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DISAPPROVAL OF THE BENTONITE EFFECTIVENESS EVALUATION OU4

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

FEB 12 1993

REPLY TO THE ATTENTION OF:

HRE-8J

Mr. Jack R. Craig
United States Department of Energy
Feed Materials Production Center
P.O. Box 398705
Cincinnati, Ohio 45239-8705

RE: Disapproval of the Bentonite Effectiveness Evaluation for OU 4

Dear Mr. Craig:

The United States Environmental Protection Agency (U.S. EPA) has completed its review of the Bentonite Effectiveness Evaluation for Operable Unit 4 at the Fernald Environmental Management Project. The report presents data which demonstrates that the K-65 Silo Removal Action (RA) has effectively reduced radon concentrations within the silos and in ambient air. However, the United States Department of Energy (U.S. DOE) concludes that it is not possible to demonstrate that the RA performance goal (0.015 picocuries per liter of radon concentration above background at the nearest residence) is being achieved. U.S. DOE also has proposed a monitoring approach to evaluate the continuing effectiveness of the K-65 Silo RA.

Although U.S. DOE may be correct in its conclusion, regarding the inability to demonstrate compliance with the RA goal, U.S. EPA has concerns regarding the statistical analysis used to support such a conclusion. Also U.S. EPA has several concerns regarding the adequacy of the proposed monitoring approach to evaluate continuing bentonite effectiveness.

Therefore, U.S. EPA disapproves the Bentonite Effectiveness Report pending incorporation of the attached comments.

(also partial action response to doe-C65C-93 (5623)

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Please contact me at (312) 886-0992 if you have any questions.

Sincerely,

James A. Saric
Remedial Project Manager

Enclosure

cc: Graham Mitchell, OEPA-SWDO
Pat Whitfield, U.S. DOE-HDQ
Nick Kaufman, FERMCO
Jim Theising, FERMCO
Paul Clay, FERMCO

Comments on the
"K-65 Silo Removal Action - Bentonite Effectiveness Evaluation"

U.S. EPA Region 5 Radiation Section

January 1993

General Comments:

1) The objective of the K-65 silo removal action was to reduce radon-222 emissions to a level as low as reasonably achievable (ALARA) and the goal is an ambient radon-222 level of no greater than that specified in the approved EE/CA work plan. The methodology for estimating radon-222 concentration reductions resulting from completion of the approved removal action was proposed by U.S. DOE. It would then seem that the purpose of this document would be to evaluate the performance of the removal action and determine whether or not additional measures prior to completion of the final remedial action are needed based on a number of factors, including the timeframe until final remediation and review of data from the monitoring program approved as part of the work plan. Unless there is to be a subsequent document that provides an evaluation of the performance of the K-65 silo removal action, this document fails to meet the aforementioned criteria.

It is stated on page ES-2 of the Executive Summary that "The objective of this study was to determine the effectiveness of the bentonite layer in reducing the radon levels in the headspace as well as to the nearest resident." This document states the reduction of radon-222 concentration in the silo 1 & 2 headspace as a result of the removal action, but does not clearly state the effectiveness of the bentonite layer in reducing the radon levels to the nearest resident. This document states instead that the determination of whether the 0.015 pCi/g performance goal (radon contribution to the nearest resident) has been achieved can not be established statistically or mathematically within an appropriate confidence level.

This document, on page 6-12 of section 6.3, mentions that a procedure for sampling the silo headspace along with a method for determining bentonite effectiveness has been developed and is currently in the review and approval stage. The description of this procedure suggests that it would be adequate for assessing the gradual degradation of the bentonite as to whether the bentonite is maintaining a reduced radon headspace concentration, but it is clear that this procedure does not assess or confirm the initial performance of the bentonite for the purpose of evaluating the performance of the removal action.

2) The raw data of all radon concentration levels, both from the Pylon and Terradex measurements at all radon air monitoring locations including background measurement locations, should be included in the appendix, clearly indicating radon concentration levels over time to allow easy comparisons between pre-bentonite and post-bentonite results. Separating the radon concentration data from all of the statistical evaluations of the data is rather difficult in the draft document.

Specific Comments:

Section #: Statistical Glossary Code: C
Original Comment #: 1
Comment: The Statistical Glossary should be complete by including all statistical terms discussed in this document, including such terms as "confidence interval" and "confidence level." Definitions of statistical terms should always include discussion of the significance of the term and its result.

Section #: Executive Summary Page #: ES-2 Para. #: 3 Code: C
Original Comment #: 2
Comment: The text states that "The effectiveness was performed in accordance with the Silo 1 and 2 Removal Action Work Plan." Please explain how effectiveness can be "performed."

Section #: Executive Summary Page #: ES-4 Para. #: 3 Code: C
Original Comment #: 3
Comment: The fifth sentence of this paragraph states that "There were several cases where the variation over a three month period at the same location had a range of 0.5 pCi/l or greater." Please state ranges in absolute numbers rather than using vague terms as "greater."

