Seismic waves in the urban environment triggering radon release from the soil (*)(**)

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Summary. — The influence of anthropogenic induced seismic waves on the radon potential is analysed in this study. The influence is determined near railway tracks, heavy traffic roads and on project sites. Generally, the radon concentration in soil gas increases due to vibrations, but the type of vibrations has a pronounced influence on the amount of increase. The spatial radius of radon increase is highest on project sites (>60 m). Along railway tracks the radius is wider (>30 m) than along heavy traffic roads (<25 m). The increase can be explained by a "pump effect". That means that mechanical vibrations of mineral particles lead to an upward movement of the entire volume of soil gas. In the course of continuing vibrations the topmost layers lose radon to the atmosphere and as a result the upward transport of radon is increased. By this process radon can be pumped into houses, where it can accumulate.

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1. – Introduction

Several years ago it was found out at project sites that the efficiency of soil venting systems is higher when the ground is stimulated (not published). Wiegand and Büchel [1] are among the first who studied the influence of vibrations on the radon potential. In the study presented here, the influence of seismic waves is analysed. Therefore, this investigation can give hints on earthquake prediction [2]. The influence was determined near to railway tracks, heavy traffic roads and on project sites within the densely populated area of the Ruhr district in the Western part of Germany. The

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measurements were carried out in natural or slightly disturbed soils and backfills above solid or unconsolidated rocks.

2. – Methods

Soil gas samples are taken by using a syringe from the depths of 0.5 and 0.8 m, in order to measure the ^{222}Rn concentration of soil gas (hereafter called radon). The measuring points are placed along a line perpendicular to railway tracks, streets or project sites. The sample is transferred into an evacuated Lucas cell and after 3.5 h is measured scintillometrically [3, 4].

3. – Results

At a location which lies to the North of the city of Bottrop, the influence of traffic vibrations caused by cars is analysed. The geological bedrock consists of a made ground (medium-grained sands). The radon concentration of soil gas, which is taken from a depth of 50 cm, was measured before and during the rush hour. Figure 1 shows the influence of traffic vibrations caused by cars and trucks on the radon concentration in this site. The radon concentration rises with the beginning of the rush hour and reaches its maximum with the beginning or during the rush hour. The measuring point to the right is situated 25 m off the street. Since the radon concentration at this point does not change, it can be concluded that the change of the other measuring points is caused by traffic vibrations. Another measuring campaign shows the same results [5]. Additionally, fig. 1 shows that the radius of the influence of traffic vibrations caused by cars and trucks is smaller than 25 m. The general decrease of radon concentrations with increasing distance from the street in the first few meters is a result of sealing the soil by the impermeable asphalt [6]. The radius of this influence lies within 1–2 m. The ratio of radon during and radon without vibrations is shown in fig. 2. The increase of radon concentration at this location reaches an average factor of 1.37, which is an increase of 37%. But the percent increase of radon concentration may vary with a greater amount of measurements. Furthermore fig. 2 shows that the ratio between radon concentration during and without vibrations stays more or less at the same level

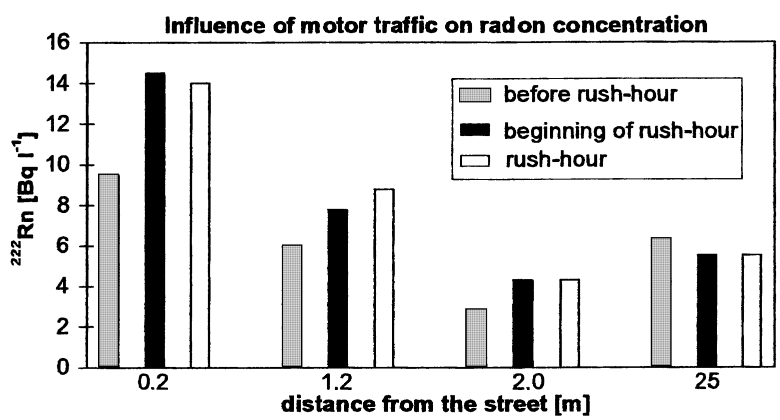

Fig. 1 – Radon concentrations in soil gas (0.5 m depth) at a test site near Bottrop.

