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OFFICE OF SECRETARY
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May 24, 1994

DOCKET NUMBER
PROPOSED RULE PR 20
(59FR 9146)

The Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555
Attn: Docketing and Service Branch

Re: 10 CFR PART 20
Disposal of Radioactive Material by Release into Sanitary Sewer Systems

To Whom it May Concern:

The City of Oak Ridge currently has several dischargers of radioactive materiais connected to its Sanitary Sewer System. The health and safety of our workers continues to be of utmost importance and concern. The continued safe disposal of waste solids from our Treatment Plant remains a concern as well.

The attached comments are intended to be in support of stricter control by the Commission of radioactive discharges. It continues to be the City's position that current regulations are inadequate to thoroughly address all the issues a municipally operated wastewater collection and treatment system must face when these materials are introduced into its system.

Should additional input be desired, please contact me at phone number (615) 482-8431.

Very truly yours,

Gary M. Cinder

Gary M. Cinder, P. E.
Director of Public Works

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City of Oak Ridge Comments on the Advanced Notice of Proposed Rulemaking on 10 CFR Part 20, Disposal of Radioactive Material by Release into Sanitary Sewer Systems

General Comments

The City of Oak Ridge has long recognized that the current approach to limiting discharges of radioactive materials into sanitary sewers is not adequate. We first became aware of the problems associated with these discharges in 1984 when elevated levels of several radionuclides, including Co-60 and Cs-137 were discovered in the sludge from our municipal wastewater treatment plant. Discharges from a state-licensed industrial facility involved in the decontamination of nuclear power plant components were identified as the primary source of these radionuclides. Since 1984 our sludge has also been found to contain elevated concentrations of I-131 and uranium. Patient excretions following nuclear medicine procedures at the local hospital were identified as the major source of I-131. Discharges from a state-regulated facility that processes uranium metal and from the Department of Energy's Y-12 Nuclear Weapons Plant were found to be the major sources of the uranium in our sludge. With the exception of I-131, discharges of radioactive materials to the Oak Ridge sewer have been significantly reduced in recent years. However, low levels of Co-60, Cs-137, and uranium, as well as relatively high levels of I-131, are still routinely detected in our sludge.

In the absence of any federal standards on acceptable levels of radionuclides in sludge, the radioactive materials present in the Oak Ridge sludge have been a source of continuing concern, and significant expense, relative to the disposal of the sludge through land application. Over the last few years, the related expenses have exceeded $100,000 per year. As a result, we have recently developed and are in the process of implementing our own criteria for controlling discharges of radioactive materials to the Oak Ridge sewer system.

While we are pleased that the NRC is considering modifications to the current regulations, we are concerned that an adequate plan for limiting discharges cannot be developed without first determining the appropriate "endpoints." From our perspective, the primary concerns are:

1) ensuring that treatment plant workers and personnel involved in maintenance and repair of the collection system are protected (i.e., limiting the concentrations discharged), and

2) ensuring that the treatment plant sludge remains acceptable for disposal by traditional methods, such as land application or landfilling (i.e., limiting the quantities discharged).

The typical approach to limiting sewer discharges, for contaminants that concentrate in sludge (e.g., heavy metals), involves determining an allowable plant loading based on the sludge limit for the contaminant and the removal efficiency for the contaminant during treatment.

Without first establishing what levels of radioactive materials in sewage sludge are "acceptable" relative to the various sludge disposal options, there is not a basis for developing appropriate quantity limits for discharges of radioactive materials to public sewer systems.

For your information we have included two publications that pertain to the behavior of radioactive materials within the Oak Ridge treatment system:

Ingvar L. Larsen, S.Y. Lee, H.L. Boston, and E.A. Stetar. 1992. Discovery of a ^{137}Cs hot particle in municipal wastewater treatment plant sludge, *Health Physics* 62(3):235–238,

Elisabeth A. Stetar, Harry L. Boston, Ingvar L. Larsen, Michael H. Mobley. 1993. The removal of radioactive cobalt, cesium and iodine in a conventional municipal wastewater treatment plant, *Water Environment Research*, 65, 630.

We have also included a report, titled *Development of Radionuclide Discharge Criteria for the Oak Ridge Sewer*, that describes the approach we have developed for controlling discharges of radioactive materials to our sewer system. These discharge criteria will be implemented through our existing Industrial Pretreatment Program.

Specific Comments

1) Form of Material for Disposal

Requiring that only soluble material be discharged is one means of reducing the fraction of a radioactive material that is removed from the wastewater during treatment and subsequently concentrated in the treatment plant sludge. However, it should be recognized that after discharge, some of the soluble material will partition to the suspended solids within the wastewater prior to reaching the head of the treatment plant. A high percentage of this solids-associated fraction will be removed during primary settling of the wastewater, and the remainder will be removed during secondary treatment. Furthermore, some of the radioactive material that enters the plant in a soluble form will become associated with the secondary treatment solids and be removed during final settling of the wastewater.

