Deployment of Rapid Assay Systems for Real-time Sorting of Excavation Spoil on Contaminated Land-19258

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ABSTRACT

To optimise segregation at source, and hence minimise waste production, NUVIA have developed and utilised the Gamma Excavation Monitor (GEM) system. The GEM was designed for land remediation projects, to provide a rapid screening tool for excavator buckets of material.

Following successful deployment in the UK, including the Olympic Park site in London, and two major Magnox land remediation projects, the first GEM unit was deployed to Canadian Nuclear Laboratories' (CNL) Chalk River Laboratory (CRL) in 2016. The GEM unit was fitted with a plastic scintillator detector; recent developments have included the utilisation of a sodium iodide. The system is initiated by the presence of an excavator bucket above the detector which triggers proximity switches that automatically start the counting routine. At the end of a short count time, typically 10 seconds, the materials category is indicated by means of a traffic light system, based on either the gross gamma activity or a photo-peak. Using this instrument, material determined not to be radioactive can be re-used on-site. In addition to the traffic light system, results are also transmitted wirelessly to a tablet device. These combined features allow operation of the system without the need to have operatives near the mechanical excavator bucket; therefore, eliminating a significant industrial hazard.

Deployments of the GEM on the CRL site have included Storm Water Management project, within the CRL controlled area, and the Foundation Road Landfill Project. The use of the GEM in these projects enabled in-situ decisions to be made regarding the segregation and sentencing of soil rather than having to wait for the analysis of samples; saving time and cost to the project. The Building 492 project involved the excavation of soil within a supervised area to prepare for the installation of modular trailer units. For this specific job, the GEM was calibrated to ensure soil met clearance criteria as stipulated in the Nuclear Substances and Radiation Devices Regulations (Canadian Nuclear Safety Commission; SOR/2000-207). A total of 326 loads of soil were monitored during this project and re-assurance sampling conducted by CNL corroborated the results produced by the GEM system.

INTRODUCTION

To optimise segregation at the excavation face, and hence minimise waste production, NUVIA have developed and utilised the Gamma Excavation Monitor (GEM) system. The Gamma Excavation Monitor (GEM) is a gamma measurement instrument designed for the rapid screening and segregation of large volumes of waste (e.g. soil, concrete, brick) in fixed volume containers such as mechanical excavator buckets (Fig. 1). The GEM system is programmed with up to 2 defined limits against which measurements are compared to differentiate up to three different waste categories (e.g. Out-of-Scope (OOS) by the UK Environment Permitting Regulations (EPR), Very Low Level Waste (VLLW) and Low Level Waste (LLW) as defined by UK Legislation). The system segregates waste by relating the gamma measurement to a radionuclide fingerprint to determine specific activity (Bq/g) of the material. The system is also automated to allow operation without the need to have operatives near the mechanical excavator bucket; therefore, eliminating a significant industrial hazard.

THE GEM SYSTEM

Fig. 1: GEM Mark 2 in operation at CNL's Chalk River site, Canada, (left) and the GEM Mark 3 in operation at Magnox's Harwell site, United Kingdom (right).

Three Generations of GEM system have been produced. The latest version of the GEM system is the Mark 3 GEM which has a footprint of 1.52 m x 0.88 m, a height of 0.75 m and a total weight of 580 kg. The detection medium utilised is either a cubic plastic scintillator (200 x 200 x 100 mm), or a cubic sodium iodide (NaI) scintillator (101.6 x 101.6 x 203.2 mm), which is heavily shielded with lead to minimise the 'background' radiation contribution. The detector is connected to a photomultiplier and the high voltage is provided by the multi-channel analyser which is set to operate with 1024 channels.

