AIR RADON CONCENTRATION DECREASE IN A WASTE WATER TREATMENT PLANT

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Radon-222 is a naturally occurring gas created from the decay of Radium-226. The long-term health risk of breathing radon is lung cancer. One particular place where indoor radon concentrations can exceed national guidelines is in WasteWater Treatment Plants (WWTPs) where treatment processes may contribute to ambient airborne concentrations. The aim of the paper was to study the radon concentration decrease after the application of corrective measures in a Spanish WWTP. According to first measures, air radon concentration exceeded International Commission Radiological1 Protection normative ((ICRP) recommends intervention between 400 and 1000 Bq/m3). Therefore, the wastewater treatment plant improved Mechanical forced ventilation to lower occupational exposure. This measure allowed to increase the administrative controls, since the limitation of workers access to the plant changed from 2 h/day (considering a maximum permissible dose of 20 mSv per year averaged over five years) to 7 h/day.

1. INTRODUCTION

Radon-222 is a naturally occurring gas, with intense radiation capacity and a short half-life (3.8 days), created from the decay of Radium-226. Further decay generates alpha rays, which can do extensive damage to internal organs since the radioactive particles get trapped in the lungs, and as those particles break down, they release energy. The long-term health risk of breathing radon is lung cancer. In 1986, the World Health Organization (WHO) declares the carcinogenic nature of radon, confirming the relationship with lung cancer after different global epidemiological studies (1), (2). According to the U. S. Environmental Protection Agency (3), radon is the second most important cause of lung cancer after smoking in many countries.

One particular place where indoor radon concentrations can exceed national guidelines is in WasteWater Treatment Plants (WWTPs) where treatment processes may contribute to ambient airborne concentrations. When the water containing radium is aerated or backwashed, elevated concentrations of radon are released. Therefore, WWTP operators may be at increased risk of 222Rn inhalation, resulting from water treatment processes when this gas moves from water to air. When radon enters an enclosure with little ventilation, the concentration can reach values that may represent a radiological risk.

According to work places, the International Commission Radiologica1 Protection (4) recommends intervention between 400 and 1000 Bq/m^3.

In Spain, the last regulation regarding the control of radon in workplaces was set in 2012, when the Spanish *Consejo de Seguridad Nuclear* (5) published the IS-33 (6) which stablish the concentrations measurement of radon in workplaces that might lead to a significant increase in the exposure of workers. The criteria of the Spanish regulation for the annual mean radon concentration during workday sets 600 Bq/m^3 as the reference level without intervention.

The aim of the paper is to give information about air and water radon concentration found in a Spanish WWTP after detecting high radium concentrations inside the water. It consist in an indoor treatment plant, with a 10000 m^3/day flow.

This paper presents the radon concentration values before and after the application of corrective measures.

To evaluate this problem, we used different radon measurement techniques in the water plant placed at Castellón (Spain). We assessed short-term (3 days period) and long term (2-3 months period) measures by monitoring air radon concentration using electrets and alpha spectrometry detector. We also analyzed water radon samples using different techniques.

2. OBJECTIVES AND METHODOLOGY

The main purpose of this study is to present the radon measures performed in a Spanish WWTP where workers were exposed to radon annual average concentration that exceeds the limitation level, 600 Bq/m^3. The paper also presents the methods applied to reduce this exposure and the subsequent radon concentrations decrease.

In this WWTP the two main workers spend an average of 2.5 hours a day inside the treatment plant according to the permanency registries supplied. Occasionally, two other maintenance technics work inside the plant, spending an average of 5 hours per month.

To evaluate the risk, we used passive and active detectors. According to the Spanish Nuclear Security Council (CSN, *Consejo de Seguridad Nuclear*) safety guide (7), we have used different type of measuring devices: Electrets (provided by *RadElec*) and RAD7 alpha spectrometry continuous monitoring (provided by *Durridge*).

This guide also states that the chosen points to place detectors should be representative of the jobs performed in it. The recommendation is to place a detector for each 200 m^2. Moreover, detectors must be exposed at least during three months, avoiding the summer period, obtaining in the majority of cases a conservative estimation of the annual average, which ensures an adequate level of protection of workers. According to this protocol, long term measures have been made during the months from February until April 2013 and one year later (after applying constructive and administrative correction measures), from June to September 2014.