Section #: Executive Summary Page #: ES-5 Para. #: 3 Code: C
Original Comment #: 4
Comment: In this paragraph, the statistical terms "p" and "CI" are used without prior explanation, which makes the text difficult to understand for those who are not statisticians. Please try to avoid this, especially in the Executive Summary and the final summary sections.

Section #: 2.1.1 Page #: 2-1 Para. #: 3 Code: C
Original Comment #: 5
Comment: Concerning the Pylon AB-5, please explain what sensitivity is with respect to the Pylon AB-5. Though the FEMP currently uses the Pylon Model 110 with a 1.0 pCi/l sensitivity, please explain why "Pylon kettles" were not used to reduce the instrument sensitivity to 0.1 pCi/l. It would seem that using a more sensitive instrument would yield better statistical results for evaluating the bentonite effectiveness.

Section #: 2.1.1 Page #: 2-2 Para. #: 2 Code: C
Original Comment #: 6
Comment: This paragraph states that the Pylon detectors have not been calibrated in the range of environmental radon concentrations; please explain why this is. It is believed that the DOE Grand Junction Colorado Project Office and/or the DOE Environmental Measurement Laboratory in New York can provide such environmental radon calibration services.

Section #: 2.1.2 Page #: 2-7 Code: M
Original Comment #: 7
Comment: Please explain why there is not a section that discusses Terradex monitoring data at the exclusion fence line, and also compares the Terradex results to Pylon monitoring data at the exclusion fence line. Such seems to have been done in section 2.1.2.3 for fence line data. Section 5.5 states that it can be inferred that the silos do have an influence on the observed radon concentrations at the exclusion fence line inward. With this being the case, a more detailed discussion of radon data at the exclusion fence line inward seems appropriate.

Section #: 2.2.1.1 Page #: 2-34 Para. #: 1 Code: C
Original Comment #: 8
Comment: It is stated that "Using Equations 2-4 and 2-5 the radon flux from diffusion is 2.6×10^{-4} pCi/l in Silo 1 and 1.27×10^{-3} pCi/l in Silo 2." Equations 2-4 and 2-5 are supposed to produce radon flux results expressed in $pCi/m^2/s$; please correct for the proper units and provide all the values (such as thickness of the dome concrete) and assumptions used to produce the stated radon flux rate for each silo. Further, it should be assured that all equations presented have units that balance given the variable and their units used. Of concern with equations 2-4 and 2-5 is that the variables D_f, l_c, and C_a use cm^2 or liters in their units while the results of the equations use m_2 in their units.

Section #: 2.2.1.2 Page #: 2-35 Para. #: 3 Code: C
Original Comment #: 9
Comment: It is stated that "The ventilation of radon to the atmosphere is assumed to be small compared to the production of radon gas; therefore, the concentration of radon in the silos (headspace) is assumed to be constant and does not deviate from equilibrium. Please explain how this assumption can be made when the daily average radon concentration in the headspace of Silo 1 varied from approximately 10,000 to 100,000 pCi/l and the daily average radon concentration in the headspace of Silo 2 varied from approximately 140,000 to 320,000 pCi/l (Figures 3-1 and 3-2).

Section #: 2.2.1.2 Page #: 2-35 → 2-39 Code: M
Original Comment #: 10
Comment: This section is not clear as to how the 1% per 15 minute ventilation rate was derived and does not clearly state the rate of radon flux through air exchange in $pCi/m^2/s$ (the value "J") for each silo. This section, and any other section discussing the calculation of values, should be rewritten to clearly indicate how these values are calculated. This should include but not be limited to clearly stating all equations and values used in computations; and having descriptive text which uses consistent terms and indicates both the value terms and their variable (in parentheses) used in an equation. For example, on the top of page 2-39 the "ventilation flux" for Silo 1 and Silo 2 is stated; it is not clear which equation was used to calculate these values. The value term (such as "radon flux from the silo through air exchange") should be stated with its variable used in an equation (such as J) in parentheses for clarity. As an example in discussing radon

flux, the following format would be appropriate: "...the radon flux from Silo 1 through air exchange (J) is 6993 pCi/m^2/s."

Section #: 2.2.2 Page #: 2-39 Para. #: 3 Code: C
Original Comment #: 11
Comment: Please explain how the accuracy of the ideal gas law, said to be within 1 percent (of what?) which sounds fairly accurate, can be compared to the 1 percent total volume change (of the headspace) to conclude that the ideal gas law is not appropriate to use.

Section #: 4.3 Page #: 4-14 Para. #: 2 Code: C
Original Comment #: 12
Comment: Please clarify whether the headspace data follows a normal distribution. This would indicate whether it is proper to assume a normal distribution in the construction of the prediction interval.

Section #: 6.3 Page #: 6-12 Para. #: 3 Code: M
Original Comment #: 13
Comment: It would seem appropriate to perform only continuous monitoring from the headspace of each silo rather than taking grab samples since the continuous monitoring apparatus is already in place. The short measurement periods of the grab samples taken may not be representative of the average weekly concentrations. Further, grab sample decay product measurements are much more susceptible to sampling error than radon gas measurements due to the highly reactive nature of the radon decay products.