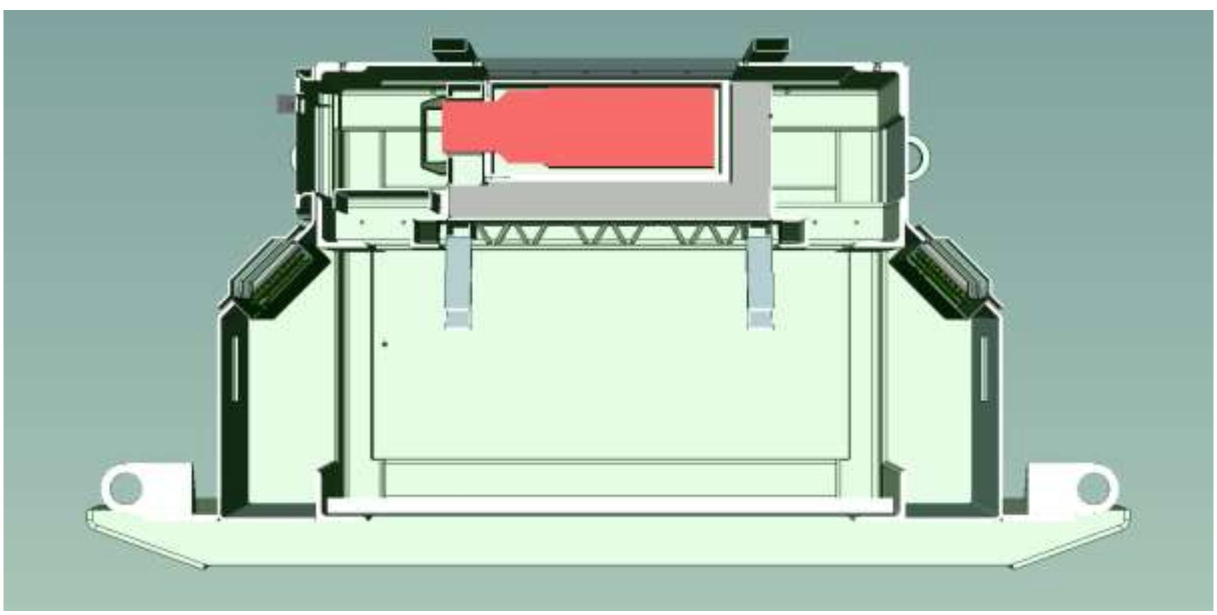

Fig. 2: Side Profile of the GEM Mark 3. The Detector assembly is highlighted in red.

The detector unit is housed within a robust steel frame with integrated suspension of sensitive components (e.g. on-board computer; Fig. 2). In addition, the system is fitted with a low sensitivity Geiger-Muller (GM) tube which acts as a fail-safe in the event of 'saturation' of the scintillation detector.

The device accommodates two proximity switches (optical detectors), which activate the system when an excavator bucket is placed above the upper platform; triggering the measurement module.

The upper platform is fabricated from 5 mm thick steel. A cut-out in the steel exposes the detector and proximity sensors which are covered by a 10 mm polycarbonate sheet (Fig. 3).

