Additional Research: Man-Made Radon Pollution? Radon Measurements in parts of Lower Saxony and a comparison to other, selected Regions

Iris M. Reuther

***Abstract* —** Radon is a geogenic, radioactive noble gas that is blamed almost everywhere in the world for health risks. Depending on geological composition, people in buildings above the affected regions can expect radon exposure to a greater or lesser extent. In this article, we present and discuss exemplary, unexpected measurement results in one German region. The author pursues hypotheses for the causes and substantiates them: she believes that caverns, which are underground stores for fossil energy sources, are a plausible cause of higher radon exposure in parts of Lower Saxony. These storage facilities, primarily for fossil fuels, have been in use since the 1970s and have been expanded ever since. In a second section, using maps that are available online, consideration is given to whether this load might also occur in other regions where underground storages were created. Only a hypothesis to date, confirmation of the surmised link could make it necessary to pursue radon exposure in these regions more intensively than has been the case, in the interests of public health protection. However, extensive research is considered necessary before a potential causality between caverns and elevated radon values inside buildings can be recognised.

***Keywords* —** caverns, lower saxony, radon exposure, public health.

I. INTRODUCTION

As radon exposure is not a topic for environmental science professionals around the world, we shall discuss a few basic principles here at the outset. I would ask readers with relevant prior knowledge to excuse this.

Radon is a geogenic, radioactive, odourless, tasteless and colourless noble gas. It is part of the decay chain from uranium to lead and exists in different isotopic forms. The relevant form is usually Rn 222 with a half-life of 3.8 days [1]. During decay it releases alpha radiation, which makes up approximately 50% of exposure to radioactive radiation from natural sources [1]. This can destroy DNA strands in cells and thus cause cancer in the longer term. If the noble gas is inhaled then the abovementioned decay occurs in the lungs, leading to damage to the cells of this organ. The human body can compensate for this to a certain extent, but increased radon exposure is considered a significant factor in the development of lung cancer. Approximately one in ten of these cases is considered to have been caused by radon. This makes it the second most common cause of lung cancer behind smoking.

Radon is also suspected of causing further illnesses or making their occurrence more probable. In general, these include respiratory illnesses [2], asthma [3] associated with higher mortality [4], COPD [5], leukaemia [6], [7] and mortality from Covid-19 [8], [9], [10]. However, research of these illnesses is in its infancy and is only known to experts [11]. Exposure to higher doses of a radioactive substance, however, can be assessed in general as harmful to health, which has made protection of the population from radon to a health policy topic in many countries [12] and it has been included in relevant European legislation, for example [13].

Increased radon exposure occurs in certain occupational contexts. In particular, these are mining [e.g. [14]], primarily uranium mining. Furthermore, oil extraction [15] and waterworks [e.g. [16]] are considered sectors in which the workers are exposed disproportionately to radon. For “normal” employees, legislation on protection from radon is relatively recent in Europe and particularly in Germany: it is only since 2013 in the EU [13] and 2013 in Germany [17] that reference values[1] have been determined for radon exposure. In Germany this stands at 300 Bq/m³ and thus far above the reference value recommended by the WHO: 100 Bq/m³ for indoor spaces. The measured values in soil air often serve as an indicator of whether elevated radon values are to be expected in spaces above a geological situation. However, it is not possible to derive one value from the other: the possible construction and ventilation-related limiting conditions are too diverse [18].

II. MEASUREMENTS AND EVALUATION

The abovementioned construction conditions justify the author’s interest in the topic: as an architect[2] she deals with structural radon protection. According to official maps no significant radon levels are to be expected in Lower Saxony (see Fig. 1 and 2). Nevertheless, the author took measurements at the three locations of her affiliation in selected indoor spaces

Iris M. Reuther, Faculty BGG, Jade University of Applied Sciences, D-26121 Oldenburg, Germany

[1] As there is no harmless dose, this is not a limit but rather a reference value.
[2] Because of this professional background, the technical terms from related but more distant disciplines may be used imprecisely in this text.

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for two periods of one year each. In contrast to other studies, these long-term measurements are considered more meaningful and legally binding because they include seasonal fluctuations.

