How Motivation Drives Participation:
A Review of Motivating Factors for Participation in Citizen Science Projects Related to Pollution

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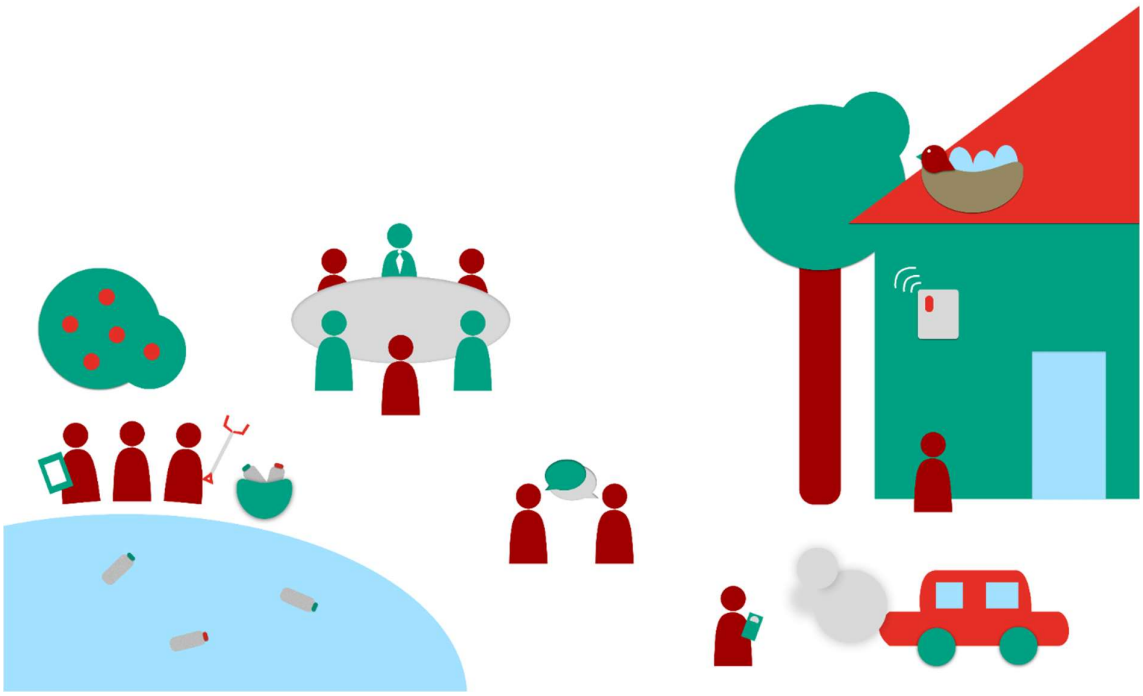

Abstract

Pollution is a major issue that has various impacts on humans and the environment. Efforts are being undertaken to address pollution, both by monitoring it and attempting to tackle it at the source. In recent years, communities have come to play an important role in monitoring through citizen science methods, in which they contribute to the scientific research process to varying degrees of involvement. This provides a valuable opportunity to empower communities and individuals looking to address pollution. However, little is known about what drives individuals to participate in citizen science (CS) projects related to pollution. Therefore, I performed a systematic literature review to investigate what factors motivate individuals to contribute to such projects and how this relates to the projects' characteristics. I made use of an adapted framework to do so and found that wanting to protect the environment was the most common motivation. I also found that the type of pollution which is addressed by the project has an influence on participants' motivations, and projects which are organised bottom-up are more frequently motivated by health concerns than those coordinated top-down. Additionally, participants' motivations changed over time during several projects; the importance of motivational factors increased, decreased, shifted towards other factors, or transformed internally. Therefore, CS projects will benefit from appealing to a variety of common motivations such as environmental protection and health, and actors should keep in mind that project design influences which motivations are invoked and that motivation is not static. However, because of the small body of available literature on motivation in pollution-related citizen science, notably in the Global South, and inconsistency in the methods used to measure motivation it is difficult to make hard statements. In the future, more literature is needed to gain a deeper, preferably standardised, understanding of the topic, especially when it comes to the motivations of participants in the Global South.

1. Introduction

Nowadays, pollution is one of the most widespread issues our environment is facing. Together with climate change and biodiversity loss it is included in the UN's Triple Planetary Crisis concept: major environmental challenges that are interconnected and pose a threat to humanity (Passarelli et al., 2021). With the rise of the Anthropocene - the proposed name for the era in which human impacts have a major influence on the Earth's environment and climate - the number of pollution sources and their intensity has increased compared to pre-industrial times (Hill, 2020). The diverse sources and resulting forms of pollution pose various threats. Air pollution is a major cause of health problems such as respiratory and cardiovascular diseases and contributes to global climate change (Manisalidis et al., 2020). Water pollution can present significant threats to aquatic wildlife, human health, and entire ecosystems (Madhav et al., 2020). Then there are forms of sensory pollution, such as artificial light, noise, and chemicals which interfere with animals' sensory perception and our own as well (Halfwerk & Slabbekoorn, 2015; Hoover, 2018). Addressing these various types of pollution is difficult due to their diffusivity and various origins, such as industry, agriculture, and transportation (Hill, 2020).

Governments and researchers have managed to make progress in tackling pollution through monitoring and consequent measures. However, governmental monitoring programmes are often resource intensive, making it difficult for them to reach their full potential (Snyder et al., 2013). This can leave certain areas and pollutants unmonitored. For example, UNICEF (2019) reported that only seven of 54 African countries have consistent real-time air pollution coverage. Furthermore, in the Global North, the discovery that PFAS has infiltrated our environment on a large scale while posing a threat to human health and wildlife has led to public outrage (Brennan et al., 2021). As a response to the perceived lack of governmental monitoring, "citizen science" (CS) has become increasingly popular. This generally refers to citizens participating in scientific research, although definitions vary and terms like community monitoring convey similar concepts (Bonney et al., 2016). CS is being implemented in various fields; in the case of environmental monitoring, a wide variety of projects exist, ranging from governments handing out air pollution sensors to concerned communities wanting to protect their local environment (Eicken et al., 2021).

Applying citizen science in pollution research can provide various benefits, such as empowering communities, educating citizens on environmental issues, and democratising the scientific process (Conrad & Hilchey, 2011). Likewise, there are challenges connected to CS, such as collecting data of sufficient quality, convincing decision-makers to use this data, and successfully setting up and maintaining a CS project. It can be especially difficult to attract and retain participants as they work on a voluntary basis in most cases (Bonney et al., 2016; Conrad & Hilchey, 2011). Therefore, it is important to understand what motivates participants to contribute to citizen science projects.

