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The Quadaq Framework: A Multi-Level Partnership Model for Sustainable Air Quality Management

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Abstract: Air quality management in rapidly urbanizing contexts requires collaborative frameworks that balance technical solutions with inclusive governance. This study introduces the QuadAQ approach, a partnership model that identifies and engages air quality (AQ) actors across four levels: micro (citizens directly affected and targeted by initiatives), meso (entities whose activities directly or indirectly reduce air quality), macro (academia, NGOs, and AQ professionals), and mega (local councils, government, media, and funding agencies). The Erasmus+ program has facilitated various air management initiatives across Europe. Two of such projects, the CitiObs and AirForAll projects demonstrate different partnership frameworks different from the QuadAQ approach to air management. The AirForAll project support micro level AQ players to "act for improved air quality and climate sustainability in your local area and in the world." expressed through the production of a non-technical knowledge toolkit accessible on the AirForAll digital platform, the platform affords micro level players the opportunity to collaborate with Macro level players for air management. This project doesn't incorporate meso and mega level players directly and thus the collaboration may not endure. The CitiObs project, focuses on empowering micro level players to become "citizen observatories in distinct cities to create/enhance/or scale up inclusive and diverse citizen observations, fostering, in particular, an active role of citizens in the observation of the urban environment using low-cost sensor technologies and wearables, with a particular focus on air quality and related environmental measures." Citizen Observatories are collaborative platforms for environmental monitoring, combining citizen participation and technology. CitiObs approach is akin to the conceptualized QuadAQ partnership framework as it hopes to engage "citizen science practitioners (public and institution-based), and policymakers at the city, regional, national and EU levels in co-design and co-creation activities, and embedding the results of those activities in a Knowledge Platform." This approach involves the mega, micro and macro level AQ players. Engaging all AQ players is an ideal framework for enduring collaboration for air management.

Keywords: Environmental planning; Air quality management; Citizen science; QuadAQ approach; Sustainable urban development

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1. Introduction

Air pollution contributes to approximately 7 million premature deaths annually, with disproportionate impacts on vulnerable urban populations. Study [1] reports that 9 out of 10 people worldwide breathe contaminated air, leading to over 7 million premature deaths. Research [2] further confirms this, noting air pollution kills 1 in 8 people globally through heart disease, stroke, and respiratory conditions. Conventional monitoring relies on a small number of fixed stations with limited spatial coverage, often unable to inform local communities about pollutant concentrations. Reference [3] emphasizes that these sparse monitoring networks are expensive and fail to capture pollution's temporal and spatial heterogeneity. The emergence of low-cost sensor technologies and citizen science methodologies has transformed environmental monitoring and governance. However, successful air quality management requires carefully designed collaborative frameworks that intentionally engage diverse stakeholders across multiple organizational levels. [4-5]

This paper proposes the QuadAQ framework; a four-level stakeholder engagement model for air quality management in urbanizing contexts. The framework conceptualizes air quality actors across four distinct levels:

1. **Micro Level:** Individual citizens and community members directly affected by air pollution.
2. **Meso Level:** Organizations and industries whose activities directly or indirectly impact air quality.
3. **Macro Level:** Academic institutions, research organizations, and professional networks.
4. **Mega Level:** Government bodies, policy-making institutions, media organizations, and funding agencies

2. The QuadAQ Framework

The QuadAQ framework organizes air quality management into four interconnected tiers, each contributing unique resources. The **Micro** level involves citizens using local experiences to identify pollution sources, while the **Meso** level includes the industries and transport companies that generate emissions. These groups are supported by **Macro** level experts, such as universities and NGOs, who provide scientific guidance, and **Mega** level government authorities and private sector funders responsible for creating regulations, policies, and allocating budgets.

There must be active collaboration across all levels rather than isolated efforts for this approach to succeed.[6] Communities need clear channels to voice concerns to industries, while researchers must ensure their technical expertise is accessible to local residents. Crucially, government and private institutions must facilitate this dialogue and clearly demonstrate how public and expert input directly shapes official air quality decisions and policies towards clean environment.

