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Citizen Science and Radioactivity

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Citizen Science and Radioactivity

Introduction

Citizen science is a term used to describe science where the general public is involved in scientific research. This article reports on a citizen science project carried out in Sweden during the autumn of 2018, where 135 secondary school classes (pupils of age 13–16) participated by collecting mushrooms, soil samples, and animal droppings. In addition, they prepared samples and performed preliminary analyses before submitting their samples and results to Uppsala University (UU) and the Swedish University of Agricultural Sciences (SLU) for further compilation and analysis. This was an interdisciplinary project where the involved departments from UU were Physics and Astronomy together with Earth Sciences. The collaboration was further strengthened with the inclusion of the Department of Forest Mycology and Plant Pathology at SLU.

Background

The aim of the school project was to determine radioactivity in sporocaps of edible fungi (commonly referred to as mushrooms) but also the link between fungi, soil, and competing species will be investigated. In Sweden, the Chernobyl accident in 1986, together with fallout from nuclear tests in the 1950s and 1960s, have distributed radionuclides in the environment and some of them can still be found in food such as mushrooms and game consumed by humans. Airborne measurements of ground deposition of the most significant radionuclides, ^{137}Cs and ^{134}Cs, were undertaken by the Geological Survey of Sweden after the Chernobyl accident [1], and since then measurements have been performed at irregular intervals on flora, fauna, fungi, soil, and water at national [2] and municipal level in the affected areas [3]. The two-year half life of ^{134}Cs means that it has decayed to negligible levels. ^{137}Cs has a half-life of 30.2 years, so today roughly halved concentrations would be expected compared to 1986. Aviation measurements today confirm that expectation, but on a local level different factors complicate the picture.

Recently, the topic of measuring more frequently and systematically has gained new attention, as meat from some wild boar has been found to have very high levels of ^{137}Cs. Wild boars were rare in the Swedish fauna in the 1980s, but have since then established a solid population. The relationship between the concentration of ^{137}Cs in 1986 and today is not elementary. Biological systems interact with and redistribute materials in an efficient manner, and consequently the ^{137}Cs concentrations will be affected. Also, the forest type, soil type, land use, precipitation, hydrology, and other environmental factors play significant roles. We therefore conclude that more measurements of ^{137}Cs in the Swedish environment would be of interest both for several scientific disciplines and for the general public.

Method

School classes all over Sweden were invited to participate in the data collection and analysis. The invitation and communication home page included an animated video that was distributed through YouTube [4]. Over 200 school classes responded to the invitation and were equipped with a "research box" containing tools, containers, data-taking protocols, and instructions. Their primary task was to forage for mushrooms and collect associated soil samples and search for animal droppings. An extensive teacher´s manual including detailed protocols for sample documentation was also prepared and made available together with information on how to get support. Earlier citizen science research has shown that good and adequate teacher's material is a crucial success factor for curriculum-based citizen science [5].

In order to raise the pupils' awareness of how radioactivity is actually measured, we also provided a simple detector in the research box (see Figure 1). The detector design was slightly adapted from similar projects [6] and consists of a circuit board with two pin-diodes and a two-stage operational amplifier. It is powered by a battery and mounted inside the lid of a tin can in order to avoid light interacting with the diodes. The amplified signal is connected to a second circuit board on the outside of the can (for noise reduction) where a micro-controller records the pulses and produces a beep.

The detector is assembled by attaching the circuit boards onto the lid and connecting cables and batteries.

Figure 1. *The radiation detector that the pupils assembled and used in their measurements. Photo courtesy of Mats Kamsten at Uppsala University.*

Thereafter the setup is tested and "calibrated" by placing readily available potassium salt in the can, which produces a few beeps per minute. The resulting beta and gamma radiation from the decays of ^{40}K in the potassium salt and ^{137}Cs in the mushroom differ in energy and intensity, and the response function of the diodes has not been determined. Therefore the calibration is limited to comparing how many beeps come from the mushroom samples with the potassium salt. Measurements are performed by counting the number of beeps during a set time. Background measurements can also be performed by counting beeps without having any sample in the can.