Several researchers have already investigated motivation among citizen scientists. Lotfian et al. (2020) have classified motivation based on various types of CS projects. Vasiliades et al. (2021) investigated citizens' motivations for joining along with their perceived benefits, goals, and constraints. Levontin et al. (2022) categorised various types of motivation in a citizen science motivational scale. However, fewer attempts have been made to acquire an overall understanding of motivations for contributing to projects specifically related to pollution. Given pollution's widespread impacts it is important to understand how individuals willing to address them are driven to do so. Moreover, the frameworks created by the above authors have not yet been employed in a systematic review to gain a holistic overview of the importance of motivating factors and how they are measured. Through the information gained from using such an approach, those organising CS projects addressing pollution can better understand how they can motivate individuals to participate. Therefore, in this systematic review I will attempt to answer the following research question:

What factors motivate citizens to participate in citizen science projects related to environmental pollution?

I will do so by making use of an adapted version of Levontin et al. (2022)'s framework, specifically fit to pollution-related motivations. I will also investigate whether certain project characteristics are related to specific motivational factors and how individuals' motivations change over time.

2. Methods

2.1. Search & Screening

For this review I conducted a systematic search through the Scopus search engine using keywords. These were "citizen science" AND "pollution" AND "motivation" and needed to occur either in the title, abstract, or keywords. I screened the papers this yielded to assess whether they fit the scope, meaning they concerned CS project(s) related to pollution and stated individuals' initial motivation(s) for participating. The exclusion criteria were therefore: "project is not citizen science", "project is not related to pollution", and "no (initial) participant motivation mentioned". I examined all papers yielded by the initial search for citations that could provide additional results. I screened sources which appeared suitable and included those which did not correspond to the exclusion criteria mentioned above.

2.2. Motivational Factors

To assess the different types of motivation CS participants have for joining a project I made use of the citizen science motivational scale by Levontin et al. (2022) (Appendix A). This scale was created based on the theoretical framework of basic human values by Schwartz (Schwartz 1992; Schwartz et al. 2012), and it aims to categorise different types of motivation among citizen scientists. I adapted the framework after the search and screening process to better fit motivations related to pollution (Table 1). First, I expanded "Security" to "Health (security)" to more explicitly reflect participants' health concerns for themselves and their relationships. Health security is a commonly used concept, but its scope and scale of definition can vary greatly (Aldis, 2008). In this case I will use health security to represent the protection of health of individuals and communities, specifically against pollution. Second, I combined the two types of "Universalism" – social and nature – into one category. I did so because concerns for social justice and environmental protection are intertwined in the concept of environmental justice when considering pollution (Brulle & Pellow, 2006). This would make it difficult to distinguish between both categories separately. Additionally, the original framework of human values does not distinguish between the two types of universalism (Schwartz 1992; Schwartz et al. 2012). Therefore, I decided "Universalism" would be the most fitting category to represent a broader motivation to protect the environment and the services it provides. Third, I decided to remove the "Benevolence" category as it shares overlap with "Health (security)"; those seeking to contribute to their community are likely already doing so in light of the health dimension which operates on the same scale. Moreover, multi-dimensional scaling by Levontin et al. (2022) found "Benevolence" and "Universalism" to be closely related. Therefore, in this case I assumed "Health (security)" and "Universalism" could adequately represent benevolent motivations. Lastly, I added the category "Information gain" to represent instances in which participants were looking to acquire data to inform their own decision-making. This includes those seeking information to act upon, rather than a broader desire to increase knowledge as is the case for the "Self-direction" category. The link between CS participation and behaviour change is a common research topic, so I deemed it worthwhile to add this category to represent those wanting to inform and adjust their behaviour (Somerwill & Wehn, 2022).

I divided the motivational categories into intrinsic and extrinsic motivations. Ryan & Deci (2000) define intrinsic motivation as doing something for its innate satisfaction rather than to achieve a certain outcome. Extrinsic motivation is the opposite and is based on the activity's instrumental value. By distinguishing between these types of motivation it becomes easier to understand to what degree

participants contribute to citizen science for enjoyment as opposed to wanting to achieve a certain outcome.

*Table 1. The adapted framework based of Levontin et al. (2022)'s citizen science motivational scale. Categories which were adapted to better fit motivations related to pollution are marked with an *.*

Motivation type	*Motivational category*	*Definition*	*Example*
Intrinsic	Self-direction	Independent thought and action—choosing, creating, exploring	"I want to learn more about pollution in my area"
	Stimulation	Excitement, novelty, and change	"I want to be part of an interesting new research process"
	Hedonism	Pleasure and sensuous gratification	"I want to be outdoors"
Extrinsic	Social expansion	Expand social groups, create and belong to a new community, meet new people	"I want to be part of a community with similar concerns"
	Achievement	Personal success through demonstrating competence according to social standards	"I want to do better than others"
	Power	Power through exercising control over people, material, and social resources	"I want to gain recognition and status"
	Face	Security and power through maintaining one's public image and avoiding humiliation	"I want to enhance my reputation"
	Routine	Everyday, ordinary, and regular	"I was doing this activity anyway"
	Conformity and tradition	Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms	"I want things to be able to continue as they are"
	Universalism*	Preservation and protection of the natural environment	"I want to protect my natural surroundings from pollution"

		and the services it provides	
	Help with research	Contribution to science	"I want to contribute to science"
	Health (security)*	Safety, and good health of society, of relationships, and of self	"I want to prevent harm to myself and loved ones"
	Teaching	Providing an educational opportunity to others	"I want to raise more awareness about pollution"
	Information gain*	Access to knowledge that can help in making informed decisions	"I want to know when and where to avoid pollution"

2.3. Synthesis

I synthesised the review outcomes by first visualising the results of the review process in a PRISMA flowchart. I created a bar chart to visualise the number of projects which mentioned each motivational category as being important and created a table showing each project and its corresponding motivations. Next, I analysed the motivational categories according to the adapted framework. I did so by elaborating on the motivations as described for the various projects, per category, from most to least frequently mentioned.

To examine the relation between project characteristics and motivation I created a radar chart to group different types of pollution and their corresponding motivations together. For this I created four groups of pollution: (1) air, (2) sensory, (3) industrial & agricultural, and (4) water & plastic. Sensory pollution includes pollutants such as noise and artificial light. I categorised pollution this way based on the pollution types I found in literature that fit the scope and to prevent the existence of groups with too little data. I chose to group industrial and agricultural pollution together because several projects specifically targeted pollution coming from these sources, and they generally produce multiple forms of pollution (Hill, 2020). Water and plastic were grouped together because the plastic-related project included in the review targeted plastic in and around rivers.