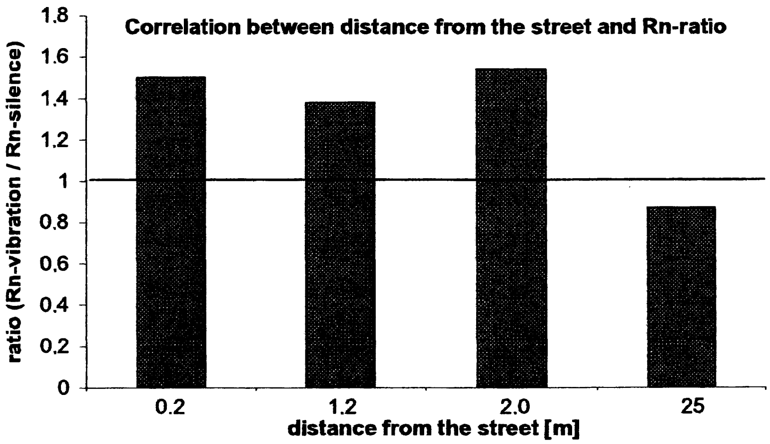

Fig. 2 – The ratio between radon concentrations during and without vibrations in dependence on the distance from the street.

with increasing distance from the street. Only the reference point at 25 m distance from the street shows a factor smaller than one, so it can be inferred that just traffic vibrations are responsible for the observed increase of radon concentrations.

The influence of trains on radon concentration was examined in the vicinity of the city of Essen [5]. Therefore, five different locations were chosen. They differ in their geological bedrock and in the distance from the tracks as well. The distance of the measuring points to the railway tracks varies between 1 and 30 m. Figure 3 shows the results of a location above solid rocks. The geological bedrock consists of Upper Carboniferous sediments, which are overlain by reassorted loess with a thickness of

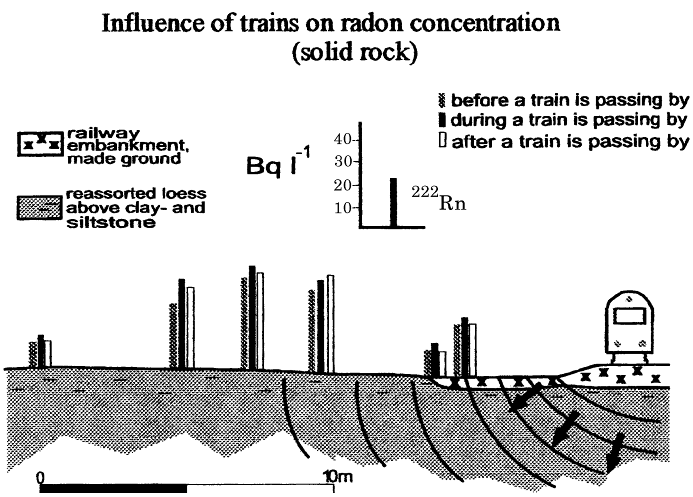

Fig. 3 – Spatial and temporal distribution of radon concentrations in soil gas (0.8 m depth) perpendicular to a railway track at a location above solid rock. The measuring point of fig. 4 is the point to the right.