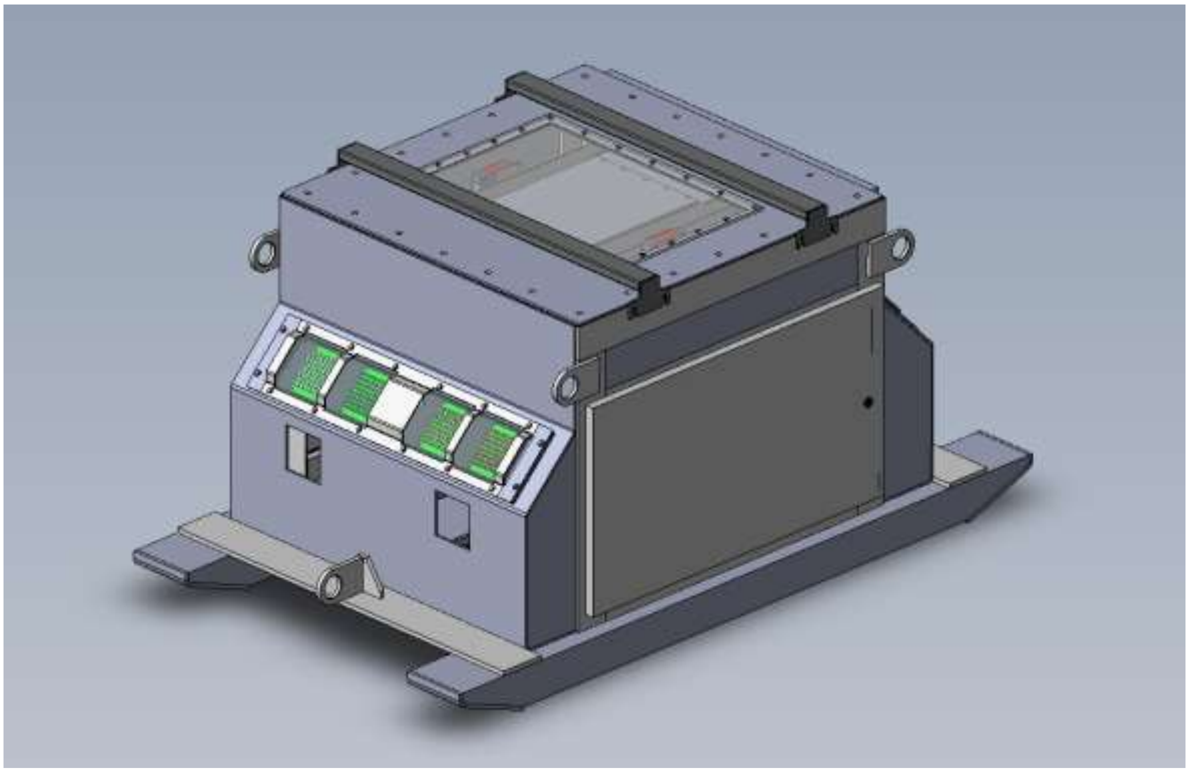

Fig. 3: GEM Mark 3

Two consoles of coloured lights are mounted on opposite sides of the frame. Each contains a white, green, amber and red light; The white light flashes to indicate that a count is in progress and results are indicated by the green, amber and red lights (i.e. three waste categories).

The GEM system software is divided into two parts: the Measurement Module and the Visualisation Application. The Measurement Module is started automatically when the GEM system is turned on and is an on-board computer operating a windows application run in autonomous mode (without user interaction). The Measurement Module processes the measurement results and saves them to a local database file.

The Visualisation Application is an android application, called 'GEM Manager', which controls the GEM system wirelessly and is installed on 7" robust tablet (IP67) operating the Google Android 4.4.2 operating system. GEM Manager shows the current status of the GEM system and is used to switch between measurement modes (e.g. Background, material or function check measurements), set measurement parameters, initiating measurements and display measurement results.

The system is powered by a 24 V rechargeable battery which should be charged following use of the GEM system (i.e. daily) using the charger provided. The battery requires 3.5 – 4 hours to fully charge. The status of the battery can be checked using the GEM Manger application; a warning notice will be displayed and the LED display unit will turn off if the supply voltage drops below 23.7 V.

GEM CALIBRATION AND OPERATION

It would be both difficult and wasteful to calibrate the system using material deliberately contaminated with the relevant radionuclides. Therefore, the calibration is performed using a combination of calculations performed with the radiation transport code Monte Carlo N-Particle (MCNP; Goorley, 2014).

The first step is to check that the performance of the detector, using measurements made with small discrete radiation sources, can be replicated using MCNP; this provides confidence that the MCNP model is correct.