Results and Outcomes

The first part of the project finished during early spring 2019. In the end, 135 school classes completed the tasks, and together they contributed 248 samples of dried mushrooms, the same number of soil samples, and about 50 samples of animal droppings (mainly from deer and wild boar). The instructions had been to collect 10 species of mushroom, with priority to the top three in the list below. They were chosen because they are edible, common in all parts of Sweden, feasible to identify by morphology, and have featured in earlier research regarding uptake and retention of radiocaesium in mushrooms (see, e.g., Ref. [7]). The 10 suggested species of mushroom were:

- *Cortinarius caperatus*
- *Suillus variegatus*
- *Agaricaceae*
- *Cantharellus cibarius*
- *Boletus edulis*
- *Craterellus tubaeformis*
- *Cantharellus lutescens*
- *Hydnum repandum*
- *Albatrellus ovinus*
- *Gomphidius glutinosus*

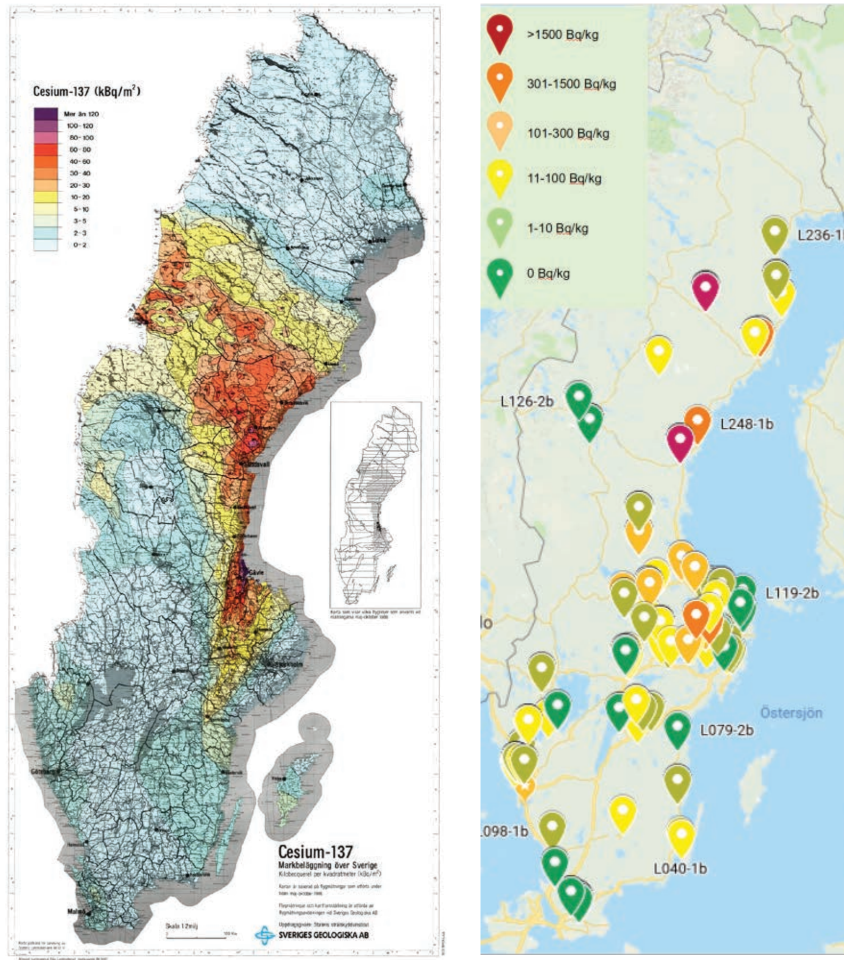


Figure 2. *The results of the airborne measurements of ^{137}Cs in kBq/m^2, performed by the Geological Survey in Sweden in 1986 (left) [1], and a Google Maps visualization of the distribution of collected mushroom samples in the citizen science project, color-coded for activity in Bq/kg (right).*