For example, an overall removal efficiency of 30% was observed for a soluble Co-58 tracer discharged to the Oak Ridge sewer (Stetar, et al., 1993). Seven-percent was removed during primary settling, and an additional 23% was removed during secondary treatment.

2) Total Quantity of Material

As discussed in the enclosed report, *Development of Radionuclide Discharge Criteria for the Oak Ridge Sewer*, the established approach for controlling discharges of nonradioactive contaminants **does** consider the "capacity and treatment methods used by the wastewater treatment plant" and the potential existence of multiple dischargers. We feel strongly that this same approach should be taken when limiting discharges of radioactive contaminants as well.

Furthermore, we believe the annual quantity limits specified by the current NRC regulations are too high to effectively limit radionuclide discharges to municipal wastewater treatment plants. For example, if a facility discharged one curie of Co-60 into the Oak Ridge sewer over a period of one year, and 30% of that Co was concentrated in the sludge as has been observed previously (Stetar et. al, 1993), the resulting average sludge concentrations would be 18,000 pCi/kg wet wt..[1] The maximum concentrations could actually be much higher depending upon the rate at which the Co-60 was discharged within the year. In addition, NRC's annual discharge limits are inappropriate for low specific activity radionuclides[2] such as ^{238}U. One curie of ^{238}U corresponds to over 3000 kg of uranium. Therefore, if one curie of depleted uranium, which is primarily ^{238}U, were discharged the result would be sludge that is significantly greater than 0.05% by weight uranium (i.e., licensable source material).

3) Types of Limits

As stated in our general comments, both concentration and quantity limits are needed to ensure protection of workers and to ensure the treatment plant sludge remains acceptable for disposal through traditional methods.

Concentration limits: We strongly disagree with the current NRC provision that allows licensees to average their discharges over the entire monthly volume of sewage when demonstrating compliance with the concentration limits. This provision encourages the use of dilution as a means of meeting the regulations. This practice has been employed by at least one radioactive materials discharger in Oak Ridge.

Quantity Limits: The residence time for sludge, as well as the degree of mixing the sludge undergoes, within the treatment plant should be considered when establishing the time period over which to limit the quantities discharged. The residence time varies from plant to plant, but rarely exceeds a month or two. Therefore, we believe a monthly discharge limit would be more appropriate than the current annual limit.

4) Exemption of Patient Excreta

We believe this exemption should be reconsidered and that a thorough evaluation of the potential impacts of these releases is warranted. Furthermore, we are concerned by the likelihood that many municipalities are not aware that patient excreta are a potentially

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[1] Based on average annual sludge generation rate of approximately 17 million kg (wet wt.).

[2] Specific activity is the activity of a radionuclide per unit mass. Specific activity is a function of the half-life of the radionuclide (i.e., the rate at which it decays). Radionuclides that decay slowly have a low specific activity.

significant source of radioactive materials or that these releases are exempt from the regulations.

As stated above, relatively high levels of I-131 are present in our wastewater treatment system. The source of this I-131 is patient excreta, primarily urine, following nuclear medicine procedures at the local hospital. One such procedure, known as thyroid ablation, which is performed several times each year, involves the administration of as much as 100 to 150 mCi of I-131. A significant fraction of the iodine is excreted to the sewer within the first 48 hours. Based on data from the local hospital, roughly 500 mCi of I-131 is released to the Oak Ridge sewer each year. For comparison, the total estimated Co-60 discharge to the treatment plant last year was less than 1 mCi. Peak I-131 concentrations measured in the treatment plant following thyroid ablations include 30,000 pCi/l in the plant influent and 46,000 pCi/kg-wet wt. in the thickened, secondary treatment plant sludge. The peak levels observed in the digested sludge as it is removed for land application are typically 1000 to 2000 pCi/kg wet wt. The maximum observed to date in this sludge is 4000 pCi/kg. If it were not for the long sludge-retention time provided by our anaerobic digestion process, the I-131 levels in our land applied sludge would be significantly higher. In treatment plants without long retention times, I-131 may be a source of radiation exposure to individuals involved in the treatment and disposal of sludge.

Although elevated concentrations of I-131 are measured in treatment plant sludge, it should be recognized that only a small percentage (5-25%) of the I-131 that enters a treatment plant is removed with the sludge. Most of this radioactive material, remains in the wastewater and is discharged with the treatment plant's liquid effluent (Stetar et al. 1993., Erlandsson and Mattsson, 1978; Erlandsson et al., 1989, and Prichard et al., 1981). The retention time for liquids within a wastewater treatment plant is short, approximately 24 to 48 hours. Therefore, it is likely that I-131 concentrations in excess of the NRC criteria for effluents to unrestricted areas are discharged by municipal wastewater treatment plants.

In addition to I-131, it is estimated that over 7 Ci (7200 mCi) of Tc-99m and 0.6 Ci of Tl-201 are released to the Oak Ridge sewer via patient excretions each year. Because these radioactive materials are short-lived they do not accumulate in the treatment plant sludge. However, we are concerned that near the point of discharge these releases, especially when combined with the high releases of I-131, are potentially significant sources of radiation exposure to personnel involved in the maintenance of the collection system.