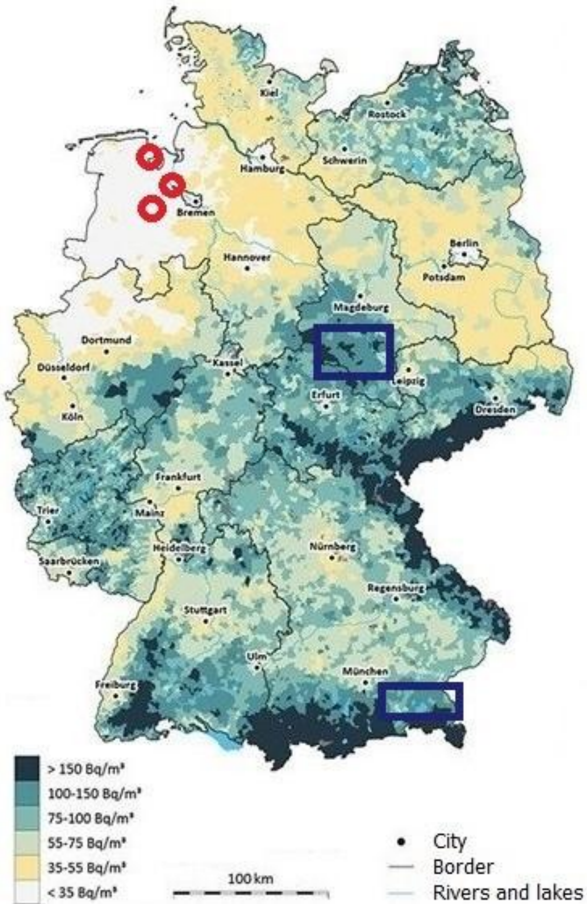

Fig. 1 Map of Germany with the average radon concentrations in homes, with the university locations marked at the top left with red circles. At the centre and bottom right there are regions with cavern locations marked with blue squares, Illustration according to [19], amended and supplemented by the author.

There is one university location each in Wilhelmshaven, Oldenburg and Elsfleth. Some of the abovementioned measurement results, namely those from Wilhelmshaven from the period 2022/23, was already published in [20], some have been incorporated into a current study by the Federal Office for Radiation Protection that has not yet (September 2025) been published [21]. Additional selected measurement results are presented here because they are unexpected in northwestern Lower Saxony.

Fig. 1 shows the concentration of radon in German homes as of 2023. In most cases this is caused by radon rising from the foundation soil. There are much higher radon concentrations there, which is also shown in the map in Fig. 2 with values from 2021. The latter map has somewhat greater resolution, which does not make it significantly more meaningful for this topic. Both maps clarify why readings in the indoor areas of the university locations that lie above the WHO reference value of 100 Bq/m³ can be considered remarkable, even though they provide a slightly different picture in some areas.

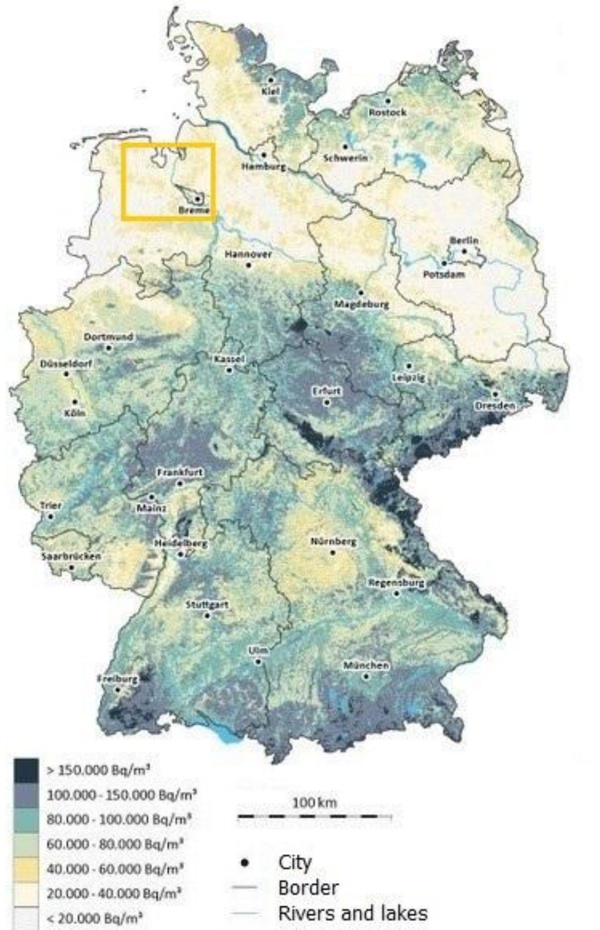

Fig. 2 Map of Germany with the average radon concentrations in the soil air showing the section depicted in Fig. 4. Map according to [19] amended and supplemented by the author

In the following the mentioned readings are listed per location in three tables, each with room number and measurement period. The measurements in 2022/23 were taken from December to December. In 2023/24 the measurements all began and ended in September / at the beginning of October. The unequal number of measurements at the different locations is partly but not wholly due to their unequal sizes and the number of buildings with rooms that touch the soil. The rooms where the radon concentration was measured are primarily used as storerooms, laboratories, workshops and, in one case, as an office.

TABLE 1
LONG-TERM RADON MEASUREMENTS IN SELECTED ROOMS AT JADE UNIVERSITY WILHELMSHAVEN.

No.	Room	Period	Radon concentration [Bq/m³]
W-1	H-K 09b	22/23	112
W-2	S-K 12	22/23	136
W-3	S-K 09	22/23	175

In total 6 measurements were taken in the rooms of the location in Wilhelmshaven (2 in 22/23 and 4 in 23/24), 9 in Oldenburg (3 in 22/23 and 6 in 23/24) and one in Elsfleth (in the period 23/24). The nine measurements not listed here resulted in values far below the WHO reference value of 100 Bq/m³. Only the results above 75 Bq/m³ are published here. The measurements in the period 2023/24 were also carried out in order to verify the results of the previous period.

TABLE II
LONG-TERM RADON MEASUREMENTS IN SELECTED ROOMS AT JADE UNIVERSITY OLDENBURG.