Section #: 6.4 Page #: 6-14 Para. #: 3 Code: C
Original Comment #: 14
Comment: It is stated that compliance with 40 CFR 192, requiring no greater than a 0.5 pCi/l contribution at the edge of the waste unit, can be established and verified. Also stated is that the site boundary is considered the edge of the waste unit; it would seem proper to assume that the exclusion fence (the K-65 silos area perimeter as indicated in Figure 2-2 on page 2-5) would denote the edges of the waste unit.

DRAFT K-65 SILO REMOVAL ACTION - BENTONITE EFFECTIVENESS EVALUATION (DECEMBER 17, 1992)

GENERAL TECHNICAL COMMENTS

1. DOE's Draft K-65 Silo Removal Action -- Bentonite Effectiveness Evaluation Report suffers from several general deficiencies. The deficiencies make the report difficult to follow and prevent independent verification of the statistical analyses. The general deficiencies should be addressed in a revised report and include the following:

   - The report is poorly organized and difficult to follow. Conclusions are sometimes presented on one section when the statistical analyses and results on which the conclusions are based do not appear until subsequent sections. Some information in the report is repeated for no apparent reason. Specific Comments 14, 18, 23, 56, and 61 present examples of these deficiencies.

   - The report contains almost no information concerning quality assurance of the radon measurements that are the basis for all of the report's statistical analyses and conclusions. See Specific Comments 9, 10, 32, 33, 51, and 72.

   - The report often does not present a complete or adequate description of the statistical methods used. In addition, in most cases, the report does not present sufficient information (raw data or summary statistics) to verify the results of statistical analyses. See Specific Comments 10, 14, 20, 25, 31, 56, and 67 for examples of these problems.

   - The report does not clearly describe the methods used to identify "outlying" data that DOE excludes from statistical analyses. In addition, the report may not be consistent in its definition of outlying data; data included in some analyses appear to be excluded from other analyses. Specific Comments 10, 13, 19, 32, 33, and 51 are related to this problem.

   - In several cases, statistical analyses presented in the report are not appropriate for the hypotheses being evaluated. See Specific Comments 24, 25, and 56.

   - Some conclusions presented in the report appear to directly contradict the results of statistical analyses. Specific Comments 22, 34, and 55 provide examples of these contradictions.

2. Data presented and analyzed in the report clearly show that the addition of bentonite to the K-65 silos has effectively reduced radon concentrations within the silos and in ambient air. Current average radon concentrations in Silos 1 and 2 are approximately 45,000 and 220,000 pCi/L, respectively; before the addition of bentonite, radon concentrations in Silos 1 and 2 were 25,000,000 and 30,000,000 pCi/L, respectively (Page 3-1). Post-bentonite radon concentrations at four silo exclusion fence monitors and at one of three FEMP fence line monitors (AMS 5) showed statistically significant reductions compared to pre-bentonite concentrations (Table 3-3).

3. Even though the addition of bentonite to the silos has reduced radon concentrations, DOE concludes that "determination of whether the 0.015 [pCi/L removal action performance] goal has been achieved can not be established statistically or mathematically within an appropriate confidence level." This conclusion appears to be correct and is supported by the following information and analyses presented in the report:

   - DOE cannot verify that the removal action goal is being met by direct measurement of radon concentrations. Currently available instruments, such as the Pylon AB-5 portable radiation monitors used at FEMP, are not sensitive enough to detect radon concentrations as low as 0.015 pCi/L. The lowest sensitivity that can be achieved with these monitors is approximately 0.1 pCi/L, almost seven times the removal action goal.

   - The original model used to evaluate attainment of the removal action goal cannot accurately predict ambient radon concentrations. This model has two components, a flux component and a dispersion component. The flux component models radon releases through the concrete domes of the K-65 silos, given the radon concentrations in the silo headspace. The dispersion component calculates air concentrations of radon as the radon released from the domes is transported downwind. Neither model component has been specifically calibrated or verified for site specific conditions at FEMP. However, even if this was done, the model components would still be subject to large uncertainties. Thus, the model cannot be used to verify attainment of the removal action goal with any degree of confidence.

- Statistical models developed by DOE in Section 4.1.3 of the report are also not sufficiently accurate to verify attainment of the removal action goal. DOE presents several statistical models (linear regression equations) that predict fence line radon concentrations using (1) post-bentonite radon concentrations in silo headspace and (2) meteorological parameters as independent variables. Although the models are all statistically significant, the relationship between fence line radon concentrations and silo concentrations is not strong. In addition, the confidence intervals around predicted fence line concentrations is large. For example, Page J-2 in Attachment J shows model predictions for fence line location AMS 5 when the temperature is 15 °C and the wind speed is 1 meter per second. Under these conditions, the model predicts that a nine-fold increase in silo headspace radon concentration (from 50,000 to 450,000 pCi/L) will result in a relatively small change in radon concentrations at location AMS 5 (from 1.05 to 1.50 pCi/L). Under the same conditions, the model predicts a fence line concentration of approximately 1.35 pCi/L when the silo concentration is 250,000 pCi/L. However, the lower and upper confidence limits for this prediction are approximately 0.50 and 3.55 pCi/L, respectively.