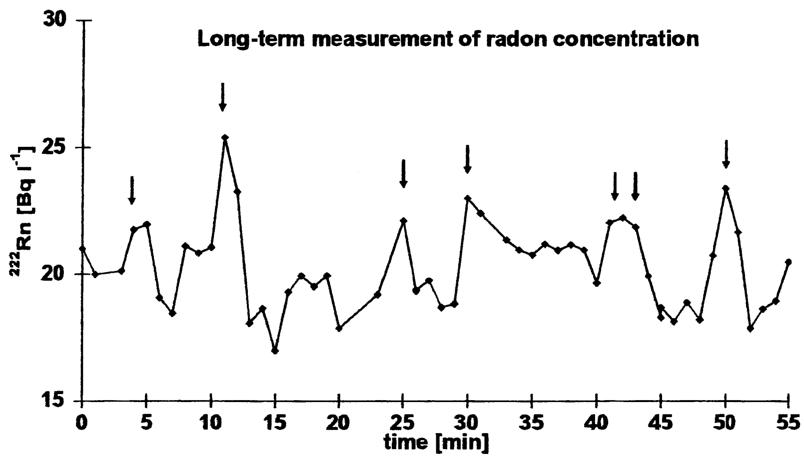

Fig. 4 – Radon concentration in soil gas (0.8 m depth) in a distance of 5 m from a railway track at the location shown in fig. 3. Arrows marking passing trains.

about 2 m. Up to a distance of 8 m the soil consists of a soil aggregation. At six measuring points with increasing distance to the railway tracks, the radon concentration was measured three times, once before, once during and once immediately after a train passed by. As fig. 3 shows, the radon concentration rises while a train is passing. At the measuring point to the right (TB2) long-term measurements were carried out. The radon concentration was analysed roughly each minute (fig. 4). As this figure shows, each time a train passes the radon concentration in soil gas rises about an average of 15% and then mostly immediately decreases. After the measurement of the 41st minute two trains were passing one after the other.

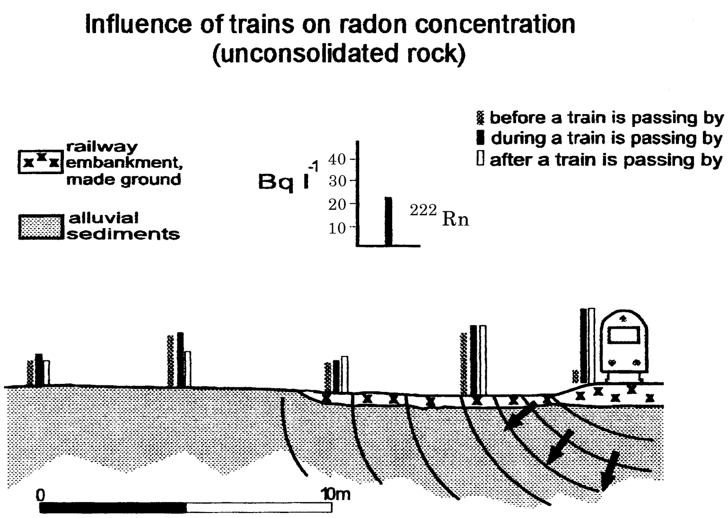

Fig. 5 – Spatial and temporal distribution of radon concentrations in soil gas (0.8 m depth) perpendicular to a railway track at a location above unconsolidated rock.

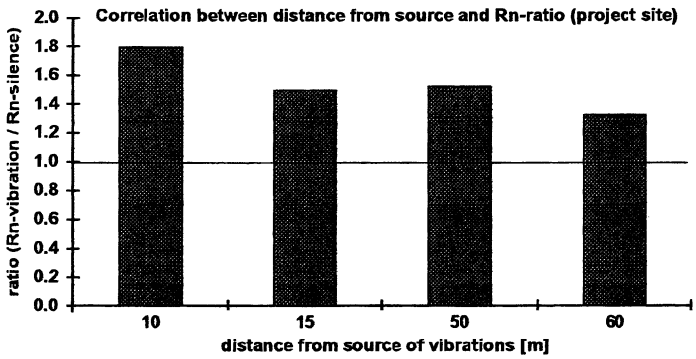

Fig. 6 – The ratio between radon concentrations during and without vibrations in dependence on the distance from the vibration source.

Therefore, the graph of the radon anomaly at this point is not sharp but wider than usual. The reason for the smooth decrease after the train of the 30th minute is questionable.