References

Elisabeth A. Stetar, Harry L. Boston, Ingvar L. Larsen, Michael H. Mobley. 1993. The Removal of Radioactive Cobalt, Cesium and Iodine in a Conventional Municipal Wastewater Treatment Plant. *Water Environment Research*, 65, 630.

Erlandsson, B., and Mattsson, S. 1978. Medically Used Radionuclides in Sewage Sludge. *Water, Air, and Soil Pollution*, 9, 199.

Erlandsson, B., Bjurman, Mattsson, S. 1989. Calculation of Radionuclide Deposition by Means of Measurements on Sewage Sludge. *Water, Air, and Soil Pollution*, 45, 239.

Prichard, H.M., Gesell, T.F., Davis, E.D. 1981. Iodine-131 Levels in Sludge and Treated Municipal Wastewater Near a Large Medical Complex. Am J. Public Health, 71, 1, 47.

TECHNICAL MEMORANDUM

DEVELOPMENT OF RADIONUCLIDE DISCHARGE CRITERIA FOR THE OAK RIDGE SEWER

Report on Tasks 5 and 8 of the Agreement Between the City of Oak Ridge and Lamar Dunn and Associates, Inc., Dated January 31, 1992

Prepared by:

E.A. Stetar
Certified Health Physicist
Performance Technology Group, Inc.

April 28, 1994

DEVELOPMENT OF RADIONUCLIDE DISCHARGE CRITERIA FOR THE OAK RIDGE SEWER SYSTEM

1.0 Introduction

The Oak Ridge Wastewater Treatment Plant receives radionuclides from state-licensed facilities, a local hospital, and the Department of Energy (DOE) Y–12 Plant. During treatment portions of the radionuclides are removed from the wastewater and incorporated in the treatment plant sludge. Radionuclide levels in the Oak Ridge sludge are relatively low. However, because there are no standards that establish "acceptable concentrations" in sludge, the presence of radioactive materials has been a continuing concern relative to the disposal of the Oak Ridge sludge through land application.

To ensure the treatment plant sludge remains acceptable for land application, the City of Oak Ridge must limit discharges of radioactive materials to the sanitary sewer. As a first step, the City developed a methodology for determining acceptable radionuclide concentrations in sludge. The City worked closely with the Tennessee Department of Conservation development and obtained their written approval on the final report, *Methodology for Establishing Radionuclide Limits for Land Application of the Oak Ridge Sludge.* The City based its acceptable levels on limiting the radiation dose to a hypothetical, maximally exposed individual from land application to 4 mrem/year. This individual is assumed to establish residency and begin farming immediately following the last application of sludge. The resulting lifetime risk of fatal cancer from a 4 mrem/year dose rate over 70 years would be approximately 1×10^{-6} (one per million). This lifetime risk value was chosen because it is the target risk used by the U.S. Environmental Protection Agency (EPA) to develop limits for other carcinogens in sewage sludge.

In this report, the "acceptable radionuclide concentrations in sludge" are used as a basis for limiting sewer discharges. Because the Oak Ridge Wastewater Treatment Plant is a Publicly Owned Treatment Works (POTW), as defined by the EPA, the City is required, under the Federal Clean Water Act, to limit any materials that are discharged to the sewer that may cause:

- Interference and/or inhibition of the operation of the treatment facility
- Pass through of toxic pollutants that adversely affect the quality of the receiving stream
- Contamination of the POTW sludge such that it is unfit for land application or landfill disposal.

In addition, the City must develop and administer an industrial pretreatment program to monitor and control waste discharges to the sewer system. Under the pretreatment program sewer discharges are limited by:

- Prohibited discharge limitations
- Categorical pretreatment limitations
- Local discharge limitations.

Prohibited discharge limitations are defined under 40 CFR 403, General Pretreatment Regulations, and address materials that are flammable, explosive, corrosive, or that, in some way, interfere with operation of the POTW. Categorical standards, which are established under 40 CFR 307(a) and (b), limit the quantities and concentrations of certain toxic pollutants that may be discharged by users that fall under specific industrial categories. When categorical standards do not exist or do not adequately protect the POTW, local discharge limits must be developed.

As discussed in the Task 3 report, discharges of radioactive materials are regulated by the Nuclear Regulatory Commission and the Tennessee Division of Radiological Health. However, as pointed out in the Task 3 report, these regulations are not adequate because they do not address the potential for radionuclides to accumulate in sludge.

1.1 Approach to Limiting Discharges

There are two primary concerns that must be addressed when limiting discharges of radioactive materials to the Oak Ridge sewer. The quantities must be limited to ensure sludge levels remain acceptable for land application, and the concentrations must be limited to ensure treatment plant workers and personnel performing maintenance on the collection system are adequately protected.

