

A Citizen Science Approach to Address Odour Pollution in Greece

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Odour pollution presents significant challenges to both environmental quality and public health, impacting the quality of life for affected communities. This issue is particularly complex and subjective, with varying individual responses to odours. In Greece, the city of Thessaloniki faces odour pollution stemming from industrial, urban development and sewage activities, necessitating comprehensive solutions. Drawing upon interdisciplinary studies and collaboration between academia, local authorities, and citizen groups, a citizen science-driven approach is proposed to comprehensively map and mitigate odour-related challenges. The paper outlines a collaborative approach aimed at defining specific steps for co-designing processes to address odour issues locally, with Thessaloniki as a pilot case. The paper aims to provide a holistic understanding of odour pollution issues, facilitate the formulation of sustainable solutions, and ensure inclusiveness across diverse socio-economic and socio-cultural realities. By engaging stakeholders and utilizing tools such as the OdourCollect App and smell diaries, the methodology successfully engages diverse communities affected by odour pollution, including those traditionally marginalized or isolated. Data analysis from the pilot application validates the existence of odour nuisance in key areas, providing qualitative and quantitative insights into the problem. This paper contributes to understanding odour nuisance and offers insights into effective community-driven interventions to tackle this complex environmental issue, while explores the replication potential of the approach in other regions affected by odour pollution.

Key words: Odour Nuisance; Odour Pollution; Odour; Citizen Science; Stakeholder Engagement; Stakeholders Consultation; Participatory Approach; Statistical Analysis; Thessaloniki

1. Introduction

Odour is an organoleptic property of a mixture of substances capable of stimulating the olfaction sense sufficiently to trigger a sensation of odour. Odours are nowadays, among atmospheric pollutants, the major cause of population's complaints to local authorities (Henshaw et al., 2006).

Several conventional pollutants are generally not perceived by population, even if they might be harmful for human health, especially if normal exposure limit concentrations are exceeded (Greenberg et al., 2013). On the contrary, some odours are perceived far below normal exposure limit concentrations, due to the presence of odorous compounds having extremely low odour detection threshold concentration.

Odour pollution is an important problem affecting communities, while addressing such an issue requires interdisciplinary studies and an active engagement and collaboration among a wide range of stakeholders. The need also for the implementation of innovative methodologies is considered imperative to comprehensively address and mitigate the impact of odour-related challenges (Arias et al., 2021; Hayes et al., 2019).

Indeed, odour pollution in urban areas is posing challenges to environmental quality and public health and arises from a variety of sources, including industrial activities, waste treatment facilities, sewage plants, and even agricultural practices near urban peripheries (Badach et al., 2018). Potential and primary odour pollutants are all those industries that generate odour in their daily activities, and which may be a potential source of nuisance in either a residential or industrial environment (waste-water treatment plants, waste management centres, pet food production, slaughterhouses, etc.). Factories and processing plants often emit Volatile Organic Compounds

(VOCs) and other odorous chemicals as byproducts of their operations. These emissions, if not adequately controlled, can spread over large areas, subjecting communities to constant or intermittent foul smells (Bokowa et al., 2021). Similarly, waste treatment and sewage facilities, essential for urban sanitation, can release unpleasant odours if not properly managed.

Addressing odour pollution requires a multicriteria and faceted approach (Vlachos et al., 2021). The approach should involve stricter regulations, improved technology for emissions control, and better urban planning to segregate residential areas from potential sources of odours. In the above context, this issue is particularly complex and subjective, while stakeholders can be affected in different ways by the problem and can have conflicting interests and goals. Thus, the way to orchestrate the engagement of different stakeholders, such as citizens, civil society organization (CSO's) and non-governmental organization (NGO's), industries, local & regional authorities, and odour experts, it is crucial (Taelman et al., 2018).