No.	Room	Period	Radon concentration [Bq/m³]
O-1	V-014	22/23	76
O-2	MR-07	23/24	77
O-3	HL-7	23/24	114

TABLE III
LONG-TERM RADON MEASUREMENTS IN SELECTED ROOMS AT JADE UNIVERSITY ELSFLETH.

No.	Room	Period	Radon concentration [Bq/m³]
E-1	-	23/24	127

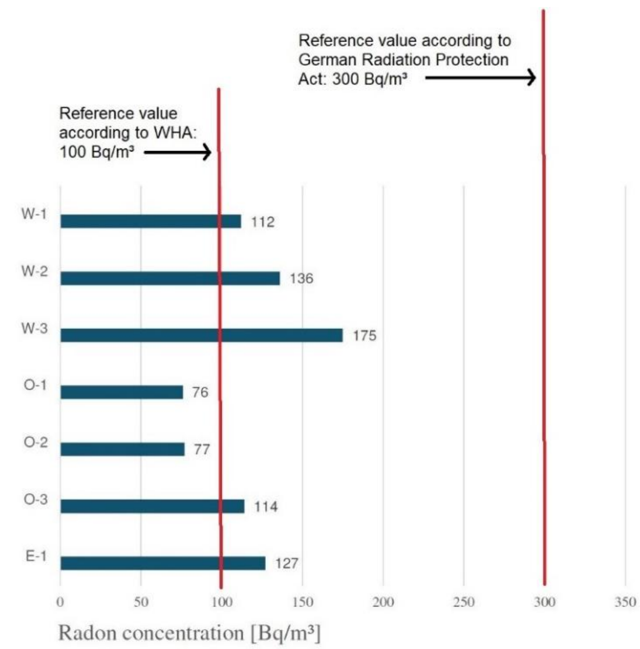

Fig. 3 Graphical representation of the measured values from Table 1 to 3 with highlighted reference values according to WHO and the German Radiation Protection Act (own representation).

From Fig. 3 we can conclude that all readings are far below the reference value of the German Radiation Protection Act. Thus there is no legal need for the university to take action. At the same time Fig. 3 also shows that the values are unexpectedly high. This can be concluded from a comparison of Fig. 3 and the average radon concentrations in the map in Fig. 1. This map expects average values for homes[3] of under 35 Bq/m³ in northwestern Lower Saxony. So if measurements in some parts reveal concentrations of far more than three times the expected radon concentration, there can be no doubt that these are "unexpectedly high values". Inside the building, increased exposure is almost[4] only to be expected if the corresponding deposits are found in the foundation soil.

Beyond a comparison with Fig. 2, a geoportal of the German Federal Office for Radiation Protection is also available for radon concentrations in soil air and it has substantially higher resolution. This geoportal mainly shows values of 20 - 40 kBq/m³ for Wilhelmshaven, Oldenburg and Elsfleth, with up to 60 kBq/m³ of soil air at a depth of 1 metre in parts. The map section in Fig. 4 confirms Fig. 2: this is a region with naturally very low radon concentration in the soil air.

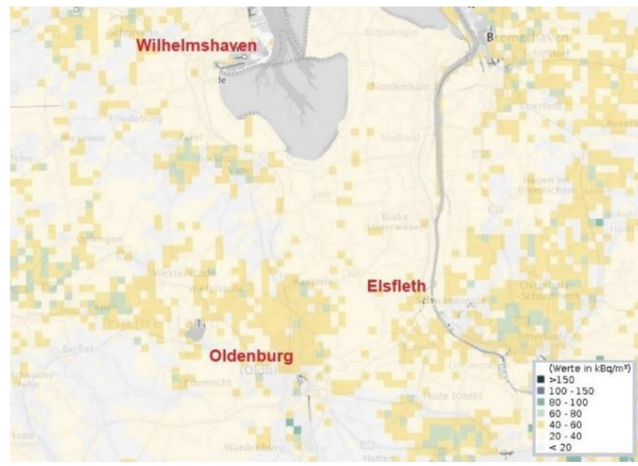

Fig. 4 Radon in the ground, excerpt from [22], modified by the author, marked the three locations of Jade University.

To put this in context: in other regions of Germany, especially former mining areas, up to 1,000 kBq/m³ are measured in the soil air. In these places, the reference values of 300 Bq/m³ for indoor air according laid out in the German Radiation Protection Act are regularly exceeded, particularly in old buildings, so that action must be taken there (see [23]).

It must also be noted that of the values not published here (the criteria is < 75 Bq/m³, as mentioned) 2 of the 6 measurement results in Wilhelmshaven and 5 of the 9 in Oldenburg were below 35 Bq/m³, i.e. below the lowest scale in Fig. 1. We can conclude from this, beyond the above evaluation, that the results in Wilhelmshaven deviate more frequently and/or more strongly from expectations than in Oldenburg. Furthermore, Elsfleth, for which there is only a single reading, is hardly representative.

III. POSSIBLE CAUSES FOR ELEVATED READINGS

We will now outline possible causes for the readings provided in Chapter II and evaluated in relation to the reference values. In classical mining regions this kind of a search for causes is obsolete, but not in northwestern Lower Saxony, as shown in both Fig. 2 and the geological map in Fig. 5.