Discharges

The methodology for establishing acceptable levels for land application is set forth in *Methodology for Establishing Radionuclide Limits for Land Application of the Oak Ridge Sludge*. This methodology which is based on limiting the radiation dose to a hypothetical, maximally exposed individual to 4 mrem/year was used to calculate acceptable levels, or sludge limits, for those radionuclides that are currently discharged, and for others that may be discharged in the future (see Appendix A, *Calculating Sludge Limits for Radionuclides*). It should be noted that the Table A-2 sludge limit for each radionuclide was calculated on the basis of the 4 mrem/year dose limit (i.e., as if it were the only radionuclide present in the sludge).

If only one radionuclide were present in the Oak Ridge sewer system, the quantities discharged could be limited using the approach established for nonradioactive contaminants. First, the sludge limit would be used to calculate the allowable plant loading— the total quantity that can enter the plant over a given period of time— using the following formula:

$$L_{mi} = \frac{C_i \times M_{si}}{R_i(1 \times 10^6 \frac{pCi}{\mu Ci} or \frac{\mu g}{g})}$$

L_{t_i} = allowable plant loading during time period t (μCi or g)
C_i = radionuclide concentration limit in sludge (pCi/g or μg/g)
M_{sl} = mass of sludge removed from digesters during time period t (g)
R_i = fractional removal during treatment.

Next, the allowable plant loading would be allocated among the existing dischargers, with a portion set aside for potential future dischargers.

However, because several radionuclides are discharged to the Oak Ridge sewer this approach is not directly applicable. As discussed in the *Methodology* report, there are three primary radionuclides of concern from the standpoint of land application—Co-60, Cs-137, and uranium. To ensure the maximum annual dose from these radionuclides, and from others that may be discharged in the future, does not exceed 4 mrem/year, the quantities of radionuclides discharged to the Oak Ridge sewer will be limited as described in section 1.2.3., below. In addition to meeting these criteria, sewer releases must also meet the pretreatment criteria in section 1.2.1, and the concentrations limits in section 1.2.2.

1.2 CRITERIA FOR SEWER DISCHARGES

1.2.1. Pretreatment

Both State and Federal radiation protection standards are based on the hypothesis that the effects of radiation exposure are linearly related to dose with no threshold (i.e., there is some risk associated with any exposure and the risk increases with increasing dose). Therefore, it is prudent to minimize radiation exposures to the extent possible. The International Commission on Radiological Protection (ICRP) recommends that the risks be minimized by the following dose limitation system (ICRP 30 Report):

- no practice shall be adopted unless its introduction produces a positive net benefit
- all exposures shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account
- the dose equivalent to individuals shall not exceed the applicable limits.

Implementation of the ALARA process has resulted in significant reductions in radiation exposures, and at this time is the primary means by which doses to workers and the public are limited in the U.S. (i.e., few individuals receive doses approaching the regulatory limits).

In keeping with the ALARA principle, radionuclide levels in sewer discharges must not only meet the applicable criteria, but must also be kept as low as is reasonably achievable. Therefore, whenever possible, radioactive material dischargers will be required to pretreat their wastewater. The specific treatment process will be a condition of the wastewater discharge permit, but at a minimum should include filtration through a 0.45 μm filter to ensure that the material discharged is soluble.

If a facility can, to the satisfaction of the City, demonstrate that pretreatment is not feasible, it will be permitted to discharge provided the concentration and quantity criteria in sections 1.2.2 and 1.2.3, below, are met. The facility must also demonstrate that their operating procedures are designed to minimize the introduction of radioactive materials into their sewer effluents to every extent reasonably achievable.

1.2.2. Concentration Limits

To ensure treatment plant workers and personnel involved in maintenance and repair of the collection system are protected, the concentrations of radioactive materials discharged to the sewer will be limited to five times the derived concentrations guides (DCGs) for water listed in Appendix B. The table of DCGs in Appendix B was excerpted from DOE Order 5400.5, *Radiation Protection of the Public and the Environment*.

1.2.3. Maximum Annual Dose From Land Application

Existing and proposed routine discharges will be evaluated on the basis of their contribution to the total annual dose from land application. A discharge, when combined with all other radioactive materials discharges, must not result in a total annual dose to the maximally exposed individual from land application greater than 4 mrem/year.

This evaluation will be accomplished using "discharge ratios" calculated as follows:

$$DR = \frac{\text{Maximum Monthly Discharge Quantity}}{\text{Allowable Monthly Plant Loading}}$$

The sum of all the discharge ratios for each radionuclide from each discharger must be less than or equal to one. For example:

$$\frac{\text{Max. Monthly Qty. of A from Facility X}}{\text{Allowable Loading for A}} + \frac{\text{Max. Monthly Qty. of B from Facility X}}{\text{Allowable Loading for B}} + \frac{\text{Max. Monthly Qty. of A from Facility Y}}{\text{Allowable Loading for A}} + \frac{\text{Max. Monthly Qty. of C from Facility Y}}{\text{Allowable Loading for C}} \leq 1$$

The methods for calculating the monthly, allowable plant loadings are discussed in Appendix C, *Calculating Allowable Plant Loadings for Radioactive Materials*. Values for Co-60, Cs-137, natural/depleted uranium and 2% enriched uranium are provided in Table C-1 of that Appendix.

