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SILOS 1 & 2 REMOVAL ACTION BENTONITE EFFECTIVENESS ENVIRONMENTAL MONITORING PLAN

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LETTER

R-008-106.7

Department of Energy
Fernald Environmental Management Project
P.O. Box 398705
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APR 16 1992

DOE-1382-92

Mr. James A. Saric, Remedial Project Director
U. S. Environmental Protection Agency
Region V - 5HRE-8J
77 W. Jackson Boulevard
Chicago, Illinois 60604-3590

Mr. Graham E. Mitchell, Project Manager
Ohio Environmental Protection Agency
40 South Main Street
Dayton, Ohio 45402-2086

Dear Mr. Saric and Mr. Mitchell:

SILOS 1 & 2 REMOVAL ACTION BENTONITE EFFECTIVENESS ENVIRONMENTAL MONITORING PLAN

Enclosed for your review and approval is the subject document which has been revised to reflect all United States Environmental Protection Agency (U.S. EPA) comments received on March 31, 1992. The Comment Response Document, as previously transmitted, is also enclosed.

As you are aware, data is being input into the Model this month for transmittal of the initial results in the April 1992 Consent Agreement Report.

If you or your staff have any additional questions or comments, please contact Randi Allen at FTS-774-6158 or 513-738-6158.

Sincerely,

Jack R. Craig
Fernald Remedial Action
Project Manager

FN:Allen

Enclosures: As Stated

Recycled and Recyclable

cc w/encs.:

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Silos 1 and 2 Removal Action

Bentonite Effectiveness [redacted]

Environmental Monitoring Plan

April 15, 1992

Continuous (i.e., real time) and integrated (i.e., passive) sampling for ^{222}Rn is being performed as part of the routine environmental monitoring program at the Fernald Environmental Management Project (FEMP). The recent removal action involving application of a bentonite sealant layer to the K-65 silos is expected to produce a reduction in the quantity of ^{222}Rn being emitted from the silos. Continuous measurements of ^{222}Rn in the head space of the K-65 silos will be utilized with a Gaussian plume model computer program and site specific meteorological data to determine what contribution residual radon emissions from the K-65 silos make to the offsite background radon concentration.

One of the objectives of the environmental ^{222}Rn monitoring and analysis at the FEMP is to determine whether ^{222}Rn emitted from the K-65 silos following the bentonite sealant application has been reduced to a level such that its contribution to offsite background is less than 0.015 pCi/l at the location of the maximally exposed individual at a non-FEMP location. Because the measured annual average offsite environmental radon background concentration is 0.5 ± 0.1 pCi/l, contributions to the radon background concentration equal to 0.015 pCi/l can be determined only by modeling since monitoring techniques are not sufficiently precise to reliably detect such a small change.

The Gaussian plume model computer code adopted by FEMP can predict what contribution to the offsite radon background is being produced from radon emitted by the K-65 silos. The flux of radon ($pCi/M^2/sec$) which is emitted from the silo dome by mechanisms of diffusion and air exchange (ventilation) will be used as the source term for the Gaussian plume model. This flux will be calculated from the measured concentration of radon (pCi/M^3) in the dome headspace.

Two pathways for emissions of ^{222}Rn from the silos are considered: (1) diffusion of ^{222}Rn in the K-65 silo air through the concrete dome and polyurethane foam and (2) free air exchange between the silo air and the surrounding air (ventilation).

Diffusion Releases

The calculations by Borak (1985) of diffusion releases of ^{222}Rn were based on one dimensional steady-state diffusion equations obtained from an National Bureau of Standards (NBS) summary technical report (Colle' et al. 1981).

From the concentration of ^{222}Rn in the silo air, the flux of ^{222}Rn diffusion through the concrete dome can be calculated by:

$$J = \frac{E_c \lambda_{Rn} l_c C_a}{\sinh\left(\frac{L}{l_c}\right)}$$

Where:

J_c = ^{222}Rn flux from the concrete dome surfaces to the foam (pCi/M²/sec, or similar units),
E_c = total porosity of the dome concrete,
l_c = diffusion length of ^{222}Rn in the dome concrete,
L = thickness of the dome concrete,
λ_{Rn} = decay constant of ^{222}Rn - (2.1×10^{-6} s^{-1})[1],
C_a = concentration of ^{222}Rn in the silo air,

The diffusion release estimate will include a Monte Carlo simulation, using a computer program, with a range of inputs as defined in the Fernald Dosimetry Reconstruction Project (FDRP) for the parameters listed below:

Parameter	Range	Distribution	Source
Diffusion Length of Concrete (l_c)	6 cm to 23 cm	Uniform	FDRP
Porosity of Concrete (E_c)	0.05 to 0.265	Uniform	FDRP
Silo Dome Thickness (L)	3 in to 4 in	Uniform	FDRP
Concentration of Radon in headspace of Silo (C_a)	Using mean & standard deviation	Normal Distribution	To be Measured

There is a foam and polyurethane coating over the surface of the concrete dome on each silo. This layer is an effective radon barrier based on the laboratory measured diffusion coefficient of 4×10^{-6} cm^2 - s^{-1} (TIM-8700/1). This foam layer will further attenuate the radon flux before the radon is emitted to the atmosphere. This attenuation is determined as follows:

[1]The decay constant of radon is assumed to have no uncertainty.

[redacted]

$$J = J_c \exp\left(\frac{-L_f}{\sqrt{D_f/\lambda_{Rn}}}\right)$$

Where:

J = ^{222}Rn flux emitted to the surrounding air (pCi/m^2-s)

Jc = ^{222}Rn flux emitted from concrete surface of the dome into the foam

L_f = thickness of the foam (10 cm)

D_f = diffusion coefficient for the foam (4×10^{-6} cm^2/s)

The total release rate (Q_{diff}) is then the product of the ^{222}Rn flux and the surface area of the dome.

$$Q_{diff} = JA \qquad (1)$$

Where:

A = the area of the dome.

Free Air Exchange (Ventilation)

Ventilation of radon from the silo is governed by the physics associated with the ideal gas law and, as such, is dependent upon the temperature and pressure changes of the gases in the silo headspace as a result in the changes in the ambient atmosphere. The rigid polyurethane foam coating, the urethane coating, and the sealing of the silo penetrations should significantly reduce the possibility of any wind induced releases of silo air to the surrounding environment. The release of silo air due to wind effects would result in a corresponding pressure change. The use of the ideal gas law, with the inclusion of temperature and pressure data would account for any significant releases as a result of meteorological conditions including wind induced effects.

The calculation of emissions of ^{222}Rn due to ventilation from the silos is, therefore, based on the expansion of the silo gases due to changes in atmospheric conditions. The ventilation of silo gases is determined from the ideal gas law using temperature and pressure data collected.

$$PV = nRT$$

Where:

P = pressure of the gases within the silo,
V = volume of the silo headspace,
n = number of moles of the gases,
R = ideal gas constant, with appropriate units, and
T = temperature, in units of an absolute scale (K or °R).

The silo gases' internal temperature and pressure has been collected and continues to be collected. This data is used to determine the release of radon due to the ventilation of silo gases.

For air exchange emissions, the assumption is made that the ^{222}Rn concentration in outside air is negligible compared to the silo concentration so that outside air does not provide a source of ^{222}Rn to the silo air. The ventilation of radon to the atmosphere is assumed to be small compared to the production of radon gases, thus the concentration of radon in the silos is assumed to be a constant which does not deviate from equilibrium. With these assumptions, the basic equation describing the rate of change in the silo air ^{222}Rn concentration can be written (NCRP 1989):

$$\frac{dC_a}{dt} = \frac{P_{Rn}}{V_0} - C_a \lambda_{eff}$$

Where:

C_a = concentration of $_{222}Rn$ in the silo air,
P_{Rn} = the constrained (by the presence of the silo) rate of release of $_{222}Rn$ into the silo air (production term) from the K-65 source material (activity per time),
V_0 = volume of the air space in the silo above the K-65 material,
λ_{eff} = the effective removal rate of $_{222}Rn$ = $\lambda_{Eff} = \lambda_{Rn} + \lambda_v$,
λ_{Rn} = decay constant of ^{222}Rn - (2.1×10^{-6} s^{-1}),
λ_v = The ventilation rate due to the daily atmospheric changes λ_v is the fraction of the silo air exhaled due to the atmospheric changes per some unit of time period, with the units of air changes per time. Therefore:

$$\lambda_v = \Delta n / n_0$$

where we define:

Δn = the change of number of moles of gas in silo headspace,
n_0 = the initial number of moles of gas in silo headspace

Based on the assumption of equilibrium of the radon in the headspace the following relationship is obtained:

$$P_{Rn} = C_a \lambda_{eff} V_0$$

Because the silo air space is a single compartment volume, it is assumed that the contained air will be well mixed. Thus, the air exchange release rate is simply the activity in the silo air space times the silo ventilation rate:

$$Q_{excn} = C_a \lambda_v V_0 \qquad (2)$$

[redacted]

where:

Q_{exch} = the rate of release of ^{222}Rn from the silo through air exchange.

then, using equations (1) and (2):

$$Q_{total} = Q_{diff} + Q_{exch}$$

The radon release rate (Q_{total}) from the diffusion process and air exchange process is then used as the source term input into the ISC model program. Both mechanisms of diffusion and air exchange (ventilation) will be considered in converting radon concentrations in the dome headspace to the radon release rate.