Furthermore, I classified the projects as either top-down or bottom-up and examined the prevalence of the motivational categories for both groups through a radar chart. Eicken et al. (2021) define a bottom-up approach as being created and executed by local communities, whereas a top-down approach is more broadly defined, often by governmental bodies and scientists. I classified the projects along more characteristics in a table, including scale, facilitation of social interaction among participants, and whether the project can be categorised as contributory, collaborative, or co-creative. Bonney et al. (2009) define contributory projects as those created by scientists and with data collection as the main task of participants. Collaborative projects are also designed by scientists but open to more participant involvement, and co-creative ones involve citizens in (nearly) all steps of the scientific process. I compared these characteristics to find commonalities within project design and organisation.

Additionally, I tracked the methods authors employed to measure motivation. I examined whether this could partially explain patterns or biases in the results. Then, I described the instances in which motivation was measured longitudinally and how these motivations changed over time. Lastly, I assessed the geographical distribution of the papers included in the review, as well as other potential sources of bias.

3. Results

After the systematic search and the screening of the results and relevant citations, 11 papers remained (Figure 1). Out of these, 8 were found using the Scopus search engine, and 3 were found through citations during the screening process. In total, these 11 papers represented 14 projects fit for analysis.

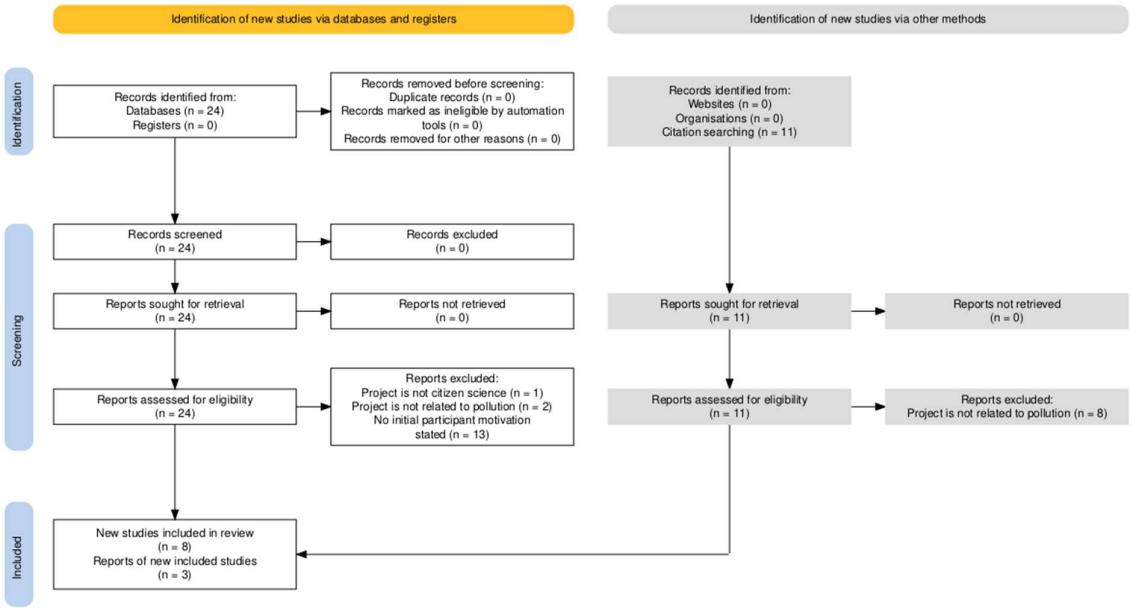

Figure 1. A PRISMA flowchart depicting the outcomes of the review process. Adapted from Haddaway et al. (2022).

3.1. Motivational Categories

12 out of 14 projects mentioned multiple motivational categories as being important for participation. Out of these, "Universalism" was mentioned most frequently, followed by "Health (security)", "Information gain", "Stimulation", and "Self-direction". "Power", "Face", and "Routine" were not mentioned (Figure 2).

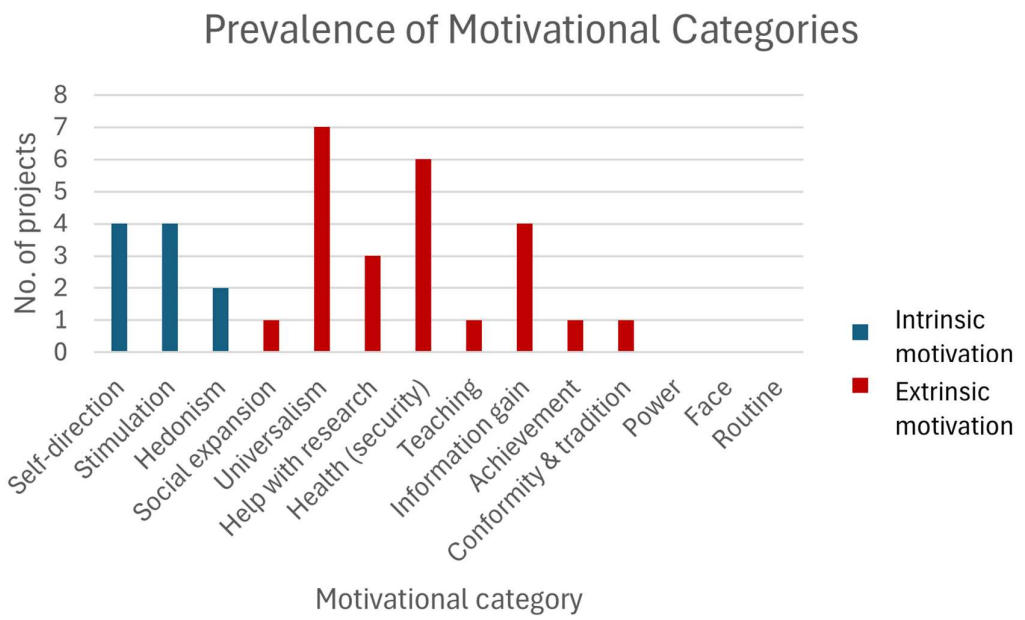

Figure 2. A bar chart showing the number of projects for which each motivational category is mentioned as important.

The 11 papers discussed citizen science projects related to various types of pollution (Table 2). Out of these, air pollution was the most common, being represented in 6 projects. Other types of pollution were noise, light, water, and plastic in and around rivers. Pollution originating specifically from industry and pesticides was also mentioned. The article by Froeling et al. (2024) investigated the outcomes of 5 citizen science projects, of which 4 fit the scope, and Commodore et al. (2017) conducted a literature review on community-based research projects related to air pollution. The outcomes of their review are not separated per initiative but rather presented as a whole because they provide a synthesis of motivations across 22 different projects. None of the review papers describing the projects stated motivations explicitly enough to be included separately. Weinberger et al. (2021) examined three projects, of which one fit the scope.