3. Case Study: CitiObs and AirForAll Projects

3.1. CitiObs Project:

CitiObs is a Horizon Europe initiative that coordinates 85 different citizen observatory groups across europe. Instead of viewing residents as data collectors, the project treats them as active partners who help design the research and advocate for a better environment.[7] This approach successfully connects different layers of society: everyday citizens work on the ground, major research institutes like Leiden University, RIVM, IHE Delft provide the scientific backbone, and government officials are engaged directly to ensure findings influence laws. Even the industries causing pollution are brought into the picture indirectly, as the project focuses on identifying exactly where emissions originate.[8]

The project uses a phased expansion strategy, starting with five lead cities before rolling out to others to ensure these efforts last. They are securing this legacy by developing a "CitiObs Cookbook" and a shared knowledge platform, which serve as practical guides for future initiatives. Beyond just creating tools, the project invests heavily in training everyone involved; from local communities to national policymakers. The ultimate goal is to ensure that community-led monitoring stops being a temporary experiment and becomes a standard, integrated part of how cities manage environmental policy.[8]

3.2. AirForAll Project

AirForAll is an Erasmus+ funded project designed to help everyday people actively reduce air pollution. Instead of using complex scientific jargon, the project offers a simple, non-technical toolkit hosted on a digital platform that makes data collection and collaboration easy for everyone. Because of this accessible approach, the project connects very strongly with local residents, specifically through its Citizens Testing Group. However, while it works well with environmental organizations, it currently operates somewhat independently, with limited direct interaction with the government bodies or the industrial companies that are actually creating the pollution.

AirForAll relies on its digital platform to keep knowledge accessible and uses its Citizens Testing Group to provide a steady stream of feedback to ensure the project lasts. Being part of a transnational partnership network also helps share ideas across borders. However, a key challenge remains for its long-term future: unlike more policy-heavy initiatives, this project currently lacks strong mechanisms to integrate its findings into official institutions, meaning its work often stays within the community rather than becoming part of permanent government policy.

4. Findings: CitiObs and AirForAll Projects

Analysis of the CitiObs and AirForAll initiatives indicates that long-term project sustainability is positively correlated with comprehensive, multi-level stakeholder engagement. The CitiObs model demonstrates that including "mega-level" actors such as municipal and national authorities is particularly decisive for ensuring that citizen-generated data is assimilated into formal governance structures. Conversely, while AirForAll validates the importance of "micro-level" citizen empowerment, without explicit mechanisms to translate this grassroots activity into policy change, the potential for long-term institutional impact remains short-lived.

A critical deficiency observed across both frameworks is the lack of explicit engagement with "meso-level" stakeholders, specifically the industrial and transportation sectors responsible for emissions. This gap represents a significant barrier to comprehensive air quality management, as direct collaboration with these actors is essential for identifying pollution sources [11] and understanding the specific technical or economic constraints that hinder emissions reduction.

Ultimately, effective participatory science requires more than organic collaboration; it demands intentional design mechanisms for knowledge integration. [9] For Citizen science to function as a robust component of air quality management, projects must implement structural frameworks that systematically synthesize distinct perspectives. This ensures that community-level insights are not isolated but are effectively combined with the scientific expertise and administrative authority necessary for systemic change.

5. Recommendations

- Future initiatives should move beyond isolated engagement strategies by adopting governance models that explicitly interlock all four QuadAQ levels (Micro, Meso, Macro, and Mega). This ensures that community observations are not treated as peripheral data points but are structurally integrated with scientific validation and administrative oversight.

- Frameworks must actively engage Meso-level actors, including industry and transportation sectors. Rather than adversarial approaches, establishing collaborative forums where communities and emitters can identify technical constraints and co-develop realistic reduction strategies.

- Initiatives must transition from temporary grant-based funding to permanent institutional support to prevent loss of momentum following project closures.

Embedding these participatory structures into local government operations can ensure long-term viability.

6. Conclusion

Air quality management in rapidly urbanizing contexts requires collaborative frameworks that engage diverse stakeholders across multiple organizational levels. The QuadAQ framework provides a useful conceptual tool for understanding and designing multi-level stakeholder engagement. This paper demonstrates that comprehensive multi-level engagement, as exemplified by CitiObs, creates stronger mechanisms for long-term sustainability and policy integration compared to more limited engagement approaches. Future air quality initiatives should prioritize comprehensive multi-level engagement, explicit policy integration, engagement of meso-level actors, investment in capacity building, and establishment of mechanisms for long-term sustainability.[10]

The transition toward more inclusive and collaborative air quality governance represents a significant shift from traditional, centralized approaches toward more participatory models of environmental knowledge production and decision-making. As European cities continue to grapple with air quality challenges, the QuadAQ framework provides valuable guidance for designing collaborative air quality management initiatives that can create meaningful, lasting improvements in urban air quality and public health.

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