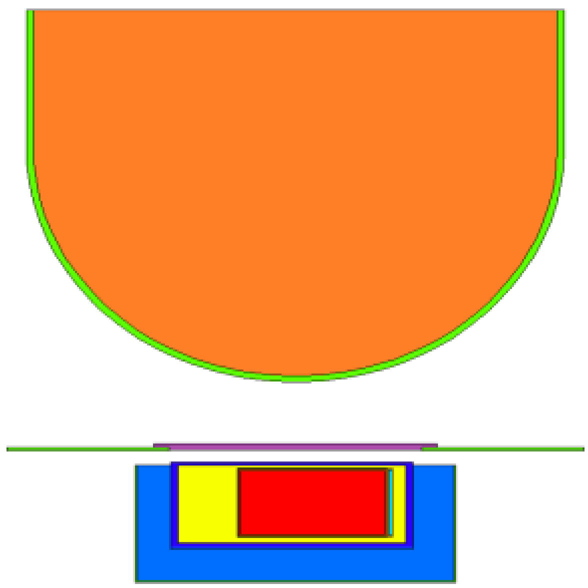

Fig. 4: Illustration of MCNP models showing position of the bucket

Secondly, the calibrations for excavator buckets are created by adapting this MCNP model of the GEM to include a simplified representation of the material contained within a mechanical excavator bucket (Fig. 4).

To undertake the excavator bucket calibrations, dimensions for the buckets that are to be used is required, in addition to the material that is to be put in the bucket and the radionuclides of interest. Activity is assumed to be homogeneously distributed in each bucket. Using this information, the limits (thresholds) between each waste category are calculated, in count per second, to produce a ‘calibration profile’.

Prior to using the GEM, the calibration profile is selected and loaded from the Android tablet; this is accompanied by a test of the lights. The operator initiates a background measurement using either an empty bucket or clean material (e.g. sand). When the empty bucket is placed in the correct position, *i.e.* centrally at approx. 15 cm from the surface of the GEM platform, the count is triggered; a white LED flashes during the count. On completion the counts are displayed on the tablet, and raw counts are subtracted from subsequent measurements. The final set-up measurement is the function check, using a pre-defined radioactive source. At the end of the count the counts need to be within the range programmed into the calibration profile, to demonstrate that the system is operating correctly; a red light will turn on and the tablet will alarm if the check fails.

The system is then ready to receive excavated buckets of material; note that the system prevents the operator from measuring materials, until the background and function checks are completed. Data can be downloaded from the GEM, onto the tablet, and then onto a PC, in Excel format, via a USB cable. The data shows the bucket ID, date and time of measurement, counts, type of measurement (e.g. background, calibration), result and calibration profile ID.

OPERATIONAL EXPERIENCE - USE ON THE CANADIAN NUCLEAR LABARATORIES CHALK RIVER SITE

Following successful deployment in the UK, including on the Olympic Park site in London, and two major Magnox land remediation projects, the first GEM unit was deployed at the Canadian Nuclear Laboratories' (CNL) Chalk River Laboratory (CRL) in 2016. The GEM unit deployed was fitted with a 200 x 200 x 100 mm plastic scintillator detector. Since this time the GEM has been involved in a number of projects across the site and a brief summary of these projects follows.

Storm Water Management Project

The Storm Water Management project was initiated by CRL to deliver improvements to the site's major storm water management process system; including the construction of a new storm sewer trunk line and a dry pond. The majority of this construction was within the Controlled Area of the CRL site, and at times, in the vicinity of known contamination and/or groundwater plumes. The project began April 2017 and ended September 2018 which included the excavation of approximately 5641 m^3 of soil, approximately 675m^3 of asphalt and approximately 85 m^3 of concrete to install new storm water drainage piping. Although the soil within the excavated areas was designated as likely clean, the GEM was used to provide real-time gamma assay of the soil, to ensure proper contamination controls were in place to effectively segregate potentially contaminated soil, as well as, to verify the soil can be replaced and re-used at the job site. Any extra soil was sent to CNL's soil re-use laydown and storage area (outside the Controlled Area). During the project, a total of 2,597 measurements of soil, were assayed. In addition, the GEM system was utilised to screen sample pails of material taken during the project. Thirteen different calibration profiles were used to support this project.