*Table 2. An overview of all relevant citizen science projects and the motivational categories that were mentioned for each of them. Snowball articles are marked in **bold**, and colour corresponds to the type of pollution: Orange = air pollution, Blue = water & plastic pollution, Green = sensory pollution, Purple = industrial & agricultural pollution*

		Intrinsic motivation			*Extrinsic motivation*										
Author	*Project*	*Self-direction*	*Stimulation*	*Hedonism*	*Social expansion*	*Universalism*	*Help with research*	*Health (security)*	*Teaching*	*Information gain*	*Achievement*	*Conformity & Tradition*	*Power*	*Face*	*Routine*
Froeling et al., 2024	CitieS-Health (Barcelona)							X							
Froeling et al., 2024	CitieS-Health (Amsterdam)					X		X							
(Wróblewski et al., 2021)	Sensor.community (Poland)							X		X					
(Commodore et al., 2017)	Community based air monitoring	X						X							
(Land-Zandstra et al., 2016)	iSPEX	X	X			X	X								
(Leonardi et al., 2014)	SecondNose		X							X					
Rambonnet et al., 2024	Clean Rivers					X									
(Kinchy, 2017)	Water quality monitoring			X		X									
Froeling et al., 2024	CitieS-Health (Ljubljana)	X	X				X								

(Weinberger et al., 2021)	Nachtlichter					X			X			X			
(Celino et al., 2021)	TESS Network	X	X	X	X	X					X				
Froeling et al., 2024	CitieS-Health (Italy)							X							
(Suman, 2022)	Analizziamo la Basilicata							X		X					
(Bieszczad et al., 2023)	INSIGNIA					X	X			X					

Universalism

Universalism was the most common motivation. Kinchy et al. (2017) interviewed citizen scientists measuring water quality in fracking areas. Interviewees frequently mentioned wanting to protect the environment and their communities from the effects of ground- and surface water pollution; by acquiring baseline data they hope to compel authorities to act when water quality deteriorates. Some said they believe their presence has a preventative effect. Because gas companies know measurements are being taken, they may be less emboldened to pollute. Rambonnet et al. (2024) found that participants in a Dutch project related to plastic pollution were mainly motivated to address the source of pollution as well as the plastic soup. They said they wanted to commit to an improved environment and help in action being taken against polluting companies and the government. Within the CS projects examined by Froeling et al. (2024), participants in a woodsmoke project in The Netherlands mentioned wanting to change their local environment. In Nachtlichter, a project related to light pollution, participants were motivated to improve the health of ecosystems and were concerned about the ecological and human impacts of artificial light, despite generally not being affected themselves (Weinberger et al., 2021). Land-Zandstra et al. (2016) found that one of the most important motivations for citizens to participate in a project measuring aerosols was to contribute to the quality of their surroundings. Bieszczad et al. (2023) interviewed beekeepers, some of whom said they wanted to contribute to the wellbeing of bees and the environment.

Health (security)

Health (security) was the second-most common motivation. Participants in most CitieS-Health projects were concerned about health effects (Froeling et al., 2024). However, this differed between project locations; in The Netherlands participants said they experienced nuisance from woodsmoke, and in Italy participants were concerned about the health effects of heavy metals, but in the Slovenian study most citizens did not consider themselves affected by the noise they were researching. They rather saw it as a problem that was situated elsewhere and impacting others. Other citizens started civic monitoring because they felt they were already being affected: Suman (2022) found that 18 out of 20 interviewees in the Basilicata region were experiencing health impacts from olive oil extraction. Sensor.community participants were mainly motivated by concern for the health and safety of loved ones and themselves (Wróblewski et al., 2021). Several of them said they had experience with poor air quality in their surroundings and hoped to reduce/avoid its effects. The review by Commodore et al. (2017) found that diseases such as cancer and asthma were among main concerns of citizens monitoring air pollution, and fear of pollution was a cause of anxiety.

Information gain

Information gain was mentioned for four projects. In the case investigated by Suman (2022), citizens started to collect data to support their activism and get media to report on their issues. Wróblewski et al. (2021) found that participants used the data they acquired through their sensors to respond to poor air quality and confirm whether their loved ones were safe outside. One participant mentioned they considered using the sensor to inform them when to go outside with their children. Leonardi et al. (2024) found a similar result and reported that contributors wanted to know the air quality in places of frequent use. The beekeepers interviewed by Bieszczad et al. (2023) were motivated by access to research data which would normally be difficult to acquire. They were concerned about the health of their colonies and stated that laboratory pesticide analysis is too costly to perform regularly. They claimed that the government is not supportive of efforts to monitor through sampling.

Self-direction

Self-direction was mentioned four times. In the iSPEX project, citizens participated because they were interested in the topics of health and aerosols (Land-Zandstra et al., 2016). Likewise, in the Slovenian

CitieS Health project, participants were motivated to gain knowledge about the topic (Froeling et al., 2024). Citizens in the TESS network were also driven by interest in the topic and willingness to learn (Celino et al., 2021). Commodore et al. (2017) found that improved air pollution knowledge was one of the expected outcomes several communities were motivated by.

Stimulation

Four projects mentioned stimulation as an important motivation. Besides gaining knowledge about the topic, CitieS-Health participants in Slovenia were motivated to learn about the research process (Froeling et al., 2024). Celino et al. (2021) found that participants wanted to challenge themselves. A large portion of iSPEX participants mentioned that they were interested in science, and 9.9% stated their interest in citizen science as a method was their primary reason for participating (Land-Zandstra et al., 2016). Users of SecondNose were initially motivated by curiosity and wanted to test the system and its functioning (Leonardi et al., 2014).

Help with research

Help with research was mentioned three times. In the case of CitieS-Health in Slovenia, citizens wanted to help scientists with their research (Froeling et al., 2024). Contributing to scientific research was mentioned as the most common reason (27.5%) for citizens to contribute to iSPEX (Land-Zandstra et al., 2016). Bieszczad et al. (2023) found that two out of four beekeepers, who see themselves as knowledge creators, wanted to support science and foster interactions between scientists and beekeepers.

Hedonism

Hedonism was mentioned twice. Kinchy (2016) stated that some citizens joined monitoring projects for the opportunity to perform outdoor volunteer activities. More broadly, Celino et al. (2021) found that personal passion was a motivation to contribute.

Social expansion, teaching, achievement, conformity & tradition

Social expansion, teaching, achievement, and conformity & tradition were all mentioned once. Celino et al. (2021) found that belongingness - meeting people with similar interests – and achieving meaningful results were important motivators. Teaching was mentioned once by Weinberger et al. (2021). Some citizens participating in Nachtlichter hoped to raise public awareness surrounding unsustainable lighting, and one team hoped to engage young people in their efforts. Additionally, some contributors were stargazers who wanted to protect the night sky to ensure they could continue their hobby. This corresponds to the tradition component of conformity & tradition.