  It is not clear why DOE did not consider monitoring stations along the exclusion fence (NW, SW, NE, SE) in the statistical modeling analysis presented in Section 4.1.3. Based on data presented in Sections 2.0 and 3.0, pre-bentonite and post-bentonite radon measurements at these stations were clearly different. Furthermore, the data are less subject to random fluctuations and the influence of sources other than the silos. Therefore, models based on data from these stations are much more likely to provide a reasonable estimate of the effects of silo headspace concentrations on ambient radon levels.

4. In Section 6.3 of the report, DOE proposes a revised radon monitoring program for FEMP. This program is based on information presented in Section 4.2 and DOE's conclusion that "the radon concentration in the headspace of both silos could reach 4×10^6 pCi/L and the contribution to the nearest resident would be less than 0.015 pCi/L above background." DOE's proposed monitoring program includes weekly grab samples from the silo headspace but does not appear to include any sampling of radon concentrations in ambient air. The proposed monitoring approach should be rejected for the following reasons:

- DOE's underlying rationale for the revised monitoring approach is not presented in sufficient detail in Section 4.2 of the report. In particular it is not clear how DOE determined that "the radon concentration in the headspace of both silos could reach 4 x 10^6 pCi/L and the contribution to the nearest resident would be less than 0.015 pCi/L above background." No information is presented to support this claim.

- DOE's stated relationship between silo radon concentrations and the 0.015 pCi/L removal action goal may be based on the combined radon flux and dispersion model described in General Comment 3. If this is the case, there is little reason to believe (1) that the relationship is accurate or (2) that the relationship can provide any reasonable assurance that the removal action goal is being achieved. Concerning the flux component of the model, DOE states on Page 2-43 that "the greatest source of uncertainty in the models used to date would be in accurately representing the release of radon from the silos." DOE further states that "release mechanisms . . . are not fully understood" and that "any attempts to identify the processes and quantify the results through studies on the silos are not likely to be successful." Concerning the dispersion component of the model, DOE states on Page 4-12 that there is "limited confidence in any estimate predicted" by the model.

- DOE's proposed monitoring approach does not appear to be adequate for evaluating the continuing effectiveness of the K-65 silo removal action. The low frequency of silo measurements (weekly grab samples) and the absence of ambient radon measurements are both of concern.

SPECIFIC TECHNICAL COMMENTS

1. Page ES-1, Paragraph 1. The report prematurely rounds off numbers. Here, the total radium inventory is given as 4,600 curies, which equates to 4.6 kilograms (kg) of radium. The report then rounds off the 4.6 kg to "nearly 5 kg, which corresponds to about 0.6 ppm." Instead, 4.6 kg would correspond to 0.525 ppm. The same premature rounding off occurs in Paragraph 1 on Page 1-4. These and other rounding off errors should be corrected.

2. Page ES-8, Paragraph 1. The text indicates that certain parameters had a "positive effect" on the radon concentrations. However, the term "positive effect" is ambiguous and should be further defined. This clarification is especially critical for stability class, which is a categorical variable sometimes denoted by letters.

3. Page ES-11, Paragraph 4. The phrase "concentration of Section 4.2 was further reduced" is incorrect and should be revised.

4. Page 1-4, Paragraph 2. The nearest "resident" is designated as the point of compliance. However, the point of compliance is usually a fixed location. As a result, the word "resident" should be changed to "residence" throughout the report.

5. Page 1-4, Paragraph 3. The phrase "effectiveness was performed" should be revised to read "effectiveness testing was performed."

6. Page 1-5, Paragraph 1. The text states that the release and transport model was not calibrated or verified for actual field conditions due in part to the limited availability of radon data. DOE should also describe other factors that prohibited model calibration and verification.

7. Page 1-5, Paragraph 1. The text states that there is no way to quantify the uncertainties associated with the release and transport modeling approach for radon. However, DOE should provide a qualitative description of uncertainties.

8. Page 2-1, Paragraph 1. The text states that radon monitoring "data are not sufficiently independent and therefore cannot be supported for this purpose." Presumably, "this purpose" refers to determining whether the 0.015 pCi/L performance goal has been met. However, DOE should clarify the meaning of "not sufficiently independent."

9. Page 2-1, Paragraph 3. The text briefly describes the main monitoring instruments. A more detailed description of monitoring instruments is needed and should include the following information:

- The relationship between the "Pylon Model 110 and 300A Lucas cells" and the "Pylon AB-5," including performance similarities and differences
- The quality assurance measures used, such as calibrations and background count rates; the actual parameters for the meters used at FEMP; and the specific standards followed, such as American National Standard Institute (ANSI) Standard NQA-1
- Performance evaluation data for the other instruments used in this study

10. Page 2-2, Paragraph 2. The last sentence states that the results of a signs test indicated that data were usable. However, the use of a signs test to determine data usability cannot be evaluated unless DOE provides the name of the signs test used, the data tested, and the results of the test. This sentence also states that the variability of the data was not random, suggesting that the detectors may have been biased. DOE should address this possibility. Finally, this paragraph indicates that "all of the monitoring data were satisfactory for use in the analyses." This statement contradicts later sections of the report where certain monitoring data have been excluded from various analyses (for example, the exclusion of background data collected before April 16, 1991, on page 2-29). DOE should address this contradiction.