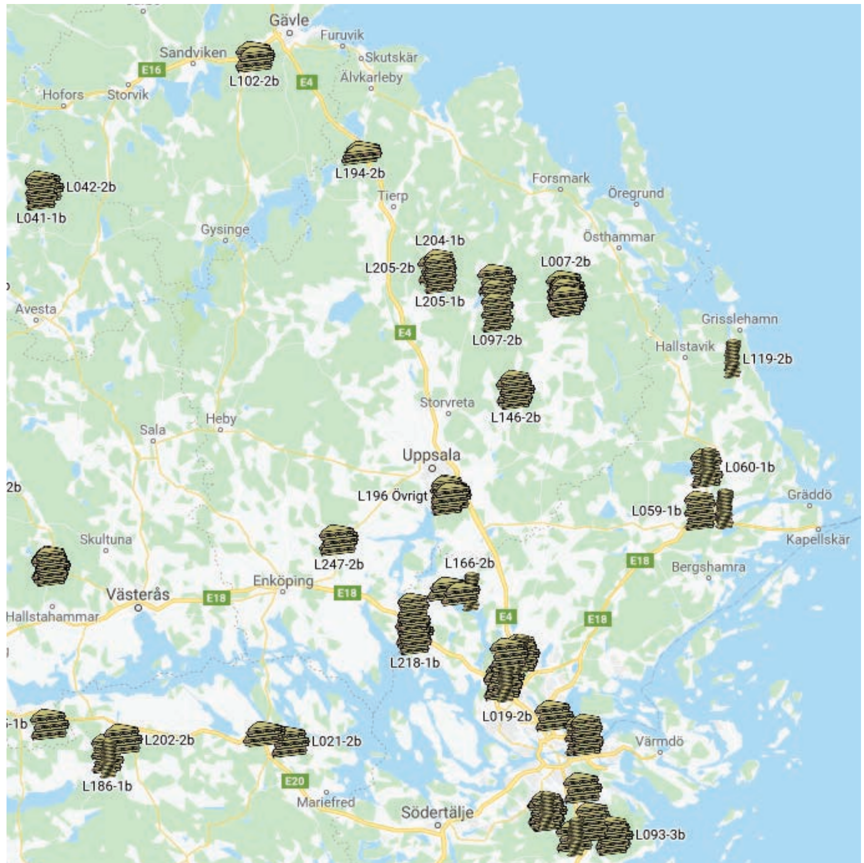
Photos of the submitted mushroom samples, taken by the pupils, were compared with the species reported by the pupils. It was concluded that out of 248 samples, 155 samples belonged to one of the preferred species in the list, and 59 were of other identified species. In total, the identification of 34 samples could not be confirmed by visual inspection of the photos.

The most abundant species collected were *Craterellus tubaeformis* (29 samples), *Suillus variegatus* (24 samples), and *Cantharellus cibarius* (23 samples). The samples were collected all over Sweden (see Figure 2), both in areas where most of the caesium from Chernobyl was deposited and in areas without deposition.

All mushroom samples have been measured with a HPGe detector, resulting in gamma spectra from which we have determined the activity of ^{137}Cs. Simulations have been performed with the Monte Carlo code Geant4 [8] in order to correct for geometrical effects in samples of different mass and volume.

The preliminary results on ^{137}Cs in mushrooms have been reported to the

Figure 3. *One of the symbols used for the mushroom sandwich index (above) and how they are displayed on the Google database (right) [10]. (Originally from The Nounproject and has been adapted, with permission from The Nounproject, by Abigail Barker.)*



participating schools and can be found in a Google database [9].

In summary, only two samples had activities above 1,500 Bq/kg, which is the threshold value for selling mushrooms in Sweden. Both were collected in northern Sweden in areas that received fallout from the Chernobyl accident. The overall distribution was largely as expected from the fallout maps. Preliminary results have been reported to the Swedish Radiation Safety Authority and the National Food Agency.

Radioactivity levels may be difficult to relate to for the general public, therefore we also decided to report the results back to the schools in the form of a "mushroom sandwich index" [10]. In brief the index shows how many mushroom sandwiches per day a person can eat during a year in order to get an extra dose equivalent to 1 mSv, with the assumption that a mushroom sandwich contains 200 g of mushroom (see Figure 3).