The City will maintain a running total of the discharge ratios for routine releases to ensure the annual dose limit for land application is not exceeded. Nonroutine releases will also be evaluated using discharge ratios; however, they will be assessed on case-by-case basis and will not be included in the running total. For any given month the sum of the discharge ratios for routine releases and for nonroutine releases cannot exceed 1.

1.3 PERMITTING

If a proposed discharge meets the above criteria, the facility will be issued a Wastewater Discharge Permit through the City's Industrial Pretreatment Program. The permit will specify the pretreatment criteria, monthly discharge quantity limits, and concentration limits for all radioactive materials discharged. If a facility is already permitted for discharges of nonradioactive materials, the existing permit will be modified to include the radioactive materials discharge criteria.

Because the Pretreatment Program will now address radioactive materials, a new section, the "Radioactive Materials Questionnaire," was added to the City's *Waste Water Survey for Nonresidential Establishments, Application for Waste Water Discharge Permit*. The new section, which is provided in Appendix D, addresses the following information:

- types, forms, and quantities of radioactive materials used
- description of specific processes involving radioactive materials
- types, quantities, and concentrations of radioactive materials released to the sewer
- description of existing wastewater treatment processes
- description of safeguards for preventing inadvertent releases to the sewer

The updated surveys were sent to all facilities on the Oak Ridge sewer system that handle unencapsulated radioactive materials to ensure the existing sources of radioactive materials discharges were identified and quantified.

Based on the responses to these surveys, there are currently three facilities that routinely discharge "measurable" quantities of radioactive materials to the Oak Ridge sewer—Quadrex Corporation (primarily Co-60 and Cs-137), Manufacturing Sciences Corporation (MSC) (depleted uranium), and the DOE Y-12 Plant (primarily slightly enriched uranium).

It should be noted that Y-12 does not intentionally discharge uranium to the Oak Ridge sewer system. The primary means by which uranium from the Y-12 Plant enters the sewer is believed to be infiltration of contaminated soils into the onsite sewer lines. For the purpose of quantifying releases and developing "discharge" criteria for Y-12, data from the City Station monitoring manhole, which includes both the Y-12 and MSC uranium contribution to the sewer, were used. It was necessary to use these data because, at present, there is not a sampling manhole that can be used to directly monitor Y-12 releases. Furthermore, discrepancies between Y-12's estimates of the MSC contribution at City Station (based on sampling of the Union Valley Industrial Park sewer line) and MSC's reported discharges (based on monitoring of batch discharges) make it difficult to determine the actual quantities of uranium entering the sewer from the Y-12 Plant. Y-12 is currently constructing a monitoring manhole which will allow a more accurate assessment of their releases in the future.

The Quadrex, MSC and Y-12 sewer discharges are summarized in Table 2. Statistical analyses of these discharges are provided in Appendix E. The calculated mean monthly discharge plus one standard deviation was used as the facility specific discharge limits for these facilities (Table 3.) In the case of Y-12, for which sampling was performed one to four days each month, the average daily value plus one standard deviation was multiplied by 30 to calculate the monthly limit.

Quadrex discharges were quantified over a two-year period from May 1991 to June 1993. Only three of the monthly Co-60 discharges and one of the monthly Cs-137 discharges exceeded the mean plus one standard deviation for this period. (i.e., the Table 3 limits). These elevated monthly discharges followed a period during which Quadrex was unable to discharge for several months due to construction on their wastewater treatment facility. Therefore, under normal operating conditions Quadrex should have no problem meeting the limits specified in Table 3. In the case of MSC, discharges were evaluated from August 1991 to August 1993. During this period, MSC's discharges decreased steadily and after February 1992 remained below the Table 3 limit.

The facility specific discharge limits in Table 3 were used to calculate discharge ratios (also provided in Table 3) using the method described above. The resulting "sum of the discharge ratios" was 0.52

Table 2. Summary of Existing Radioactive Materials Discharges

Facility	Radioactive Material	Minimum Monthly Discharge	Maximum Monthly Discharge	Average Monthly Discharge
Quadrex	Co-60*	0 μCi	216 μCi	68 μCi
	Cs-137*	0 μCi	62 μCi	12 μCi
MSC	Nat./Depleted U*	6 g	31 g	16 g
DOE Y-12	2%-enriched U**	•	•	470 g

*Based on reported discharges from 1991 through 1993
** Based on measurements by the Y-12 Plant at City Station monitoring manhole in 1991 (i.e., includes Union Valley Ind. Park (MSC) contribution). Sampling consisted of 24-hour composites collected one to four days each month. Average monthly = average grams/day x 30 days/month.

SUMMARY

Under the Federal Clean Water Act and the Tennessee Water Pollution Control Act, the City of Oak Ridge is required to establish protection criteria for its POTW to "prevent contamination of its sludge such that it is unfit for land application or landfill disposal." In the absence of state or federal standards for radioactive materials in sludge, the City developed its own methodology for establishing acceptable levels of radionuclides in their treatment plant sludge.

