DeGeN – Measurement Vehicle for Radioactive and Nuclear Material

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Introduction

A conventional station wagon was equipped with a measurement system for searching and detecting covert nuclear and radioactive material. The system comprises highly sensitive neutron and gamma scintillation detectors. The car‘s position is recorded, tagged with GPS signals, and synchronized with the measured data. All measurement results are shown on a display located at the car‘s front. The measurement system was designed to fit in any station wagon of considerable size.

Detectors

Neutron Detection

Neutron detection is achieved by two rows of large-area Slab counters with ^{3}He tubes on both sides.

Detection reaction:

n + ^{3}He -> p + ^{3}H + 765 keV

Signals on both sides are computed separately, enabling a left-right discrimination. A typical measurement interval for neutron measurements would be 2 seconds.

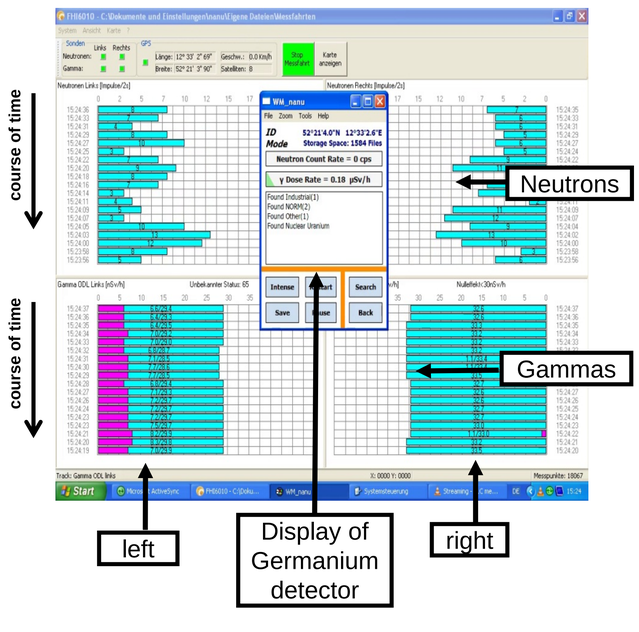
Type	JCC 71SS (Canberra)
Gas Filling	^{3}He (4.2 · 10^5 Pa, 5 · 10^4 g/cm^3)
Diameter	2.54 cm (per tube)
Length	33 cm (per tube)
Number of Tubes	6 per counter 6 counters per car side => 36 tubes / side altogether
Moderator	Polyethylene (at least 1.7 cm)
Efficiency	0.12 % (for a single Slab Counter with respect to a Californium source at a distance of 1 m to the detector‘s surface)

Gamma Detection

Two NBR (Natural Background Rejection) probes are used for gamma measurements. A discrimination between natural, artificial, and abnormal radiation is displayed. An abnormality is signaled when an oversized fraction of high energy gamma radiation, an unusually large portion of ^{40}K or ^{228}Th in the background radiation, or neutron radiation is present.

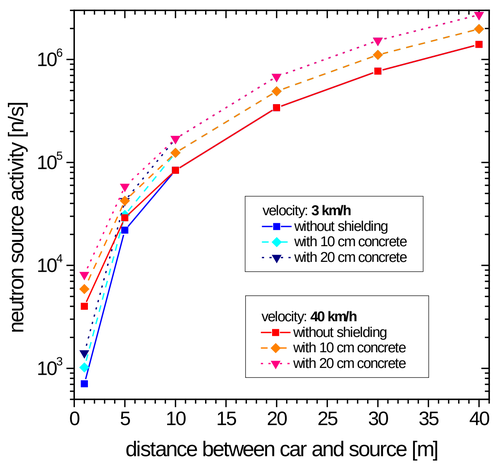
Display of Measurement Results

The measurement values are displayed separately for both sides and detector types by means of bar diagrams. The surpassing of selectable thresholds is signaled both visually and acoustically. Alternatively, a measurement value can be displayed on a map during a drive. The depiction of the map may also be used for navigating. The use of pre-scanned maps which can be geo-referenced during the operation is also an option. An electrically cooled Germanium detector can be remotely controlled from the main display and serves as an isotope identifier.