[3] Given the absence of meaningful maps for other types of indoor spaces, those for homes are used as a comparison for the workplaces.

[4] Old buildings in which radon-containing materials were used in construction are the exception. There is no evidence of this here.

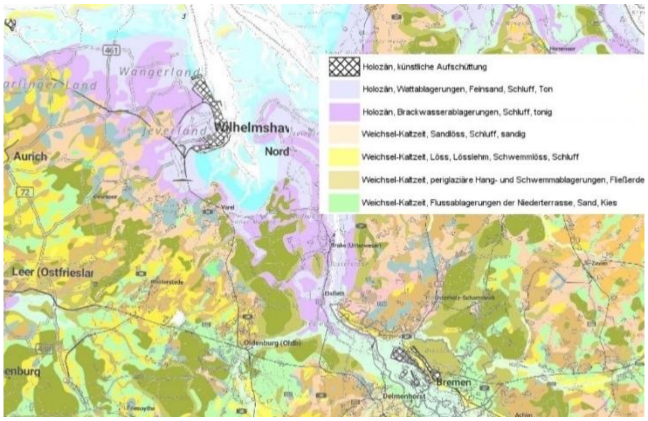

Fig. 5 Soil map of Lower Saxony for the areas of Wilhelmshaven, Oldenburg and Elsfleth, excerpt from [24], supplemented by the author.

Although Fig. 5 is a relatively large excerpt, it does show the fundamental conditions. The fundamental, geological information for the three places are listed in Table 4.

TABLE IV
ALTITUDE ABOVE SEA LEVEL, GEOLOGICAL ERA AND SOIL TYPES IN ACCORDANCE WITH [24] FOR WILHELMSHAVEN, OLDENBURG AND ELSFLETH

City	Altitude above sea level [m]	Geological era	Soil type(s)
Wilhelms-haven	1,88	Holocene	Artificial filling, dredging
Olden-burg	4,39	Weichselian glacial	Sand, gravel, river deposits
Elsfleth	0,85	Holocene	Silt, brackish water deposits

In geological terms, Wilhelmshaven and Elsfleth can be classified as the geological present and Oldenburg as the last ice age [24]. Thus these are young geological conditions. High radon values tend to be found more frequently in older formations.

A. Wilhelmshaven

In [20] it is presumed that the radon concentration in Wilhelmshaven is man-made or at least was intensified by human activity. To be specific, to the best of our current knowledge, there appear to be two related factors that can be considered as the cause.

Firstly, Etzel, a place in the direct vicinity of Wilhelmshaven, has one of the largest cavern systems in the world. There are also caverns below the Wilhelmshaven district of Rüstringen [25]. These are artificially created underground cavities that are flushed out from salt domes at great depth using water. They are approximately 70 m in diameter and 300-500 m high, located in Etzel at a depth of approx. 900 - 1,300 m [26]. In 1979 there were already 33 caverns there for approx. 10 million tonnes of crude oil [27]. 841 million m³ of natural gas have been stored there for years as part of the national reserves [28], trending upwards. In March 2016 there were 99 and the final status, decided in 2011, was to be 144 caverns [27], each designed to be used for about 100 years. Fig. 6 illustrates this kind of cavern.

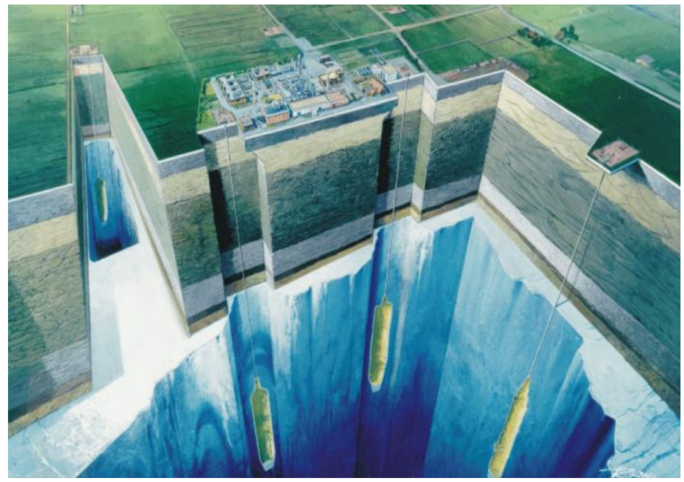

Fig. 6 Huge salt caves like those used for natural gas storage. They are flushed out from the salt dome, graphic in [29].

It has long been known that radioactive substances are brought up from the soil to the surface in the course of oil and gas extraction. It is true that mineral oil is comprised for the most part of carbon compounds, but the up to 17,000 components also include radioactive elements[5] [30] like uranium, thorium, radium etc. The resulting NORM radiation intensity even exceeds those from nuclear tests in Kasachstan, for example [15]. Increased radioactivity in a radius of 20 kilometres was measured according to [31].