Table 3. Calculated Facility Specific Discharge Limits and Discharge Ratios

Facility	Radioactive Material	Discharge Limit	Discharge Ratio
Quadrex	Co-60	130 µCi	0.271
	Cs-137	30 µCi	0.007
MSC	Nat./Depleted U	25 g	0.002
DOE Y-12	2%-enriched U	840 g	0.24
			SUM = 0.52

The City developed its acceptable levels, or sludge limits, based on limiting the radiation dose to the maximally exposed individual from land application to 4 mrem/year. In this report, the sludge limits are used as a basis for evaluating and limiting the quantities of radioactive material discharged to the Oak Ridge sewer. In addition, pretreatment criteria and concentration limits for sewer discharges are established. The criteria established in this report will be implemented through the City of Oak Ridge's existing Industrial Pretreatment Program.

REFERENCES

Environmental Protection Agency (1986). "Radioactivity of Municipal Sludge." Office of Water Regulations and Standards, Wastewater Solids Criteria Branch.

Stetar, E.A. (1992) Memo to Bob Dominak on Radioactive Contamination in Municipal Wastewater Treatment Plants. Northeast Ohio Regional Sewer District, 3826 Euclid Avenue, Cleveland, Ohio.

Stetar, E.A., H. L. Boston, I.L. Larsen, and M.H. Mobley (1993). The removal of radioactive cobalt, cesium, and iodine in a conventional municipal wastewater treatment plant; *Water Environ. Res.*, 65, 630-639.

APPENDIX A

Calculating Sludge Limits for Radionuclides

The methodology for establishing "acceptable" radionuclide concentrations in the Oak Ridge sludge was set forth in *Methodology for Establishing Radionuclide Limits for Land Application of the Oak Ridge Sludge*. First, the RESRAD code is used to calculate soil guidelines that correspond to a 4 mrem/year dose limit to the maximally exposed individual from land application. These soil guidelines are then converted to acceptable sludge concentrations, or sludge limits, using the appropriate dilution factor. RESRAD based soil guidelines for 11 radioactive materials are presented in Table A-1. Calculation of the guidelines for natural/depleted and 2%-enriched uranium, using the RESRAD dose-source ratios (mrem/year per pCi/g-soil), is discussed below. It should be noted that each of the soil guidelines corresponds to the 4 mrem/year dose limit.

The soil guidelines in Table A-1 were converted to acceptable sludge concentrations, or sludge limits, using a dilution factor (DF) of 5.6×10^{-2}:

$$\text{Sludge Limit} = \frac{\text{Soil Guideline}}{\text{DF}}$$

The DF is based on the assumptions that 1) the sludge is applied at a rate of 4 tons/year for 15 years and 2) the sludge is uniformly mixed with soil to a depth of 0.15 m.

Because no credit was taken for radioactive decay or loss due to leaching and weathering during the 15 year application period, the dilution factor is appropriate for any application rate provided the total cumulative loading per acre does not exceed 60 tons.

The calculated sludge limits are provided in Table A-2. It should be noted that each of these sludge limits corresponds to a 4 mrem/year dose limit. If more than one of the radionuclides is present a "sum of the ratios" approach should be applied to ensure the maximum annual dose does not exceed 4 mrem.

Table A-1. RESRAD Soil Guidelines for Individual Radionuclides Based on 4 mrem/year Dose*

Radionuclide	Concentration (pCi/g-dry wt)**
Am-241	9.0
Cs-134	0.70
Cs-137	1.5
Co-60	0.35
Mn-54	1.3
Ra-226	0.46
Sr-90	8.9
Th-232	2.8
2%-Enriched Uranium	14 ppm
Natural and Depleted Uranium	36 ppm

* Each soil guideline corresponds to a 4 mrem/year dose limit.
** Units are pCi/g-dry wt. unless otherwise specified.

Table A-2. Sludge Limits for Individual Radionuclides*

Radionuclide	Concentration (pCi/g-dry wt)**
Am-241	160
Cs-134	13
Cs-137	27
Co-60	6.3
Mn-54	23
Ra-226	8.2
Sr-90	160
Th-232	50
2%-Enriched Uranium	250 ppm
Natural and Depleted Uranium	640 ppm

*Each value corresponds to a 4 mrem/year dose from controlled land application to a total cumulative loading of 60 tons/acre with a mixing depth of 0.15 m. If more than one radionuclide is present in the sludge, a "sum of the ratios" approach should be used to ensure the total dose limit is not exceeded.
** Units are pCi/g-dry wt. unless otherwise specified.