Detection Limits

Neutrons



Calculated example: 10 m distance

10 m distance	Neutron source activity [n/s]	RgPu	WgPu
without shielding	8.40 · 10^4	260 g	1.6 kg
with 10 cm concrete	1.25 · 10^5	390 g	2.4 kg
with 20 cm concrete	1.70 · 10^5	540 g	3.3 kg

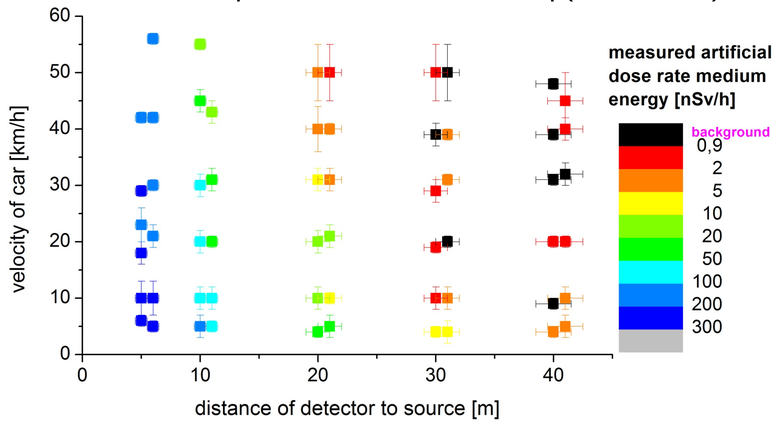
Relative neutron rates:
RgPu (Reactor Grade Plutonium): 324 n/(s·g);
WgPu (Weapon‘s Grade Plutonium): 53 n/(s·g)

Distance source to vehicle > 5 m:
Neutron detection limit independent of velocity (3 – 40 km/h)

Distance source to vehicle < 5 m: Neutron detection limit decreases at falling velocities

Gammas

Measured example: ^{60}Co source, 50 MBq (unshielded)



Natural Background Variation

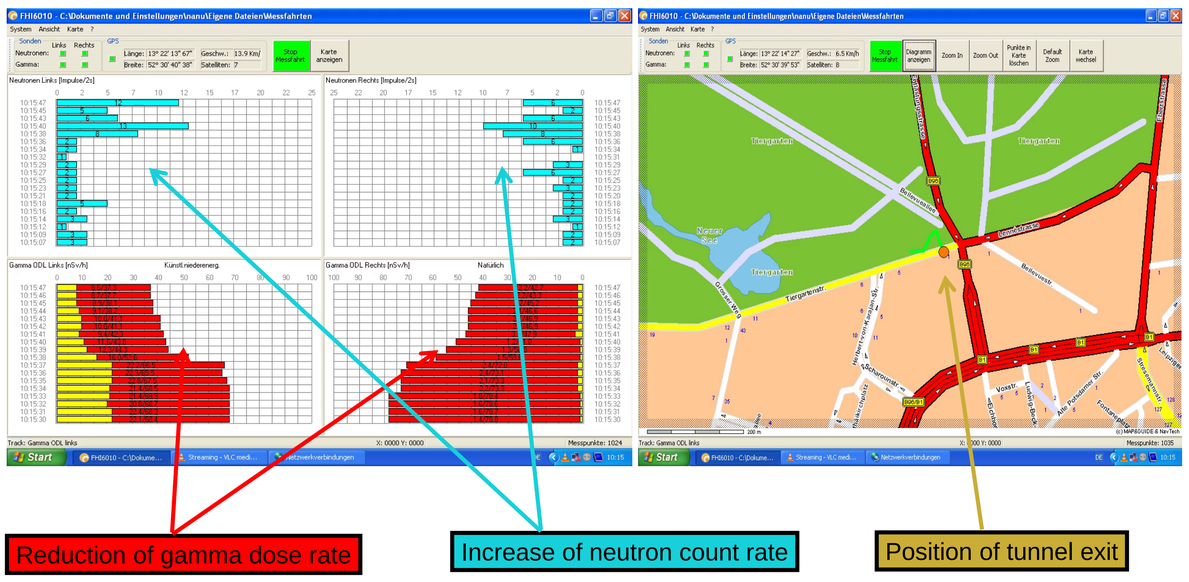
The natural background radiation is caused by two components: terrestrial and cosmic radiation. Terrestrial radiation is generated by naturally occurring nuclides (Uranium, Thorium, and Potassium nuclides) which are present within the Earth’s crust and upper mantle with a higher density close to the Earth’s surface. Different materials such as concrete, asphalt, soil, and gravel contain different concentrations of these nuclides and therefore emit different levels of background radiation. Moreover, Radon nuclides created in the Uranium decay chain tend to fumigate from the solid materials, adding to the natural background especially in basement rooms and tunnels which the Radon gas cannot leak from. In contrast, neutron background radiation is caused by cosmic radiation predominantly and is therefore usually lower in basement rooms and tunnels because of their shielding effect.

