Investigation and Reduction of Personnel Exposure Levels in Bavarian Water Supply Facilities

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1. Abstract

Within the framework of a study covering the whole of Bavaria, water supply facilities were investigated with regard to radon concentrations in indoor air as well as radon exposure to the staff working in these buildings.

Bavaria can be divided into ten geological regions of different geogenic radon potential. The highest geogenic radon potential within Bavaria with indoor radon gas concentrations of up to 1400 $kBq \cdot m^{-3}$ was observed in the East Bavarian crystalline region. About ten percent of the process controllers in this region were exposed to an annual effective dose of more than 6 mSv. In the other Bavarian regions, only 1.4% of staff exposure levels exceeded this limit.

The management of supply facilities responsible for process controllers exposed to very high annual radon levels were asked to take remedial actions.

There are several remedial actions, which have proven successful. It is inexpensive to reduce the radon exposure by reducing the time spent in the units. On the other hand buildings can be ventilated with stationary or mobile devices. In one case, a combination of an effective ventilation system with a separating wall between the water purification basins and the water supply control centre reduced the annual effective dose of the process controller from about 100 mSv to 6 mSv.

Due to long duration of stay and very low ventilation in elevated reservoirs the radon exposure of the staff during cleaning can be very high. The most effective way to reduce the radon exposure is to decrease the radon concentration in these buildings by blowing fresh air inside directly to the workplace.

2. Introduction

The protection of the health of workers and the general public against the dangers arising from natural radiation was provided in the German radiation protection ordinance [1] in 2001. The limit of the annual effective dose is 20 mSv. Therefore the European Council directive 96/29/EURATOM [2] was implemented in German law. This directive was based on the awareness that high exposure to radon and its progenies through inhalation can cause lung cancer. This insight resulted from

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several epidemiological studies on American and Canadian miners [3]. High radon concentrations that can lead to increased radon exposure have also been measured at other work places such as visitor caves and mines, radon spas and water supply facilities [4].

In an earlier study [4], it was found that Bavaria can be divided into ten geological regions with different geogenic radon potential according to the geological formation and the main aquifers. Those regions are displayed in Figure 1. The highest potential is thereby assigned to the East Bavarian region (No. 5) and region Nr. 10 with mainly granite and gneiss substructure (Figure 1). The large East Bavarian region is a mostly rural area with mainly small water supply facilities operated by local authorities.

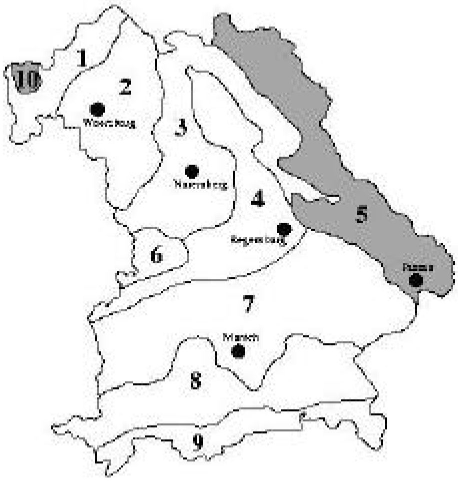

Figure 1. The ten main geological regions of Bavaria. The regions with the highest "geogenic radon potential" are marked in gray. Rock types of the regions: new red sandstone (1); shell limestone, Keuper (2); Franconian Keuper (3); Upper Jurassic, Dogger, Cretaceous (4); Granite, Gneiss (5, 10); Ejection material of the Ries meteorite (6); Sediment rocks, Molasses (7); young moraine (8); Trias, Jura, Tertiary (9).

3. Radon measurements and results

In Germany, the federal states, such as Bavaria, are responsible for the enforcement of the radiation protection ordinance [2]. Consequently, all 2550 Bavarian water supply facilities were investigated with regard to radon concentrations in indoor air as well as the radon exposure to the staff working in these buildings.

To estimate the radon exposure level, the processing plant workers had to wear a personal track-etch detector for three months. When not in use the personal detector was stored near a reference detector at a place with low radon concentration. To obtain the mean room concentration, track-etch detectors were exposed for a period of two weeks in mainly reservoirs and purification units.

2000 personnel exposure level and 5000 room concentration measurements were carried out. Personnel exposure levels of up to 400 mSv per year and room concentrations of up to 1000 $kBq \cdot m^{-3}$ were found. In 1.2 % of all Bavarian water supply facilities, the annual exposure level of the staff exeeded the limit of 20 mSv. In 1.7 % of all water supply facilities, the annual exposure level of the staff was between 6 and 20 mSv. Considering only the crystalline East Bavarian region (Figure 1 Nr. 5), the annual exposure level of the staff exeeded the limit of 20 mSv in 4.7 % of the water supply facilities there. In 5.6 % of the East Bavarian water supply facilities, the annual exposure level of the staff was between 6 and 20 mSv. In all mentioned water supply facilities the exposure level of the staff is constantly monitored and remediation measures are in progress.