Nuvia worked closely with CNL throughout the project to ensure screening levels and counting times worked cohesively with fluctuating backgrounds within different locations of the Controlled Area. The project saved time by replacing the use of the GEM with traditional RP monitoring techniques typically used for screening buckets of soil. The GEM also ensured any soil leaving the Controlled Area met the unconditional release levels required for waste management's acceptance criteria into the soil re-use and laydown area. Otherwise, the project would have been required to stop work and send representative drums of soils to the Waste Characterization Facility. The project was successful in ensuring Controlled Area soil re-use and waste management area limits were not exceeded.

Foundation Road Landfill Pilot Remediation Pilot Project

CNL's Landfill 3, also known as Foundation Road Landfill, has not been operational since 1960 but was once a disposal area for construction debris. The area of land is approximately 9 acres, therefore, Chalk River Laboratories (CRL) Site Planning has identified Foundation Road Landfill as an ideal land area for redevelopment and reuse due to its proximity to the main built-up portion of the CRL site. However, intrusive site investigations completed to date have identified localized areas of radiological contamination, as well as, a large metal knoll containing a significant amount of buried metal debris. The extent of contamination and the identity of buried objects remains unknown. Therefore, the first phase of an intrusive characterization campaign was initiated fall of 2018 to determine associated risks before recommendation for re-use at the area landfill can be provided. The GEM was utilized during excavation for every bucket of soil in order to segregate clean soil from active soil. A total of 177 measurements were taken during this first phase, pilot project with the GEM. The GEM identified 19 failures due to the presence of anthropogenic radioactive material hidden within the buckets of soil. The GEM deployment was successful in soil segregation, narrowing down sampling locations, and finding rogue radiologically material hidden within the excavator buckets.

Fig. 5: GEM Mark 2 deployed on the Foundation Road Landfill Project, Chalk River

COMPLIMENTARY TECHNIQUES

The GEM system is one of a 'toolbox' of technologies that NUVIA have developed, to aid delineation, segregation and assay of materials to support land remediation projects, where real time data is required to enable in-field decision making. The technologies are all gamma based, which is the simplest to use, because they enable a significant volume of material to be interrogated. In addition, they all have spectral capability, hence providing data for various radionuclides; the latest version of the GEM system can be interchanged with a sodium iodide detector. The 'toolbox' of technologies essentially optimises the remediation process in terms of time and cost. These technologies and their purpose summarised are as follows:

1. Groundhog™ [a] Fusion, is a sodium iodide (NaI) detector coupled to a radiation spectrometer and mapping grade GPS receiver. Used to rapidly delineate surface contaminated areas and post processing provides surface radiation contour maps and the ability to use processing tools to assess the data.
2. High Resolution Gamma Spectrometry (HRGS) system, utilised to quantify gamma emitting radionuclides, to facilitate onward disposal. To provide a mobile and easily deployable system,

[a] Groundhog is a registered trademark of Nuvia Limited in the UK and/or other countries

NUVIA developed the High Resolution Assay Monitor (HIRAM), which comprises a trailer fitted with a cabin and turntable.

The Groundhog™ Fusion system is configured with a 76 x 76 mm sodium iodide detector coupled to an advanced gamma radiation spectrometer. The system is also configured with a high-accuracy Global Navigation Satellite System (GNSS aka GPS), which is used to record the position of radiation measurements to sub-metre accuracy. Measurements are taken once per second as the operator walks over the survey area, so that on average there is one full spectral measurement in every square metre of the survey area, *i.e.* a high density of survey measurements. Nuvia uses the ESRI ArcGIS software and has extended it to improve the analysis of radiation survey data. These features include the ability to select, group and analyse the gamma radiation spectra that can be collected during Groundhog™ surveys (Fig. 6), *i.e.* sum spectra over arbitrary domains, in time and space; as individual spectra are rarely of use, typically with only 200-300 counts.

