citizen-Led Air-Quality Monitoring Project is a CS initiative developed by the Citizen Sense group, an academic project at Cambridge University (UK), funded by the European Research Council under the European Union's Seventh Framework Program. Volunteer residents, not a specific civic organization, were involved in this project, which took place in fracking communities located in north-eastern Pennsylvania.

The initiative began by reviewing existing monitoring practices and engaged in a participatory approach and practice-based research to understand and make relevant the environmental harm experienced by the community. Working with local residents, the Citizen Sense group developed a monitoring kit to measure exposure to air pollution, addressing the specific contaminants of concern to the community. After several meetings, residents completed 30 logbooks with information on current monitoring practices, observations, and notes on what should be monitored and by whom. This feedback formed the basis for developing the monitoring kit.

Nearly 30 kits were distributed to participants, who used them over a period of seven months. Some participants produced continuous datasets and records of their experiences, while others contributed for shorter periods. This approach aimed to test the political and environmental capacities of sensor technologies and to understand how monitoring practices are integrated into the lived experiences, communities, and complex relationships to the economies and environments of energy extraction (Gabrys, 2017).

Brief history

Hydraulic fracturing, or fracking, is an emerging and growing industry that is having considerable effects on environments and health. Yet fracking often lacks environmental regulations. Citizens Sense engaged in this initiative while other monitoring activities were ongoing. One of the initiatives created at the time of the study was the Pennsylvania Alliance for Clean Water and Air, a group of concerned citizens in Western Pennsylvania with the common goal of protecting local natural resources and the environment- primarily from the dangers of hydraulic fracturing. This civic initiative established a 'List of the harmed', which documents residents in locations across Pennsylvania and the wider US who have experienced harm from fracking. Their work highlights and gives coverage online of the evidence of impacts on humans and animals. Hence the project leaded by Citizens Sense emerged in a moment of awareness rising about fracking in the region. This CS was carried out from 2013 to 2015 under the supervision of Professor Jennifer Gabrys at the University of Cambridge.

Monitoring system

A DIY air monitoring kit was developed by Citizens Sense in collaboration with residents. It included a Speck PM2.5 sensors, BTEX badges (for monitoring benzene toluene, ethylbenzene and xylene, volatile organic compounds commonly associated with petroleum-related activities), a community platform for mapping monitoring locations and viewing real-time and historic data, and a Frackbox, which monitored nitrogen oxides, ozone, volatile organic compounds, temperature, humidity and

wind direction. Residents were also provided with a logbook of instructions, which suggested several options for recording observations of environmental conditions and health effects.

The monitoring period ran for over 7 months. During peak monitoring activity, there were 23 active monitoring sites, and there was consistent monitoring taking place at up to 16 sites over a period of 7 months. The data stories are generated using the Citizen Sense Airsift Data Analysis Toolkits, which were developed to allow for citizen-led interpretation of datasets. The core data available for interpretation is the PM2.5 sensor data using the Airsift PM2.5 Data Analysis toolkit. The Frackbox data and Airsift Frackbox Data Toolkit are also available as part of the resources section of our website. The Airsift toolkits use and adapt the open-source software, openair, developed by atmospheric scientists for the analysis of air pollution data. In order to blur the exact monitoring locations, the monitoring locations have been labelled with township locations, which can be found in relation to Pennsylvania counties.

The Citizen Sense initiative monitored various parameters and pollutants in the air, including benzene, toluene, ethylbenzene, xylene, volatile organic compounds commonly associated with petroleum-related activities, nitrogen oxides, ozone, temperature, humidity, and wind direction.

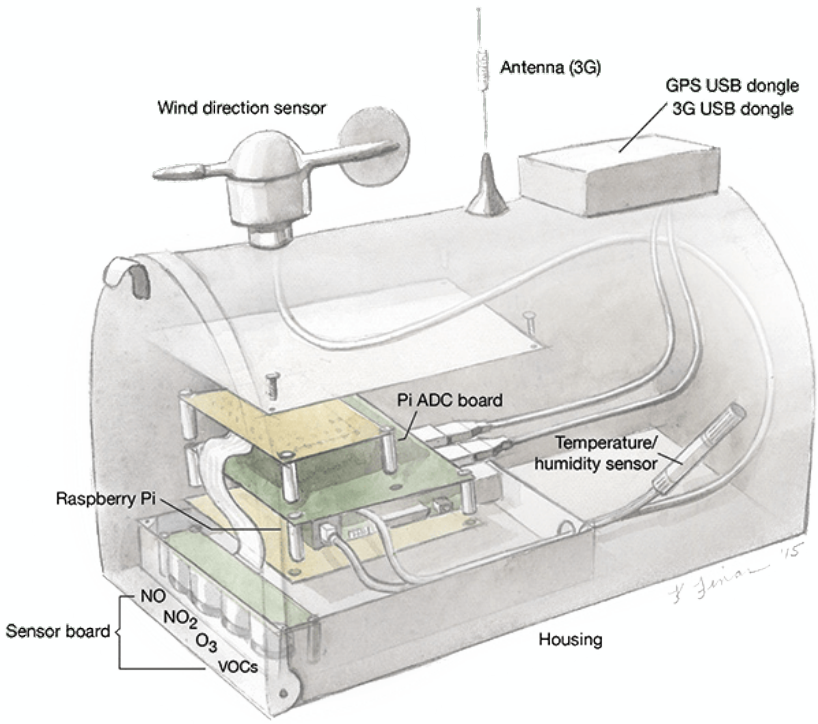

Figure 4. Frackbox Kit (2014) with instructions on how to build a Frackbox[7].

The monitoring initiative did not have direct effect on regulation, but it instigated follow-up monitoring and the expansion of institutional monitoring initiatives.

[7] https://manifold.umn.edu/projects/citizens-of-worlds/resource-collection/citizens-of-worlds-toolkits/resource/frackbox-kit

Actionable data

Two residents that took part in the air monitoring initiative arranged a teleconference with the Pennsylvania Department of Health (DOH) and the Agency for Toxic Substances and Disease Registry (ATSDR), along with Citizen Sense, to discuss their findings. While agencies and regulators were sceptical about devices used, their calibration and use, as well as the validity of the data, those two residents were able to use a combination of data and experience of lived exposure to make the case for follow-up monitoring to be undertaken by regulators at one of their homes. A report from the ATSDR (2016) documenting their follow-up monitoring in relation to citizen monitoring efforts was subsequently released just after the Citizen Sense participant data were made public and sent to numerous regulatory agencies. The report documents how elevated PM2.5 levels were found at the test monitoring location, and were likely attributable to nearby infrastructure, which also led the ATSDR to recommend that the DEP develop more robust practices for mitigating emission sources, particularly from industry. Just after the ATSDR made its report public, the DEP (2016) announced it was undertaking an 'unprecedented expansion' of its PM2.5 monitoring network (Gabrys, 2017).

3.1. Oil extraction

Based on the initially described methodology and the expertise of the Cova Contro organization, four cases were identified: three in the Basilicata region of Italy and one in Nigeria. The Basilicata cases were included separately due to their distinct focuses: one on human health impacts, another on environmental contamination of water sources, surface soil, and animals, and the third on air quality. The fourth case, located in Nigeria, also focuses on air quality.

4.2.3. Oil extraction in Basilicata (Italy) I

Fossil fuel Project

In the Basilicata region, oil extraction operations are conducted by ENI S.p.A. (60.77%) and SHELL Italia E&P S.p.A. (39.23%). Oil extraction began in Val d'Agri in 1996, and in 2001, the Oil Centre Val d'Agri (COVA) started operating as a hydrocarbon mixture separation plant, processing natural gases and groundwater from surrounding wells. The plant performs initial treatments on the extracted hydrocarbons, which are then transported to the Taranto refinery via the Viggiano-Taranto oil pipeline, active since 2001.

Socio-environmental conflict

The largest Italian gas and oil pretreatment plant is placed in Val d'Agri. Here there are 20 of the 38 oil wells used by ENI in the region. One the one hand the refinery is perceived locally as a source of

stable jobs, on the other hand the environmental and health damages have become more visible to locals. Since the 90s, the lack of information and consultation mechanisms for citizens and local authorities in decisions relating to extractive projects, has triggered social mobilization. Active citizens are reporting the lack of systematic controls on water, quality of the air, the soil and the health of the population, as well as the failure by institutions of controlling emissions or establishing rigid bans on extraction in protected areas (EJAtlas, 2022). ENI is on trial in two lawsuits for the 2016 and 2017 environmental disasters, when 400 tons of oil leaked from the oil center polluting land and water of for approximately 26 thousand square meters.

Citizen science initiative

Organizations and campaigns

The citizen science initiative "Project for the evaluation of the impacts on health VIS_VG_VdA" is a crowdsourced study without involvement from a specific civil society organization. Although there is no dedicated website for the initiative, information previously published on municipalities' and the Region's websites is now inaccessible. However, the study can be accessed through the magazine of epidemiology and prevention[8].

The project VIS_VG_VdA aimed at defining a VIS – Valutazione di Impatto sulla Salute, to assess the impacts of the oil centre COVA on public health. Following a multidisciplinary approach, the initiative conducted analysis on water, air, soil, and odours. A large epidemiological investigation sampled the population in the municipalities surrounding the oil centre, in order to assess their health state. Perception of risks was also investigated, as well as residents' trust in the information received on health and environment. Citizens took part in the study in different ways, both as volunteers in the epidemiological study, as well as active sentinels in the monitoring of air and odours. This was through providing residents dosimeters for monitoring air, and a phone number for contributing to georeferencing odour emissions using the phone-based alarm system.

The VIS has shown that in the municipalities of Viggiano e Grumento Nova, mortality and hospital admissions between 2000 and 2014 are higher to the regional average and the 20 municipalities of the Val d'Agri Concession. A microgeographical study made it possible to establish a risk association between the increase in mortality and/or hospitalizations for diseases of the circulatory system, in particular ischemic ones, for respiratory system diseases and exposure to COVA emissions, particularly in women. From an environmental point of view, the volatile organic compounds (VOCs) present around the plant resulted potentially harmful to humans. It also emerged that the pollutants emitted, such as hydrogen sulphide or nitrogen oxides, spread up many kilometres away going to impact the neighbouring municipalities in an east and north-east direction.

The analysis of risk perception and information on environment and health highlighted a striking concern about the risks associated with the proximity of the plant, as well as a medium-low level of trust towards institutional actors, media and associations. As detailed in the final recommendations, the results of the HIA clearly indicate the need:

[8] https://epiprev.it/attualita/epichange-2.indicazioni-emerse-dalla-vis-a-viggiano-e-grumento-nova-pz

- To implement health protection standards based on the most advanced scientific knowledge, which often suggest a more severe precautionary approach than simply based on legal limits, which do not exist for all substances released
- To continue the study of the environmental and health situation of the population of the two municipalities (VIS_VG_VdA, 2017).

According to Irwan (2005) this study is a citizen science project of Level 1 in which citizens simply gather information as a form of crowdsourcing.

Brief history

From the beginning of COVA emerged social discontent and protests organised by several civic groups such as Organizzazione ambientalista lucana (Ola); mamme e donne del Contro olio-Vigne (onda rosa); comitati No Triv; Legambiente Basilicata; A sud.

Following more than a decade of protests, the municipalities of Viggiano and Grumento Nova commissioned the Institute of Clinical Physiology of the National Research Council, IFC-CNR, to carry out a health impact assessment in their territory to study the effects on health and the environment produced by the Oil Center Val d'Agri (COVA). This was the first epidemiological study conducted in 20 years. The study involved 29 researchers and technicians from three CNR institutes, the Institute of Clinical Physiology (IFC-CNR), the Institute of Atmospheric and Climate Sciences (ISAC-CNR) and the Institute for the Study of Ecosystems (ISE-CNR), of the Department of Biology of the University of Bari and the Department of Epidemiology of the Health Service of the Lazio Region.

The monitoring initiative took place from 2009 to 2017, with the specific VIS study conducted between 2015 and 2017. Stakeholders included volunteers, CNR, University of Bari, and the Department of Epidemiology from the Lazio Region. The initiative engaged 200 residents in a health survey and involved 30 academic researchers.