Extraction in Germany to date has been almost exclusively limited to offshore oil and gas close to the coasts with a tiny scope - seen globally and nationally - of only 2% of its own requirements. The federal government has announced, with regard to onshore fracking, that “radon from the reservoir rock enters the natural gas” [32], and that the “sludges and residues from the extraction, processing and treatment of (mineral oil and) natural gas are named [in the Radiation Protection Ordinance]” [32] and are subject to the Atomic Energy Act from certain monitoring limits. Nevertheless, there is hardly any awareness of this problem outside specialist circles.

There is even less awareness that the reverse process can certainly also go hand in hand with the release of radioactive radiation. Parts of the NORM in crude oil or natural gas reenters the soil for storage in caverns, so that elements like radium / radon are likely to be present there also. There are currently 39 caverns in Wilhelmshaven-Rüstringen for 11 million m³ of crude oil [33]. In 2022 there were 51 caverns in Etzel, near

[5] This Natural Occurring Radioactive Material is generally abbreviated to NORM and differentiated in part from technologically enhanced naturally occurring radioactive materials (TENORM).

Wilhelmshaven, for 3.9 billion m³ of natural gas and 24 caverns for 10 million m³ of crude oil [34]. Both the numbers and the distribution between gas and oil vary there because oil cavern use has already been switched to gas in Etzel. The first factor that the author considers to be a cause of the readings in Wilhelmshaven is the relatively large quantities of crude oil and in part also natural gas that have either been brought underground or that exist there.

The second possible cause is closely related to the first, namely the process for creating the caverns. There is a description in [35] that radon is also created there and comes to the surface, where salt is flushed out of the subsurface through natural processes. The authors of [35] determined elevated radon concentrations in the soil air at the edges of active salt domes in 2011. They believe two kinds of transport to be possible in permeable soils. Firstly, groundwater transport is influenced by (flat) salt domes (higher salt content, higher temperature). This means that deep salt water with high radium content can come to the surface in the vicinity of a salt dome. Secondly, scree, sand and clay layers can serve as absorbers for radium in deeper, tertiary deposits. If these deposits are transported to the surface by the rising, salty water, then radioactive elements will also arrive there [35] p.94. Exogenous and petrophysical factors for the radium transport can be ruled out, only the halokinesis is decisive. Both of the routes named above, through which radon comes to the surface due to natural salt tectonics, are shown in Fig. 7 on the left and at the centre.

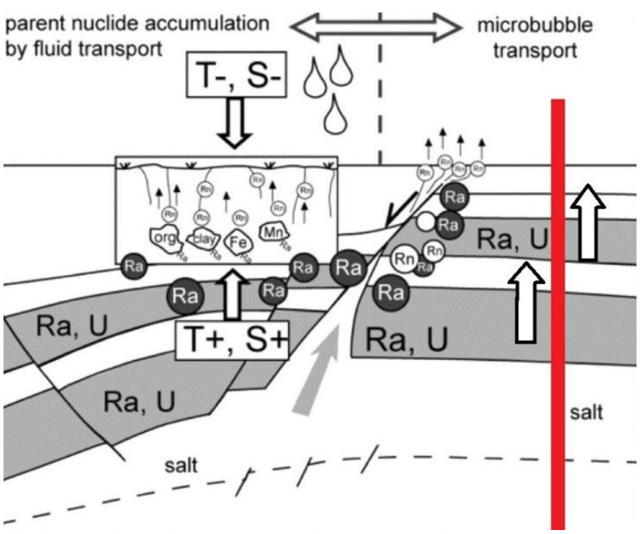

Fig. 7 Schematic sketch summarizing the possible sources for elevated Radon activities in the soil gas of a salt dome environment; T = Temperature, S = salinity. Mn and Fe stand for Fe- and Mn-oxides and -hydroxides and org = organic matter. The red line symbolises a non-natural disturbance of the geological structure: drilling for a cavern and/or for its neck. Illustration from [35] page 94, modified and supplemented by the author.

If increased radon concentration is already caused in the soil air close to the surface by slow, natural processes in salt tectonics, how much more must this also apply to man-made processes and changes close to underground salt deposits? "The increased salt content in other soil layers promotes the decomposition of rock components and thus leads to increased release of radon" [35] p. 83 – this is a key sentence for the second potential cause of the unexpectedly high radon values in Wilhelmshaven. As described, the caverns are created through flushing with water. Highly saline water is thus transported from below to above in large quantities through several hundred metres of existing geological strata. The author considers it very probable that the radium transport processes described in [35] also take place during this procedure. This may occur differently in detail because the water is transported at far greater speeds and in huge quantities, but it nevertheless appears to be a plausible way for radium and/or radon enrichment to occur in soil layers near the surface. This transport along the flushing pipes and/or the cavern neck is shown in Fig. 7 on the right in a highly schematic manner in addition to the natural transport processes.

B. Oldenburg

Nine long-term radon readings were taken at the Oldenburg premises of the Jade University of Applied Sciences, of which only one gave a result above the WHO reference value, see Fig. 3. There are no known oil or gas-filled caverns below the city (see Fig. 9). Sand, gravel and river deposits (see Table 4) are considered permeable but not in connection with radon, which is why they are not obvious potential causes for this value. Prompted by [35] however, we shall look at the salt map of northern Germany. A small excerpt from this document is shown in Fig. 8.