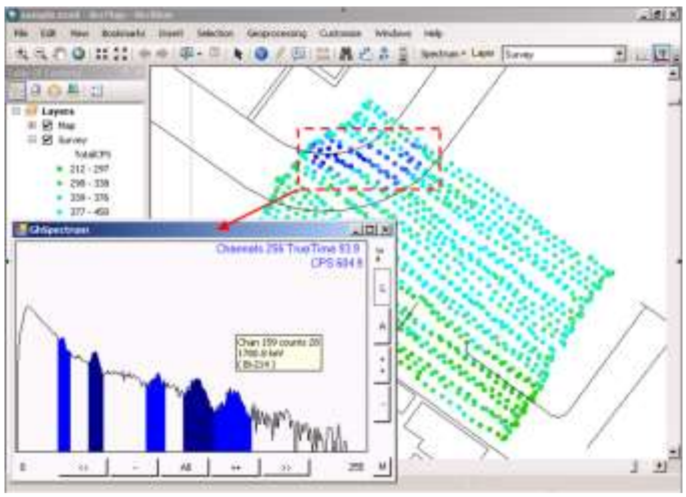

Fig. 6 Spectral summing achieved by dragging the mouse over an area of interest; spectra are automatically summed and displayed.

The HRGS system comprises a detector, multi-channel analyser (MCA), collimators, laptop, and scissor-lift table. The basic arrangement for the system is that the detector sits on the scissor lift table, which is usually positioned to view the mid-point of the waste package that is located on the turntable.
The equipment is installed on a purpose built trailer, known as the High Resolution Assay Monitor (HIRAM; Fig. 7).

The turntable is operated from inside the cabin and the rotation allows the detector to view all around the waste package, hence the process 'samples' a significate amount of the waste package contents (Bull et al. 1996). Note that the segregation process provided by the GEM essentially provide a homogeneous activity distribution within the waste package, hence providing reassurance that no radiologically 'hot' material is shielded in the centre of the package.

To provide real time data, the HRGS systems are automated, so that following input of a few simple parameters into the laptop software, a unique efficiency calibration is generated for each waste package and a spreadsheet of results is produced at the end of the count time.

The HRGS system can also be set-up in other configurations, as required. An example of this is the UK Harwell

Fig. 7 Photograph of the High Resolution Assay Monitor (HIRAM)

Fig. 8 Photograph of concrete shielding units housing high resolution gamma spectrometry systems for assay of bulk bags

Liquid Effluent Treatment Plant land remediation project, where a throughput of 555 bags of waste was required to be assayed and consigned off-site on a weekly basis. Fig. 8 shows the configuration of four HRGS systems in concrete shielded units. To provide a complete waste management solution and aid the consignment process, Nuvia developed a database and associated software (known as the Information Management System), which captures gamma spectrometry results with scaling factors, waste category, nuclear material and transport calculations, and waste acceptance criteria calculations from the automated HRGS systems result spreadsheets. This means that the information can be used to automatically generate consignment and Duty of Care documentation, hence mitigating the introduction of transcription errors. Waste packages are tracked, and their status queried, by making use of barcoding for each package.

The complimentary techniques discussed can be used in conjunction to efficiently segregate and characterise waste for onward disposal and/or reuse.

CONCLUSION

The Gamma excavation monitor has proven to operationally meet the needs for both investigative and verification work for areas where relatively little was known with respect to extent of contamination. The deployment of the GEM has helped offset sampling costs and increase efficiency in finding localized areas of contamination when compared to traditional monitoring techniques. In areas where gamma emitting radionuclides are predominant, the GEM can meet the most restrictive action limits for unconditional clearance. The success of the GEM for these initial pilot projects has led to the purchase of further GEM units to support CNL site characterization needs and remediation efforts.

REFERENCES

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