Monitoring system

About odours, an innovative and integrated methodological approach was developed ad hoc to face specific issues related to odour emissions. A monitoring strategy implied the use of a smart sensor network consisting of eight photoionization detectors (PIDs; LabService Analytica srl) placed at different distances around the plant. More specifically, seven PIDs were installed in the populated area around the plant, at different distances from it. The distance between each monitoring site and the COVA ranged from about 2.4 (PID 2) to 6.5 (PID 5) km as the crow flies. In correspondence with PID number 3 (4.1 km as the crow flies from the COVA), meteorological sensors were also installed. This approach allowed to obtain VOCs concentration-time profiles as well as a mapping of the territory. This was integrated by a telephonic system that systematized the population complaints. Each citizen (called the receptor) was georeferenced on the map and using a telephone switchboard, communicated the odour perception and also its intensity choosing among three levels of intensity.

About air, a series of passive samplers were used, arranged in a way to cover the area around the COVA and a network of 8 innovative PID sensors for continuous monitoring. This was complemented by monitoring conducted by residents carried out through personal dosimeters in order to measure properly direct exposure of individuals to emissions. Three sampling campaigns lasting three days,

while high resolution monitoring using the PID network was conducted over 5 months. These were accompanied by a meteorological model.

About Superficial soil and water, the study of the geo-pedological cartography of the Val d'Agri was based on the analysis of the anomalies in rocks and composition of the soil. The analysis looked at the physical and chemical characterization of the soils around the plant, identifying 44 sampling sites in an area of approximately 2.7 square kilometres, between the municipalities of Viggiano and Grumento Nova. In addition, 21 water samples taken following instructions from the administrators were analysed premises in natural bodies of water and in aqueducts.

Various parameters and pollutants were monitored across different environmental matrices in the study: air pollutants included benzene (C6H6), carbon monoxide (CO), ethylbenzene, hydrogen sulphide (H2S), m-xylene, p-xylene, methane (CH4), non-methane hydrocarbons (NMHC), nitrogen monoxide (NO), nitrogen dioxide (NO2), nitrogen oxides (NOx), ozone (O3), o-xylene, PM2.5, PM10, sulphur dioxide (SO2), and toluene. Meteorological analysis encompassed wind direction, wind intensity, precipitation, pressure, solar radiation, net radiation, temperature, and humidity. Additionally, superficial soil and water were analysed for heavy metals (As, Cd, Cr, Cu, Ni, Pb, Zn, V) and hydrocarbons (C<40) across layers ranging from the most superficial (0-2 cm) to deeper layers (up to 20 cm). Sensors used included eight photoionization detectors (PIDs) from LabService Analytica srl for odour detection and PID sensors for air quality monitoring. See Figure 5 for odour guide detection.

Compound	Retention time (min)	Odor description	Odor Intensity
Dimethyl ether	2.55		
2-Propanone	2.73	Solvent	2
Methyl ethanoate	2.90		
Cyclopentane	3.13		
Ethyl acetate	3.55		
Methyl ethyl ether	3.66		
2-Methylbutanal	4.06		
Heptane	4.78		
Methyl butanoate	5.31		
Dimethyl disulfide	5.83		
Toluene	6.40		
Octane	7.38		
Ethylbenzene	9.60		
m,p-Xylene	9.90	Sweet	2
Styrene	10.75		
o-Xylene	10.85	Sweet	2
Nonane	11.10		
Δ-3-Carene	11.31	Fresh, herbaceous	1
1,2,4-Trimethylbenzene	12.15		
Octatriene	12.31		
2,6-Dimethyloctane	12.56		
5,6-Dimethyl-1,3-cyclohexadiene	13.11		
Camphene	13.20		
Propylbenzene	13.40		
β-Pinene	13.93		
1,2,3-Trimethylbenzene	14.07	Aromatic/strong	3
Ethyltoluene	14.26	Solvent	2
1,3,5-Trimethylbenzene	14.48	Aromatic/strong	3
α-Terpinene	16.25		
1-Methyl-4-(1-methyethyl)-cyclohexene	16.46		
Unidentified	17.53	Burnt	3
γ-Terpinene	18.15		
α-Terpinolene	19.34		
Undecane	19.84		
Unidentified	22.34	Sweet	2
Dodecane	22.50		

Figure 5. Odour guide detection

The results of the VIS indicated the need for implementing health protection standards based on scientific knowledge, continuing the study on the population, as well as the need for a phase of discussion at an administrative and public level. However, the study had not yet consequences on legislations and regulation.

Actionable data

Data accuracy was ensured by the participation of scientific bodies. However, other scientists commissioned by ENI have dismissed the evidence. After the publication of the study in 2017, Eni commissioned a counter-study in which a panel of experts made up of professors from the La Sapienza and Tor Vergata Universities of Rome and researchers from the Istituto Superiore di Sanità, as well as various Italian experts based in New York – contested the validity of the VIS and agrees that there is not health alarm in Val D'agri (La Reppublica, 2017). The study, instead of opening the way to other studies, ended up in a dead end.

The study was co-financed 60% by the Municipalities and 40% by the managing bodies, for a total of Euro 1,200,000.

4.2.4. Oil extraction in Basilicata (Italy) II [9]

Fossil fuel Project

In 2013, Cova Contro was founded, and in 2015 the association decided to use the social media Facebook to create a public group through which to ask for offers by posting photos, videos, documents and in general data related to the environmental impacts of our territory, especially the fossil industry and its allied industries. Since then, through crowdfunding, we have raised funds to analyze water, soil, air and food near mining areas by publishing the results and using them for campaigns to raise awareness of both local communities and regulators.

On the group first and on the later linked website, we post bills, problems, legal threats and retaliation, anonymous and non-anonymous reports, requests for action, and organize meetings and surveys.

[9] **Description done according to the following links:**
https://covacontro.org/mercurio-piombo-ed-idrocarburi-nelle-falde-vicino-il-pozzo-gas-policoro-001-dir-bis/
https://www.sciencedirect.com/science/article/pii/S2666765724000164
https://www.facebook.com/groups/1629909763929204
https://covacontro.org/punto-zero-dellaria-a-gorgoglione-consegnato-il-monitoraggio-prima-che-tempa-rossa-entri-in-funzione/
https://covacontro.org/augusta-la-rada-e-una-discarica-dove-gli-inquinatori-deridono-lo-stato-ed-i-finti-controlli-non-trovano-colpevoli/
http://movimentovalbasento.altervista.org/idrocarburi-diffusi-valbasento-anomalie-nellacqua-potabile-pisticci/
https://covacontro.org/neanche-il-covid-blocca-lo-smog-a-bolzano-tra-dicembre-e-febbraio-tre-sforamenti-mensili-da-biossido-di-azoto/

To date, thanks to this work, we have achieved groundwater prohibition orders, seizures and several criminal prosecutions, initiated environmental characterization and remediation processes on dozens of sites affected by oil and gas mining, and adjoining waste disposal.

The fossil industry in Basilicata started about 60 years ago, with a new phase of massive and extensive drilling from 1980 until today. Over 400 wells have been drilled, currently around 40 are productive, and there are two active oil centres, an LPG centre, an oil wastewater purification center and hundreds of contaminated well areas awaiting remediation. This activity spans over 200 km of connecting oil pipelines, and high-water consumption.

Socio-environmental conflict

Oil in Basilicata is extracted in rural areas or areas with low population density, but rich in water, agriculture, natural parks and tourism, as well as hydrogeologically fragile. High and chronic unemployment, low average per capita income and low information/education and strong functional illiteracy have historically made the area open to any form of colonization or hetero-direction aimed at exploiting local resources in violation of the environmental, democratic and health names typical of a European nation. Within this framework some vanguards have organized over time, with alternate paths and results, in defending the territory. Today, the current economic crisis, war and general international instability and speculation have rekindled a fossil rush, making democracy and institutions increasingly aligned with fossil companies and less and less transparent and participatory or incentivizing toward direct democracy practices.

Citizen science initiative

Organizations and campaigns

The CS initiative "Analizziamo la Basilicata" operates through a perpetually ongoing crowdfunding campaign, which have enabled the detection of heavy metals above legal thresholds in more than 10 properties/farms as well as in state-owned places such as lakes, springs and rivers. The results once published have been used by victims for legal litigation, local authorities for prohibition ordinances and the initiation of cleanups, the judiciary, political representatives, students, researchers and journalists. In this way, a network of anonymous sentinels has been strengthened over time, who provide us not only with funds but also with data from their respective areas.

The samples were conducted both by volunteers of the association and by technicians in charge and employees of the analysis laboratories. The problems to be studied were either identified by us on the basis of our knowledge or assumptions or reported by the network of followers on Facebook. The initiatives included in the "Let's analyze Basilicata" campaign to date have been: the baseline on the air quality of Tempa Rossa, the satellite research of oil spills in the port of Augusta-Priolo, the support for the study of the Higher Institute of Rome on the pollution of Pertusillo through our sampling, food analysis in Val Basento and the air quality monitoring in Bolzano. These initiatives are carried out independently by Cova Contro with the collaboration of other associations, or in support of research bodies studying environmental contexts already the subject of our investigations.

The monitoring activities began in 2015 and continue to date, involving citizens, associations, committees, and victims, totaling more than 30 participants.

Brief history

In 2013, a group of humanities graduates developed the belief that the local environmental control machine was not working, and that the oil industry would use this weakness to do everything with total impunity.

Given that under Italian laws anyone can take any environmental sample, legally responsible for the sampling methods and reserving every benefit of doubt on the quality of the procedures, and therefore to raise environmental problems it was enough to find pieces of truth and try to put them together over time, and so it was. To date no one has refuted our analyses, in turn exhibiting analyses comparable to ours, this lack of comparison has strengthened our complaints which over time have found growing confirmation.

In 2017, an association from Gorgoglione, Tempa Rossa Oilfield, raised funds so that we and one of our partner associations could measure the quality of the air before the start-up of the local oil centre, to carry out a pre-impact baseline for polycyclic aromatic hydrocarbons. The results were published online.

In 2021 a committee of citizens of Augusta asks us if with the satellite we can see something on the body of marine water in front of the city during the miasma waves. We notice numerous spills, especially from the NATO pier, we report it to the local authorities, but we receive no feedback.

From 2017 to today we have constantly monitored Lake Pertusillo, the largest drinking water basin surrounded by oil wells and pipelines. We have collected so much quality data that we have been identified by the Istituto Superiore Sanità as a data provider, providing video images, samples and satellite images. The research continues and 4 articles have been published.

In 2017 we ask for support from an association from Pisticci to jointly finance the search for anthropogenic and oil contaminants in the local food chain, given the presence of farms close to the oil wastewater purification site. The results generated panic, the authorities investigated without issuing any charges, except against us. In Bolzano a local association asked us to use our instruments to measure the quality of the air impacted by fossil fuel traffic in 2021/22. The results were ignored by local authorities, including the judiciary.

Monitoring system

The monitoring does not have pre-established time intervals but is scheduled based on the available budget and the potential media impact of a positivity. On average we carry out 2 analyses per month, with an average cost 400 euros each. Funding comes from private funds and readers/supporters.

Parameters and pollutants monitored include heavy metals, total hydrocarbons, phenols, solvents, IPA (Isopropyl alcohol), and nitrogen dioxide (NO2). These are assessed across various environmental matrices such as groundwater, drinking water, topsoils, crude milk, liver and beef, sheep meat, and air quality. Monitoring utilizes gas chromatography in laboratory settings with detection limits above

0.01 mcg/l for various pollutants. For NO2 detection specifically, the AQ 500 Aeroqual sensor is employed with detection limits set at 0.005 ppm.

Where checks were omitted, legal disputes between the parties involved started decades late and local public opinion was sensitized. Unfortunately, the timescales of Italian justice remain very slow and therefore, once the union orders have been issued to ban the use of groundwater, the recognition of damages and those responsible is still underway in most cases, in others the energy companies have already been condemned or have recognized the damage without opening disputes.