Periodic analysis of the predicted and measured offsite radon background concentration will provide information to determine the gross effectiveness of the model. Data collected from the silo headspace radon monitor will determine the relative integrity of the bentonite unrelated to changes in meteorological parameters.

The Gaussian plume model computer code, ISC version #3.4, December 1988, is currently being used to calculate what contribution ^{222}Rn emitted from the K-65 silos makes to the offsite background radon concentration. ISC is composed of two programs designed to predict the atmospheric dispersion of air emissions: ISC Short Term for predicting concentration over 1, 2, . . ., 24 hour periods and ISC Long Term for calculating quarterly, seasonal, or annual concentration. The radon monitoring data being collected at FEMP is best analyzed using ISC Long Term. Although a new version of ISC Short Term is currently available for testing, ISC Short Term will not be implemented at this time for these analyses.

Site-specific meteorological parameters and the calculated ^{222}Rn release rates are used as input to the ISC Gaussian plume model computer code to predict the radon concentration at any predetermined location relative to the K-65 silos as the source of ^{222}Rn. Predictions of the Gaussian plume model will be compared to results of actual ^{222}Rn monitoring data, although the contribution of ^{222}Rn from the K-65 silo to offsite ^{222}Rn background is expected to be very small and may not be measurable at the site boundary unless there is an unexpected release of radon due to a failure of the bentonite sealant.

The annual average offsite ^{222}Rn background is approximately 0.5 pCi/l ± 0.1 pCi/l. Therefore, it is not possible to confirm by measurements whether ^{222}Rn emitted from the K-65 silos increases the offsite radon background in excess of 0.015 pCi/l for the maximally exposed individual. However, the ISC computer model calculations, which use as a source term the ^{222}Rn concentration actually measured in the headspace of the K-65 silos, will predict how much of the offsite ^{222}Rn background is due to ^{222}Rn emissions from the K-65 silos.

Real-time ^{222}Rn monitoring data, including measurement of ^{222}Rn in the K-65 silo headspace, will be generated and recorded hourly. Permanent files of the hourly data are available on computer discs. Data from integrated radon measurements are available on a quarterly basis since samples are collected

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for a three month period. For a fixed location, variations in the radon concentration are due, primarily, to changes in meteorological parameters which impact the amount of mixing and dilution experienced by the ^{222}Rn emitted from the K-65 silos. Likewise, periodic changes in ^{222}Rn flux from the K-65 silos are due to diurnal changes in certain meteorological parameters, such as, barometric pressure, wind speed, temperature and solar radiation.

Evaluation of the predicted contribution to offsite radon background, using the ISC Gaussian plume model computer code with values of the radon release rate calculated from actual headspace concentration measurements in the K-65 silos and site-specific meteorological parameters, will be accomplished by comparing the model's predictions to the actual measured results of offsite radon background using both continuous and integrated samplers. This evaluation will be performed to determine compliance with the 0.015 pCi/l limit and to provide a gross independent assessment of the model accuracy.

The Gaussian plume computer model will use hourly measurements of the radon concentration in the headspace of the K-65 silos along with site-specific meteorological parameters to predict radon concentration at any location. Sets of data will be generated to produce a weekly average concentration for all offsite monitoring locations. Analysis of the average weekly predicted radon background concentration and the actual measured average values will be reported. Although field monitoring techniques do not have the precision to detect a variation in the offsite background ^{222}Rn concentration of 0.015 pCi/l, the computer model, which uses measurements of ^{222}Rn in the K-65 silo dome headspace to predict the actual contribution to offsite ^{222}Rn background, is adequately precise to calculate these values.