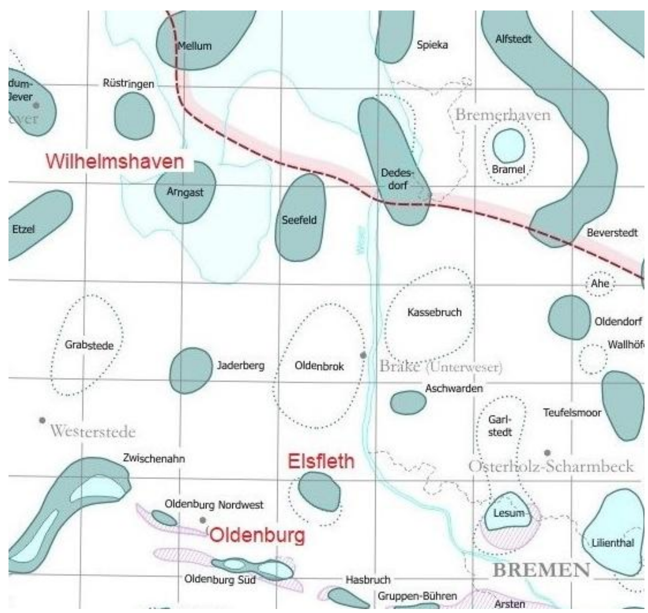

Fig. 8 Salt structures in northern Germany showing Wilhelmshaven, Oldenburg and Elsfleth, map extract from [36], supplemented by the author.

There are several so-called salt intrusions shown near Oldenburg. In these areas, saline water penetrates into geological layers dominated by fresh water or reaches the surface. There are also several salt domes in the Oldenburg area with cover of (newer or older) sediments and the construction of canals and the lowering of the groundwater level that is not only necessary for this purpose have a long tradition in Oldenburg. For this reason it is easy to imagine that geological processes occur at the limits of the salt domes and in the area of the intrusions shown at the left and centre in Fig. 7: increased salt content in the subsoil leads to increased radon concentration in soil layers close to the surface [35]. Leaks in the building shell that touches the soil, as they could occur in the room with the measurement O-3, an old building from the Wilhelminian period, radon can penetrate inside and result in higher readings, see e.g. [1] or [23].

C. Elsfleth

There is only one measurement for the Elsfleth site of Jade University of Applied Sciences. Its results can therefore neither be considered representative nor meaningful. Nevertheless, the map of underground storage facilities in Germany (Fig. 9) also shows caverns there, in the district of Huntorf, a few kilometres from the university.

According to this map from the State Office for Mining, Energy and Geology we can presume a use for gas storage. However, a “rare bird from the energy transition” has also been located there since 1978 [37], namely one of only two compressed air storage power station that exist in the world. There, air is compressed to up to 72 bar using a lot of energy, causing it to heat to 50 °C. If this air is able to escape again via turbines, then the pressure energy is converted back to electrical energy [37]. The efficiency is low at 42%. Originally built in order to store excess power at night, today the power station above the caverns primarily helps to compensate for grid fluctuations, which have increased greatly since the development of so-called “renewable energy sources[6]” [38]. Research is currently being conducted into converting the power station into a “carbon-free hydrogen compressed air storage power station” and thus “replacing conventional natural gas with green hydrogen” [39]. For pressure below ground it is irrelevant which raw material is used to operate the machines generating the pressure.

Natural gas is a purer hydrocarbon mixture than mineral oil and has a lower proportion of NORM, from which radon can be produced. Nevertheless, the unexpectedly high radon measurements in Elsfleth can probably also be attributed to the caverns, and not only from the drilling and/or the cavern neck (as explained in Section A), but also because of the increased temperature underground. Looking at Fig. 7, we can see that a slightly higher temperature underground resulting from natural conditions can already lead to higher radon values in the soil air close to the surface. It is true that the caverns are located at depths of hundreds of metres, but over the decades of cavern operation the radioactive natural gas could have penetrated various soil layers on the way to the surface and thus increased natural radioactivity.

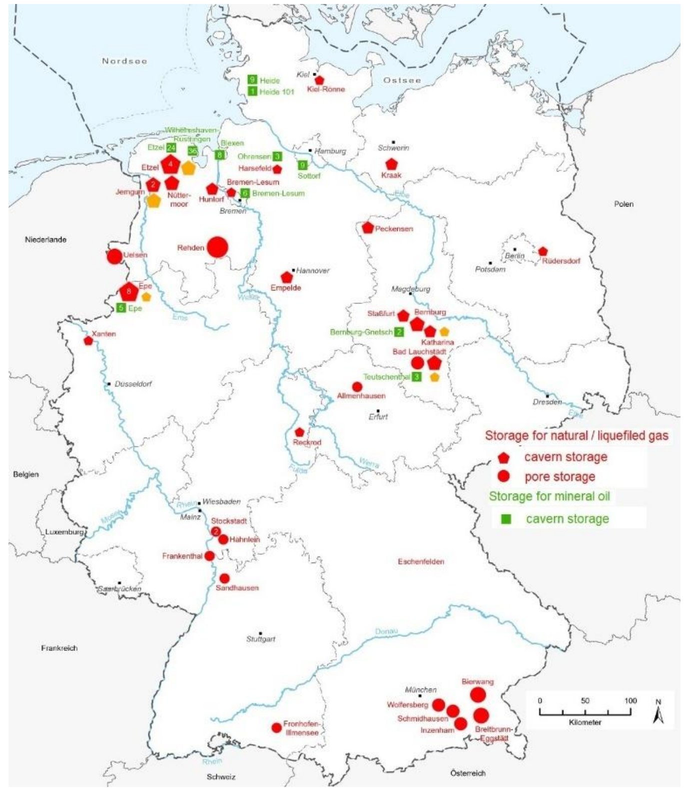

Fig. 9 Overview map of underground storage facilities for natural gas, mineral oil, liquefied gas, illustration from [34], modified and supplemented by the author.