Actionable data

The accuracy of the data is the responsibility of the analysis laboratories, the timeline is linked to the emergency if reported, in these cases we have carried out environmental checks where no one had officially done them. The communication of data is standardized for everyone, citizens and institutions, therefore premise and context reconstruction, results compared to the legal thresholds and to the available literature on the origins or causes. On quality, obviously in trying to guarantee the best standard, in reality a compromise is sought between cost and quality, and even the most accredited laboratory analysis can actually be contested in the absence of a truly documented procedure. The trust factor is fundamental for this reason, in cases more delicate we send multiple aliquots of the same sample to multiple laboratories at the same time

Other relevant information

It is necessary to legally protect ourselves when exposing the data. In Italy, the crime of defamation in the press is criminal, therefore it is necessary to pay attention to verbal forms, punctuation and syntax and not to establish any causal link, carefully evaluating all the information. Meticulous bibliographic research is needed, always leaving room for doubt or uncertainty and protecting the anonymity of citizen science sources or volunteers.

4.2.5. Oil extraction in Basilicata (Italy) III[10]

Fossil fuel Project

Val d'Agri is an area located in Basilicata, southern Italy, where oil was discovered in the first half of the 20th century. By the early 1990s, the area became home to the largest onshore oil and gas field in continental Europe, at an average depth of 2.400 meters below sea level. In 1996 the Italian Energy Hydrocarbons Corporation ENI S.p.A. began exploiting hydrocarbons, currently operating 26 oil wells (Mise 2018) and managing the Val d'Agri Oil Center (COVA), the largest Italian gas and oil pre-treatment plant situated in a densely populated area with significant environmental complexity. Recently, Total has also begun exploiting the Tempa Rossa oil field in Media Val d'Agri.

[10] **Description done according to the following link:** https://assets-global.website-files.com/5d9bafe75f6edb09b82b5aaf/60473a7f34cb2e71fb786b6a_Agri_sezione_Aria_grafica.pdf

The Val d'Agri Oil Center (COVA) is located in the industrial area of Viggiano (PZ), covering approximately 171.700 square meters. In 2011, it was modernized to achieve a treatment capacity of 104.000 barrels of oil per day and 3.100.000 Sm^3/d of natural gas. The crude oil entering the facility undergoes all necessary treatments for commercialization: separation and subsequent processing of the three phases present in the extracted fluid (crude oil, gas, and water).

Socio-environmental conflict

The extraction activities with high environmental impacts have affected the valley's agriculture and tourism (CDCA 2015). The industrial area is very close to the "Appennino Lucano, Val d'Agri, Lagonegrese" National Park and built-up areas, and is located in the Agri River Basin, near the Casale stream. Nearly 30 years after extraction began, the impacts on local communities and territories are still not fully assessed, leading to distrust among citizens excluded from decision-making processes. This discontent led to the formation of committees and associations in the late 1990s, aimed at denouncing social, economic, and environmental issues and the lack of redistribution of extraction proceeds. The traditional economy, based on agriculture and nature tourism, has weakened. Numerous associations, such as COVA Contro, Onda Rosa, Laboratorio per Viggiano, Comitato per la tutela del Pertusillo, OLA, and local branches of national organizations like Legambiente and WWF, have emerged to fight for greater environmental and health protection.

Citizen science initiative

Organizations and campaigns

The CS initiative "Che aria tira in Val d'Agri?" was initiated by the NGO Source International to address ongoing concerns from citizens and associations regarding environmental risks associated with human exposure to substances emitted by the Val d'Agri Oil Center (COVA) and its industrial area in Viggiano and Grumento Nova municipalities. COVA, known for atmospheric contaminants from odours, fumes, and flaring, has sparked significant health concerns among the local population.

The study focused on air quality in Viggiano and, to a lesser extent, Grumento Nova, concentrating on the residential area of Le Vigne and the industrial area surrounding COVA, where approximately 3,500 technicians and workers are employed. Air quality monitoring included particulate matter (PM10), total volatile organic compounds (TVOCs), and passive sampling for hydrogen sulphide (H2S).

Community involvement was a critical aspect of this initiative. Local residents, who have long expressed their concerns about the environmental and health impacts of the oil industry, were actively engaged in the monitoring process. This participatory approach empowered the community by involving them directly in the scientific process. Their participation helped ensure that the data collected was comprehensive and reflective of their lived experiences, fostering a sense of ownership and responsibility towards addressing the environmental issues at hand.

This citizen science initiative provided valuable data that could be used to advocate for better environmental policies and regulations. By involving the community, the study aimed to increase transparency of environmental monitoring and air quality levels.

Brief history

Air quality measurements were conducted during a single campaign in the dry season between July and August 2020. Given the proximity of the Val d'Agri Oil Center (COVA) to the residential areas of Viggiano and Grumento Nova, air quality monitoring focused on particulate matter (PM10), total volatile organic compounds (TVOCs), and passive sampling for hydrogen sulphide (H2S). The selection of these parameters was based on their significance as indicators of pollution from oil extraction and processing facilities like COVA, due to their potential health risks.

PM10 is known for its adverse effects on respiratory and cardiovascular health. TVOCs encompass a variety of chemicals that can have both immediate and long-term health impacts. Hydrogen sulphide, characterized by its distinctive rotten egg odour, can pose serious health risks even at low concentrations.

Currently, there are no specific regulatory limits for TVOCs and hydrogen sulphide at the national or international level, highlighting the importance of this monitoring initiative. The collected data aimed to provide a clearer picture of the air quality and its potential health impacts on the local population, informing both community awareness and advocacy efforts for stricter environmental regulations.

Around 20 stakeholders, including Source International, ReCommon, OSSERVATORIO POPOLARE PER LA VAL D'AGRI, COVA CONTRO, local citizens, journalists, and activists, are involved in the initiative.

Monitoring system

Air quality measurements were conducted during a single campaign in the dry season between July and August 2020. The selection of sampling points and spot measurements (upwind and downwind from the investigated source) was based on the prevailing wind direction (from southwest to northwest; and from north to south) and the presence of sensitive receptors (residents and workers in the area facing COVA).

The following pollutants were monitored with their respective instruments:

Hydrogen sulphide (H2S) was monitored through passive sampling using Radiello. Nine fixed stations for passive sampling of hydrogen sulphide were installed for approximately one month in the area surrounding COVA, primarily concentrated downwind.

The measurement of atmospheric particulate matter PM10 was performed as an indicator primarily originating from combustion processes. Turbines, chimneys, and generators, fuelled by gas combustion, represented the main sources of atmospheric particulate matter, along with vehicular traffic associated with COVA and the industrial area. PM10 remains in the air for a considerable period and can be transported over long distances. PM10 causes various health effects, including respiratory disorders. Particulate matter was measured with a particle counter (Aeroqual S500 model, based on photoionization detection PID). Measurements were conducted continuously (24 hours) for approximately one month (from July 21, 2020, to August 23, 2020), with data recording every 2 minutes. Measurement stations for particulate matter were installed upwind and downwind from COVA.

Volatile organic compounds (VOCs), particularly non-methane hydrocarbons (NMHCs), were analysed, mainly originating from fossil production processes, storage tanks, pipelines, discharge areas, and flares. Some are classified as carcinogens or potential carcinogens for humans and are key precursors to ozone. Exposure to VOCs produces a wide range of harmful health effects. VOCs were measured using a portable instrument (AEROQUAL S500 model). Spot measurements (minute measurements recorded over a total of 30 minutes) were conducted at 15 points around the COVA area in the territory comprising the municipalities of Viggiano and Grumento Nova, according to west-east and north-south gradients; fixed measurements (minute measurements for a total of 28 days) were located in the Le Vigne locality, in the municipality of Viggiano, downwind from COVA.

As for the pollutants, it is an extremely toxic, irritating, and suffocating substance. The first sign of hydrogen sulphide presence is its unpleasant odour, which even at low concentrations, causes discomfort to the population. The measurement of atmospheric particulate matter PM10 (aerodisperse particles with an aerodynamic diameter less than 10 µm) was performed as an indicator primarily originating from combustion processes. PM10 causes various health effects, including many respiratory disorders.

Total concentrations of VOCs (volatile organic compounds) were analysed, which include a wide range of gases harmful to human health produced by fossil extraction and processing processes.

The Sensors used and detections limits were: Radiello (H_2S) - The limit of detection is 30 ppb for 1 hour exposure or 1 ppb for 24-hour exposure; and AEROQUAL S500 (VOCs, PM10) - Range 0-1000 mg/m^3 Minimum detection limit 0.001 mg/m^3

Actionable data

Measures were collected and analysed by a group of specialists using accurate sensors with an acceptable level of precision. They were used to create maps and all these results were published in scientifical reports and simpler versions to ask local authorities to improve monitoring measures.

4.2.6. Oil extraction in the Niger Delta (Nigeria)[11]

Fossil Fuel project

The Port Harcourt Refining Company, (abbreviated PHRC), is a Nigeria-based oil and gas company primarily specializing in the refining of crude oil into petroleum products. It is headquartered in Port Harcourt metropolitan area of Rivers State, southeastern Nigeria. The company is a subsidiary of the

[11] **Description done according to the following links:**
https://www.theguardian.com/environment/ng-interactive/2022/jun/01/oil-pollution-spill-nigeria-shell-lawsuit
https://datacab.org/air-reading/
https://www.google.com/maps/d/u/0/viewer?hl=en&hl=en&mid=1thpZYIkm2jr0LRZbK4pJf6GTTz1UX4Lc&ll=4.85594439066165%2C7.0089552611111205&z=10
https://migrazioniontheroad.largemovements.it/oil-spills-niger-delta-environmental-health-disasters-nigeria/

Nigerian National Petroleum Corporation (NNPC). This is a refinery complex comprising two refineries at Alesa-Eleme near Port Harcourt in Rivers State.

Port Harcourt II (New Refinery) is a complex, conversion refinery with a nameplate distillation capacity of 7,500,000 MTA (150,000 bpd). It came on stream in 1988 and was originally intended to serve as an export refinery. It has been subsequently dedicated to domestic market service given frequent interruptions in supply from the other three refineries in Nigeria. Port Harcourt II has considerable clean fuel capability, including lead-free gasoline.

Socio-environmental conflict

The Niger Delta is an oil-rich region in south-eastern Nigeria, where, since 1956, the activities of multinational oil companies (such as Shell, Exxon Mobil, Chevron Texaco, Total Fina Elf, Eni/Agip) have caused serious environmental, social and economic damages, due to oil extraction and drilling, crude oil leaking from old pipelines and gas flaring. People living in these areas breathe polluted air, eat contaminated fish and drink water mixed with oil and, as a consequence, the spread of health diseases has increased. In the Niger Delta's coastal communities, oil pollution of the marine environment has depleted the fishing and water resources that people have traditionally depended on for their livelihoods. The only ones to get rich from oil are the multinationals and the local elites: a situation that has led to protests and mobilisation on the one hand, and violent repression, on the other, by the state and private security agents hired by the companies.

Citizen science initiative

Organizations and campaigns

The Media Awareness and Justice Initiative (MAJI) is an independent media group based in Nigeria that is using new low-cost technologies to monitor air pollution. With the data created, they are helping local villages hold big companies accountable after decades of exploitation in the Niger Delta. With the evidence created by the project, MAJI has been campaigning and mobilising radio shows to raise awareness among the population as well as among local and global partners. MAJI also continues to use the data generated by the project for policy engagement and discussions with government agencies and policy stakeholders. The Ogale Community in Rivers State is now using qualitative and quantitative data about the air pollution in the pursuit of its legal case against SPDC in the Supreme Court of the United Kingdom for the pollution of their environment and destruction of community lives and livelihoods.

Brief history

MAJI started with the training of 20 grassroots civil society community-based organisations on environmental data collection, analysis and use. They also deployed air quality sensors with mobile data connectivity during the project's duration from November 2021 to May 2022. Initially 10 sites were covered by the sensors, and this was later expanded to 15 locations in a partnership between MAJI and the Open Culture Foundation (OCF), a non-profit organisation founded by members of Taiwan's open-source community that donated Taiwanese air sensors that can monitor PM 2.5 to MAJI. The two organisations, both APC members, have been an active voice to speaking up against

pollution. Over time, the sensor-network data was fed into an online air quality data collection portal (DATACAB), developed to gather the information and, by using graphics and pictures, provide a visual analysis of the pollution level. Since 2015, rural and urban communities have identified a constant increase in the level of PM 2.5, PM 1.0 and PM 10 amorphous carbon and an alarming deterioration in air quality. MAJI reported it in its report to the APC's Connecting the Unconnected initiative, which provided financial resources for the MAJI project.