Uranium Soil Guidelines

RESRAD calculates soil guidelines and dose-source ratios (mrem/year per pCi/g-soil) for the individual uranium isotopes U-238, U-235, and U-234. As discussed in the *Methodology* report, the dose-source ratios can be used in the following formula to calculate soil guidelines for mixtures of these nuclides. The formula can be used for natural, depleted or enriched uranium, provided the isotopic ratios are known so that the appropriate substitutions can be made.

$$(\text{U-234 Concentration} \times 0.11\ \frac{\text{mrem/yr}}{\text{pCi/g}}) + (\text{U-235 Concentration} \times 0.63\ \frac{\text{mrem/yr}}{\text{pCi/g}})$$

$$+ (\text{U-238 Concentration} \times 0.17\ \frac{\text{mrem/yr}}{\text{pCi/g}}) = 4\ \text{mrem/yr}$$

The activity ratios for natural uranium are U-234/U-238 = 1 and U-235/U-238 = 0.046. Using these activity ratios and the corresponding substitutions:

U-234 concentration = U-238 concentration
U-235 concentration = U-238 concentration x 0.046,

a natural uranium soil guideline of 25 pCi/g (36 ppm) was calculated.

For depleted uranium (< 0.7% U-235), the soil guideline will be slightly higher than the natural uranium value. However, for simplicity, and because the isotopic ratios are often not known for depleted uranium, the more conservative natural uranium value was also used as the depleted-uranium soil guideline.

For enriched uranium (> 0.7% U-235), the soil guideline should be lower than the natural uranium value. The actual guideline value depends on the level of enrichment, with the guideline decreasing as the level of enrichment increases. At this time, the only known discharges of enriched uranium to the Oak Ridge sewer are from the Department of Energy's Y–12 Plant. In 1991, their discharges ranged from 0.4% U-235 (depleted) to 2.7% U-235 (enriched) with an average of roughly 1%, and thus far in 1993, the Y-12 discharges have ranged from 0.85 to 3.4% with an average of 1.4%. Assuming an enrichment level of 2% and activity ratios of U-234/U-238 = 4 and U-235/U-238 = 0.13, an enriched uranium soil guideline of 24 pCi/g (14 ppm) was calculated.

APPENDIX B

Chapter III, DOE Order 5400.5,
Derived Concentration Guides

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APPENDIX C

Calculating Allowable Plant Loadings for Radioactive Materials

The allowable plant loadings, for the Oak Ridge Wastewater Treatment Plant, for Co-60, Cs-137, natural/depleted uranium, and 2%-enriched uranium are provided in Table C-1. These are the values that will be used in the calculation of discharge ratios. With the exception the 2%-enriched uranium value, the Table C-1 allowable loadings were calculated on the basis of limiting the concentrations in the digested sludge to the Appendix A sludge limits. The methodology used for these calculations is described below, in section C.2, "Allowable Loadings Based on Appendix A Sludge Limits." The methodology used for calculating allowable loadings for 2-% enriched uranium and special nuclear materials is described in section C.1.

A 25% safety factor was included in the calculation of the allowable plant loadings in Table C-1 (i.e., the values were reduced by 25%). This safety factor was necessary to compensate for uncertainties such as:

- potential unidentified sources of radioactive materials
- inherent uncertainties associated with measurements of radioactivity
- errors in flow or volume estimates for discharges
- potential changes in plant operating conditions that may affect radionuclide removals.

C.1. Allowable Loadings for Special Nuclear Materials

For special nuclear materials, such as enriched uranium, it is not only the sludge concentration that must be considered. In addition, the total quantity of the fissionable material present in the treatment plant at any given time must be limited. Under the Atomic Energy Act, quantities of special nuclear material greater than those listed in Table C-2 must be licensed by the federal government (i.e., licensed by the Nuclear Regulatory Commission (NRC) under a Special Nuclear Materials License).

To ensure the Oak Ridge treatment plant is not subject to NRC licensing, the allowable plant loading for special nuclear materials will be established such that the total quantities present in the treatment plant at any one time do not exceed the quantities in Table C-2. The two compartment model shown in Fig. 1 will be used to determine the plant loadings that correspond to these quantities.

In addition, the allowable loadings will be calculated based on the Appendix A sludge limits. These plant loading values will be compared to those obtained with the model, and the more restrictive of the two will be used as the basis for limiting sewer discharges.

Table C-1. L_m — Individual, Allowable Monthly Plant Loadings for Selected Radioactive Materials

Radionuclide	L_m
Co-60	480 μCi
Cs-137	4050 μCi
Natural or Depleted Uranium	16,000 g
2%-enriched Uranium	3450 g

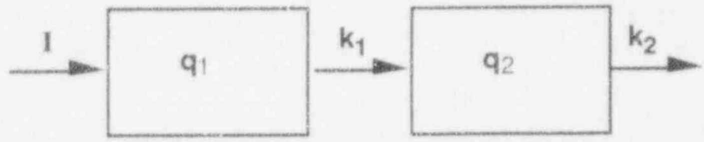
*If more than one radionuclide present, the "sum of the ratios" must not exceed one.

Table C-2. Maximum Quantities of Fissionable Materials That Car be Possessed Without a Federal SNM License

Uranium enriched in U-235	350 g contained U-235
Uranium-23.	200 g
Plutonium	200 g

* If more than one sp. ial nuclear material is present, the "sum of the ratios" must not exceed one.