D. Summary of the potential causes for unexpectedly high radon readings

The possible reasons for the unexpectedly high radon readings as shown in the sections A-C of this chapter include several plausible, but unconfirmed causes. They are summarised in Fig. 10.

City	possible underground reason(s)
Wilhelmshaven	caverns mineral oil storage
Oldenburg	salt intrusions
Elsfleth	caverns high pressure / temperature

Fig. 10 Potential causes for elevated radon readings at the three locations of Jade University of Applied Sciences, own illustration.

It is to emphasise again that the potential causes are plausible hypotheses, but are not documented evidence. The very low number of cases alone rules out any other description of what is presented here.

[6] This term is misleading and contradicts the law of the conservation of energy, but it has become established.

IV. VIEW OF OTHER GERMAN REGIONS WITH CAVERN LOCATIONS

As a result of the uncertainty that characterises Chapter III, we look in the following at two other German regions with underground storage locations. They are both marked in Fig. 1 with blue rectangles. Fig. 9 shows them individually: they are located in Saxony-Anhalt to the south of Magdeburg (mainly red pentagons = cavern storage for gas in the centre of the map) and in Bavaria to the south-east of Munich (red solid circles = pore storage for gas, lower right of the map of Germany), whereby the latter area stores only gas, no mineral oil. The following important Fig. 1 and 2 are not shown here for reasons of space; the two regions are already marked in the illustrations at the beginning of this publication.

A. Saxony-Anhalt

A small number of the cavern systems in Saxony-Anhalt are from the 1970s but most are substantially younger, of a similar age to those in Lower Saxony. Some are from 50 years ago but most were created 10 or 20 years ago [40], [41].

Fig. 2 there is an almost uniform colour from the south of Magdeburg to almost in line with Erfurt. This shows that the radon concentration in the soil air there is shown on the map as very similar and relatively high, but not at the highest level. In contrast, the same region is not uniform in Fig. 1, showing areas of medium radon concentration in homes. Specifically, there are several small areas that are almost black on this map and thus marked with the highest value level of average radon concentration.

Verification of whether these areas are more or less in the direct vicinity of the caverns shown in Fig. 9 would require better map materials. In order to support the hypothesis put forward in this text it would also be necessary to carry out mainly long-term measurements in significant numbers in rooms in this region that are in contact with soil. As it is, it can only be concluded that a superficial comparison supports the author's thesis stating that caverns used for oil storage in particular lead to increased radon concentrations in the soil air near the surface.

B. Bavaria

Fig. 2 shows relatively uniform colours to the southeast of Munich. This means that radon concentrations in the soil air there are very similar and classified in the medium to high area of the scale on the map. Fig. 1 also shows a uniform picture there, with higher average radon concentrations in homes only occurring in the Alps area bordering further to the south.

As mentioned, underground storage in Bavaria is exclusively in the form of pore storage. In this type no artificial cavities are flushed out of a salt dome - as for caverns - but rather former mineral oil and gas fields where extraction has been completed are used again to store gas. This gas penetrates the pores of the stone, where natural gas was stored before extraction and was locked in from the top with a gas-tight “geological cap”. These locations are frequently sandstone, with gas being pressed again into its pores. This kind of storage is suitable for large quantities but because of the slow rate of filling and above all extraction it is only suitable for seasonal offset and not suitable for the fast release of gas [42].

This storage principle and the use of gas in place of oil as a storage medium also explains why, in accordance with the author’s hypothesis, there is no significant local deviation in radon values between Fig. 1 and Fig. 2: the salt and thus radon transport processes described in Chapter III Section A do not take place. This is why, in connection with these pore reservoirs, there is likely to be only a slight, civilisation-enhanced increase in radon concentrations in the soil air.

Chapter IV can be summarised by saying that there are indications in cavern stores outside Lower Saxony of similar processes to those in the hypothesis set out in Chapter II for the possible causes of elevated radon concentrations. There is less evidence to support this for pore storage facilities for natural gas. It therefore appears that, in addition to the type of filling material (oil or gas), the type of underground storage facility is also relevant to the radon exposure of those living above it.