This CS initiative, ongoing from 2021 to the present, involves stakeholders such as The Media Awareness and Justice Initiative (MAJI), the Association for Progressive Communications (APC), the Open Culture Fund (OCF), the French Embassy in Nigeria, and journalists, with an undefined number of participants.

Monitoring system

This system implemented solar power-based air quality sensors across 15 urban and rural communities, facilitated by a platform for citizen data collection. The Open Culture Fund (OCF) contributed Taiwanese air sensors for this project. Parameters and pollutants monitored include PM 1, PM 2.5, and PM 10, focusing on environmental matrices such as air. The initiative utilizes 10 cellularly configured AIR-NOTES Devices and 2 non-cellularly configured MAPS V6.0 devices deployed in rural and urban communities situated in upland and riverine areas of Rivers State

MAJI has been campaigning and mobilising radio shows to raise awareness among the population as well as among local and global partners. The Ogale Community in Rivers State is now using qualitative and quantitative data about the air pollution in the pursuit of its legal case against SPDC in the Supreme Court of the United Kingdom for the pollution of their environment and destruction of community lives and livelihoods.

Actionable data

Accurate, accessible and continuous monitoring.

4.3. Coal extraction

In the case of coal extraction, Google Scholar was utilized to find articles on CS projects related to monitoring the environmental and health impacts of the activities on local communities. Keywords, phrases, and the names of energy companies were also used to search the internet for additional sources, including non-academic articles, blog posts, and newspapers. To contextualize the findings, the research included browsing the websites of individual projects and the implementing institutions. Below are 5 cases of which only 2 are located in Europe and the first of them is global in nature since it was applied in 70 countries around the world.

4.3.1. Coal extraction in Poland[12]

Fossil Fuel project and socio-environmental conflict

Two main types of coal mining can be characterized in Poland, these are hard coal mining extracted mainly from underground through shaft and corridor technology, and lignite mining through the open-pit method.

Hard coal mining is currently concentrated in the Upper Silesian and the Lublin Voivodeship. And it is mined from a depth of about 700 m to as much as 1300 m[1] . On the other hand, the mining of lignite, which is considered more harmful to the environment (lignite contains more sulphur and ash and has a lower calorific value than hard coal[2]), is concentrated in several key regions with significant reserves of this resource. These areas are managed by several large mining companies that are responsible for the exploitation of lignite resources are concentrated in the Lower Silesian, Greater Poland and Lodz Voivodeships.

Characteristics of the most important lignite mining areas in Poland:

The Turów mine is located near the town of Bogatynia, in the Lower Silesian province. The mine exploits the resources of the Turoszów deposit, has been in operation since the 1970s and is a key supplier of lignite to the Polish energy industry. Mining at Turoszów has been causing controversy for years due to its impact on the environment, including groundwater and border ecosystems. The international dispute is over the mine's negative impact on the environment and society[3] . The Czech Republic is concerned that further coal mining at Turow will cause further environmental degradation, including the problem of the depression funnel in particular, which has triggered negotiations and a dispute at the European level 9. In 2020, the conflict escalated when Polish government decisions to extend the mine's operations were used by the Czech Republic to complain at the CJEU, which ended up imposing a financial penalty on Poland[4] . Poland responded with a cassation complaint, and the dispute continued at various European institutions. Finally, in 2022, after long negotiations, Poland and the Czech Republic agreed on an agreement. The Turów mine was granted permission to continue its operations[5] , but as early as March 2024, the Warsaw Regional Administrative Court upheld the complaints of several environmental organizations, among others foreign ones, and revoked the decision of the GDOŚ (Chief Director of Environmental Protection) specifying the environmental conditions for further exploitation of the Turów lignite deposit. Currently, the mine continues to extract coal.

[12] **Description done according to the following links:**
https://www.sggw.edu.pl/wp-content/uploads/2024/03/Raport_Nauka-obywatelska-citizen-science-jako-metoda-pozyskania-danych-o-jakosci-wod-oraz-oceny-zasolenia-wod-powierzchniowych-w-Polsce.pdf?x69619
https://www.dailymotion.com/video/x8tbybi
https://www.sggw.edu.pl/swiatowy-dzien-wody/
https://niechzyjeplaneta.onet.pl/zywiol-wody/wplywowi/sprawdzilem-jak-dziala-splawik-pozwalajacy-wedkarzom-badac-jakosc-wody/hm7rqzk
https://nowymarketing.pl/wplywowi-ruszyla-akcja-ktora-pomaga-monitorowac-czystosc-wod-w-polsce/
https://publicrelations.pl/w-trosce-o-nasze-rzeki-rusza-akcja-wplywowi/

It is worth mentioning here the great ecological disaster in the Sudetes , In the 1970s and 1980s there was a massive die-off of forest stands, which led to the declaration of a state of ecological disaster in 1982 in the former Jelenia Góra Province. The disaster covered an area of about 15,000 hectares in the entire Sudetenland, particularly affecting the Jizera Mountains and the Giant Mountains. Massive die-off of tree stands was also observed in the Eastern Sudetes, such as in the Śnieżnik Massif. One of the main reasons for this catastrophe was lignite, at the end of the 20th century, power plants and combined heat and power plants in the area of the Polish, Czech and German borders burned huge amounts of lignite (It is estimated that about 3 million tons of pollution were emitted annually, accounting for 30% of the total SO2 emissions at the time)[6] . It was mined from nearby rich deposits, leading to high emissions of air pollutants. These pollutants, combining with water droplets, formed aggressive sulfuric and nitric acid, which was present in all types of hydrometeors, acidifying not only rain, but also snow, fog and dew.

The Belchatow mine is located near the city of Belchatow, in the province of Lodz. It is one of the largest lignite mines in Europe and feeds the Belchatow Power Plant, one of the largest coal-fired power plants in the European Union. The mine exploits lignite deposits with great environmental impact. Belchatow mining requires intensive drainage of groundwater, leading to significant changes in the hydrology of the area. The mine and power plant are also a source of carbon dioxide emissions and other atmospheric pollutants, which has a negative impact on air quality and the health of local residents.

The Adamów, Konin mines are located near the city of Konin, in the Greater Poland province. The mines are part of Kompania Węglowa Konin and exploit lignite deposits in the Konin area. The mined coal is the main source of power for the Konin Power Plant. Mining requires groundwater drainage, which affects local ecosystems and groundwater. In addition, mining and energy activities in the area have a negative impact on air quality and greenhouse gas emissions. An example of the mine's destructive activities is the lowering of the water level by 1.5 meters in Ostrowskie Lake (the beach has expanded by 200 meters)7 However, these are scientifically anecdotal data. In 2010, it was planned to open a new lignite opencast field in the vicinity of Gopło, but the defense of Gopło and the areas over goplańskie was stood up by the Municipality of Kruszwica and the environmental organization Greenpeace, which jointly filed a complaint with the European Commission8 . As a result, the European Commission on January 26, 2012 admonished Poland for violating environmental regulations. The EC's allegation concerned the failure to carry out an environmental impact assessment of an open-pit mine in a Natura 2000 protection area on Lake Gopło9 . A new field has been built and water levels in the surrounding lakes have plummeted10 .

Lignite mining in Poland continues to be a key component of the country's energy sector, but it is also a source of significant environmental problems. The open-pit method that is used leaves great local damage in the form of dumps and mine outcrops, which can lead to environmental degradation and loss of ecosystems[11] . Intense groundwater drainage, changes in the landscape, and emissions of pollutants are major issues that must be addressed by appropriate management and environmental protection strategies.

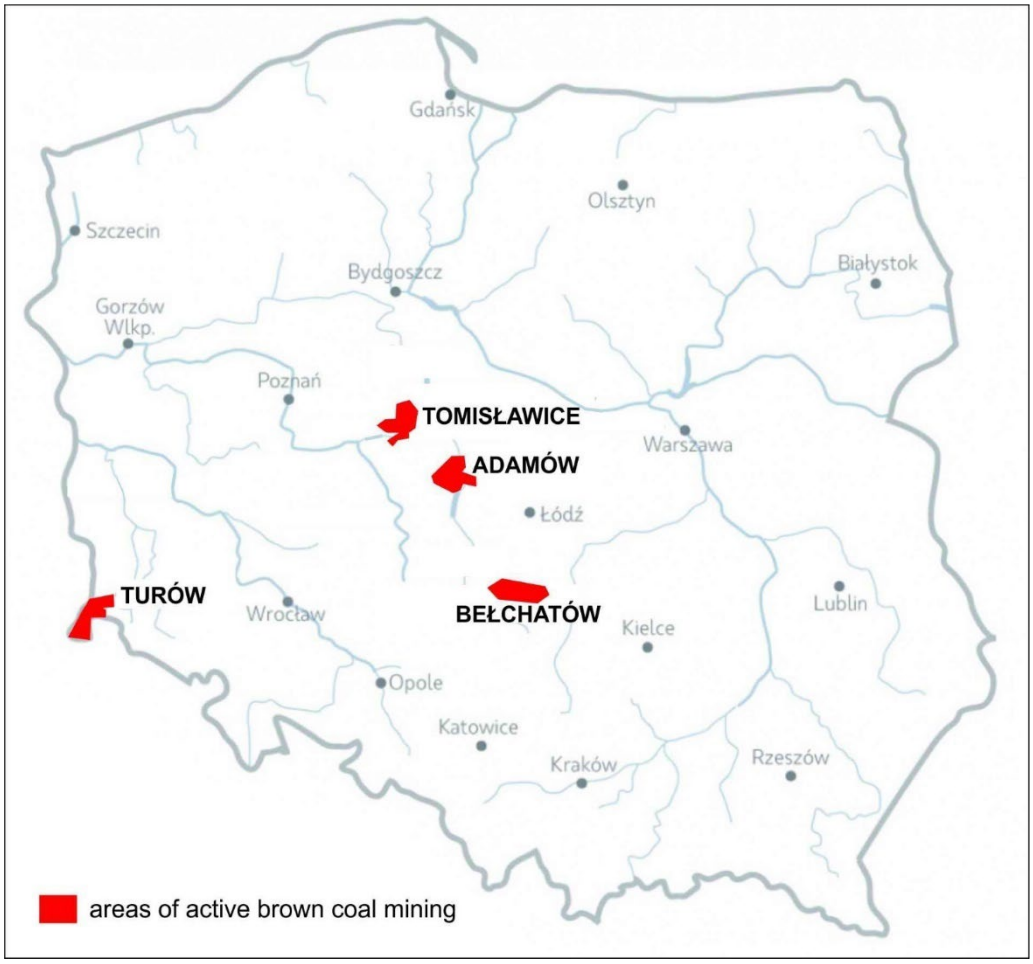

Figure 6. Areas of active brown coal mining in Poland

Modified on the basis of: https://rt-on.pl/wiadomosci/item/229-eksploatowane-i-planowane-kopalnie-odkrywkowe-wegla-brunatnego

During the summer of 2022, a mass mortality event involving fish, beavers, clams, crayfish and other wildlife occurred in the Oder River in Poland. Over 100 tonnes of dead fish were removed from the Polish section of the river, and a further 35 tonnes from German sections, causing concern that the water was poisoned. At first the cause was not clear. It was later determined to be an algal bloom and large amounts of salt in the water. In February 2023 European Commission reported that the direct cause of the ecological disaster in the Oder River was prymnesin toxins from Prymnesium parvum algae. The Polish authorities were slow to react, causing a scandal and resulting in the dismissal of officials responsible for water management and environmental protection. One of the reasons for such a high salinity of the Oder may have been the discharge of water from nearby mines, as suggested, among others, by the Chief Inspectorate of Environmental Protection[13].