Before placing long term detectors, short term measures were taken in the months of January and February 2013 (period of measurement 3 days) to establish a first approximation of the radon levels detected in the plant.

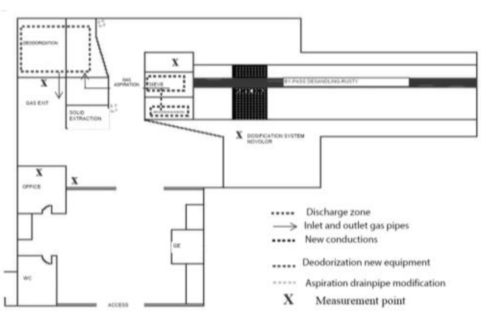

Figure 1. Sampling points at the WWTP

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Sampling points in the water treatment plant (figure 1) are representative of the jobs performed in the office and solid waste disposal room.

The office room is approximately 4x2 m^2. It is next to the pumps moat of the residual water. Detectors were placed at 50 cm from the wall of the enclosure and at a height of 1 m above the ground level.

The water treatment room is approximately 200 m^2 in which the system of solid waste disposal is placed at the entrance of the residual water. The detectors were placed on the left side of the room and at 2 m from the ground. The other sampling point was near the first step of coarse grating.

It was also considered convenient to measure the concentration of radon in the annexed building. Since the results of the sampling carried out in January showed that in this adjacent building radon levels were well below the limits of reference, following surveys carried out did not considered necessary to continue measuring radon in this place.

We collected water samples and radon activity concentration in water was measured using the E-PERM water measurement kit (8) and the H2O probe of the RAD7 device.

Measurement procedures have been validated for high and low radon concentrations. Electret measurement was validated at high concentration, 30000 Bq/m^3, at Saelices, in the area of an old uranium mine of ENUSA, near Saelices el Chico (Salamanca, Spain). Electrets were placed in a room at the ground floor where the exposure is more 20 time higher as normal background value in order to test the measurement of natural radiation under typically variations of temperature, pressure and atmospheric pressure (9).

Low concentration measures validation was also performed at the radon Chamber of the radon group of University of Cantabria (Spain). In this case, RAD7and Electrets measurement techniques were certified. Detectors were exposed to two different concentration of radon, one below 200 Bq/m^3 and the other above 1000 Bq/m^3.

2.1. Radon in air measurement

Short-term measurements were performed using Electret Passive Environmental Radon Monitor (E-PERM) devices in short term (3 day test) and long term (3 months) configuration, using S chambers and L chambers respectively.

The RAD7 continual radon measuring instrument from Durridge Company,USA (10), was used also for air radon concentration. RAD7 Detector is based on electrostatic collection of alpha-emitters with spectral analysis using a passivated Ion-implanted Planar Silicon detector.

2.2. Radon in water measurement

Radon activity concentration in water was measured using the E-PERM water measurement kit. An E-PERM is placed in a measurement jar, suspended in the air above the water collected. The lids of the measurement jars are closed and sealed to make them radon-tight. Radon reaches equilibrium between the water and air, which the E-PERM measures. At the end of the desired exposure period, the measurement jars are opened and the E-PERM is removed.

Radon activity concentration in water was also measured using the RAD H_2O which is an accessory for the RAD7 that enables to measure radon in water. A vial containing a water sample is set up in a closed air loop with the RAD7. The RAD7 pump operates automatically for five minutes to aerate the sample, distributing the radon that was in the water throughout the loop. The RAD7 waits a further five minutes while the 218Po count rate approaches equilibrium and then the radon concentration in the water is calculated.

3. RESULTS

Tables 1 and 2 show the mean air radon concentration obtained in treatment room and office respectively in 2013, before applying the correction measures. It is observed that in the treatment room the concentration exceeds in all evaluated points 2000 Bq/m^3, which must include a high intervention level control according to CSN guidelines.

Table 1. Mean air radon concentration measured in the treatment room - 2013.

Exposure begins	Exposure ends	Days	Rn-222 (Bq/m^3) Measured by electrets
21/1/2013	24/1/2013	3	2590±129
11/2/2013	14/2/2013	3	2199±110
14/2/2013	24/4/2013	69	4702±249

Table 2. Mean air radon concentration measured in the office – 2013.

