



# A proposal for monitoring environmental radiation via the mobile phone network

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## ABSTRACT

Currently, environmental radiation monitoring is increasingly necessary to ensure the population's protection against nuclear or radiological accidents. To this end, some countries have already implemented environmental monitoring networks. Despite this, Brazil not only lacks a radiological survey of its subsurface, but only a small fraction of its urban environment has been monitored so far, and it does not yet have a network of monitoring stations. Therefore, the objective of this paper is to present a system already under development that consists of an alternative way to permanently monitor environmental radiation. The proposed system is based on a device developed for this type of monitoring, as well as on work related to low-cost "citizen science" initiatives. In this case, the device is self-sufficient that can take all readings and send them over the mobile phone network, and it relies solely on battery power. Each device is a mobile station composed of a Geiger counter, a sensor for temperature, humidity, and atmospheric pressure, as well as a microcontroller associated with a phone chip and a Global Positioning System (GPS). The system is currently undergoing calibration and adjustments, with results from a preliminary study that collected more than 25,000 readings over a period of approximately 15 days. Since the system is already operational, even if not yet fully, a total of 180,000 readings has already been collected so far. The results, although preliminary and requiring adjustments to the filters and map visualisation, demonstrate the applicability and full potential of the proposed system.

**Section:** RESEARCH PAPER

**Keywords:** Environmental radiation monitoring; citizen science; Brazil; mobile phone network

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## 1. INTRODUCTION

Despite advances in radiological protection, the need to monitor environmental radiation to ensure public protection is increasingly evident today, whether due to nuclear accidents (such as Chernobyl and Fukushima), radiological accidents (such as those in Goiânia, Brazil, and Ciudad Juárez, Mexico), mining effluents, or to prevent acts of terrorism [1].

In view of this, some countries have already implemented environmental monitoring networks. Germany, for example, has a network of more than 1,800 fixed monitoring stations equipped with Geiger detectors. Europe as a whole has a network of more than 5,000 monitoring stations [2].

Despite this, Brazil not only lacks a radiological survey of the subsurface of its entire territory but also monitors only a small fraction of its urban environment. Moreover, the country lacks a

network of monitoring stations [3]. As a result, our population is exposed to risks such as the delayed identification of accidents, which can lead to the exposure of a large number of people [2], [3].

In recent years, citizen science (CS) projects involving the development of apps and sensors have begun using smartphones to collect data in various fields, including environmental radiation [4]–[14].

Thus, CS for environmental monitoring is a developing area, driven by technologies that enable the mass collection of geolocated data. In this sense, some types of personal dosimeters have been developed not only for personal monitoring but also for environmental radiation monitoring. For example, a thermoluminescence dosimeter (TLD) and passive dosimeters have also been tested for monitoring environmental radiation [4].

Another example is the area of smartphones developed as geolocated multitasking assistants, where a multitude of applications related to health and the environment have emerged. Measuring environmental quality is a major focus of interest, and websites and apps have been developed to make data collected by public agencies available. Some of these devices only indicate the presence of radiation, while others can transmit readings wirelessly to the user's smartphone, which then associates them with georeferenced data and relays them to a central location. The use of free software applied to different projects is also highlighted, contributing to cost reduction [5]–[9].

Furthermore, a mobile air quality monitoring system, using low-cost sensors deployed in fleets of routine vehicles, has already been used for the continuous detection of pollutant variations [10]. Given the growing popularity of this new participatory science, the French Nuclear Safety and Radiation Protection Authority (ASNR), the French Institute of Instructors in Major Risks and Environmental Protection (IFFO-RME), Planète Sciences, and the FabLab of Sorbonne Universities have created a website to collect dose rate measurements taken by citizens in the environment, called the OpenRadiation Project [8]. Another study emerged in post-Fukushima Japan, where citizens generated their own radiation data and measurement devices to provide the public with actionable environmental data. Contributed radiation data from the Safecast project has been shown to provide a reliable estimate of the spatial distribution of high radiation concentrations around Fukushima when compared with government data. The advantage of contributed data over government data is that they are collected over a longer period of time and have greater spatial coverage [9], [10].