[13] https://www.sggw.edu.pl/wp-content/uploads/2024/03/Raport_Nauka-obywatelska-citizen-science-jako-metoda-pozyskania-danych-o-jakosci-wod-oraz-oceny-zasolenia-wod-powierzchniowych-w-Polsce.pdf?x69619

Several decades ago, the Oder River was highly polluted due to heavy industrialisation including many large coal mines in Lower Silesia (e.g. Walbrzych and Turow). Fish die-offs were reported by anglers around Oława in March 2022. On 11 August 2022, volunteers and anglers removed at least 10 tonnes of dead fish from the 200 km stretch of the river north of Oława in southwest Poland. The German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, called the situation a catastrophe and a shocking ecological disaster. The catastrophe has temporally made the issue of the seriousness of the consequences of increased water pollution (salinity) a leading topic of public debate and heightened civic vigilance regarding the need to observe the state of our rivers and lakes. Water pollution is less talked about in Polish society than air pollution. Water resource problems have begun to receive attention due to prolonged periods of drought and locally due to the impact of lignite mining. According to the WWF Poland Foundation, the industry responsible for the majority of salt (mainly chloride) discharges into the country's waters - and thus for the salinisation of river waters - is mining. Every year millions of tonnes of salt enter Polish rivers from the mining sector as a result of mine drainage.

Citizen science initiative

Organizations and campaigns

The CS initiative #WPŁYWOWI in Upper Silesia, led by the Polski Związek Wędkarski (Polish Angling Association), began operations on April 22, 2024 (Earth Day)[14]. The initiative includes the deployment of Aguard float devices to monitor water quality. The Polish Angling Association not only promotes angling but also actively protects water quality through education and pro-environmental initiatives, leveraging anglers' unique ability to observe and report changes in aquatic environments, thereby contributing valuable data to environmental monitoring efforts.

Polish Angling Association promotes angling but also works to protect water quality. The association plays a key role in education and pro-environmental initiatives, which shows their commitment to keeping Polish rivers and lakes clean. Anglers who spend time on the water are in a unique position to observe and report changes in water quality. Their daily observations are an invaluable source of information about the state of the aquatic environment.

The Aguard Smart Float is a smart fishing tool that measures the electro-conductivity of water. Equipped with sensors, the device connects to the Aquard app, allowing for real-time monitoring of water levels. The data collected by Aguard can serve not only anglers, but also hydrological services. The information collected helps to respond quickly to environmental threats and to manage water resources more effectively.

Aguard is the result of cooperation between the private sector (Expert Float, BNP Paribas bank), the scientific sector (the Warsaw University of Life Sciences SGGW) and environmental organisations (Polish Angling Association). Together they have created a tool that can make a real difference to the protection of Polish waters. The Aguard float allows the user to quickly measure the salinity of waters, which can indicate water pollution. The data resulting from the measurements is archived. With the

[14] https://www.sggw.edu.pl/swiatowy-dzien-wody/

Aguard float, each user is able to conduct his or her own monitoring, the results of which can later be analyzed on a larger scale[15].

The initiative has gained widespread media support, including NowyMarketing[16], PublicRelations[17], Noizz.pl[18] and the Onet Group, where press report on first use was published[19].

The SGGW also conduct guest lessons, during which elementary school students from Warsaw learn about the issue of water flow in the environment and learn about our university as an important center for water resources research.

The initiative has started in the spring of 2024. The pilot group is expected to reach 2,000 people – that is the number of floats available from 6 May to 10 December 2024 as part of BNP Paribas Bank's #WPŁYWOWI campaign.

Monitoring system

The Aguard float, which monitors electrolytic conductivity in water, is currently unavailable for purchase; however, until December 10, 2024, or until the pilot float pool of 2,000 units is depleted, it can be acquired by opening an account with BNP Paribas bank.

Aguard floating sensor. The Aguard float measures the electro-conductivity of the water and, in combination with a specially developed mobile app, offers the possibility to: 1) measure the salinity and temperature of the water, 2) assess whether the measured value falls within the permissible categories of the standard for this parameter, 3) archive the measurement and transfer it to a database. A micro-device based on a microcontroller, Bluetooth low energy, a battery and a sensor is installed in the Aguard® float, which generates an electrical voltage in the water. As a result, a current flows through it, whose intensity and voltage depends on the conductivity, and the sensor keeps it constant and assesses the change in voltage. The more substances dissolved in the water, the higher its electrolytic conductivity, which most often indicates contamination. The application used in the device immediately sends the measurement results to a central database. The database is updated continuously and is coordinated by a team of hydrologists from the Warsaw University of Life Sciences, who oversee the archiving and analysis process. The Aguard app[20] is available on both the App Store and Google Play. When the float connected via Bluetooth is submerged in the water, it will launch and display the measurement result. If the measurement result indicates that salinity standards are exceeded, an alert will appear in the app which will also be visible to the scientists.

[15] https://www.sggw.edu.pl/swiatowy-dzien-wody/
[16] https://nowymarketing.pl/wplywowi-ruszyla-akcja-ktora-pomaga-monitorowac-czystosc-wod-w-polsce/
[17] https://publicrelations.pl/w-trosce-o-nasze-rzeki-rusza-akcja-wplywowi/
[18] https://www.instagram.com/noizzpl/reel/C7TpV2Do4YW/
[19] https://niechzyjeplaneta.onet.pl/zywiol-wody/wplywowi/sprawdzilem-jak-dziala-splawik-pozwalajacy-wedkarzom-badac-jakosc-wody/hm7rqzk
[20] https://play.google.com/store/apps/details?id=pl.com.aguard&pli=1

4.3.2. Coal extraction in Stara Zagora (Bulgaria)[21]

Fossil Fuel project

The Maritsa Iztok Complex is the largest energy complex located in Stara Zagora region (Southern Bulgaria) in Southeastern Europe. Maritsa Iztok 1 and 3 located entirely within Stara Zagora Province in south-central Bulgaria while Maritsa Iztok 2 is split with eastern neighbouring Sliven Province. It consists of three lignite-fired thermal power stations. TPP Maritsa East 2 EAD is the biggest innovated thermal power plant in the Republic of Bulgaria and on the Balkan Peninsula[22]. The complex is located in a large lignite coal basin, which includes several mines, enrichment plants, a briquette plant and its own railway system. The development of the thermal power and mining complex at Maritsa Iztok began in 1952, but the lignite deposits used to be known well in the mid-19th century. The Maritsa Iztok mines and power plants are interdependent as the only market for coal is the power plants, while the power plants have no other supplier of coal but the mines. The complex is the largest source of CO2 emissions in Bulgaria with 142,913,573 tons emitted in 2020. Mini Maritsa iztok (MMI) operates the largest open pit lignite coal mine in the country (Bgenh, 2024).

Socio-environmental conflict

According to Greenpeace, when it comes to air quality, Bulgaria is one of the most polluted countries in the EU. Stara Zagora Stara Zagora as a region of industry and agriculture, it also suffers from poor air quality and the worst coal pollution in Bulgaria.

Citizen science initiative

Organizations and campaigns

The citizen science initiative "Dustcounters," led by Greenpeace Bulgaria, began in October 2016 to monitor pollution in the Stara Zagora region, particularly from the Maritsa 3 plant, which emitted sulphur dioxide, nitrogen oxides, and dust. In 2023, Greenpeace activists staged a protest at the Maritsa 3 TPP by spelling out "CRIME" on its cooling tower, symbolizing their call to end environmental harm. The monitoring initiative ran until February 2017, with involvement from stakeholders like Robotev. Greenpeace Bulgaria engaged 25 volunteers from the region through an information session and workshop where they assembled monitoring devices (Kogut et. al. 2022: 17-22).

[21] **Description done according to the following links:**
https://www.greenpeace.org/international/story/7314/citizen-science-in-action-open-source-air-pollution-monitoring-in-bulgaria/
https://www.academia.edu/106967918/D2_2_Citizen_Science_Landscape_Review
https://www.wecompair.eu/post/citizen-science-projects-in-bulgaria-germany-belgium-and-greece-a-brief-introduction

[22] https://en.wikipedia.org/wiki/Maritsa_Iztok_Complex

Monitoring system

In collaboration with the Robotev robotics lab, Greenpeace created and designed the Dustcounter – an easy to use, easy to assemble, do-it-yourself device that allowed users to measure the levels of dust and particulate matter near their homes or workplaces. The innovative design allowed for straightforward assembly from easy to find hardware and was created with open-source technology (Arduino), making the device affordable and easy to build and operate for non-professionals without technical expertise. A network of citizen air quality monitoring stations based on an open-source platform has been developed. in cooperation with the Robotev technology lab. The campaign began with a workshop for volunteers and activists from Stara Zagora. The dustcounter took measurements of pollutive dust levels in the air, every hour. Once a day, the data was sent to the Greenpeace Bulgaria website, where people viewed the results for each device[23].

The pollutants monitored were particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), carbon dioxide (CO2), as well as additional atmospheric information e.g. pressure, temperature, humidity, background radiation.

The board used an ATmega 328p and made it easy to attach a dust sensor and fan. They also had a WiFi module so data could be relayed and posted to Greenpeace's site each day. The instruction for creating DIY air pollution monitor was once available here (in Bulgarian). The innovative design of Dustcounter devices meant that they could be easily assembled from common hardware components. Moreover, they were created with open- source technology (Arduino), which made them affordable and easy to operate by non-professionals without technical expertise.

4.3.3. Coal extraction in Hwange (Zimbabwe)[24]

Fossil Fuel project

In the Hwange region of western Zimbabwe, several companies are involved in fossil fuel projects, including Makomo Resources, Zambezi Gas Zimbabwe, Hwange Colliery Company Limited, and Chilota Colliery Company. Zimbabwe possesses significant high-grade coal deposits, classified as fossilized carbon, with estimates from business research firm Frost and Sullivan suggesting reserves could

[23] https://www.greenpeace.org/international/story/7314/citizen-science-in-action-open-source-air-pollution-monitoring-in-bulgaria/

[24] **Description done according to the following links:**
https://youtu.be/D1BhJkJBlFc
https://www.eawag.ch/en/info/portal/news/news-detail/citizen-science-knowledge-as-a-weapon-in-the-fight-for-clean-water/
https://istp.ethz.ch/news/2022/02/citizen-science-knowledge-as-a-weapon-in-the-fight-for-clean-water.html
https://www.research-collection.ethz.ch/handle/20.500.11850/535761
https://www.frontiersin.org/articles/10.3389/fenvs.2021.754540/full
https://doi.org/10.1016/j.worlddev.2022.105952.
https://www.sciencedirect.com/science/article/pii/S0305750X22001425
https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/574276/1/Online_Dissertation_Ruppen_Desiree_03_10_2022.pdf
https://www.research-collection.ethz.ch/handle/20.500.11850/577069

sustain production for approximately 200 years at a rate of 5,000 tons per annum. These reserves are well-suited to supplying feedstock for coal-powered thermal power stations.

In Sep. 2011 the country had awarded 20 licenses for coal exploration and mining. The five firms awarded licenses were Makomo Investments, WK Blasting, Clidder, Apex and Liberation Mining. The majority of the 20 companies receiving prospecting licenses are joint ventures with Zimbabwean partners. In addition, the Zimbabwe Electricity Regulatory Commission recently licensed 13 independent power projects. Zambia is the main export market for Hwange where it is supplying coking coal for copper smelting. Operations began in chronological order: Hwange Colliery Company Limited was founded in 1889, followed by Makomo Resources in 2010, Zambezi Gas Zimbabwe in 2017, and Chilota Colliery Company in 2020.

Socio-environmental conflict

In and around the town of Hwange, bituminous coal has been mined and processed since colonial times. The Deka River in the Hwange district is heavily polluted by coal mining and the coal-fired power plant, and is a serious health risk for the people who drink its water or for the fish in it. Community members from the villages close to Deka use the river water for catching fish as their main source of protein, breeding baskets, feeding their livestock and also as a direct source of fresh water due to lack of functioning drinking water boreholes.

Citizen science initiative

Organizations and campaigns

Mining can have serious consequences for nature and the health of the populations in countries of the Global South, where environmental laws are often only inconsistently implemented. In Hwange, in western Zimbabwe, people have been fighting water pollution from coal mining for years. They were powerless against the operators – until doctoral student Désirée Ruppen (2022[25]) launched a citizen science project in 2018. This project, conducted from December 2018 to March 2020, engaged 13 individuals from various villages, spanning ages from 16 to almost 70. The Swiss Federal Institute of Aquatic Science and Technology (Eawag) supported this initiative, marking a significant step in empowering local communities to monitor and address environmental challenges caused by mining activities.