4. Reduction of personnel exposure levels

The measures presented here are only strategies. They have to be adapted to every single building. Further on there is no foretelling of the magnitude of the reduction. This may not sound very promising, nevertheless these strategies have been proven successful in all cases as is illustrated with the examples below.

4.1 Strategy 1

It is inexpensive to reduce the radon exposure by reducing the time spent in the units. This strategy can be applied in almost all cases. To achieve this enhanced awareness amongst staff, information about radon and its characteristics were distributed. One application of this strategy can be the relocation of the office to a building outside the supply facility (e.g. the building yard or the administration building of the local authority). In some water supply facilities a simple chemical analysis of the raw water is done by a process controller inside the raw water sources or wells. Another application is therefore to analyse the water outside the raw water sources or wells. In one case this reduced the annual exposure of the worker from 11 mSv to 1 mSv.

4.2 Strategy 2

Another very effective way to reduce the radon concentration inside buildings is to blow fresh air directly to the workplace of the staff with stationary or mobile devices. An example is shown in Figure 2. Here the active ventilation reduced the indoor radon concentration from an average of 20 $kBq \cdot m^{-3}$ (without ventilation) to about 1 $kBq \cdot m^{-3}$. This method can also be used for the annual cleaning of the basins and reservoirs as well as actions in badly ventilated pits, see Figure 3. In one reservoir the radon concentration was reduced from 400 $kBq \cdot m^{-3}$ to 8 $kBq \cdot m^{-3}$ during cleaning.

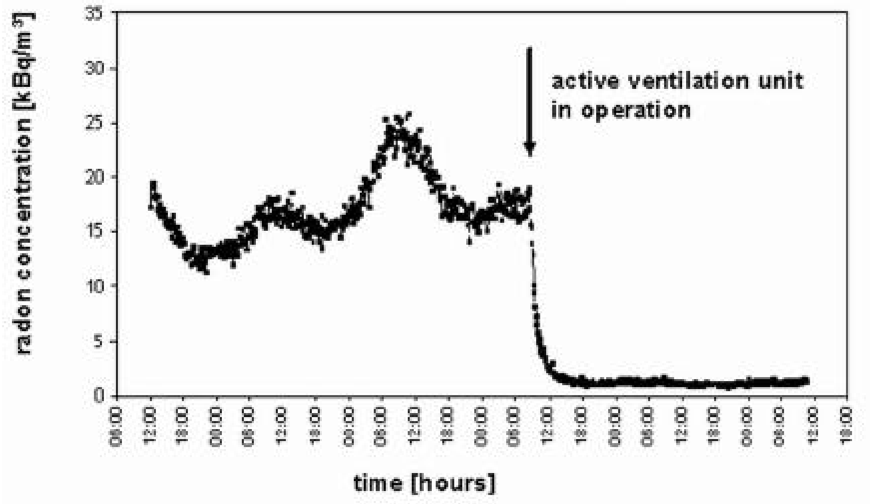

Figure 2. Indoor radon concentration in a water purification building. When the active ventilation unit is in operation, the radon concentration drops from an average of 20 kBq·m^{-3} to about 1 kBq·m^{-3}.

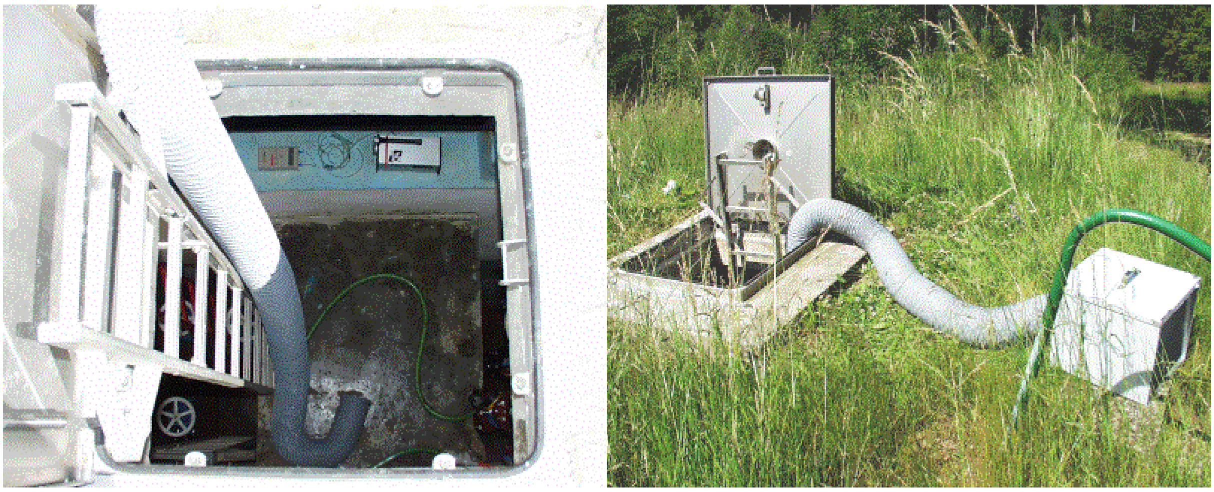

Figure 3. Example of a mobile ventilation unit for cleaning of basins and reservoirs as well as actions in badly ventilated pits. Left: air tube to the bottom of the basin. Right: ventilation aggregate with attached electric generator (not shown).