Safecast is a freely accessible environmental dose rate (EDR) project focused on measuring environmental dose rates worldwide. Currently, more than 120 million observations have been used to calculate average values of equivalent dose rates in 330 cities around the world [8], [11].

Despite their relevance, some of these devices only indicate the presence of radiation, while others are capable of transmitting readings wirelessly to the user's smartphone, which associates them with geotagged data and relays them to a central location [4]–[14].

Thus, the objective of this article is to present a system already under development, which consists of a proposal not only for a radiological survey but also for an alternative way of carrying out permanent monitoring of environmental radiation.

## 2. MATERIALS AND METHODS

The proposed system is based on a device specially developed for this type of monitoring (Figure 1). This system, like other studies, seeks low-cost alternatives, such as those found in citizen science initiatives [4]–[8].

In this case, the device is self-sufficient that can take all readings and send them over the mobile phone network, and it relies solely on battery power or the vehicle itself, eliminating the need for any user intervention.

Each device is a mobile station consisting of a Geiger counter, a sensor for temperature, humidity, and atmospheric pressure, and a microcontroller associated with a telephone chip and a Global Positioning System (GPS).

A C++ program was developed for this microcontroller to count the Geiger pulses. It also collects temperature, humidity, and atmospheric pressure data from the environment, as well as



Figure 1. Low-cost equipment developed for monitoring. Source: The author.

georeferencing, and transmits them via the telephone network to a virtual computer in the cloud.

This computer is active, with internet access 24 hours a day and 7 days a week and is constantly receiving data. After an initial setting, it makes the data available for georeferenced access, and it is able to issue alerts directly to the mobile phones of the individuals concerned, when necessary.

These stations would not be placed in vehicles for exclusive or specific use, but in vehicles that usually travel long distances, such as buses, trucks, taxis, as well as vehicles linked to public agencies or service providers.

## 3. RESULTS AND DISCUSSION

More than 25,000 readings were collected over a period of about 15 days. Since the system is already operational, even if not yet fully, a total of 180,000 readings has already been collected so far.

The post-processing program groups the various readings from the same location, filtering and calculating the average value, standard deviation, etc. The preliminary results demonstrate the applicability and full potential of the proposed system, as shown in Figure 2. Readings are presented in counts per minute (com).

These results already show the benefits of remote monitoring conducted by devices connected to the internet.

By monitoring locations that are inaccessible to technicians, the system enables offices, for example, to have access to field information in real time, including issuing alerts, which would otherwise be more difficult.

Initially, regular mobile telephony chips from two major nationwide operators were used. However, during the tests, it was observed that as vehicles were moving, there were frequent losses of connection with the mobile network, and reconnecting to the network was often challenging.

To overcome this difficulty, the adopted solution was to use a list of Access Point Names (APNs) composed of APNs from

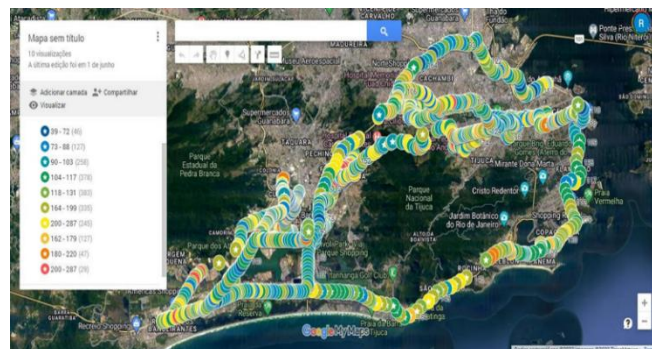


Figure 2. Dataset collected in a 15-day pilot study. Source: The author.

nationwide operators. If the microcontroller fails to establish a connection with one APN, it attempts to connect to the next one on the list, and so on. This solution showed improvement but still presented some problems.

The equipment calibration was performed using the Large Planar Sources of the Institute of Radiation Protection and Dosimetry (IRD), comparing the results with those of the Eberline-600.