Power, face, routine

Power, face, and routine were not mentioned as motivators for participating in citizen science.

3.2. Influence of pollution type and organisation

Participants' motivations varied based on the type of pollution addressed by the project (Figure 3). Notably, "Hedonism" and "Universalism" were the only categories mentioned for the projects related to water & plastic pollution. Air pollution triggered other motivations, of which "Health (security)" was the most prevalent one. This was also an important motivation in projects related to industrial and agricultural pollution, together with "Information gain". Sensory pollution covered the largest number of categories, but these did not include "Health (security)" or "Information gain".

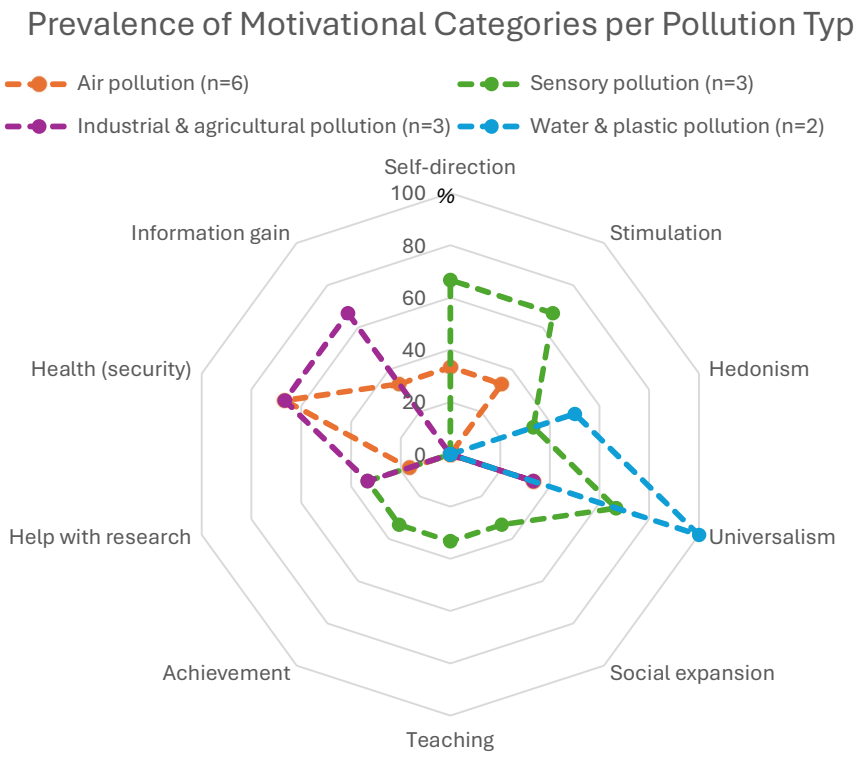

Figure 3. A radar chart showing the prevalence of motivational categories among projects, grouped by the type of pollution they address. Values are in percentage of projects for which each category was mentioned.

6 of the projects could be classified as top-down and 8 as bottom-up. In several categories both organisation types showed similar prevalences or had little data to compare (Figure 4). However, "Information gain", "Universalism", "Stimulation", and "Help with research" were more prevalent motivations in top-down projects. Bottom-up projects featured "Health (security)" most commonly, whereas all other categories except for "Teaching" were mentioned less frequently than for top-down projects. There were notable differences between top-down and bottom-up projects regarding other project characteristics (Table 3). All top-down projects except for Clean Rivers were contributory, and they most frequently operated on a national scale. Bottom-up projects were mostly co-creative and local, and most of them facilitated forms of social interaction among participants, such as meetings, workshops, and joint fieldwork. Top-down projects, however, rarely facilitated interaction among participants. Only Clean Rivers did so through feedback sessions on their results and annual conferences (Rambonnet et al., 2024). Lastly, participants were self-selected in all projects. In most cases, participants were recruited through social media and platforms related to the project contents. For the two regional bottom-up projects, participants mostly organised themselves and recruited more individuals through community resources (Kinchy, 2017; Suman, 2022).

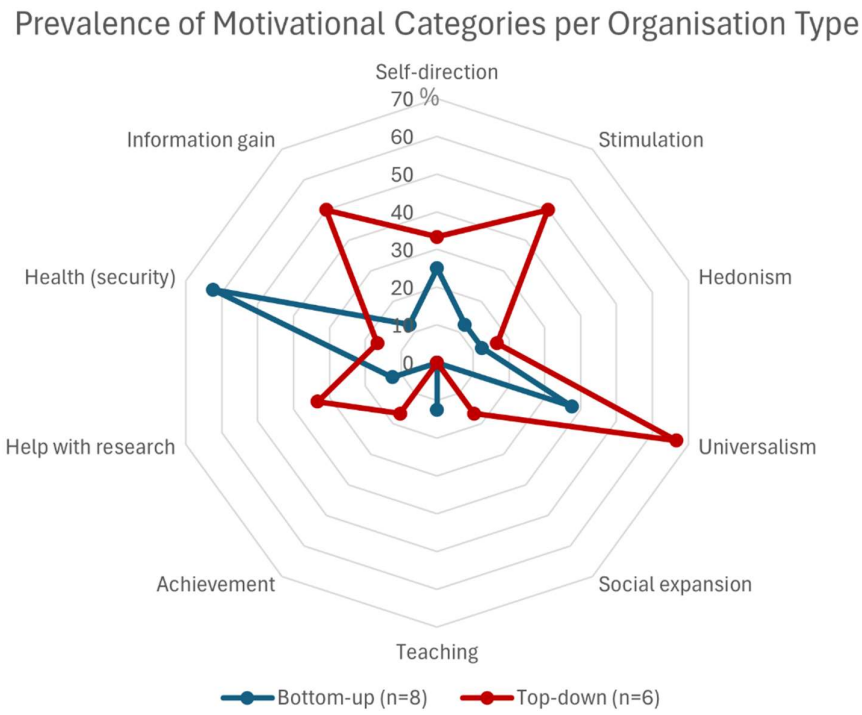

Figure 4. A radar chart showing the percentage of projects which mention each motivational category, grouped by whether the project is classified as bottom-up or top-down.