11. Page 2-2, Paragraph 3. The text describes the monitoring stations located at exclusion fence, within the production area, and at Westwood. However, the locations of these monitoring stations are not identified on Figure 2-1. DOE should revise Figure 2-1 to clearly identify the locations of all monitoring stations described in the text.

12. Page 2-4, Paragraph 3. The text states that Figure 2-2 shows the locations of on-site radon monitoring locations that use Terradex cups. However, the locations of air monitoring stations (AMS) 1 through 4, 8, and 9, which also use Terradex cups, are not shown in Figure 2-2. The figure should be corrected.

13. Page 2-4, Paragraph 4. DOE should explain why Terradex cup data from the third quarter of 1991 were omitted from the analysis given that preparation and installation of bentonite was conducted during the fourth quarter of 1991. Third quarter 1991 data for Pylon detectors were analyzed; Terradex cup data from the third quarter should also be analyzed.

14. Page 2-7, Paragraph 2. The text indicates that a t-test was used to test hypotheses concerning pre-bentonite and post-bentonite radon concentrations at each monitoring location. However, the analyses that follow in Section 2.1.2 are comparisons of radon concentrations at monitoring stations with background levels. (The pre-bentonite versus post-bentonite comparison for monitoring locations is eventually presented in Section 3.2.) In addition, DOE does not present sufficient information with which to check t-test results. Summary statistics (means and variances) in Tables 2-1 and 2-2 are rounded off, and the data plotted in Attachments B and C cannot be used for this purpose.

15. Page 2-13, Paragraph 2. The discussion presented in the text exaggerates the "insight" that can be obtained from the results of the statistical tests. The key issue, pre-bentonite versus post-bentonite results, is ignored here (although this issue is addressed in Section 3.2). Furthermore, other (non-silo) sources of radon are consistently ignored. The only "insights" provided by the test results are that (1) the radioactivity at FEMP exceeds the background radioactivity, as expected, and (2) the silos are not the only radon sources at FEMP. DOE should revise the text to place less emphasis on the results of these statistical tests.

16. Page 2-13, Paragraph 3. The "difference in the maximum observed value" at each site boundary location is not less than 1.0 pCi/L as stated. Tables 2-1 and 2-2 show that the difference in the maximum observed values at location AMS 5 is 1.77 pCi/L.

17. Page 2-14, Table 2-3. Table 2-3 should present the t value, the critical statistic, for each of the comparisons listed.

18. Page 2-15, Paragraph 1. It is not clear why the results of statistical tests of pre-bentonite and post-bentonite radon concentrations are discussed here, when the analysis of this data is not presented until Section 3.2.

19. Page 2-15, Paragraph 4. The text states that outlying data were excluded from the statistical comparison. DOE should specify the test used to identify outlying data and should provide an example of its application. Otherwise, there is no way to verify that the outlying data have been properly excluded and do not represent real release data. DOE should also indicate (1) whether the cited tests were done using the raw monitoring data or using data corrected for background and (2) how the multiple background stations for the Terradex cup measurements were handled.

20. Page 2-17, Paragraph 2. DOE should clarify how the tolerance limits cited in the text were calculated and if the same procedure was used for each calculation.

21. Page 2-17, Paragraph 3. The text indicates that AMSs 5 through 7 represent the "best available monitors for interpolating" the radon concentrations expected at the point of compliance. Actually, the correct term is extrapolating, since the point of compliance lies beyond these locations. In addition, only AMS 6 seems to represent the best monitor because AMS 5 and 7 are approximately 1 kilometer south and north of the silos, respectively. DOE should review and revise the text as necessary.

22. Page 2-21, Paragraph 2. The second and fourth sentences in this paragraph are contradictory. The second sentence states (and Table 2-3 shows) that radon concentrations at most pylon locations were statistically significantly different from background. The fourth sentence states that "radon concentrations at the site boundary are not significantly above what is observed at the 'background' location." The later statement is false, given the data presented in the report.

23. Page 2-22, Paragraph 2. Table 2-7 does not present a pre-bentonite versus post-bentonite comparison as stated in the text. This comparison is not presented until Table 3-3.

24. Page 2-24, Paragraphs 2 and 3. DOE should define the "single factor analysis of variance" (ANOVA) discussed in the text. The text implies that tests were conducted to compare several on-site stations to a single background station. If so, ANOVA is not appropriate; ANOVA can only indicate whether there is a difference but it cannot identify the means that differ. In addition, the reason for including this analysis is not clear. DOE has already demonstrated (by t-test in Table 2-3) that radon concentrations at each individual location are significantly different from background for both pre-bentonite and post-bentonite measurements. Finally, DOE does not address a more relevant question that could be answered by ANOVA--whether significant differences exist among fence line monitors (AMS 5, AMS 6, and AMS 7) or among exclusion fence monitors (NW, SW, NE, SE).