This study proposes a citizen science-driven approach to comprehensively map and mitigate odour-related challenges emphasising on the collaboration between academia, local authorities, and citizen groups. The objective is to identify a common agenda amongst key stakeholders, balance expectations and interests, and encourage dialogues with public authorities and emitting industries to co-design potential mitigation options and good practices to reduce the odour impact. More particularly in Greece, the city of Thessaloniki faces odour pollution stemming from industrial, urban development and sewage activities, necessitating comprehensive solutions (Vlachos et al., 2021). The paper aims to outline a collaborative approach aimed at defining specific steps for co-designing processes to address odour issues locally, with Thessaloniki as a pilot case.

2. Overview of the selected case study

In an attempt to properly select an area for the pilot case study analysis in Greece, several regions were analyzed. The overview of the specific characteristics of the under-consideration potential cases and the analysis conducted in order to decide the case study region is provided in Table 1.

Table 1: Potential cases for pilot application.

Case Location	Affected population (est.)	Odour sources	Pros	Cons
Thessaloniki	ca. 100,000	Industrial activities (Refinery, petrochemicals, metal processing, logistics facilities, etc.) located in proximity to urban areas. Dendropotamos river that receives untreated effluent of wastewater. Urban activities such as illegal burning of improper material.	<ul style="list-style-type: none"> • There is good communication with local authorities and more specifically with the Regional Authority of Central Macedonia. • Data on air quality is available from the industry. Citizen engagement is more organized through social network initiatives. • Similar cases are frequent in many industrial areas around the country. 	No field studies on odour.
Kavala	ca. 50,000	Fertilizers chemical industry	Availability of results on various environmental parameters.	<ul style="list-style-type: none"> • No field studies on odour. • Not organized citizen initiatives
Peloponnese Region	ca. 80,000	The refining process to produce pomace oil	Existing results on various environmental parameters (air pollution, SPM - Suspended Particulate Matter).	<ul style="list-style-type: none"> • No field studies on odour. • The local industries are not cooperative. • Not organized citizen initiatives.

Piraeus	ca. 100,000	WasteWater Treatment	Not defined.	<ul style="list-style-type: none"> • No verification that the odour is coming from the WasteWater Treatment Plant. • No field studies on odour. • Not organized citizen initiatives
Volos	ca. 100,000	Cement production factory & burning of illegal and unsuitable material by individuals	Availability of measurements on various emissions due to the environmental permit requirements.	<ul style="list-style-type: none"> • No field studies on odour. • Not organized citizen initiatives.

Thessaloniki, as the second most populous city in Greece, presents an interesting case study region for various reasons. Firstly, the city's high population density of approximately 7100 people per sq. km creates a unique urban environment where issues such as odour nuisance can have a significant impact on the quality of life for residents. Additionally, Thessaloniki has a history of multiple complaints regarding odour nuisance over time, indicating a pressing need for investigation and potential solutions to address this issue.

More particularly, the area of Kalochori-Evosmos-Kordelio-Menemeni-Dendropotamos (Figure 1) within Thessaloniki stands out as the most degraded part of the city, with various industrial activities taking place in proximity to residential areas. This mix of industrial and urban settings, including petrochemicals, metal processing, and logistics facilities, contributes to the complexity of environmental challenges faced by the local community. Moreover, the social characteristics of the area, such as the presence of refugee and gypsy communities, add another layer of complexity to the environmental and social dynamics at play, which is of great interest for researchers and policymakers since valuable insights could be elicited regarding the intersection of industrial activities, social demographics, and environmental quality within an urban setting.