Table 3. An overview of the projects and their characteristics. Colour corresponds to the type of pollution: Orange = air pollution, Blue = water & plastic pollution, Green = sensory pollution, Purple = industrial & agricultural pollution

Author	*Project*	*Bottom-up/top-down*	*Scale*	*Contributory/collaborative/co-creative*	*Is social interaction among participants facilitated?*
Froeling et al., 2024	CitieS-Health (Barcelona)	Bottom-up	Local	Co-creative	Yes
Froeling et al., 2024	CitieS-Health (Amsterdam)	Bottom-up	Local	Co-creative	Yes
(Wróblewski et al., 2021)	Sensor.community (Poland)	Top-down	National	Contributory	No
(Commodore et al., 2017)	Community based air monitoring	Bottom-up	Local	Collaborative & Co-creative	Unspecified
(Land-Zandstra et al., 2016)	iSPEX	Top-down	National	Contributory	No
(Leonardi et al., 2014)	SecondNose	Top-down	Local	Contributory	No
Rambonnet et al., 2024	Clean Rivers	Top-down	National	Collaborative	Yes
(Kinchy, 2017)	Water quality monitoring	Bottom-up	Regional	Collaborative	Yes
Froeling et al., 2024	CitieS-Health (Ljubljana)	Bottom-up	Local	Co-creative	Yes

(Weinberger et al., 2021)	Nachtlichter	Bottom-up	National	Co-creative	Yes
(Celino et al., 2021)	TESS Network	Top-down	Global	Contributory	No
Froeling et al., 2024	CitieS-Health (Italy)	Bottom-up	Local	Co-creative	Yes
(Suman, 2022)	Analizziamo la Basilicata	Bottom-up	Regional	Co-creative	Unspecified
(Bieszczad et al., 2023)	INSIGNIA	Top-down	National	Contributory	No

3.3. Study methods & longitudinal characteristics

The papers included in this review made use of various methods to measure motivation. Most authors employed interviews (4) or structured online surveys (3). Two papers made use of mixed methods: Froeling et al. (2024) employed surveys, discussion groups, and community meetings, and Kinchy (2017) acquired their results through participant observation and interviews. Weinberger et al. (2021) got their findings from observations by the researchers who were leading the Nachtlichter project. Lastly, Commodore et al. (2017) performed a literature review; they were not in contact with the project participants but deduced and synthesised their motivations from the papers within their scope.

Three papers described developments in participants' motivation while contributing to a CS project (Figure 5). Rambonnet et al. (2024) performed a longitudinal study and found that action-related motivations increased significantly, meaning universalism became more important to them. Kinchy (2017) found that many participants expected to 'catch' polluters when initially joining but had to adapt to monitoring baseline data. This caused some volunteers to lose motivation as they did not believe in the meaningfulness of the results that were found so far. Others continued monitoring because they still believed in the cause and/or enjoyed spending time in the wild ("Hedonism"), bonding with other volunteers ("Social expansion"), and the experience as a whole ("Stimulation"). The usage of SecondNose sensors decreased over time and the main motivation for use changed from curiosity to wanting to be aware of pollution and checking whether perceptions matched with measured data (Leonardi et al., 2014). This could be seen as a different form of "Information gain" and a decrease in the importance of "Stimulation".

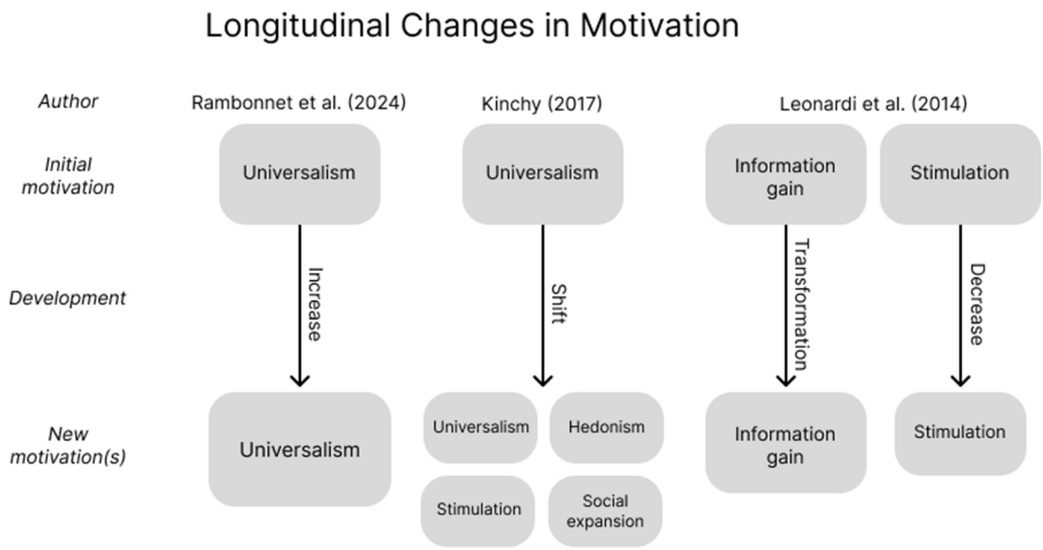

Figure 5. A diagram showing the longitudinal changes in participants' motivation as described in the three relevant papers.

3.4. Geographical Distribution and Bias

The projects included in this review were based in 8 different countries (Figure 6). 2 papers discussed projects in the USA, and 8 concerned EU-based projects, with high representation for Italy and The Netherlands. Only the TESS network investigated by Celino et al. (2021) operates on a global scale. This means citizen science projects in the Global South and several other regions were underrepresented, and the motivations of their participants in relation to pollution remain largely unknown. Other biases may have occurred during the review process. For example, smaller scale citizen science projects are likely to have gained less attention from research, meaning there are less publications available on such projects in the Scopus database. Vasiliades et al. (2021) reviewed the demographics of citizen scientists and found that highly educated adults were the most common participants. There are likely other socio-demographic factors which play an important role in CS participation and motivation, but these are not covered in the results. Therefore, it is possible that socio-demographic biases have distorted the outcomes.