REFERENCES

Borak, T. B. Calculation of radon emission, dispersion and dosimetry from K-65 Storage Tanks at the Feed Materials Production Center. (1985) in: History of FMPC radionuclide discharges. Cincinnati, OH: Westinghouse Materials Company of Ohio; FMPC-2082; 1987

Colle', R; Rubin, R. J.; Knab, L. I.; Hutchinson, J. M. R. Radon transport through and exhalation from building materials: a review and assessment. Washington, DC: National Bureau of Standards, U.S. Department of Commerce; NBS Technical Note 1139; 1981

NCRP (National Council on Radiation Protection and Measurements). Control of radon in houses. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 103; 1989

Radiological Assessments Corporation, The Fernald Dosimetry Reconstruction Project, Tasks 2 and 3: Radionuclide Source Terms and Uncertainties - 1960 - 1962 (Draft), Submitted to the Centers for Disease Control in Partial Fulfillment of Contract No. 200-90-0803, December, 1991

Nielson, K. K., Rogers, V. C., Radon Diffusion Coefficient Measurements of Polyurethane Materials and Radon Attenuation Calculation for K-65 Silos, Technical Information Memorandum, TIM-8700/1; October 13, 1987

Response to U.S. EPA Comments
On
Revised Silos 1 and 2 Removal Action
Bentonite Effectiveness Environmental
Monitoring Plan
Dated March 13, 1992

General Comments

1. U.S EPA Comment: Diffusion release calculations follow the method of Borak and Colle' while the free air exchange calculations follow the method of the Fernald Dosimetry Reconstruction Project (FDRP). One major observation is that while the latter uses a range for silo parameters, this monitoring plan selects a single value (from the FDRP range) but without justification for the selection. Either the specific parameter used should be justified or the most conservative parameter from each range should be used.

   Response: The diffusion release estimate will include a Monte Carlo simulation, using a computer program, with a range of inputs as defined in the Fernald Dosimetry Reconstruction Project (FDRP) for the parameters listed below:

Parameter	Range	Distribution	Source
Diffusion Length of Concrete (l_c)	6 cm to 23 cm	Uniform	FDRP
Porosity of Concrete (E_c)	0.05 to 0.265	Uniform	FDRP
Silo Dome Thickness (L)	3 in to 4 in	Uniform	FDRP
Concentration of Radon in headspace of Silo (C_a)	Using mean & standard deviation	Normal Distribution	To be Measured

   The decay constant of radon is assumed to have no uncertainty.

   The thickness of the foam cover was obtained from the Project Completion Report (Grumski and Shanks 1988) and the diffusion coefficient of the foam was obtained from the Technical Information Memorandum "Radon Diffusion Coefficient Measurements of Polyurethane Materials and Radon Attenuation Calculation for K-65 Silos".

Response to U.S. EPA Comments
On
Revised Silos 1 and 2 Removal Action
Bentonite Effectiveness Environmental
Monitoring Plan

2. U.S. EPA Comment: This monitoring plan includes temperature driven ventilation while the FDRP includes both temperature and wind driven ventilation. Justification should be given as to why wind driven effects are not also included in this plan, especially in terms of consistency.

Response: The period of assessment is different for this estimate than the FDRP. The latest period estimated in the FDRP is 1987. In 1979, the openings in the silo domes, including the gooseneck pipe and other penetrations were sealed, with gaskets installed to prevent radon emissions. (Boback 1980; Grumski 1987 as referenced in the FDRP). In December of 1987, a rigid polyurethane foam layer and urethane coating were applied to the exterior of the silo dome surfaces to weatherproof the silos (Grumski and Shanks 1988; Shanks and Vogel 1988 as referenced in the FDRP).

The release estimates in the FDRP for the period 1980 - 1987 are based solely on the data available for the temperature effects. The wind effects were "arbitrarily assumed" to range from zero to the equivalent of the temperature related releases following a uniform distribution.

The rigid polyurethane foam coating, the urethane coating, and the sealing of the silo penetrations should significantly reduce the possibility of any wind induced releases of silo air to the surrounding environment. The release of silo air due to wind effects would result in a corresponding pressure change. The use of the ideal gas law, with the inclusion of temperature and pressure data, currently being measured, would account for any significant releases as a result of meteorological conditions including wind induced effects.

<u>Specific Comments</u>

1. U.S EPA Comment: It would be helpful to number the equations. Also equations which are tucked into paragraphs, but which are major culminating equations, should be separated from the text like the other equations. Specifically, this is referring to Q_{diff} on page 2 and Q_{total} on page 4.

Response: Will modify.

2. U.S. EPA Comment: For the equation PV=nRT on page 3 the definitions can be improved. Specifically, (1) state units

[redacted]

on pressure, volume, and temperature, (2) decide whether the calculation will be in °K or °R, and (3) state whether the volume is of the silo or just the headspace.

Response:

(1) Appropriate and consistent units will be utilized in the calculations.

(2) Appropriate and consistent units will be utilized in the calcultions.

(3) V = Volume of the silo headspace.

3. U.S. EPA Comment: For the second equation on page 3, clarify the definitions also.

Response: λ_v will be clarified.

[redacted]