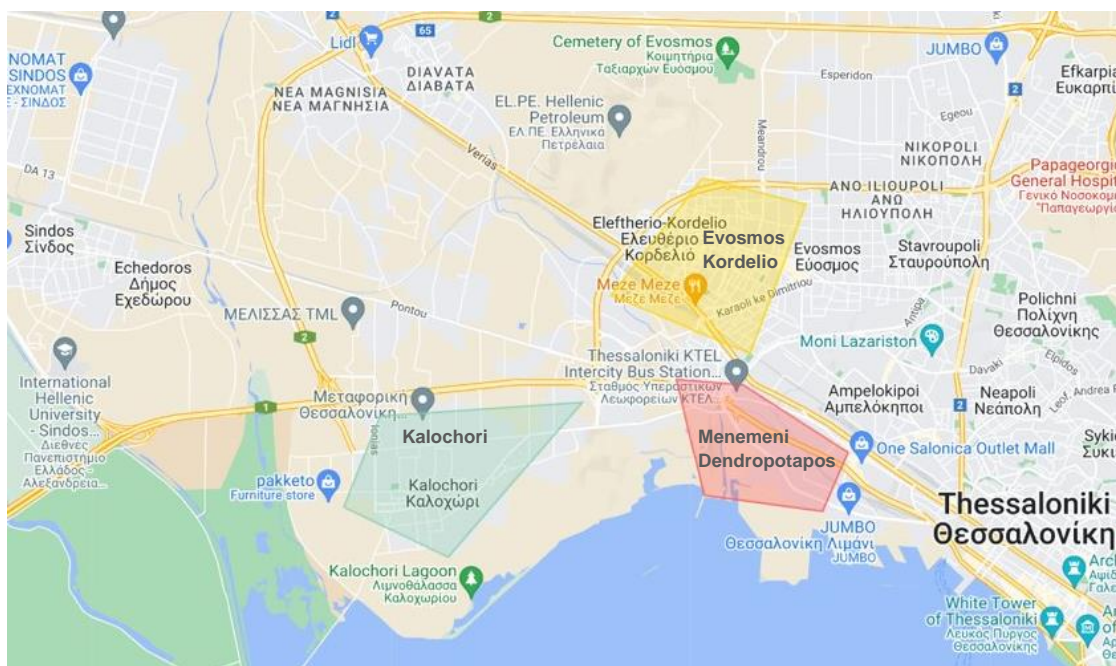


Figure 1: Map of the pilot case study selected area.

Thus, Thessaloniki, particularly the area of Kalochori-Evosmos-Kordelio-Menemeni-Dendropotamos, offers a rich and complex urban environment that is well-suited for a case study on odour nuisance and its implications for community well-being.

3. Mapping and assessing odour issues: The case of Thessaloniki

The methodology followed for mapping and assessing odour issues for the case of Thessaloniki includes four main steps:

- Step 1: Key stakeholder groups identification and mapping
- Step 2: Stakeholders' engagement for data collection
- Step 3: Data analysis of the extracted input
- Step 4: Results analysis and conclusions

3.1 Stakeholders Analysis

Stakeholders and target groups to be engaged in the interventions and awareness raising actions during Thessaloniki's pilot case have been identified, as well as possible motivations and barriers for engaging them (Figure 2).

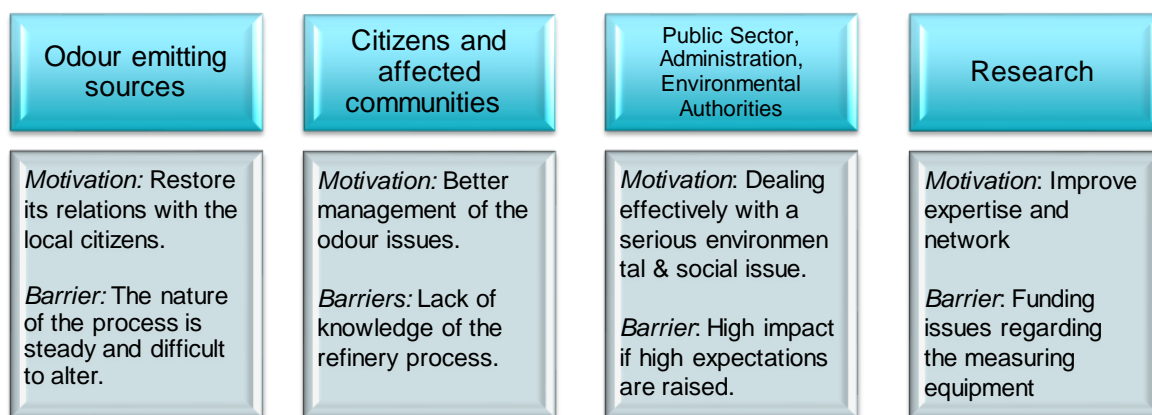


Figure 2: Stakeholders motivations and barriers.