Monitoring system

According to the article (Ruppen *et al.*, 2021) on December 14, 2018, researchers conducted a sampling training workshop at the primary school in the village of Mashala. The training introduced community members to fundamental knowledge about water quality and sampling. Using an illustrated training manual, the training focused on measuring pH by using test strips and taking water samples while minimizing sample contamination. The so-called “community monitors” were also encouraged to store the samples safely in dry and dark places in their houses.

[25] file:///C:/Users/User/Downloads/Online_Dissertation_Ruppen_Desiree_03_10_2022-2.pdf

During the training meeting and subsequent test sampling, the community members and the scientist jointly decided about eight monitoring locations on the Deka River and a tributary that transports wastewater from the mines and the coal-fired power plant. . With weekly to bi-weekly frequency, participants of the project filled water into plastic tubes and measured its pH value.

Community monitors took unfiltered 50 ml water samples in polyethylene falcon tubes provided by the project. In total, they collected 420 grab samples in the time span of December 2018 to March 2020[26]. 350 additional samples taken by the coordinator and a young scientist from the University of Zimbabwe at other locations.

The project was supported by an ETH Zürich ISTP Research Incubator Grant. It was implemented in a collaboration between the School of Earth and Mineral Sciences, University of Zimbabwe and the ISTP, ETH Zürich. The research permit was granted by the Research Council of Zimbabwe.

The parameters and pollutants monitored included pH, rainfall data, chlorophyll a (Chl a), conductivity, temperature, fluorescent dissolved organic matter (fDOM), turbidity, and dissolved oxygen (DO) in water and rainwater environmental matrices.

Citizens measured pH in the flowing water using test strips (Merck pH-Indicator strips pH 2.0–9.0 MColorpHast™) and recorded data in their notebooks including date and time of sampling, weather condition, water colour, observations about the ecosystem condition such as presence of fish and insects.

In the rainy season of 2019/2020, community monitors agreed to record rainfall data in order to fill the gap of missing rainfall records. They used conical rain gauges (plastic, max holding capacity 100 mm, electrosales, Zimbabwe) at three locations in the Hwange District and recorded daily precipitation.

With the support of the community monitors, scientists installed three YSI EXO2 Multiparameter Sondes in September 2019. Before the probes were installed, the sensors were calibrated using water-saturated air for the DO sensor and pH buffer solutions (pH 4.01 and pH 7 Merck Supelco ®) for the pH sensor respectively. Readings were cross-checked with those of the handheld WTW Multiprobe 340i. One probe (named ZIM 1) was installed in Deka River downstream of the inlet of Sikabala.

The samples were shipped to Switzerland for chemical analysis and filtered with 0.45-µm nylon membrane filters. We diluted the samples in ratios between 1:10 and 1:1,000 with 1% HNO_3 in distilled de-ionized (DDI) water depending on the metal concentration. For the chemical analysis, we used the Inductively Coupled Plasma Mass Spectrometer (ICP-MS) facilities at ETH Zurich and Eawag: Agilent models 7,500, 8,900 and 7,900. In the majority of the measurement series, we determined the concentration of 29 elements: Li, Be, B, Na, Mg, Al, Si, K, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Rb, Sr, Mo, Cd, Cs, Ba, Tl, Pb, Bi and U using multielement standards (ICP-MS Multielement Standard Solution ROTI®STAR by Carl Roth, Art No 6802.1 and Multielement-Standard 21 Elemente by Bernd Kraft; Art No. 32195.0000). To estimate the limit of detection (LOD) and limit of quantification (LOQ) we measured a set of 12 blank samples (1% v/v HNO_3 69% in DDI water). Merck X Multi element standard was used as reference standard for digestions of water samples and NIST 1643 f reference

[26] https://istp.ethz.ch/news/2022/02/citizen-science-knowledge-as-a-weapon-in-the-fight-for-clean-water.html

standard was used as a quality check for ICP-MS measurements. To evaluate total metal concentration, we additionally digested 231 samples using 2 ml of sample and adding 3 ml of HNO_3 69% and 1 ml of H_2O_2. The samples were transferred into MLS-Ultraclave for microwave digestion under a pressure of 160 bar and a temperature of 200°C. For a series of 144 samples, we measured the concentration of anions such as sulphate, fluoride and chloride using Ion Chromatography (Metrohm 930 Compact IC Flex, AuA Laboratory, Eawag Dübendorf, Switzerland).

Community members now have scientific data at hand for the first time in their fight against the energy companies. According to the coordinators (Ruppen 2021), it was fascinating to see how people adopted the scientific vocabulary, for example, when discussing pH levels with government officials[27]. With the knowledge acquired they can speak up and are taken more seriously than before. In one case, a young woman admitted that since she joined the project, she has been invited to village elders' meetings because she has something valuable to say about water. The project has thus equipped her with new competencies and given her a higher social status among the local community.

Based on the data of the community-based monitoring, the research showed that coal mining and combustion are degrading the water quality of the Deka River.

Since the Deka River also provides drinking water, mainly manganese and to a lesser degree nickel and arsenic are of concern for a human health perspective.

The coordinators suggest commissioning a public health study in the Hwange District to determine potential health effects related to high manganese exposure.

The community-based monitoring in Hwange proved that citizen science works in a low-resource setting, including taking water samples in a technically correct manner, measuring quality parameters, and reporting field observations. It also showed that a science-society collaboration is a promising approach to establish an extended dataset in a remote area over a longer period.

Actionable data

The raw data from the chemical analysis and all field measurements supporting the conclusions of this article are available under the following link: https://www.research-collection.ethz.ch/handle/20.500.11850/516619.

The Supplementary Material for the article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2021.754540/full#supplementary-material

Other relevant information

Every few months, from December 2018 to March 2020, researchers organized meetings in the rural area to exchange experiences and challenges of the sampling, to ensure continuity and maintain the motivation and quality of the effort

[27] https://www.eawag.ch/en/info/portal/news/news-detail/citizen-science-knowledge-as-a-weapon-in-the-fight-for-clean-water/

Analysing the water samples at the aquatic research institute Eawag because of a lack of laboratories in Zimbabwe with the required quality standards. According to Ruppen (2021) local universities in Zimbabwe (similarly to other developing countries) often lack analytical equipment for trace element analysis and commercial laboratories delivered poor quality results at a comparatively high cost. For the project's purposes samples were shipped abroad for analysis, what was logistically challenging and costly. In addition, it was not possible to find a strong partner, in civil society or else, with enough interest, scientific literacy and financial resources to continue to manage the monitoring project.

4.3.4. Coal extraction in Dawei (Myanmar)[28]

Fossil Fuel project

The coal deposits at Ban Chaung were first surveyed under Burma's past military regime during 2003, 2006 and 2007. Mining permits covering 2,100 acres (ca.850 ha) were granted to the Myanmar Mayflower Mining company during 2010-2011, in an area heavily affected by past fighting between the Karen National Union (KNU) and the Myanmar Army.

In November 2011, East Star Company received a concession from KNU under a 25-year concession term, which expires in 2036. In November 2012, Energy Earth Company signed an agreement with East Star Company to jointly operate the project. Ban Chong According to the 2012 annual report of Energy Earth Company, East Star Company is the recipient of a concession area of 504.8 acres. The coal mine is operated by Energy Earth Company. It has also been stated that Energy Earth Company is the source of funds for this coal mining operation. According to Inclusive Development International (IDI), as of 2017 the mine had proposed an expansion to double the size (which would be an additional 0.18 million tonnes per annum).

Socio-environmental conflict

According to Tanapon Phenrat from Naresuan University in Thailand (2020) since 2015, a large heap of improperly disposed coal-mine waste in Ban Chaung, Dawei district, Myanmar, has repeatedly spontaneously combusted, affecting an indigenous community. Although coal is stable underground, the exposure of coal and coal-mine waste to oxygen in the air during and after mining may result in oxidation, an exothermic reaction, and eventually, spontaneous combustion. After the government intervened in 2017 and ordered the mine to improve the management of the mine waste heap to stop and prevent further spontaneous combustion, the mining company chose to use surface sealing for both suppression of existing fire and on-site storage of the mine waste but did not install any long-term monitoring system. Despite the suspension of the mine since 2017, the community is still at risk,

[28] **Description done according to the following links:**
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2020GH000249
https://www.burmalibrary.org/docs21/TRIPN-2015-10-We_Used_to_Fear_Bullets-Now_We_Fear_Bulldozers-en-red.pdf
https://www.inclusivedevelopment.net/wp-content/uploads/2017/09/2017.06.09-NHRCT-Ban-Chaung-coal-mine-complaint-for-upload.pdf
https://ejatlas.org/conflict/ban-chaung-coal-mine-karen-state-myanmar
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2020GH000249

as the coal-mine waste continues to burn, releasing toxic fumes. Furthermore, the community lives in fear and uncertainty that the spontaneous combustion may trigger wildfire, since the waste heap is in the middle of a richly forested area.

According to the Ban Chaung Coal Mining Report (2015: 24-31) local community suffers from air pollution from mining activities, respiratory infections, betel nut trees damage, waste dumping, water contamination caused by acid mine drainage and coal fires releasing toxic elements (e.g. arsenic, mercury, selenium) that could be inhaled, damage crops or threat fish and livestock. Coal fires also release large amounts of carbon into the atmosphere, contributing to climate change.

Citizen science initiative

Organizations and campaigns

The monitoring initiative took place from July to August 2019 and involved a collaboration among professional scientists, non-professional volunteers from the affected community, Ecolab (an accredited laboratory service in Myanmar), the Research Unit for Integrated Natural Resources Remediation and Reclamation (IN3R) at Naresuan University, Phitsanulok, Thailand, and the Center of Excellence for Sustainability of Health, Environment, and Industry (SHEI) at the Faculty of Engineering, Naresuan University, Phitsanulok, Thailand.

Brief history

According to Phenrat (2020) the objective of the research, that is, to allow the affected community to participate in risk management decision-making for the mine waste heap. While the regional Myanmar government has compelled the mine to properly manage the mine waste heap. Affected villagers made risk management decisions via a community citizen science approach.

- For this purpose, field surveys were conducted with the affected community to identify hot spots on the heap releasing gaseous pollutants that may exceed permissible levels. The main strategy was to establish a research team consisting of both a professional scientist and the local monitoring group, which is made up of volunteers from the affected community.
- Monitoring data previously collected by the community were interpreted as clear evidence of past poor waste management. Information about suppression of existing fire and mine waste storage options was presented to the community for them to make an informed decision about the most appropriate corrective action that should be taken by the mine.
- The scientists informed the community about available risk management options for the spontaneous combustion of coal-mine waste, evaluated those options based on US EPA's nine criteria for remedial option selection (United States Environmental Protection Agency, 1990), and equipped the community with sufficient scientific knowledge to make a decision about the most appropriate corrective action for the mining company to take.
- The community's choice was surface sealing with preventive monitoring together with emergency response, which is the more scientifically appropriate option.
- The outcome was forwarded to the regional government to influence decisions, elevate democratic capacity, and empower marginalized individuals and communities. The study is the

first record of field-scale community citizen science in Myanmar, especially for risk management of mine waste, a significant environmental crisis in Myanmar affecting not only the ecosystem but also quality of life and human rights (Phenrat 2020).

Monitoring system

The monitoring system included a comprehensive database of affected villagers and their locations, records of previous incidents such as historical photos and fire frequency counts, past environmental monitoring results from water and air samplings, and a survey of health impacts. It encompassed knowledge of hot spots, seasonal effects on combustion incidents, and locations of impacted agricultural land and surface water. A channel was established for community concerns and risk management decisions with a responsible government agency. Field and remote scientific techniques were utilized for preliminary risk assessment and site inspections in July and August 2019, facilitated by a handheld thermal infrared camera. Monitoring sites included the mine, waste heap areas, mine lake, affected agricultural land, and residential areas for gaseous pollutant evaluation. Composite samples of coal, coal-mine waste, and soil were analysed using X-ray fluorescence (XRF), while water samples were collected from affected surface water bodies. An unaffected area served as a control for temperature, air quality, and water quality measurements, highlighting observations of air pollution, surface water, and soil contamination.

