Considerations for Involving Citizen Science in an Integrated Waste Management System – 17506

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ABSTRACT[3]

The U.S. Department of Energy's (DOE's) goal is to develop solutions for the long-term, sustainable management of the nation's spent nuclear fuel (SNF) and high-level radioactive waste (HLW). The DOE has been exploring options for an integrated waste management system to transport, store, and dispose of SNF and HLW from commercial electricity generation, as well national defense activities. To support its efforts, DOE has been exploring ways to seek broad input from the public.

The role of citizen science in a wide range of projects is increasing. In the U.S. 2013 and 2015 Open Government National Action Plans, the U.S. government encouraged all Federal agencies to pursue public participation through citizen science, and a large number of agencies and organizations have responded.

This paper explores the potential for considering citizen science projects as part of an integrated waste management system, including the siting of facilities. A literature review was performed to gain insights into how citizen science projects can be effectively developed and deployed, including success factors and lessons learned. Results highlight the experiences shared by many people who have developed and implemented citizen science projects, which provide valuable context for potential application to a facility siting process.

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[3] This technical paper reflects concepts which could support future decision-making by DOE. No inferences should be drawn from this paper regarding future actions by DOE. To the extent this technical paper conflicts with the provisions of the Standard Contract, the Standard Contract provisions prevail.

INTRODUCTION

In December 2015, the DOE issued an Invitation for Public Comment in the Federal Register soliciting input on important considerations in designing a fair and effective process for siting facilities for SNF and HLW [1]. One of the questions asked was "What models and experience should the Department of Energy use in designing the process?"

This paper explores some considerations regarding the potential inclusion of citizen science projects as part of an integrated waste management system including the siting of facilities, building on previous work [2].

Citizen science is broadly described as public participation in research to increase scientific knowledge, often in collaboration with professional scientists and scientific institutions. Volunteers engage in citizen science projects in different ways, ranging from simple crowd-sourced data collection to complex community-initiated projects. A majority of citizen science projects occur in association with an organization such as a museum, university, or government agency. In fact, citizen science is becoming a global phenomenon because governments are adopting and implementing a wide range of citizen science projects to engage the public in their evaluation and decision processes.

The U.S. government has prioritized citizen science across all its federal agencies, as described in the 2013 and 2015 Open Government National Action Plans [3,4]. In response, the U.S. Environmental Protection Agency (EPA) and a number of other agencies and organizations (including SciStarter, https://scistarter.com/) have compiled information about citizen science projects and technologies to create online resources for citizen scientists. Similarly, counterparts in the United Kingdom have published resources for citizen science projects and initiated new projects (including to monitor biodiversity), while the Canadian government has involved citizens in activities such as water quality monitoring through well sampling.

This paper explores some considerations for possibly including citizen science projects as part of early implementation of a siting process, in providing communities the opportunity to learn more about potentially hosting a facility. Characteristics of successful citizen science projects can provide valuable context, including information about engaging volunteers, using sensors and other technologies, establishing baseline conditions, training participants, and assuring data quality. In addition, lessons learned by past and current citizen science projects can serve as examples for early planning of citizen science as a potential part of a siting process framework.

DESCRIPTION OF APPROACH

To frame an approach for involving citizens, through citizen science, in the early stages of a siting process, a literature review was performed to identify information about citizen science project development, focusing on success factors and lessons learned. Argonne National Laboratory library databases were searched using general terms such as *citizen science* and *crowdsourcing* along with refining terms like *project*, *technology*, and *air quality*. More than 400 journal articles, presentations, and conference proceedings relevant to citizen science were downloaded and reviewed. These reviews revealed that many organizations and citizen scientists have shared their experiences about developing projects. Insights into key "success factors" were compiled and additional considerations were described to provide context for the potential inclusion of citizen science within a siting process.

DISCUSSION OF RESULTS

This section highlights the key success factors, lessons learned, and insights drawn from the literature related to citizen science project development. Considerations for potentially developing citizen science projects within a siting process framework are also discussed.

Reasons to Implement Citizen Science

Involving citizens in the scientific process can be a promising opportunity for many projects led by formal science organizations and agencies. Citizen science promotes scientific discovery by meaningfully engaging the public in addressing topics that are important to them. It allows the public to better understand the scope of a larger project, which can increase transparency and ultimately lead to better trust. For such projects, citizen science can increase public understanding of key decisions and actions. One reason this occurs is because citizens who participate in the project begin to prioritize scientific reasoning over their emotions. For example, the House Sparrow Project found that participants who initially favored nonlethal means for controlling the songbird population began to think scientifically about the problem after participating [5]. The public is more likely to listen and understand all aspects of a problem when they are involved in data collection, which is why citizen science can be an effective way to promote cooperation.

Citizen science can also be implemented in a variety of ways, making it very flexible to fit each project. According to Arnstein's ladder of public participation [6], there are eight levels of citizen engagement. The first two levels fall under nonparticipation, which is when professional scientists inform interested parties about the project's topic and possible solutions. The next level seeks feedback from the public through consultations. Citizen science then appears in the next levels, which is when the public is actively involved in data collection and analysis, collaborating to make a decision based on the results, and sometimes independently making a decision [7].