Exposure begins	Exposure ends	Days	Rn-222 (Bq/m^3) Measured by electrets
21/1/2013	24/1/2013	3	2157±108
11/2/2013	14/2/2013	3	1245±62
14/2/2013	24/4/2013	69	3156±159

Assuming that long term measures register accurately concentration variations, we considered the concentration level at treatment room as 4702 Bq/m^3. For this concentration level in air and assuming an equilibrium factor of 0.4, the effective dose rate is 26.58 microSieverts per hour, which implies that it was necessary to take measures to reduce radon exposure.

To estimate the effective dose we use the Spanish regulation directives on health protection against ionizing radiation (RD 783/2001) (11). This regulation establishes workplaces conversion factor from effective dose per alpha potential exposure unit (Sv per Jhm^{-3}) of 1.4. This value comes from the ICRP65 publication: “Protection against Radon-222 at Home and at Work”. Similarly, the conversion factor for exposure to radon daughter’s $2.22\cdot10^{-6}$ mJhm^{-3} per Bqhm^{-3} (considering an equilibrium factor 0.4) comes also from the ICRP 65.

It must be noted that obtained results in the adjoining outbuildings to the WWTP, around 60 Bq/m^3 are clearly below the reference levels, so tables 1 and 2 show only the results obtained in water treatment plant facilities.

According to these measures, the wastewater treatment plant made the following actions to lower occupational exposure to airborne radon. Since the most important factor in lowering radon concentrations was ventilation, mechanical forced ventilation was improved in the treatment plant, installing a new extractor to renewing air 10 times per hour.

Moreover, administrative controls were also introduced, and it was limited the workers access to the plant to 2 h/day (considering a maximum permissible dose of 20 mSv per year averaged over five years). Since gamma background dose rate inside the treatment plant was around 0.25 µSv/h, triple of outside values, workers began to wear TLD dosimeters.

Table 3 presents the values obtained from June to September 2014.

Table 3. Mean air radon concentration measured in the WWTP -2014.

Sampling location	Days	Rn-222 (Bq/m^3) Measured by electrets	Rn-222 (Bq/m^3) Measured by rad7
Office	3	466±25	-
Treatment room	3	677±34	614±8
Office	Week	-	466±4
Office	3 months	692±40	-
Treatment room	3 months	625±37	-

Comparing values measured in 2014, it can be seen that radon concentration has decreased more than 50%, reaching the low reference level (between 600-1000 Bq/m^3) according to CSN guidelines, which implies that workers access to the plant has been increased to 7 h/day.

Water treated in this WWTP comes from a marsh located at the Mediterranean coast, on the North of the Comunidad Valenciana. According to a previous study by the University of Barcelona (12), the values of radon concentration in water range from 100 to 500 Bq/L depending on the sampling point.

Table 4. Water radon concentration

Collected and analyzed WATER samples	Rn-222 (Bq/L) Measured by electrets	Rn-222 (Bq/L) Measured by RAD7
Outlet water 26/03/2013	29±1.5	-
Outlet water 24/4/2013	25± 1.3	-
Outlet water 24/3/2014	16± 0.9	-
Outlet water 27/03/2014	25± 1.3	24.2±1.9
Outlet water 3/06/2014	29±1.4	-
Inlet water 3/06/2014	58±2.9	-
Inlet water 6/06/2014	39±2.1	37.4±2.4
Inlet water 10/09/2014	23± 1.3	25.1±2.2

With results obtained in this work, we can conclude that radon levels decreases during its transport from the marsh to the treatment plant where the values are below 100 Bq/L. Table 4 presents the value of radon concentration in water measures at both years.

4. CONCLUSIONS

Because airborne 222Rn concentrations in water plants can reach levels considered unsafe for workers, it would be prudent to monitor airborne 222Rn concentrations in water plants which aerate water as part of their treatment process. If operators are exposed to higher levels of radon, or are exposed for longer periods of time, then some operators may accumulate enough exposure to exceed the EPA guidelines.

The concentration of radon measured in the WWTP studied was above the 400 Bq/m^3 annual average guideline suggested by ICRP. Administrative controls and construction improvements (air extractor) were carried out, reducing radon concentrations and maintaining within permissible radon concentrations the WWTP air.

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