25. Page 2-25, Paragraph 1. The text states incorrectly that the results of ANOVA "indicate that there is reason to believe that in all cases the mean radon concentrations observed at the FEMP are different from the background." As stated in the previous comment, this conclusion cannot be reached from the results of ANOVA. Finally, F-statistics, which are the end results of ANOVA, are not presented.

26. Page 2-25, Paragraph 2. The text discusses the "coefficient of determination or (R^2)," which is a term more relevant to regression analysis than ANOVA. In addition, the low R^2 value, coupled with low p values, is due primarily to the inclusion of background results in the ANOVA; see Specific Comment 24.

27. Page 2-26, Paragraph 1. The term "SAS" refers to a statistical data package known as "Statistical Application System" published by SAS Institute, not "Special Analytical Services" as indicated in the text.

28. Page 2-26, Paragraph 2. The discussion of autocorrelation in the text, and the following applications of autocorrelation, completely ignore the key parameter: the time lag between the observations being compared. DOE should revise the text to correct this omission. In addition, this paragraph states that "the trend in concentration appears to be related to climatic conditions, with higher concentrations appearing in yearly seasons associated with warmer temperature and higher humidity." This trend is not apparent from the plots of radon concentrations versus time in Attachment B, and no other support for this statement is presented in the report.

29. Page 2-27, Paragraphs 1 and 2. The use of daily averages in the comparisons obscures diurnal effects and accentuates seasonal effects, especially those related to insolation. DOE should consider using hourly data in this analysis.

30. Page 2-27, Paragraph 3. The choice of Equation 2-1 should be thoroughly justified. It would be much better to use a series of models and determine which is best. Also, normal autocorrelation analysis consists of determining which time lags are significant. However, DOE assumes that only the two-day lag is relevant. No justification is provided for this assumption.

31. Page 2-29, Paragraph 1. The text indicates that certain data were excluded from the statistical analysis. DOE should justify these exclusions, especially for "highly influential data" discussed in the text. In addition, DOE should explain what is meant by "highly influential." This justification is especially important considering that high concentration data appearing to be statistically outlying data can actually be due to some real life phenomenon at FEMP, as noted in Specific Comment 19. DOE states that data collected on three days were excluded because they "appeared to be biased across all monitoring stations." This statement also needs further explanation.

32. Page 2-29, Paragraph 2. DOE states that background data collected prior to April 1, 1991, were excluded from the time series analysis. Excluding this data for the pre-bentonite period will obscure possible seasonal effects. In addition, if DOE believes that the pre-April 1, 1991, data is of questionable value, it should explain why this data was included in other statistical analyses (t-tests in Table 2-3 and ANOVA in Section 2.1.3).

33. Page 2-30, Paragraph 3. Given the results from monitoring stations at the exclusion fence (NW, SW, NE, SE), it is difficult to understand how DOE can state that "there is insufficient evidence to draw a conclusion that the silos are influencing the radon concentration at the air monitoring stations." Further, the results in Table 2-8 appear to show that the silos influence concentrations measured at the fence line monitors (AMS 5, AMS 6, and AMS 7). The estimated difference from background at these monitors ranged from 0.22 to 0.34 pCi/L in the pre-bentonite period. The estimated difference dropped to 0.11 to 0.18 pCi/L in the post-bentonite period. The logical conclusion from these results is that the reduction in radon concentrations at the fence line is a result of the greatly reduced concentration in the silos after bentonite addition.

34. Page 2-31, Table 2-8. This table ignores the essential question, whether the post-bentonite data differ from the pre-bentonite data. A crude comparison, using the confidence intervals listed in the table, suggests that concentrations at the four exclusion fence stations decreased, but effects at the three boundary stations (AMS 5 through 7) are unclear.

35. Page 2-32, Paragraph 2. The text refers to the confidence level appropriate for the evaluating compliance with the performance goal. However, it does not specify the confidence level. DOE should specify the numerical value of the required confidence level.

36. Page 2-33, Paragraph 0. The text refers to the "average conditions at the surface." DOE should specify which surface (the silo dome or the foam cover) is referred to in the text. "Average conditions" at this specified surface should also be described.

37. Page 2-33, Paragraphs 1 and 2. The text presents a model of radon flux through the dome using the ideal gas law. However, diffusion through a maze (the bentonite atop the waste and the dome itself) is far from ideal conditions. DOE should use a more realistic approach (such as an empirical comparison of radon concentrations in the dome headspace with radon concentrations outside the dome) to model the radon flux through concrete.

38. Page 2-35, Paragraph 0. The text indicates that the flux from diffusion can vary by two orders of magnitude. DOE should specify the actual range of flux variation.

39. Page 2-35, Equation 2-6. The term "P" in this equation is defined as "pressure of the gases within the silo." However, a more accurate definition of "P" would be "absolute pressure of gases within the silo." DOE should revise the text for accuracy.

40. Page 2-35, Paragraph 2. The text states that "the ventilation of radon [from the silo] to the atmosphere is assumed to be small compared to the production of radon gas." However, considering the structurally questionable physical condition of the silos, this assumption may not be valid. DOE should provide sufficient justification for this assumption.