4.3 Strategy 3

It is also possible to install a separating wall between the water purification basins and the control centre, often accompanied by a matching effective ventilation system. In one specific case these measures reduced the annual effective dose of the process controller from about 100 mSv to 6 mSv. An example is shown in Figure 4.

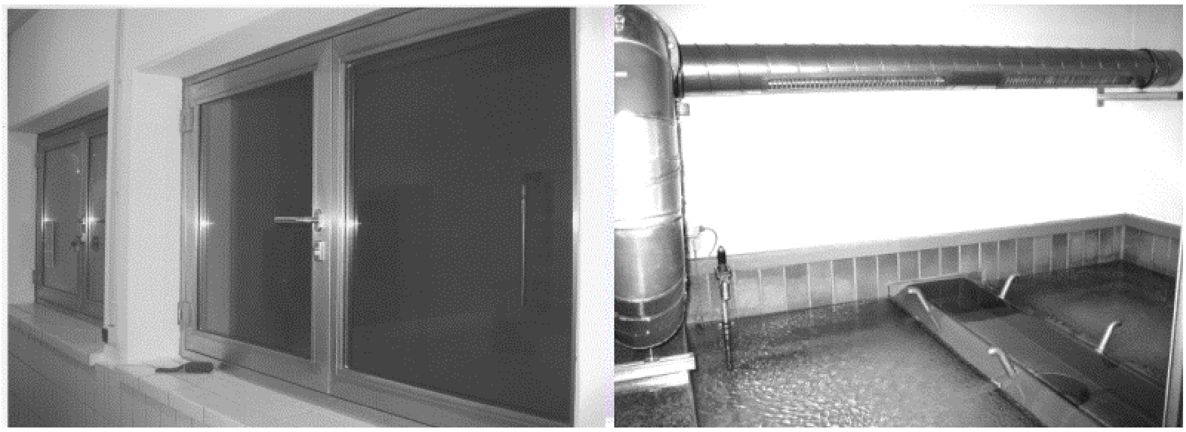

Figure 4. Example of a separating wall and a ventilation system. Left: separating wall between filter basins and vestibule. Right: ventilation system inside the separated filter basins.

4.4 Strategy 4

An alternative way to reduce the indoor air concentration is to avoid any transfer of radon polluted air exhausted from purification tanks to the indoor air. In one case the indoor air concentration in the purification building was reduced from 4.6 $kBq \cdot m^{-3}$ to 0.5 $kBq \cdot m^{-3}$. An exemplary construction is shown in Figure 5.

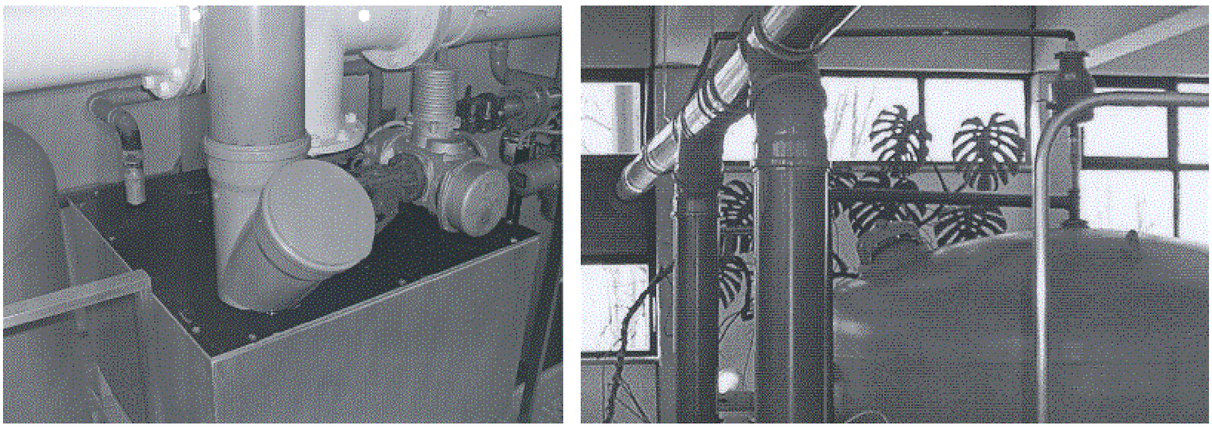

Figure 5. Example of a sealed system. Left: sealed basin for collecting and conducting the waste water of the filter cleaning process. Right: the exhaust air of the filter tanks is collected and conducted outside by large pipes. There is no connection to the indoor air.

5. Conclusions

Due to high annual effective doses to the staff working in several Bavarian water supply facilities, remediation measures have been taken. The strategy is often to ventilate the buildings. In any case the measures have to be adapted with respect to the building as the radon concentration is influenced by many factors.

6. References

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