One important aspect is the impact a citizen science project has on the participants and their views and ideas about science. Therefore, we also sent out questionnaires to both teachers and pupils. They were answered by 600 school pupils and 42 teachers and we are presently analyzing and compiling the replies. The pupil questionnaire contains questions about knowledge and interest in science but also tries to capture impacts regarding the views about science and participating in scientific research. Figure 4 shows the response from the pupils to the questions "Did you before the project know how radioactivity is measured?" and "Do you after the project know how radioactivity is measured?" There is a significant difference in the number of pupils answering "Yes" to these two questions, indicating that the project did have an impact on their knowledge about radioactivity and measurement techniques. We believe that a major part in this result was the detector that the pupils assembled and used.

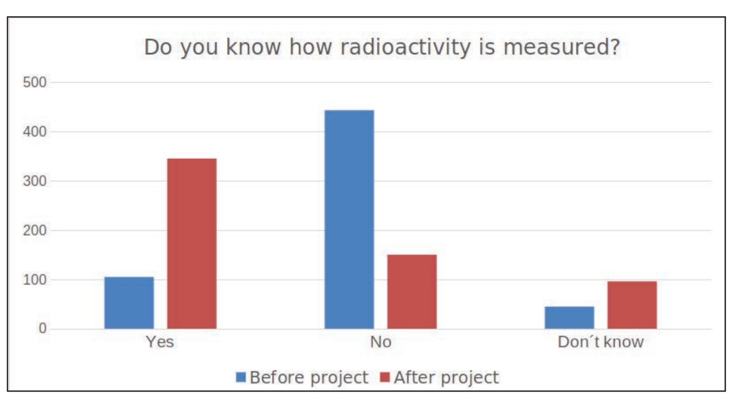


Figure 4. *One result from the pupils' questionnaire showing an impact on their knowledge about how to measure radioactivity.*

Outlook

Following delivery of the preliminary results, there is a lot of interesting research to pursue. Presently we are working on DNA sequencing of soil samples to establish which competing species exist in the same environment as the individual mushroom samples. Together with the sampling of mushroom species themselves, this can give important information about how different fungi species in different surroundings take up radiocaesium. At the same time, a master diploma student is developing methods for radioactivity measurements of the soil samples, which are much denser and gamma-absorbing than mushroom tissue. Following these activities there will be DNA sequencing and activity measurements of animal droppings to map the transfer of caesium in food chains. We will also look closer into the uptake of naturally occurring radionuclides, such as ^{40}K, in different mushroom species.

We believe that the citizen science part of this project has been an important effort to bring interest and knowledge about science to a young audience. The project has been interdisciplinary, involving radiation physics, biology, and ecology, and has also introduced scientific methodology to the pupils. Furthermore, we have tried to bring perspective to a topic that is perceived as dangerous; after all, the main danger with mushrooms may be the consumption of poisonous species.

Acknowledgments

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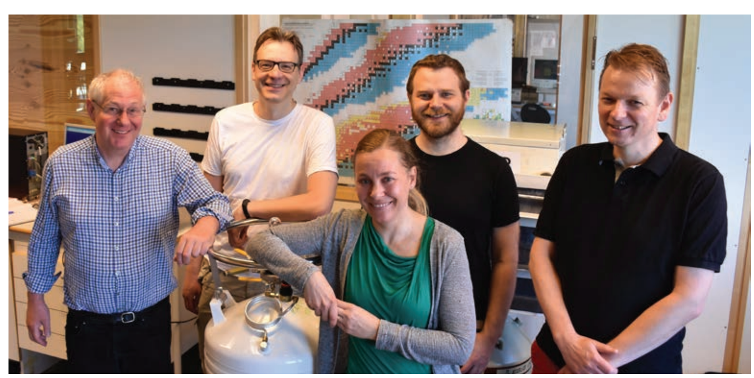

From left to right: Voker Ziemann, Marek Jacewics, Cecilia Gustavsson, Erik Andersson-Sundén and Mattias Lantz. (Photo by Camilly Thulin, Uppsala University.)