V. RELEVANCE AND IMPLICATION

Somewhat broader contexts must be examined for the relevance of the hypotheses discussed here beyond northwestern Lower Saxony. As mentioned, there is further development of the caverns in Wilhelmshaven [25] and a compressed air storage facility is already in operation in Elsfleth [39]. In Saxony-Anhalt there are plans for the storage of hydrogen as well as mineral oil and natural gas. Caverns are currently being created for this for test operation with a volume of approx. 3,800 tonnes of hydrogen [43]. These examples are no exception in Germany. Hesse is trialling the storage of hydrogen underground, some in caverns and some in pore reservoirs [44]. Other studies are even looking for opportunities in Europe outside Germany to create caverns in salt domes for the storage of hydrogen [45] [46]. In a European comparison, the largest onshore storage volumes are located in Germany, whereas Norway and the Netherlands have considerable offshore storage potential [45], p. 134.

These German studies and pilot projects are a consequence of the so-called "Energy transition", which is outlined here in extremely broad terms for international readers due to Germany's unique approach to climate policy in this regard. Many states around the world have set out climate goals, in particular the reduction of CO2 emissions and emissions as a whole. This is the reason why primarily the high-emission, coal-fired power stations in many countries, not only in Europe, are being successively replaced by “renewable energies” in combination with base load and black start capable energy sources such as nuclear power. However, Germany has ended the use of this technology for political reasons, in accordance with a decision taken in 2011. In this step, concerns about radioactive radiation following the accident in Fukushima were accentuated in public discourse (radiation exposure from nuclear technology for the population of Germany was < 0.01 mSv/a, that from the reactor accident in Chernobyl was < 0.02 mSv/a, and that from medical applications averages 1.9 mSv/a [1]). Although the European Union considers nuclear energy to be sustainable [47] and other economies are investing in technologies that are further developed in this regard, parts of nuclear power plants are being demolished in Germany (e.g. [48]). Germany is searching more intensely for alternatives to nuclear power than is the case in other countries because base load and black start capable gas power stations in Germany are not (yet) available to a sufficient extent (and are also not carbon neutral at all). The approaches described here for the compressed air and hydrogen storage in caverns to operate power stations are examples of this.

The discussion surrounding the rapidly changing energy supply in Germany are becoming increasingly controversial, whereby the greatly increased costs for both the industry and the consumers [49] are obviously also a crucial aspect. Protection from radioactive radiation was the official reason for terminating the use of nuclear energy in Germany. If, however, according to the hypothesis put forward in this article, the caverns created as some of the alternatives to nuclear power increase the population's exposure to radioactive radiation through the transport and decay of radium/radon [50], this can only be described as highly counterproductive. The natural and civilisation-enhanced average exposure to radiation from radon of the German population is already at approximately 1.1 mSv/a anyway [1]. An increase in this value cannot be desirable, with the opposite being in the interest of public health. Construction measures to retrofit radon protection in old buildings can be expensive for owners. This kind of thing is not taken into account in the economically determined costs of the development of cavern locations [46].

This is understandable, as the hypothesis presented in this article has not yet been supported by further research, which is why the first conclusion is that further research is needed, in particular measurements above existing caverns. Secondly, the experts and decision-makers involved could learn from what is now seen as the hasty response to the Fukushima disaster and take less obvious risks into account in the frantic search for alternatives to coal and nuclear power plants. It is possible that caverns in salt domes as storage for raw materials are advisable in sparsely populated regions (such as those in parts of the USA or Russia), but not in very densely populated Germany, for reasons of health protection.

VI. Conclusion

This article presents radon readings in northwestern Lower Saxony. They are below the reference value in Germany but, at the same time, unexpectedly high for this region. Possible causes could be geological processes in the vicinity of salt domes, especially artificially created caverns and their filling with mineral oil, natural gas or compressed air. A superficial examination of other underground storage facilities supports this theory. This hypothesis is relevant because of the potential harms to health of radon exposure and the planned expansion of this kind of underground storage facilities. Further research is necessary in order to confirm or refute these hypotheses.

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This publication is published in black and white. If you are interested in a colour version, please do not hesitate to contact me. Most of the sources in this work, as well as a small part of the labelling, are written in German. The author will also be happy to help in this regard if you are interested in the subject.

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Iris M. Reuther was born in Franconia, a part of Bavaria in the south of Germany. She studied architecture at the Würzburg university of applied sciences (Germany), the University of Stuttgart (Germany) and the Royal Institute of Technology in Stockholm (Sweden). She wrote her doctoral thesis at the Graz University of Technology (Austria). In addition to two diplomas, she also holds a degree as an expert for damage to buildings from the HTWG Konstanz and a doctorate in technical sciences.

She began her career with planning tasks. After around 1.5 years, she switched to project management. She gained most of her 25-years-experience in the construction management of healthcare projects. She has been Professor of Building Construction at Jade University in Oldenburg (Germany) since the beginning of 2022. Her research interests lie in the areas of radon protection, building damage prevention and construction in existing buildings, as well as healthcare buildings and topics in the area of construction management. Her latest publications can be found at https://orcid.org/0009-0001-0537-5376 or https://www.growkudos.com/profile/iris_m._reuther.

Prof. Dr. techn. Reuther is member of the Architektenkammer Bayern (architects chamber of Bavaria), the German-Chinese Institute for Sustainable Engineering and Construction at Jade University of applied sciences and the Wissenschaftlich-Technische Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege e. V. (International Association for Science and Technology of Building Maintenance and Monuments Preservation).