Many citizen science projects are conducted entirely by citizens, meaning they organize the data collection, analyze the data, draw conclusions, and make a decision without being associated with professional scientists. Because of its variability in practice, citizen science can be effectively applied to a wide range of projects in a wide range of communities. Even minimal involvement of the public can promote more effective transparency.

Who to Involve as a Volunteer?

Involving volunteers in the collection and/or analysis of scientific data is the primary reason organizations and practitioners create citizen science projects. Volunteers can provide benefits to the project, and the project can provide benefits to the volunteers. For this reason, it is very important to consider who to involve as volunteers in order to maximize the effectiveness of a citizen science project. Certain demographics of volunteers can actually collect better data in certain projects because they may have historical knowledge about their local environment, they will likely be more invested in the project if it directly affects them, or they may hold necessary skills based on certain experiences that contribute to accurate data collection. People often bring indigenous knowledge when participating in a citizen science project within their own communities, so engaging native volunteers can improve data collection and analysis [8]. This approach is illustrated by citizen science activities in New Zealand, where local communities partner with scientists to solve environmental problems. The local people hold sought-after knowledge about their environments, which helps contribute to the success of their projects [9].

Local volunteers are also more likely to be invested in the citizen science project because the environmental concern they are addressing directly affects them. This is illustrated in south Chicago, where community members who live near large petroleum coke waste piles are partnering with Public Lab and other citizen science organizations to address a problem of fugitive petroleum coke dust. Local community members better understand the scope of the problem and are likely to be very interested in improving their community by participating in the citizen science project. In addition, they can provide professional organizations like Public Lab (see publiclab.org) detailed information about their concerns, steps they have already taken (e.g., in terms of collecting and reporting data), and outcomes or updates as a result of any actions already taken.

Beyond just providing key benefits to citizen science projects, involving local volunteers can make the results of a project even more meaningful. Engaging locals in a citizen science project allows them to take a contributory role rather than passively observing, which can increase the benefits they receive from the results. By involving local volunteers, the public is more likely to understand key decisions because they were directly involved in the steps that lead to them. When citizens are invited to participate, they becomes more socially and ecologically resilient as a result of cooperation between members [10]. These communities will have greater interest and understanding of their environment, and they will be more empowered to act in the future as a result of participating in the project. In a Jamaican project for monitoring coral reefs, plans for monitoring and protecting the reefs include tourism as well as local interests, building on the growing use of ecotourism that links tourism with citizen science [11]. In many cases, citizen science projects involve collecting data to improve a community, and this example illustrates how failing to involve local volunteers can ignore this purpose.

Different Levels of Volunteer Engagement

Volunteer participation in a citizen science project takes on many different forms depending on the type of project. One of the first levels of volunteer engagement is crowdsourcing, which is when scientists collect, record, or analyze data using many volunteers. Crowdsourcing is a very common way for citizens to participate in scientific projects, and there are many ways to crowdsource. At the least-involved level, citizens will contribute to a project by participating online. Zooniverse, for example, is a website where participants identify celestial objects in pictures to help astronomers map the night sky. Eyewire is an online game where players turn two-dimensional pictures of neurons into a three-dimensional model by coloring in cross-sections of the brain. These crowdsourcing projects require small time investments and there is no risk to participate, reasons which increases the number of people willing to volunteer. The internet is a valuable tool for such projects since it allows people to easily contribute without being a major time commitment.

The next level of engagement involves citizen scientists who collect data for the project. This form can be extremely useful to projects, as large amounts of data can be collected over a large geographic area, which is especially useful for ecosystem monitoring. Because most ecosystems exist on large scales, it is difficult to survey all the plants and animals necessary to understand the biological characteristics of a given area. For many projects, it is effective to use a large number of volunteers to collect short-term and long-term biodiversity data. For example, the Coastal Observation and Seabird Survey Team (depts.washington.edu/coast/) trains coastal residents to collect data about seabirds over time in order to establish a baseline for future ecological monitoring. A popular short-term crowdsourcing project is BioBlitz, which is an annual large event where many volunteers gather to characterize the biodiversity of a specific area (www.nationalgeographic.com/ explorers/projects/bioblitz/).

Involving citizen scientists in data collection can save project organizers time and money, and it can also improve the results of the project. A large number of participants can collect high-resolution data that is more useful for analysis and decisions. Also, increasing the number of volunteers can improve accuracy, which can be seen in the results of a deforestation website-based project where increasing from 5 to 15 volunteers improved agreement among participants from 87.5% to 95.83% [12].

Effective Training Methods

In order to assure citizen volunteers collect data correctly, many citizen science projects implement some type of training method for participants. Training can come in a variety of forms and levels of intensity. In many projects, only printed or online instructions are necessary. For example, many biodiversity citizen science projects, such as BioBlitz and iSpot (www.ispotnature.org/communities/global) provide multimedia field guides to aid volunteers in data collection. This approach includes providing participants annotated images with the ability to see microscopic samples and to learn about pollution tolerance values of specific organisms. This dynamic approach for an image-rich resource has proven to offer new benefits for volunteers [13].