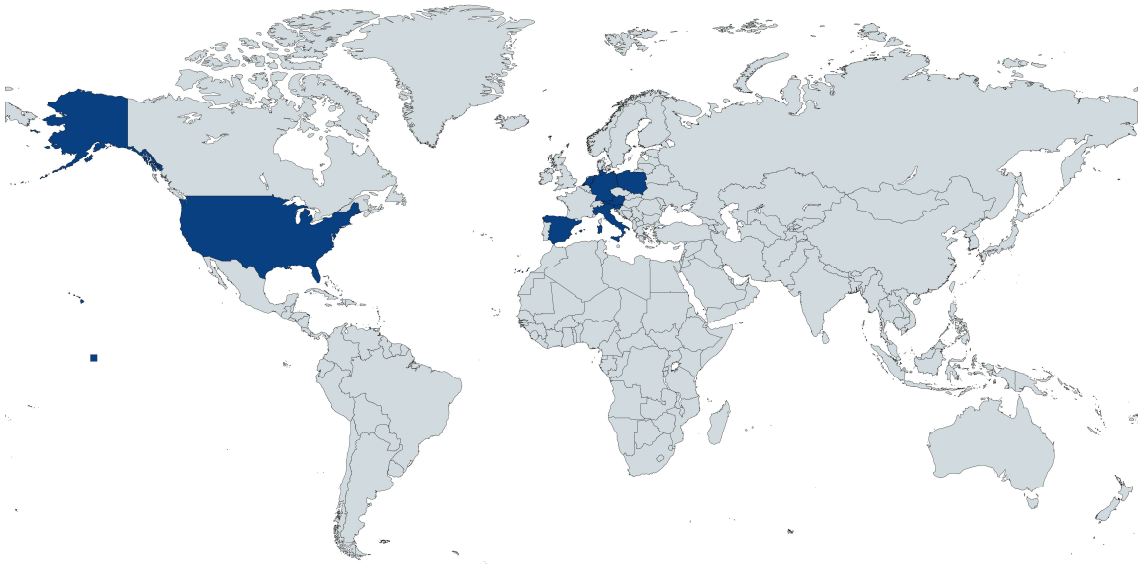

Figure 6. A map showing the 8 countries in which the projects included in this review are located. The TESS network, which operates on a global scale, is not included in this map.

4. Discussion

4.1. Interpreting results

The results indicate that there is a wide variety of motivations that drive individuals to participate in CS projects related to pollution. Furthermore, within a single project multiple motivations are often important to contributors. Several motivations were more common than others. "Universalism" was mentioned most; participants often felt motivated to protect the environment and the services it provides. This motivation was followed by motivations which were aimed at the individual themselves, namely "Information gain", "Stimulation", and "Self-direction". "Health (security)" concerned the individual's own health and in several cases that of others. These major motivations were not always mentioned together, meaning they are presumably not related directly.

Notably, “Face” and “Power” are two of the three categories which were never mentioned. These motivations could be absent for a variety of reasons. Respondents may have felt uncomfortable mentioning these motivations because it could paint them as selfish. Therefore, they might have listed other categories instead. The methods employed to measure motivation could also play an influential role; surveys might be better able to prompt participants to mention motivations such as face and power than unstructured interviews. However, because none of the authors using surveys found these motivations this is likely not the sole explanation. Additionally, addressing pollution may not offer as many opportunities to increase social status or influence as other fields of CS research. “Routine” also remained unmentioned. This might be because pollution monitoring is an activity which is currently not embedded into most people’s and communities’ everyday life. Several of the low-ranking categories are found to be less prevalent in other projects as well; Levontin et al. (2022) found power, achievement and conformity to rank low on their scale for the projects they examined, which is in line with the outcomes of this review.

Lastly, the absence and low prevalence of certain motivations could be related to project design. For example, none of the projects which are part of this review included direct rewards except for access to data. Cappa et al. (2018) discovered that monetary and acknowledgement rewards increased citizen scientists’ participation and enjoyment. Although more participants could be attracted by providing such rewards, more research is needed to determine what influence this has on the various motivational categories. Other projects make use of game-based elements; for example, a game called Pollution Runner uses sensor data of real-time air quality in a game made to raise awareness and change behaviour (Fortunati & Galizia, 2023). Vergara et al. (2024) found that using game-based elements can increase participation and encourage citizens to care for the environment.

Intrinsic and extrinsic motivation

There appears to be no clear pattern in the division between intrinsic and extrinsic motivational categories. However, all projects for which participants listed one or more intrinsic motivations as important were supported by extrinsic motivation(s) as well. This implies that participation in pollution-related CS is at least partially motivated by a desired outcome and is in most cases not completely motivated intrinsically. Thus, intrinsic motivations can increase participation but are presumably not the sole reason for contributing to pollution-related CS.

Project characteristics: pollution & organisation

Results differed based on project characteristics. The type of pollution appears to influence participants’ motivations. Air pollution and industrial & agricultural pollution were largely motivated by “Health (security)”, indicating that participants perceived these types of pollution to be harmful to humans. For example, one Sensor.community participant mentioned feeling suffocated by poor air quality, and others expressed concern for the health of their children (Wróblewski et al., 2021). “Information gain” was another important category for both pollution types, indicating that participants with health interests may be in search of information to act on these concerns. Contrarily, “Health (security)” was not mentioned as a motivation in the projects related to sensory pollution and water & plastic pollution, but “Universalism” was an important category for both. This implies that participants may not consider themselves and their loved ones as affected by these types of pollution but are instead motivated by a desire to protect the environment. This was also reflected by citizens involved in Nachtlichter, most of whom were not physically affected but cared about negative secondary impacts of artificial light on wildlife, ecosystems, and unspecified humans (Weinberger et al., 2021). Lastly, self-direction and stimulation, both intrinsic motivations, play an important role in sensory pollution CS. This may imply that this is a field which is particularly engaging to contributors.

The way the project was organised also played a role. Vasiliades et al. (2021) discovered from a sample of 119 CS initiatives that citizen scientists were most involved in monitoring and data collection and submission, whereas designing the research process or participating in decision-making

and other ways of follow-up rarely involved citizens. This would suggest that most citizen science projects are organised top-down and contributory rather than bottom-up and collaborative/co-creative. The review's results do not correspond to their findings; most projects were bottom-up. However, several projects employed citizens as 'data collectors' and did not involve them in other ways, which fits the pattern observed by Vasiliades et al. (2021). Results showed that "Health (security)" was a strong motivator to contribute to bottom-up projects. The paper by Suman (2022) described an instance in which a project was created out of local health concerns. Likewise, the design of the CitieS-Health projects was largely shaped by citizens' concerns (Froeling et al., 2024) in a co-creative manner. Top-down citizen science, on the other hand, often covers issues which operate on a larger geographical scale, which means local health concerns may receive less attention (Eicken et al., 2021). This coincides with the finding that most top-down projects included in this review operated nationally, and "Health (security)" was less prevalent than in bottom-up projects.

Motivations are closely linked to participant expectations. Commodore et al. (2017) found that study outcomes align better with community expectations in co-creative projects. When expectations are met, it is also likely that participants' initial motivations and contributions are sustained for longer (Robinson et al., 2021). However, these claims are not fully reflected in the findings. "Stimulation" was a more prevalent category in top-down contributory projects even though one might expect bottom-up co-creative projects to be more stimulating as they involve citizens in a greater part of the research process. Bottom-up projects also facilitated interaction among participants more often. This discrepancy may have occurred because participants might view top-down projects differently from bottom-up ones; it could be that bottom-up CS is more appealing to those seeking results, whereas individuals wanting to be part of a research process prefer top-down CS. More research is needed to understand to what degree participant expectations are met in various types of CS projects.