Measurements

Measurements of the variations of environmental radioactivity were performed with the measurement car DeGeN. We examined the effects of different materials implemented in buildings or road surfacing as well as the effect inside an underground passage-way.

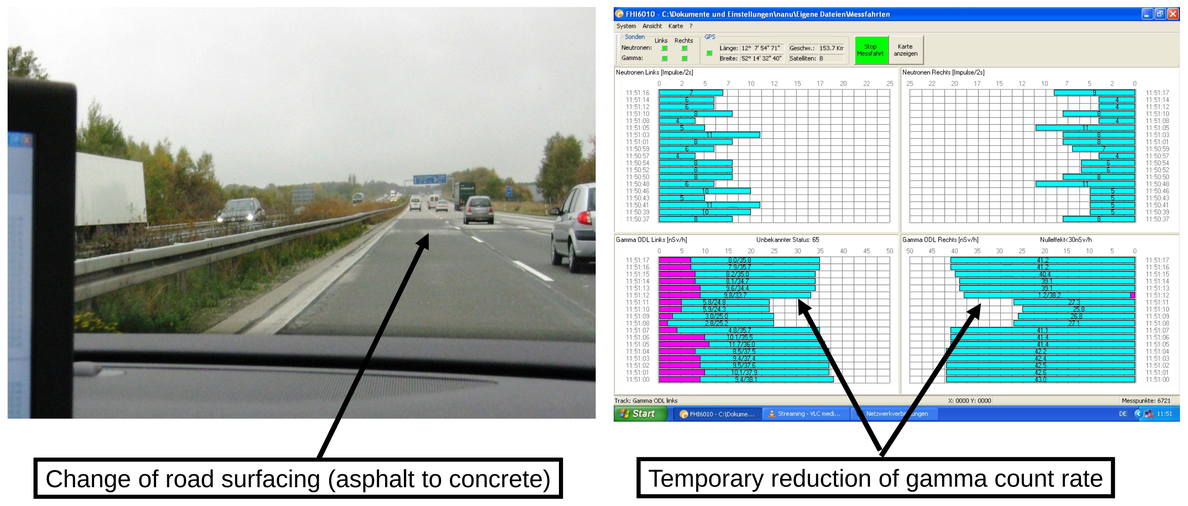
Underground Tunnel

The effects of an increased concentration of Radon nuclides could be verified with the measurement vehicle when passing an underground tunnel. Such a measurement is illustrated below. The figure on the left shows the measured data at the exit of the city tunnel in Berlin with a considerable decrease of the gamma dose rate (the bars move downward, so the most recently measured value is shown on top) because of the reduction of the Radon concentration outside the tunnel. A slight increase of the neutron count rate can also be seen. The figure on the right shows the corresponding position of the vehicle at the tunnel exit in a chart where this position is marked with a red dot.



Road Surfacing

The effect of different road surfacing could also be verified as shown in the figures below. The figure on the left visualizes a change of the track surface on a German motorway, namely a transition from asphalt to concrete. The corresponding variation in the measured gamma dose rate is shown in the figure on the right. The measurement refers to a transition from concrete to asphalt and back which is only partly visualized in the left figure. The change of the gamma dose rate during this transition is obvious whereas the neutron background did not change with respect to the typical deviations of the neutron count rate.



Summary

The measurement system DeGeN comprises gamma and neutron detectors with high sensitivity suitable for detecting radioactive and nuclear (RN) material. Because of the high sensitivity, even minor changes of the natural background radiation can be registered which is tremendously important for the discrimination between the presence of actual RN material and mere modifications of the natural background. Knowledge about such a discrimination is absolutely necessary in order to be able to evaluate the measurement results correctly. Questionable results which could lead to wrong response measures are more likely to be prevented then.