41. Page 2-35, Equation 2-7. The text defines the term "P_{RN}" as the "concentration (by the presence of the silo) rate of release of radon into the silo air (production term) from K-65 source material (activity per time), pCi/s." This definition of P_{RN} is confusing because the units of a "concentration rate of release" would be pCi/L/s whereas the units for P_{RN} are given as pCi/s. DOE should clarify the definition.

42. Page 2-37, Paragraph 2. The information presented in the text is not clear. For example, the text states that "change of pressure between days varied from 29.274 and 30.354 in Hg." Instead, the text should read that "daily pressure ranged from 29.274 to 30.354 in Hg."

43. Page 2-37, Paragraph 3. The meaning of "degree differential pressure" is not clear. DOE should revise the text to clearly present the information. In addition, the temperature data presented show only that there may be a relationship between ambient temperature and the temperature in Silo 1. DOE presents no information to support the statement that a "temperature change in the silo during the day is caused by . . . a change in ambient degree temperature."

44. Page 2-38, Paragraphs 2 and 3. It is not clear from the text how DOE determined that "the change in moles between measurements . . . in Silo 1 and Silo 2 was less than 0.2 percent" or that "the uncertainty associated with the ideal gas law is 1 percent." The assumptions and data supporting these statements should be presented.

45. Page 2-42, Paragraph 3. The phrase "A complete and calibration effort validation" is ambiguous. DOE should revise the text to make it more clear.

46. Page 3-1, Paragraph 1. The text states that "Daily changes in headspace concentration tend to be relatively consistent among the two silos." This statement should be supported with data and the results of any statistical tests that DOE has conducted on the data.

47. Page 3-4, Paragraph 1. Again, the text draws attention to apparent outliers ("data for July 20, 1992, through July 22, 1992, and July 28, 1992, through August 12, 1992, are likely invalid for Silo 2, as it is several orders of magnitude lower than the other days"). The presence of such outliers among radon measurements within the silos, which are expected to be relatively stable, implies poor performance of the monitoring instruments, inadequate quality assurance, or both. DOE needs to present possible explanations for the outliers. Without such explanations, the validity of the remaining data is questionable.

48. Page 3-4, Paragraph 3. Many tests are available to determine whether data fit a theoretical distribution. DOE should use one of these tests to support the assertion that "daily averages tend to resemble a normal distribution for each silo."

49. Page 3-9, Paragraph 1. The results of stepwise forward regression models indicated that dew point and barometric pressure were "significantly associated" with headspace radon concentration in Silo 1 but not in Silo 2. DOE states that dew point and outdoor temperature are highly correlated and "contribute similar information to the model." However, this statement applies to data from both silos and does not explain why dew point is significant for Silo 1 but not Silo 2. The different results for two physically similar silos located next to each other suggests that the significant association for Silo 1 may be the result of a statistical anomaly, rather than a real effect of dew point and barometric pressure on radon concentrations. DOE should address this issue.

50. Page 3-10, Table 3-2. Footnote 1 should be clarified to indicate that the values listed in the "Estimated Change" column are the regression coefficients from the stepwise regression procedure used to fit the model shown in Equation 3-2.

51. Page 3-11, Paragraph 4. DOE should clarify the meaning of the phrase "The test for significance was 0.05." In addition, the last sentence, which states that "silos have little or no contribution to ambient radon concentration," needs to be revised. Table 3-3 presents data for eleven monitoring locations. Results in Table 3-3 suggest that decreases in radon concentrations in the silos resulted in decreases in ambient radon concentrations at eight of the eleven locations.

52. Page 3-12, Table 3-3. Comparisons of pre-bentonite and post-bentonite measurements in this table are based on data presented in Tables 2-1 and 2-2. Several problems with DOE's presentation of the data are readily apparent. First, from Tables 2-1 and 2-2, the pre-bentonite and post-bentonite means for location AMS 6 are both 0.71 pCi/L. Thus, the t value for this comparison should be zero, and the significance level should be 1.00 rather than 0.458 as presented in Table 3-3. This problem is likely due to rounding off the data in Tables 2-1 and 2-2. Second, the t value for the pre-bentonite and post-bentonite comparison of background data, based on the means and variances in Tables 2-1 and 2-2, is closer to 1.9. The significance level is less than 0.05, not 0.958 as presented in Table 3-3. This problem cannot be attributed to rounding off. Either the background data presented in Tables 2-1 and 2-2 are incorrect or the t value has been calculated incorrectly. Finally, the hypothesis DOE tests in Table 3-3 is whether Sample 1 (pre-bentonite) is greater than Sample 2 (post-bentonite). For background measurements, the post-bentonite mean (0.58 pCi/L) is greater than the pre-bentonite mean (0.54 pCi/L). Based on these values, a one-sided t-test is not appropriate, and the hypothesis should have been rejected without a statistical test.