The Parameters/pollutants monitored on air, soil, surface and water were: Volatile organic compounds (VOCs), Hydrogen cyanide (HCN), Ammonia (NH3), Hydrogen sulphide (H2S) (RAE, Model multirae Lite), Lower explosive limit (LEL), Oxygen (O2), Nitrogen dioxide (NO2), Nitrogen oxide (NO), Sulphur dioxide (SO2) (Industrial Scientific, Model IBRID Mix6), Carbon monoxide (CO) (Smart Sensor, Model AS8900), ph and conductivity of water, Ambient air quality, Daily records of smouldering and spontaneous combustion incidents and Surface temperatures in the vicinity of the mine

For this purpose several devices were used such as a Normal camera for taking photos of the waste heap and hot spots, three types of portable gas detector, PS device to collect coordinates of the boundaries of the waste heap and a Thermal Infrared Sensor (TIRS) of the Landsat 8 satellite.

This project successfully empowered the local community to select the best strategy for mitigating the impact of the landfill. It led to governmental intervention and directives aimed at the company, raising awareness among the local community about risks and potential resilience strategies. The community prioritized grouting or inert gas injection with inhibitors to suppress existing fires, followed by off-site disposal, as the most preferable corrective actions.

Other relevant information

The study has shown that a community citizen science approach provides social learning and empowers and emancipates marginalized individuals and communities. With sufficient scientific data and understanding, an empowered community can meaningfully participate in and influence a risk management decision.

4.3.5. Global Coal Mine Tracker

Citizen science initiative

Organizations and campaigns

The Global Coal Mine Tracker (GCMT) is a worldwide dataset of coal mines and proposed projects. The tracker provides asset-level details on ownership structure, development stage and status, coal type, capacity, production, workforce size, reserves and resources, methane emissions, geolocation, and over 30 other categories.

The Global Coal Mine Tracker launched in January 2021 as part of the Global Energy Monitor (GEM). It provided information on 1200 coal mines in 70 countries worldwide. In June 2021 the tracker included over 1500 mines from more than 4000 companies. In January 2022 - 3016 coal mines and reached 93% global coverage. In July 2022 - 3670 coal mines. In April 2023 - 4300 coal mines and mine projects, providing coverage for approximately 95% of global coal mining operations. Today (May 20th 2024) the tracker include 6646 mines. There are 90 people involved in GEM, with 15 specifically dedicated to working on coal issues (Global Energy Monitor, 2024d).

Local non-governmental organizations tracking mining permits and mine operations (not listed); researchers, analysts, and volunteers from countries around the world each contributing their part; GreenInfo Network[29].

The Global Energy Monitor project collaborates extensively with various organizations and initiatives worldwide such as: Asset Resolution,- Carbon Tracker Initiative, Center for Media and Democracy, Centre for Research on Energy and Clean Air (CREA), Analyzing China, Coal Action Network Aotearoa, Coal Action Network United Kingdom, CoalWatch, Earthjustice, Eco-Jurisprudence Project, Ember, E3G, Fossil Fuel Non-Proliferation Treaty Initiative and Carbon Tracker Institute, Institute for Sustainable Development and International Relations (IDDRI), Investigate Europe, Leadership Group for Industry Transition (Leadit), Private Equity Stakeholder Project and Americans for Financial Reform, Raven Ridge Resources, RENEW-Industry, Stockholm Environment Institute, TransitionZero, Urgewald and WattTime

These collaborations encompass a diverse range of activities including data collection, economic modelling, legal research, policy development, and environmental impact assessments, contributing significantly to global efforts in energy transition and climate action.

The tracker was designed and produced by Global Energy Monitor. The coalfield base-layer was created by Alice McGown (LINGO). Web/GIS programming was done by Tom Allnutt (GreenInfo Network), with support from Tim Sinnott (GreenInfo Network). The information in the tracker has been verified by researchers familiar with particular countries, including current contributors: Jelena Babajeva, Wynn Feng, Tiffany Means, Xiaojun Peng, Claire Pitre, and Mingxin Zhang. The project manager is Dorothy Mei, with project support from program manager Flora Champenois. Appreciation is also extended to the tracker's past contributors: Özgür Acir (Association of Geological Researches – JADE), Noorafsha Adbulla (Conservation Action Trust), Paula Baker (GEM), Mary Beckman (GEM),

[29] https://www.greeninfo.org/

James Browning (F Minus), Bob Burton, Gregor Clark, Dulguun Gantulga, Anne Grainger (Coal Action Network), Celia Hack, Julie Joly, Prasad Khale (Conservation Action Trust), Madhuresh Kumar (NAPM India), Yedan Li, Ted Nace, Kerry Nelson, Dan O'Beirne, Christine Shearer, Ryan Driskell Tate, Adrian Wilson, Aiqun Yu, Ege Yuzbas, Scott Zimmerman, and Medha Kapoor (Global Energy Monitor, 2024c).

Monitoring system

Global Energy Monitor is supported by a diverse array of institutional backers, including the African Climate Foundation, Bloomberg Philanthropies, Children's Investment Fund Foundation, Climate and Environment Foundation, Climate Imperative Foundation, ClimateWorks Foundation, Energy Foundation, European Climate Foundation, Ford Foundation, Herlin Foundation, Institute for Energy Economics and Financial Analysis, KR Foundation, Pooled Fund on International Energy, Quadrature Climate Foundation, Rockefeller Brothers Fund, Rockefeller Energy Transition Fund, Rockefeller Family Fund, Stockholm Environment Institute, Tara Climate Foundation, WattTime, Windward Fund, and others. Their collective support has enabled tracking of 6,646 mines worldwide.

This initiative develops monitoring of closed and existing coal mines as well as proposed projects, ownership structure, development stage and status, coal type, capacity, production, workforce size, reserves and resources, methane emissions, carbon dioxide emissions, geolocation.

Tracker data are quoted in the press and scientists belonging to the project speak out as sides in local conflicts. The tracker was mentioned in NATURE article which was accessed 15000 times (Jasansky *et al.*, 2023)

Actionable data

GEM tools are freely available to the world—granting unrestricted access to anyone with an internet connection.[30] If anyone using the tracker notices a malfunction, they can report instantly online [31].

Data are available to download[32] and viewable with interactive mapping[33] and aggregate dashboards and summary tables[34]. Each coal mine is linked to its own separate factsheet[35] that provides references and further background, including news about project financing, civil society opposition, labour activity, and workplace accidents.

Other relevant information

Global Energy Monitor's Global Coal Mine Tracker uses a two-level system for organizing information, consisting of a database of the world's mines and a separate factsheet on Gem.wiki that provides a repository of information, including project background, financing, environmental impacts, labour activity, public opposition, aerial photographs, videos, links to permits, and maps[36]. A preliminary list of coal mines in each country were first gathered from public and private data sources in 2020. The

[30] https://globalenergymonitor.org/about/who-uses-gem-data/
[31] https://globalenergymonitor.org/home/error-reporting-gcmt/
[32] https://globalenergymonitor.org/projects/global-coal-mine-tracker/download-data/
[33] https://globalenergymonitor.org/projects/global-coal-mine-tracker/tracker-map/
[34] https://globalenergymonitor.org/projects/global-coal-mine-tracker/summary-tables/
[35] https://www.gem.wiki/Main_Page/
[36] https://globalenergymonitor.org/projects/global-coal-mine-tracker/methodology/

project manager and researchers continue to gather data on mines in every country on a daily basis. This information is vetted against additional sources: 1) Government data on individual coal mines, 2) Reports by state-owned and private mining companies, 3) News and media reports, 4) Local non-governmental organizations tracking mining permits and mine operations, 5) On-the-ground contacts who can provide first-hand information about a project or mine. Where possible, coal mine data is circulated for review to researchers familiar with local conditions and languages (Global Energy Monitor, 2024b, 2024a).Global Energy Monitor employs its Global Coal Mine Tracker to estimate methane emissions at individual mines worldwide, aggregating the data on national and global scales. They provide baseline estimates for coal mine methane emissions, which utilise mine-level activity data, such as production, operating depth, methane content at depth, and an emission factor to account for methane from over and under burden, following the (Kholod *et al.*, 2020).

5. Discussion

Citizen science and the improvement of the environmental regulation of the industry

The above-described Citizen Science (CS) cases display different degrees of success in changing environmental regulations and limitations to the fossil fuels extractive industry. Regarding oil extraction, the cases of Marseille and Sarroch show that CS initiatives can lead to the onset of new emissions limits relatively quickly, through the involvement in the municipalities, which pushed for the reduction of the exposure threshold. In both cases the CS projects have obtained a policy change through action pursuit in formal channels. While other CS initiatives did not enjoy the same direct effect on regulation, they have created awareness at different levels, triggering further studies and advancing methodological approaches. Various projects have generated evidence of pollution and related epidemiological studies have shown the association of this pollution with the erosion of public health and increased cancer and other diseases, in the same way, air monitoring initiatives have shown the association between respiratory diseases and fossil fuel and petrochemical activities in the surrounding of industries.

However, the case of Viggiano shows how corporative stakeholders can stop the onset of new regulations through scientific and legal maneuvering of corporative stakeholders, producing partisan scientific counter studies for the area. As for the case of Milazzo, it was only a decade after the first study that institutions decided to start setting up new regulations.

The coal extraction studies illustrate how CS projects can empower vulnerable people, by allowing them to fight against the factors that threaten their health and their environment, by acquiring new skills and tools to identify the eventual damaging effects of fossil fuel extraction, processing and storage. Since these initiatives are based on collaboration between professional scientists and volunteers, the latter can see their social status changed and be acknowledged in their own

community. CS initiatives can have in this way further effects than providing evidence in conflicts between the communities and the industries or energy companies.
However, in Europe, CS projects related to oil extraction are scarce and the few existing ones often have limited efficiency in triggering actual policy change. The CS projects primarily spark activist initiatives and opposition movements have called for a halt to oil drilling with varying degrees of success. These initiatives primarily focus on protests, official complaints, and alternative communication and information, while there are very few documented cases where citizen science has been used to produce scientific data aimed at improving the environmental performance of the oil industry. A notable example within Europe is the Val d'Agri region in southern Italy, where activists have mobilized to monitor and denounce environmental pollution using data and scientific evidence. The principal association advocating for the protection of Val d'Agri and its population, Cova Contro, has conducted numerous monitoring campaigns and legal initiatives. Although they have not succeeded in significantly improving the environmental performance of the industry, their efforts have served as a psychological deterrent and, in some cases, forced companies to adopt best available technologies (BATs) and make targeted investments such as purchasing radiometric gantries, proper waste storage, and other non-marginal improvements. While these efforts have influenced small and medium-sized companies, they have had limited impact on the practices of larger corporations, affecting mainly their communication strategies and investments in environmental impact mitigation and controls.

Citizen science and the production of actionable data

The cases analyzed strongly suggest that data produced by citizen science can only be actionable when criteria of accuracy, timeliness and accessibility are satisfied. Achieving this requires a combination of proper training, technological tools, standardized protocols, centralized platforms, and targeted communication. When these elements are in place, citizen science data can significantly contribute to informed decision-making and effective environmental management.

Often, actionable data is produced by scientists, although collected by citizens. In cases such as the one in Marseille, the results of the studies have shown the association between the collected evidence of pollution and public health issues. Results have been used in legal cases, pushing new regulations, as well as fostering state agencies to punish the emitters through fines.

To ensure quality, citizen scientists need proper training to ensure they collect data accurately. This involves workshops, detailed protocols, and continuous support from professional scientists, clear guidelines as to how when and where to collect in order to minimize errors and variability. It also entails implementing quality control measures such as cross-verification by multiple participants, periodic audits, and using calibration tools.

Users should be hence aware that a sensor's accuracy, precision, and bias can change over time. It is recommended that users carefully review and compare the sensor data collected with other nearby reference instruments to ensure that the data look reasonable: Depending on available resources (funds equipment, expertise), users might be able to set up a reference instrument nearby; to set up a sensor which was recently calibrated through a reference monitor and provides comparable results; then compare trends and concentrations with several nearby sensors and consider whether similarities/differences are expected or surprising. The accurate choice of the technological tool can

enhance the precision of the data, for example using apps and devices with built-in checks can help maintain accuracy. For instance, GPS-enabled devices ensure location accuracy, while automated sensors can reduce human error. Leveraging technology for real-time data collection and transmission can ensure data is up to date. Mobile apps and online platforms allow immediate reporting and sharing of findings. Establishing a regular schedule for data collection and reporting ensures that the information remains current. This could be daily, weekly, or monthly depending on the nature of the data. Quick analysis and dissemination of data help to make timely decisions. Automated data processing tools and AI can further assist in rapid data analysis.