The vibration effect on the radon potential caused by trains was also analysed at locations above unconsolidated rocks. The diagram of fig. 5 shows one of those test sites. Here, the geological bedrock is composed of alluvial sediments. In the direct vicinity of the tracks (just 1 m distance) a dramatic increase of radon concentration of about 400% was observed. A general increase of radon concentrations due to vibrations was observed above unconsolidated and solid rocks. Therefore, the increase of radon concentrations seems to be independent of the geological bedrock; in both cases the increase amounts to an average of 11%. Other measurements verify that even 30 m away from the tracks an increase of radon concentrations can be stated. Thus, the radius of the influence of these traffic vibrations can exceed 30 m.

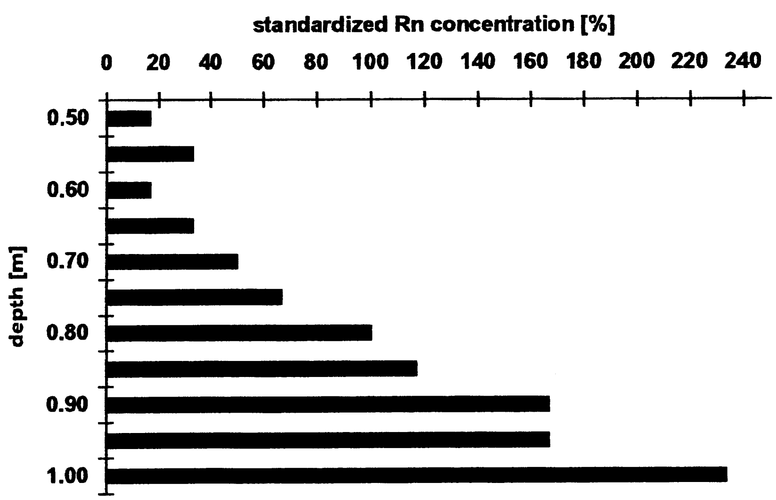

Fig. 7 – Standardized radon concentrations in dependence on the measuring depth at the measuring point of fig. 4. The radon concentrations are standardized to the depth of 0.8 m.

Beside the two described vibration sources, project sites were used as such. At those sites, very strong vibrations can occur, when metal panels are rammed into the ground. The bedrock of the chosen project site in the city of Essen consists of Cretaceous sediments, which are overlain by a backfill. The results of the measurement are shown in fig. 6. The radon concentration of soil gas was analysed during and immediately after the ramming of the panels. The figure shows the ratio between the two analysed radon concentrations with increasing distance to the vibration source. As can be seen, the ratio decreases with increasing distance from the vibration source. The nearest measuring point shows an increase of radon concentration of about 80%. Even at a distance of 60 m influence of the vibrations can be observed, which shows that the radius of this influence amounts to more than 60 m.

4. – Model

The obtained results can be explained by a "pump-effect". That means that mineral particles are shaking in response to the vibrations, whereby the whole volume of soil gas is raised. During the vibrations soil air is exhalated from the ground and afterwards the air is sucked back into the soil. Because of the inevitable radon loss to the atmosphere, the upward directed radon diffusion within the soil is reinforced [7]. Therefore, doing measurements during vibrations, soil gas from deeper layers is sampled. The radon gradient of within the soil, *i.e.* the increase of radon concentrations with depth, is shown in fig. 7. The radon concentrations are determined at the same measuring point of fig. 4, and standardized to the concentration measured in 0.8 m depth. Comparing fig. 3 and 7, it can be stated that a rise in soil gas of about 5 to 10 cm is sufficient to explain the observed increase of radon concentrations.

5. – Conclusions

The measurements carried out show that vibrations can modify the local radon potential. This should not be neglected with determinations of radon potentials. Due to the pump-effect radon can be pumped into houses so that a radon accumulation in houses is likely. Especially houses in the direct vicinity of sealed areas are affected. Furthermore, the increased upward directed radon diffusion leads to a long-term effect. This means that the additional radon delivery is reinforced and the radon potential in the vicinity of vibration sources is generally enhanced.

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