53. Page 3-14, Paragraphs 2 and 3. DOE should further explain the use of a 2-day lag for the time series statistical model presented in Equation 3-3. The text states that the daily average radon concentration "is influenced by the values of the daily averages for the previous 1 or 2 days at that station." The report should present the data or assumptions that support this statement. In addition, the report should indicate why other time lags were not evaluated to investigate possible seasonal and other longer-term effects.

54. Pages 3-19 through 3-22, Tables 3-6 through 3-9. These tables have several problems. First, the titles of the tables do not match those described in the text on Page 3-18. Second, DOE should explain why predicted minimum daily average concentrations at monitoring stations AMS 5 through 7 are higher for the post-bentonite period than the pre-bentonite period. Third, the "Date of Predicted Value" columns in all tables indicate that the date for prediction is presented in the form of month and year; the dates are actually presented as month and day. Finally, the confidence intervals on many dates encompass an entire year, implying that the time series modeling is irrelevant and that random fluctuations predominate at most locations. DOE should revise the tables and text to address all the above issues.

55. Page 3-29, Table 3-10. The 1991 data column in this table should probably be corrected to "µrem/hr." In addition, DOE should explain why the units for 1991 are different than the units for the other three years in the table.

56. Page 3-29, Paragraph 2. Although Section 3.5 is titled "The Mechanistic Model," the models presented are empirical. Little information is presented concerning the "mechanisms" by which terms in the model (silo headspace concentration, outdoor temperature, or wind speed) affect ambient radon concentrations.

57. Page 3-29, Paragraph 2. The purpose of Section 3.5 is not clear. All of the information presented in this section is repeated (almost verbatim) in Sections 4.1.2, 4.1.3, and 4.1.4.

58. Page 3-31, Paragraph 1. Wind direction should be defined more precisely. It is not clear whether wind direction is to or from the monitoring station, and the base point for azimuths is not presented.

59. Page 3-32, Paragraph 3. DOE should clarify the phrase "predicted concentrations observed."

60. Page 3-33, Paragraph 2. The plots in Appendix K do not support the conclusion in this paragraph. DOE should test frequency histograms of the data against a uniform distribution.

61. Page 4-5, Paragraph 1. DOE should clarify the phrase "linear interpretation."

62. Page 4-6, Paragraph 1. Although the models on Page 4-3 show Log (Y_t) as the dependent variable, Model 1 results presented in Table 4-1 and Attachment J indicate that the dependent variable is really Y_t. Using the parameter estimates for monitoring station AMS 5 in Table 4-1, the wind speed and temperature listed on page J-2, and a combined silo headspace concentration of 250,000 pCi/L, Model 1 predicts a result of 1.33. This value closely matches the predicted radon concentration (in pCi/L) for AMS 5 shown on Page J-2. If the model result was really the logarithm of the radon concentration at AMS 5, the actual concentration would be 21.4 pCi/L.

63. Page 4-12, Paragraph 2. DOE should describe how the numbers 108,000 and 355,000 were derived. These numbers appear to be upper confidence limits for individual radon concentration measurements in Silos 1 and 2 (as opposed to confidence limits for mean silo concentrations). In addition, the last sentence states that "statistical methods have provided a much better estimate of the expected radon concentration."

It is not clear from this sentence what comparison is being made. Finally, the phase "an order or more less" in the last sentence needs to be clarified.

64. Page 5-1, Paragraph 1. The statements and conclusions in Section 5.0 should be supplemented with specific data and properly referenced to data tables and figures in previous sections. In addition, this section is not appropriately titled. Most of the statistical analyses conducted in the preceding sections are designed to show associations between variables. However, other considerations, such as a conceptual site model, are needed to convert these associations to cause-and-effect relationships.

65. Page 5-1, Paragraph 4. The text indicates that the cause of above-background radon concentrations at fence line monitoring stations cannot be inferred, which is incorrect. Above-background radon concentrations are expected at fence line stations because of the extensive radiological activities at FEMP. In addition, as noted in Specific Comments 34 and 55, statistical analyses presented by DOE suggest that silo radon concentrations have an effect on fence line concentrations.

66. Page 6-6, Paragraph 2. The text draws attention to the shortcomings of using atmospheric dispersion models to predict ambient air concentrations. DOE should support such statements with references to published literature.

67. Page 6-12, Paragraph 4. The text refers to a proposed silo monitoring program which would eventually require weekly samples from the silos. The text states that if weekly samples are outside established prediction intervals, daily samples will be collected until consecutive daily samples are within the prediction interval. DOE should specify number of days for which consecutive daily samples are to be within the prediction interval.

68. Attachment A. Attachment A raises several questions. First, DOE indicates that the Pylon detectors used to obtain most of the data analyzed in the report were calibrated in the range of 100 pCi/L, well above most of the measured ambient radon values. Some evidence (in addition to manufacturer's claims) should be presented to show that instrument response is linear down to the 1 pCi/L range where most measurements were made. Second, Attachment A uses manufacturer's claims for estimating the lower limits of instrument response. DOE should supplement this claim by presenting data from instruments actually used, especially those that have been in service and exposed to weather for some time. Finally, the formulas presented for calculating lower limit of detection (LLD) and minimum detectable activity (MDA) should be properly referenced.