Online training resources are effective for reaching many volunteers across a large geographic area, and they are especially useful for small-scale projects. Zooniverse, a website-based crowdsourcing project, provides simple instructions for volunteers to perform a simple task of identifying objects in a picture. Since Zooniverse is a straightforward project that is entirely online, it attracts a large number of participants that contribute towards accurate and useful results. Online training has been shown by many citizen science projects to be quite successful, especially for large numbers of volunteers performing simple tasks.

When tasks increase in difficulty, the number of volunteers will usually be smaller and data collection will be more involved. For these projects, it may not be possible to adequately train and evaluate volunteers on data collection using printed or online methods (e.g., projects using sensor technologies that require calibrations and user controls). In-person training, then, is necessary for these more complex and larger-scale projects that require in-depth field work for data collection.

For example, the citizen science project MPA Watch (www.mpawatch.org) requires two mandatory classroom sessions that provide necessary information about data collection for the project. This in-person format teaches participants to accurately identify activities in a Marine Protected Area. Because the training is much more involved than just online instructions, MPA Watch volunteers provide high-quality data that can be used by the State of California’s environmental protection agencies to create or revise policies as necessary.

Even though in-person training is not as easy as online training, it can drastically increase participant retention even when just supplementing an online approach. A retention rate test on Virginia Master Naturalist members shows that in a hybrid online and in-person approach achieved a 75% retention rate while an online only approach achieved less than 10% [14]. Even minimal in-person training can significantly improve the success of a citizen science project, and it has been shown to be the most effective training format for large-scale projects that require involved tasks.

Assuring Appropriate Data Quality

To use volunteer-collected data for policy decisions and scientific conclusions, it is important for citizen science practitioners to ensure the data quality is appropriate. Project leaders should establish the necessary data quality at the outset of the project and incorporate the necessary elements in the training program to ensure that level is met. They should also determine an appropriate number of volunteers, considering that more volunteers can be more likely to produce data that agree. After data are collected, depending on capabilities, project leaders and/or the volunteers can perform statistical analyses on the data to present the information in a way that is acceptable by other scientists and policy makers.

Using accurate and reliable sensor technology can also contribute to high-quality data. For some measurements, accuracy is determined by widely accepted scientific standards. For example, consider the standard that particulate matter (PM) measurements must be able to achieve to indicate the presence of particles 2.5 micron or smaller if the objective is to inform a regulatory action related to the air quality standard for PM2.5. Citizen scientists, including Public Lab practitioners, commonly use inexpensive optical sensors for air quality monitoring to detect fine particulate matter in the air at a low cost. These measurements, however, are not able to explicitly quantify PM2.5 and cannot be used for regulatory decisions. Citizen scientists who purchase their own sensors are often looking for ones that are inexpensive and easy to use. Because of this, smartphone sensors are becoming increasingly prominent in citizen science projects since they can provide accurate readings and are simple to use; smartphones are also one of the most effective technologies for citizen science because one device contains many integrated sensors (commonly including an accelerometer, global positioning sensor, gyroscope, and more).

When higher data quality is needed, citizen science practitioners will often purchase more expensive sensors. With technology access options for citizen scientists including build, borrow, or buy, government organizations often provide the technology tool to the volunteers, especially when it is relatively expensive and consistent data collection between volunteers is necessary. For example, a Canadian groundwater monitoring project asks volunteers to monitor water levels in their wells to determine the characteristics of the region's aquifers. Project leaders provided volunteers with a water level sounder and sterilization equipment for 700 Canadian dollars, which is much higher than the average maximum cost of 50 USD for citizen science sensors [15]. The groundwater monitoring project is run by a government environmental monitoring organization, and providing a high-quality water level sounder was important to help ensure volunteers collected high-quality and consistent data. Higher cost does not always indicate a more suitable technology, so sensor specifications are an important consideration when choosing one for a citizen science project.

CONCLUSIONS

Citizen science is being increasingly implemented throughout the world as a means to engage stakeholders in important projects as volunteers. Citizen science is a promising opportunity for future actions by government agencies and other organizations to expand joint engagement and transparency. It often fosters a strong relationship between professionals and the public, allowing for open dialogue and participation that will ultimately lead to more effective and supported decision-making.

Many citizen science practitioners have shared their insights about developing a successful project. These insights provide useful framing context for possibly including citizen science projects as part of a process for siting facilities including those for managing SNF and HLW. Citizen science may also be useful for early environmental planning and stakeholder engagement in other future actions for an integrated waste management system.

Successful citizen science projects often involve a large number of local volunteers, who benefit the project with their indigenous knowledge and by helping make the results of the project as influential as possible to the decision to be made. The level of engagement volunteers will have in the project, whether it is simple data analysis or it involves data collection, and the associated data quality requirements should be determined at the outset. From that determination, effective training methods can be developed and implemented that are best suited to the level of skill required for the data collection (with in-person training being the most effective approach) and the necessary equipment (such as sensors) is identified and acquired.

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