An active network of key local stakeholders was established and engaged within the framework of the of EU funded Horizon 2020 D-NOSES project (Grant Agreement No 789315) in order to elicit the necessary input. Stakeholders that included local authorities, researchers, local universities, schoolteachers and residents of the affected area were engaged using several engagement activities, such as training and community workshops, bilateral meetings and consultations, as well as sensory walks (Spennemann et al., 2023; Vlachos et al., 2021).

3.2 Pilot application and key tools utilized

The pilot application used two main tools to gather odour observations. On the one hand, paper-based smell diaries were used, while on the other hand the OdourCollect App developed within the frame of the H2020 D-NOSES project (Capelli et al., 2020; D-NOSES, 2020) were used in the three areas of interest in order participant to record odours. Smell diaries using the same structure of questions and contents as the OdourCollect App were prepared and shared with those who were unable to use the application app. However, the majority of data collected derived from the OdourCollect App, which was the main tool for observing odour incidents. During the period of December 2020 until June 2021 of the pilot application in Thessaloniki approximately 460 observations were recorded, providing evidence about significant odour issues in the three areas of interest (Evosmos-Kordelio, Dendropotamos and Kalochori). Approximately 350 observations were collected using the smell diaries, while 110 observations were collected through the OdourCollect App.

During the pilot application, a 3-layer approach was followed to perform a data plausibility check (Figure 3). Two sets of measurements with an in-field olfactometer for each of the three areas of interest (Evosmos-Kordelio, Dendropotamos and Kalochori) were conducted. The first set of measurements were taken during days that the wind direction was coming from the source under investigation and the second set, during days that the wind direction was coming from the opposite side. The measurements indicated that during days with wind direction coming from the source towards the point of measurements, the odour concentrations were higher than in the other cases. Following, a validation check of all observations was implemented, through a comparison with wind direction during the entire period of data collection. Wind data were acquired from two different sources: the Hellenic National Meteorological Service and the Copernicus database. All observations were checked against the meteorological data and the valid data for Kalochori reached a percentage of 83%, Evosmos-Kordelio 73%

and Dendropotamos 68%. Finally, during this pilot phase data analysis was presented to specific group of stakeholders that are aware of the situation in Western Thessaloniki via a public consultation in order to provide feedback.

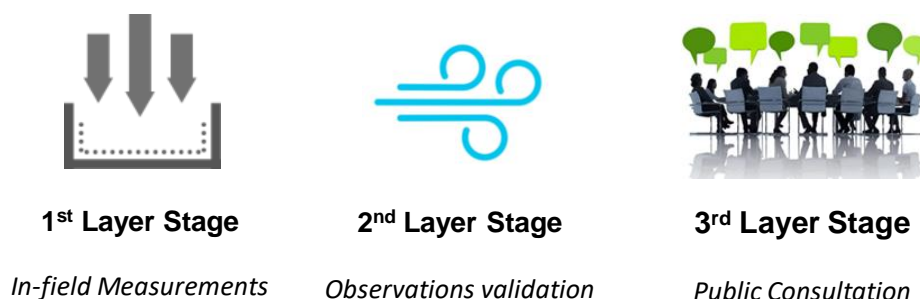


Figure 3: A 3-layer approach to perform a data plausibility check.

Qualitative data gathered from the data collection tools concerned the intensity and the hedonic tone of the observations and the quantitative the number of observations per section of the pilot areas. Data analysis indicated that the observations in proximity to the refinery (Evosmos-Kordelio) refer to either industrial (95%) or urban smells (4%) (Figure 4). This implies that various industrial activities of petrochemical nature affect the area and at the same time, heavy truck traffic due to these industrial activities is also contributing to the overall problem. On the other hand, untreated sea water smells (53%) comprised the majority of the observations taken in the area around the Dendropotamos river-Menemeni, but also urban smells (47%), such as traffic were noticed, highlighting the problem of trucks passing between industrial and urban areas (Figure 4). The vast majority concerns unpleasant smells with medium intensities. Observations from the area of Kalochori (in proximity to an industrial area), which is further to west of the refinery and the river area (Figure 1), has predominantly nice smells (e.g. grass, flowers pleasant, smell of food etc.) (64%), as well as urban smells (36%), such as heavy truck traffic (Figure 4).