As for the general availability of data, adopting open data policies ensures that data is freely accessible to anyone who needs it. This includes policymakers, researchers, and the public. Using clear and understandable data visualization tools like graphs, maps, and dashboards helps in interpreting data correctly. Tools that allow interactive data exploration can enhance user engagement and comprehension. Creating centralized, user-friendly online platforms where data is stored and can be easily accessed by all stakeholders ensures that data is readily available, such as GEM.wiki. Scientific articles, even if open access, may not reach the local community, especially if they are written in the scientific jargon of a particular discipline. This is why direct engagement with the community involved is key - citizen science initiatives require, firstly, an initial interview to diagnose existing activities, problems and needs, secondly, workshops to explain how to monitor and use the tools, and thirdly, workshops on data interpretation and how to use the resulting database.

Ensuring data reaches the right audience also involves targeted communication strategies. This could include email alerts, social media updates, and reports tailored to specific stakeholders such as local authorities, environmental agencies, and community groups. Furthermore, data should be contextualized to be actionable. This means providing background information, trends, and comparisons to help users understand the implications of the data. Working closely with regulatory bodies and policymakers ensures that data is used effectively for decision-making. This collaboration can lead to the development of new regulations or the enforcement of existing ones. Engaging the public through awareness campaigns and advocacy efforts ensures that data drives community action and influences policy changes. Establishing feedback mechanisms where users can comment on the data and its presentation helps in continuously improving data collection and dissemination practices.

Advantages and disadvantages of citizen science for environmental monitoring

Citizen science holds significant potential and can positively impact the environmental performance of the industry by enhancing monitoring, transparency, and community engagement. Despite their potential, these initiatives still face many challenges, including data quality, data accuracy, acceptance of data for legal actions, participant support and the need for training and resources for participants. Ensuring the scientific validity of the data collected by non-experts is crucial for these initiatives to be effective.

The acceptability of data by institutions is also an important point. The Italian cases show how this acceptability is linked to the credibility of the institutions that are proofing data quality. Besides, there is an issue of trust in data accuracy that goes beyond the scientific realm of data collection and processing. The case of Viggiano, where the fossil company had conducted its own scientific counter-study to contest the CS study -leading the latter to a dead end- shows how the funding mechanism is

crucial to social and political acceptability. In this case, it can be said that there is a positive association between data accuracy and the independence and public nature of funding sources.

There are further obstacles related to data quality and management such as problems to get a sufficient number of participants involved, maintaining the interest of participants until the end of the project and after its finalization, or the matching of tools to financial possibilities and technical skills. In some cases, the CS initiatives lack tools, or they are not certified, or there are no existent specific monitoring methods, which leads to difficulties when using CS data in legal cases.

CS can also have complex implications depending on the social context: cases of exploitation, occupational and political blackmail, retaliation, social marginalization... have been identified among others. In depressed areas the results of SC can have impacts on the existing social tissue, the results can be used in multiple directions, and sometimes the participants in these initiatives may not be ready or aware of the consequences. This is why a preventive risk analysis and a sort of informed consent on the implications could be beneficial, in order for communities to receive preparation on CS and its implications before the start of the actual monitoring activity.

On the positive side, CS has been shown to raise awareness among the population and institutions, helping citizens to feel empowered and more connected to their environment, which potentially leads to more sustainable behaviours. When data are useful to legal actions and published in the press, there is potential for public accountability and corruption control. Citizen scientist can besides collect data across wide geographic areas and over long periods, providing a coverage difficult to achieve by only professional scientists. In addition to this citizens often bring local knowledge and insights that enhance the quality and relevance of the data.

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7. Annexes

3.2. Focus groups methodology

The local partner chose between various strategies for carrying out the focus group interview(s) depending on the local context (Confrontational approach, Aligned approach or Mixed approach).

Confrontational approach

It assumes that through confrontation of very diverse views it is possible to obtain a rich picture of a given matter or work out new perspectives. Participants in the interview should represent various groups, it is possible to put together representatives of adversary groups, i.e. environmental groups and industries. The role of the moderator is vital in this case, as that person should be able to mitigate potential conflicts and moderate the discussion towards constructive outcomes. Prior to the discussion it is advised to write down a short code of conduct for the meeting where mutual respect and avoidance of any kind of hate speech should be agreed upon. In this scenario, one focus group interview could be organized to involve all of the recruited participants.

Aligned approach

It assumes that through a discussion held among people representing similar positions on a given matter or taking similar positions in the local community (i.e. representing the same sector or type of activities), it is possible to obtain an in-depth understanding of this category of citizens and draw a perspective that is unique to them. Participants in the interview should represent groups that share some experience, points of view, perspective, who cooperate with each other or have similar positions in a given context. For example, representatives of the public sector could participate in one focus group interview and representatives of the business sectors could participate in another one. The role of the moderator is to encourage participants to delve deeper into their experience, get a better understanding of it, search for similarities and differences, or think about the uniqueness of their situation as compared to other groups of citizens in a given context.

Mixed approach

In this case, a local research team may decide that better results can be obtained by holding a separate focus group interview with a particular category of citizens (i.e. because of its unique perspective or its aggressively confrontational position towards other citizen groups invited to participate in the project), while all others can take part in another focus group interview.

Irrespective of the selected strategy, focus group interview should not last longer than 3 hours (the whole meeting 3,5h). It is advisable to plan a coffee and snacks break after the first 1,5 hour. The FGI scenario should be divided into sections that can be clearly communicated to the participants:

Introduction of the meeting and the project

Welcome FGI participants, present ERICA project, the moderator and the project team members taking part in the meeting, clearly communicate the purpose of the meeting, tell the participants how the interview relates to the project purpose, how will it serve to develop the project further. It is advised that FGI participants receive 1 page of the project description, including information on funding sources and institutions involved in the project. If the FGI is going to be recorded obtain voluntary consent from the participants in writing or as a vote or individually voiced statement "yes, I agree to record this meeting". Inform the participants how (whole or what parts) of the interview discussions will be transcribed, how they will be anonymized and used to write the project report. Tell the participants what will happen to the recording and how it is going to be stored, or deleted, who will have access to it.

Introduction of the participants

The moderator should organize a short round of introductions where participants can say their first name and briefly speak about their professional background or their relation to the local place, their interests in well-being of the local community.

Agreement for the code of conduct

The moderator should propose a short set of basic rules for good communication during the meeting, i.e. respect what others have to say, do not take too much time and let others speak too, listen carefully, if you disagree say it with respect, no hate speech, and asks if any points should be added. Consider announcing that the moderator will be timing participants' statements in order to provide equal opportunities to speak for everyone.

Relation to place

The moderator launches a discussion about participants' relation to the place of residence by asking questions whether their family has lived there for several generations or moved in not long ago, ask about their ties and what do they value the most locally, from this turn to the questions about their experience of the local fossil-related infrastructure, however, be specific, ask about oil, gas, coal infrastructure, how do they experience the infrastructures (through their professional engagement, as residents living in its proximity)? Ask what they value about it and what they would like to change with regard to it?

Impacts of the fossil infrastructure on participants' professional engagement and their livelihoods

The moderator moves on to ask participants whether fossil infrastructures have any impact on their professional work, their businesses, etc. What kind of impacts? Are they positive or negative? How do

they monitor these impacts? Do they mitigate these impacts? What measurement and mitigation tools do they use?

Impacts of the fossil infrastructure the environment

The moderator steers the discussion towards more general impacts of the fossil infrastructure to diagnose their environmental awareness. In this part it is recommended to provide the participants some materials to work with, i.e. match indicators of environmental impacts with different types of activities locally.

Institutionalized environmental monitoring practices

The moderator launches a discussion asking participants whether they are aware of institutionalized practices of environmental monitoring around the area of the fossil-related infrastructure. Do they cooperate with other local actor institutions with regard to these impacts? What does this cooperation involve? Does it meet their needs or not? Have they ever issued a complaint about the impacts of the fossil infrastructure on their professional activities? If yes, to whom and what resulted from the complaints? If not, why have they never done that? What would have to change so that they voiced their complaints? What would they expect from this action? If at the discussion there are any officials from the public institution responsible for environmental monitoring, the moderator asks that person to respond to this question as the last in the round in order to first explore whether the participants have any experience or knowledge that they want to share. The moderator invites the participants to share their concerns about the existing practices, information shortages, procedural problems, etc. and explains that the representative of the environmental monitoring institution should not regard these points as expressed against the institution that s/he represents but can also feel free to clarify some misunderstandings, the moderator should restate that the purpose of the meeting is to exchange experience which may be very diverse and that it should not be evaluated in normative terms.

Non-institutionalized environmental monitoring practices

The moderator asks participants if they have come across or been engaged in any environmental monitoring practices beyond the existing institutions: what kind of practices? With regard to what area, aspects of the environment? With what tools? By what means? Individually or collectively? Regularly or incidentally? What data were gained? How they were collected, processes and stored? What happened with the collected data? Was that knowledge shared, with whom, for what purpose, with what results? Were there any practical implications of this action: protection schemes, new infrastructure, technologies, etc.?

The most pressing environmental concerns and the most pressing needs for environmental monitoring

The moderator invites people to list out and rank environmental concerns that they find most vital from their perspective and list out the most pressing areas, matters, substances, processes, etc. that require environmental monitoring. The moderator can use a flipchart, pens and sticky notes for this exercise.

Conclusions and recommendations

In this part, the moderator divides the participants into pairs and asks them to write down the main conclusions about the strengths and weaknesses of the existing environmental monitoring practices, as well as recommendations for improving the weaknesses. At the end of this task, the moderator asks the pairs to present their conclusions and recommendations to the whole group.

Ending

The moderator thanks the participants for their time and for sharing their experience and knowledge and asks participants to share their impressions from the meeting asking it if was useful, if they gained something from it and whether they would organize it differently in the future. Ask about their expectations towards the training workshops which we plan to organize in the project. Hand in the questionnaire to evaluate the meeting itself.

7.2. Questions for the focus groups

1. What environmental challenges are prevalent in your region due to the fossil fuel industry? Specifically, which pollutants from this industry are causing the most concern?
2. Could you provide the name of the fossil fuel company operating in your area? What details can you share about their project and when did they commence operations?
3. Are there any civil society organizations or citizen science initiatives related to combating environmental impacts from fossil fuel industries present in your locality? If so, could you provide the name and possibly share if they have an associated website?
4. Have there been any notable socio-environmental movements related to fossil fuel industries in your region? If so, approximately how many people were involved?
5. Is there an ongoing citizen science for environmental monitoring initiative related to combating environmental impacts from fossil fuel industries in your area? If yes,

    - Since when has it been active, and what monitoring systems or tools are being utilized (e.g. frequency, number of monitoring sites, time and economic cost, funding sources, etc.)?
    - What pollutants or parameters are being analysed?
    - Where are these pollutants or parameters analysed [5 options: soil, sea water, freshwater, biological samples, air]?
    - Are you aware of the detection limits?
    - Could you outline the advantages and disadvantages of these monitoring tools, as well as their cost and accessibility?

- Are there any do-it-yourself (DIY) monitoring tools available, and if so, how can they be acquired or made? Are these affordable and DIY sensors adequate to monitor pollutants related to the fossil fuel industries? Why?
- Do you know any tutorials or handbooks related to these DIY monitoring tools?
- How did these citizen science initiatives use the data collected to transform reality? How do they assure data accuracy (e.g. involvement of universities)? What audience, stakeholders and policy makers do they target?
- Which methodologies are used to track back emission sources and establish causality between environmental levels and sources and corporations' responsibility?

6. What valuable lessons have been gleaned from your involvement in any citizen science for environmental monitoring initiatives?
7. Have there been any discernible changes in the environmental impact of the fossil fuel industry following socio-environmental monitoring initiatives? Have there been changes in operational standards, legislation/regulation, increased control by state agencies?
8. What notable achievements or insights have emerged from your experiences and involvement?

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