Changes in motivation

The longitudinal changes in motivation indicate that participant motivation does not remain static. In two cases the initial motivational category remained the same, but it became more/less important or underwent a transformation. In the other case, additional categories motivated participants to continue contributing. Two out of three of these categories were intrinsic, which corresponds to Tiago et al. (2017)'s claim that intrinsic motivations are important for continuous project involvement when extrinsic motivations weaken. Rotman et al. (2012) found that egocentric motivations were leading for new participants, and long-term ones were motivated more by altruistic and community motivations. This development was not reflected in this review's results, but the number of included papers was too low to observe notable patterns. More research on longitudinal changes in motivation is needed regarding projects related to pollution.

4.2. Limitations

The review process and the papers' contents had several limitations. First, the Scopus search engine has likely excluded relevant papers which could have contributed to the results. This is evidenced by the three snowball articles which fit the scope but were not found through the search. Second, the literature available on this topic is limited. This has restrained the ability to draw conclusions, and more research would be needed to perform a quantitative analysis. Third, there was inconsistency between papers in the way motivation was recorded. For example, Celino et al. (2021) used an adapted version of Levontin et al. (2022)'s scale in an online survey, whereas Kinchy (2017) conducted rigorous interviews. Other papers used various survey designs, mixed methods, research insights or literature to examine motivation. This inconsistency has produced results which are partially dependent on the methods used to acquire them and made it more difficult to accurately classify motivations into the framework's categories. Fourth, motivations which fit a certain category at first glance may be guided by other, underlying motivations. For example, individuals who claim they want to protect the environment may

mean they want to do so because they believe protecting the environment is important for their health. However, this overlap between categories may simply indicate participants have multiple motivations for contributing. Lastly, longitudinal changes in motivation were only observed in 3 out of 11 papers. More evidence would be needed to make any robust claims.

4.3. Implications

Several implications follow from the review outcomes. First, no CS project is the same, which means one should be careful making general statements. Nevertheless, certain motivations such as "Universalism", "Health (security)", "Information gain", "Stimulation", and "Self-direction" seem to be more common among citizen scientists addressing pollution, and project designers should take these into consideration to create an appealing project. Simultaneously, they should attempt to support a wide range of motivations, including intrinsic ones. This is especially important to guarantee continuous engagement for when initial motivations diminish (Tiago et al., 2017). Those involved in CS design should also consider what motivations they want to appeal to when deciding on the level of citizen engagement. Citizens participating out of health concerns may want to be involved throughout the entire research process, whereas those seeking information may simply want to collect data. Additionally, citizens have different motivations based on the type of pollution that is addressed. Sensory pollution and water & plastic pollution seem to be considered less impactful on health than the other pollution types, so those trying to recruit volunteers may need to convey the significance of these pollutants' health impacts or promote project aspects other than health.

Future research should aim to collect more data on CS motivations related to pollution, preferably in a standardised manner for ease of comparison. Using an adaptable framework such as the one by Levontin et al. (2022) to create surveys or guide interviews can help researchers as well as CS managers to understand motivations within a community. Given the low number of studies available, this review has identified that there is a literature gap in the field of research into participant motivation for contributing to CS projects related to pollution. More information is especially needed on changes in motivation that participants undergo while contributing to a CS project for a longer time. In addition, the body of research on CS motivations would benefit from a broader range of investigated projects, including those in the Global South and smaller in scale. More details on participants and their backgrounds would also help to understand their motivations.

This systematic literature review has revealed that "Universalism", i.e. protecting the environment, is the most common motivation among participants in CS projects related to pollution. Various types of pollution correspond to different motivations, and whether the project is organised top-down or bottom-up also makes a difference; especially bottom-up projects have "Health (security)" in common as an important motivation. Motivations can also change over time, emphasising the importance of continuous engagement. If those involved in CS design manage to better understand their participants' motivations for contributing, CS can become more successful in contributing to the real-world change citizens are looking for.

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6. Appendix

A. Citizen science motivation scale by Levontin et al. (2022)

Table A. The original citizen science motivation scale and its 15 motivational categories and definitions by Levontin et al. (2022).

Motivational category	*Definition*
Self-direction	Independent thought and action—choosing, creating, exploring
Stimulation	Excitement, novelty, and change
Social expansion	Expand social groups, create and belong to a new community, meet new people
Hedonism	Pleasure and sensuous gratification
Achievement	Personal success through demonstrating competence according to social standards
Power	Power through exercising control over people, material, and social resources
Face	Security and power through maintaining one's public image and avoiding humiliation
Routine	Everyday, ordinary, and regular
Conformity and tradition	Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms
Benevolence	Preservation and enhancement of the welfare of people with whom one is in frequent personal contact
Universalism-social	Commitment to equality, justice, and protection for all people
Universalism-nature	Preservation of the natural environment
Help with research	Contribution to science
Security	Safety, harmony, and stability of society, of relationships, and of self
Teaching	Providing an educational opportunity to others

B. Additional project information

Table B. Additional information about the projects in this review, including a description, methods used to measure motivation, and whether longitudinal data was provided.

Author(s)	*Citizen-science project(s) name*	*Project description*	*Method*	*Longitudinal data? (yes/no)*
(Rambonnet et al., 2024)	Clean Rivers	A Dutch project aimed at cleaning up plastic pollution near rivers.	Survey	Yes
(Froeling et al., 2024)	CitieS-Health	A project comprising multiple epidemiological studies across five different countries. These included investigations into various types of pollution and their relation to health.	Mixed: surveys, discussion groups, community meetings	No
(Suman, 2022)	Analizziamo la Basilicata	The olive oil extraction industry in Basilicata, Italy has caused various forms of environmental pollution. Citizens are collaborating to monitor this pollution.	Interviews	No
(Weinberger et al., 2021)	Nachtlichter	A German project in which participants collect data about artificial lighting at night.	Lead researcher insights	No
(Wróblewski et al., 2021)	Sensor.community (Poland)	A project in which participants receive air quality sensors they can hang in and outside their home.	Interviews	No
(Celino et al., 2021)	TESS Network	An international project in which participants use	Survey	No

		sensors to monitor sky brightness.		
(Commodore et al., 2017)	-	Air quality studies in the USA which used community-based participatory research	Literature review	No
(Kinchy, 2017)	-	Participatory water monitoring in fracking areas in the northeastern United States	Mixed: survey, participant observation, interviews	Yes
(Land-Zandstra et al., 2016)	iSPEX	A Dutch project in which participants can use their smartphones to measure aerosols.	Survey	No
(Bieszczad et al., 2023)	INSIGNIA	A project in which beekeepers collect samples from their colonies for scientists to monitor pesticide pollution and biodiversity. Those interviewed for this study were based in Austria	Interviews	No
(Leonardi et al., 2014)	SecondNose	An Italian project in which citizens monitor air quality and environmental parameters using sensors	Interviews	Yes