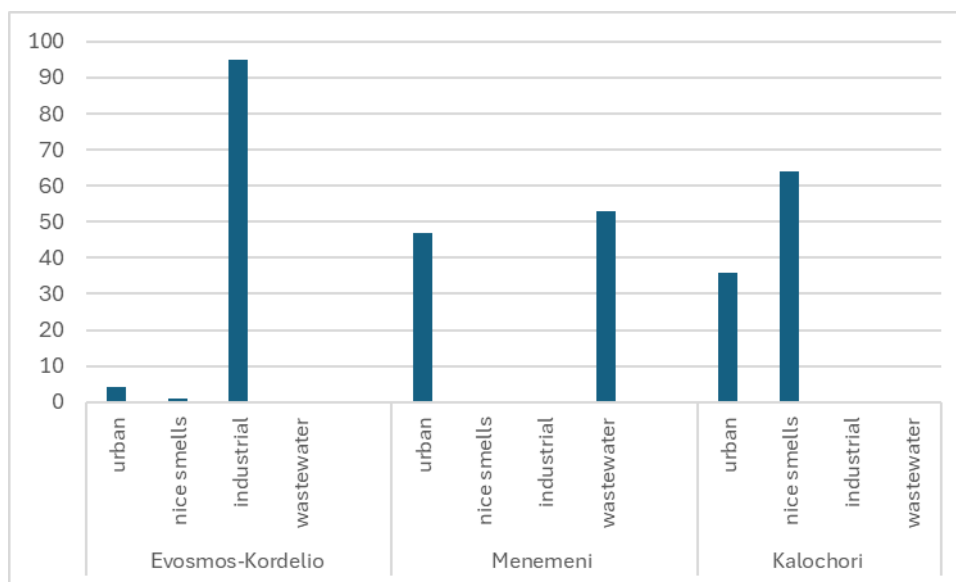


Figure 4: The type of odours observed in the under-examination area of Thessaloniki.

4. Conclusions

This paper contributes to understanding odour nuisance and offers insights into effective community-driven interventions to tackle this complex environmental issue. Thessaloniki was selected as a case study region, since researchers can explore the interplay between industrial activities, social dynamics, and environmental quality, ultimately contributing to the development of effective strategies for addressing odour issues and

promoting sustainable urban development. The methodology followed successfully engages diverse communities affected by odour pollution, including those traditionally marginalized or isolated, by engaging stakeholders and utilizing tools, such as the OdourCollect App and smell diaries. Data analysis from the pilot application validates the existence of odour nuisance in key areas, providing qualitative and quantitative insights into the problem.

Public awareness and community engagement are crucial, as they can drive demand for cleaner practices and support for regulatory measures. The pilot application of the proposed methodology to the key affected areas of the city of Thessaloniki indicated that the willingness of local authorities to participate in collaborative efforts, along with the active involvement of citizen groups with an environmental orientation, creates a conducive environment facilitating decision making towards addressing the problem. The establishment of meteorological and ambient air quality monitoring stations within the area further enhances the research infrastructure available for investigating odour nuisance and its impacts on the community.

The results also indicate the diversity of the affected pilot areas in terms of odour emitting activities covered, socio-cultural contexts, type of solutions that can be put in place to mitigate the problem and the level of complexity for implementing them, both at the technical and the stakeholder engagement levels. There is a need of implementing comprehensive strategies to manage and reduce odour pollution in Thessaloniki to enhance the living conditions for their residents and promote healthier, more sustainable urban environments.

Finally, it should be mentioned that without a harmonized national or even European approach, addressing odour at local level is challenging and leaves citizens who have to deal with odour nuisance in their daily lives, to their own devices, while odour emitting industries also do not have the benefit of a clear regulatory framework or a continuous monitoring system to adapt their activities.

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