The detector calibration unit for in situ gamma spectrometry in Brazil is installed at the IRD and is a FIXED PORTABLE model. The system consists of eight concrete discs measuring 3 metres in diameter and 50 centimetres deep, and a central disc measuring 4 metres in diameter and 70 centimetres deep.

The sources were built of a mixture of materials, with the proportion being one part CP-320 cement, two parts No. 1 gravel, and three parts sand (ratio 1:2:3). The detectors were also calibrated using the IRD planar source system at three heights: in contact with the source or at 0 cm, at 10 cm, and at 1 m. Due to the size of the SPARCS system pod, the geometric centre of the pod was aligned with the centre of the planar source, considering the distance from the surface to the bottom of the pod.

The accuracy of the equipment can be verified according to the results for four prototypes with the U2 source. A total of 20 readings at different heights relative to the ground were averaged and compared with the Ederline-600 readings, and the calibration factor was then calculated.

The adopted control and telecommunications module integrates a SAMD21 microcontroller with an A9G GPRS/GSM/GPS module, operating at frequencies 850MHz, 900MHz, 1.8GHz, and 1.9GHz. The SAMD21 microcontroller performs the counting of the signals/interruptions generated by the Geiger counter and, according to a predetermined time interval (15 seconds), stops the counting. A program was developed in C++ language, so that this microcontroller can perform counting and georeferencing analyses, transmitting the data via the telephone network to a virtual computer in the cloud.

This computer is active, with internet access 24 hours a day and 7 days a week and is constantly receiving data. After an initial setting, it makes the data available for georeferenced access, and it is able to issue alerts directly to the mobile phones of the individuals concerned, when necessary. All communication with the GSM network is carried out using AT commands. AT commands are a set of commands that allow GSM devices/terminals to communicate with the GSM network and follow the GSM 07.07 specification.

#### 4. CONCLUSION

This paper presents the implementation of an interconnected network of gamma radiation sensors for an environmental radiation monitoring system. The devices were in a car during the tests. Results showed that all areas where the devices are placed have a high coverage range with low interference and packet loss.

The use of this device in vehicles would enable it to measure thousands of points per day along a route, as well as to take several readings from the same location over time, as the vehicle repeats the route.

This would be possible because the coverage of the existing mobile telephony network in Brazilian cities and roads encompasses over 2,000 cities, and approximately 50 % of the federal paved road network is covered. Additionally, there are

contracts in place for the installation of coverage in practically the entire remaining federal paved road network.

Considering that mobile network coverage is better in densely populated areas, and the road network is also denser in these regions, monitoring systems of this nature already present significant potential and are likely to become even more efficient. Although there are still many areas without mobile network coverage, the trend is for these areas to decrease rapidly.

As noted above, the system, even in its preliminary form, already shows all its potential. At the moment, details are being developed, regarding data filters to be presented in the visualisation of results, as well as treatments related to measurements of the same location at different times.

While one advantage of the system is the use of third-party fleet vehicles, which are non-dedicated and travel long distances daily, it also leads to a certain diversity of vehicles and variations in coverage quality, including areas with good coverage, poor coverage, or no coverage, as well as switching between different mobile operators during the same trip.

Another aspect yet to be considered is the retransmission of readings that were not sent due to a lack of connection. For example, if the device loses connection on a road due to coverage issues, it will transmit all the data that was not sent in the previous section as soon as it reconnects.

In this case, the device is self-sufficient that can take all the readings and send them via the mobile telephone network, depending only on the energy provided by a battery or the vehicle and eliminating the need for any user intervention.

#### AUTHORS' CONTRIBUTION

Renato P. da Silva – conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, visualization and writing (original draft).

Elder M. de Souza – conceptualization, formal analysis, investigation and methodology.

Fernando B. Razuck – formal analysis, visualization, writing (original draft) and writing (review & editing).

Ana C. de M. Ferreira – conceptualization, data curation, formal analysis, investigation, methodology, project administration, validation, visualization and writing (original draft).

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