Fig. 1. Two Compartment Model with Flow Through



$$\frac{dq_1}{dt} = I - k_1 q_1$$

$$\frac{dq_2}{dt} = q_1 k_1 - k_2 q_2$$

Where I is the input to the sludge, q_1 is the quantity of the fissionable material in the primary and secondary treatment sludges, and q_2 is the quantity in the primary and secondary digester sludges. The loss rate constants, k_1 and k_2, were derived from data obtained during a radiotracer study conducted at the Oak Ridge plant in 1990 (Stetar, et al., 1993). The allowable plant loading can then be calculated as follows:

$$L = \frac{I}{R_i}(SFR)$$

I = Input to sludge (g/unit time)
R_i = fractional removal during treatment
SFR = safety factor reduction-(0.75) for 25% reduction

Using the spreadsheet calculations in Table C-3, the maximum allowable input of U-235 to the treatment plant was estimated to be 2.3 g/day or 70 g/month. This monthly quantity of U-235 corresponds to a monthly allowable plant loading for 2%-enriched uranium of 3450 g. For comparison, the allowable plant loading for 2%-enriched uranium calculated on the basis of limiting the sludge concentration to 250 ppm is 6250 g. For calculation of the U-235 allowable plant loading a fractional removal of 0.9 was assumed. The basis for this assumption is provided below, in section C.2., subsection R_i — Fractional Removal During Treatment.

C.2 Calculating Allowable Loadings Based on Appendix A Sludge Limits

The following formula was used to calculate the allowable loading values for Co-60, Cs-137, and natural/depleted uranium which are listed in Table C-1:

$$L_{m_i} = \frac{C_i \times M_{sl}}{R_i(1 \times 10^6 \frac{pCi}{\mu Ci} or \frac{\mu g}{g})}(SFR)$$

L_{t_i} = allowable plant loading during time period t (μCi or g)
C_i = Concentration limit in sludge (pCi/g or μg/g)
M_{sl} = mass of sludge removed from digesters during time period t (g)
R_i = fractional removal during treatment.
SFR = safety factor reduction-(0.75) for 25% reduction

C_i—Concentration Limit in Sludge

The sludge limits in Table A-2, Appendix A, were used in the calculations of the allowable plant loadings.

M_{sl} — Mass of Sludge Removed from Digesters Monthly

A period of one month was chosen for calculating the allowable plant loadings because the radionuclides are assumed to mix within at least a 30-day sludge volume prior to removal from the plant for land application. This assumption is based on the following:

- the retention time for solids in the plant is approximately 70 days
- the sludge undergoes significant mixing within the treatment plant
- peak concentrations have been observed in the digested sludge approximately 30 days following a pulse input (Stetar et al., 1993).

Approximately 400 dry tons (3.6 x 10^8 g) of sludge are removed from the Oak Ridge treatment plant digesters each year. For these calculations, it is assumed that the sludge was removed a constant rate of 3 x 10^7 g/month.

R_i — Fractional Removal During Treatment

Fractional removal values for cobalt and cesium in the treatment plant were determined to be approximately 0.30 and 0.15, respectively, during a radiotracer study performed in 1990 (Stetar, et al. 1993). In this study soluble radioactive cobalt and cesium were mixed in the treatment plant influent and allowed to equilibrate for 4 hours. The equilibration period was designed to allow representative partitioning of the tracers between the solid and liquid phases of the wastewater. A 4-hour period was chosen because it approximates the average transit time for radionuclides discharged into the Oak Ridge sewer. Soluble tracers were used because the Co-60 and Cs-137 discharged to the Oak Ridge sewer are primarily soluble. The largest contributor of Co-60 and Cs-137 to the Oak Ridge sewer is required by their Tennessee Radioactive Materials license to pass all sewer discharges through a 0.45 μm filter prior to release. Furthermore, the City's pretreatment criteria, specified in section 8.2.1 of this report, will require radioactive materials discharges to be filtered through 0.45 μm filters.

The mean fractional removal for uranium was estimated to be 0.6 based on measurements of plant influent and effluent concentrations made over 5 consecutive days in 1991 by DOE Y-12 plant personnel (DEUSS 1991). The daily removals over this time period ranged from 0.5 to 0.9. These values were calculated using the following formula:

$$R = \frac{I - E}{I}$$

R = fractional removal
I = influent concentration
E = effluent concentration

The errors associated with the Y-12 measurements are not known. However, because the influent and effluent concentrations were very low, on the order of 0.004 mg/l, the errors are assumed to be significant. Considering this uncertainty, the maximum observed removal of 0.9 (i.e., the most conservative) was used in the plant loading calculations.

Background Radionuclide Concentrations in Sludge

Uranium is a naturally occurring radioactive material that is present in all soils in varying quantities. Low levels of Cs-137 and Co-60 (both man-made radionuclides) are also present in soils, primarily as the result of previous nuclear weapons testing. Because these radionuclides are present in the environment, they are also found in wastewater treatment plant sludges, usually at very low concentrations. To determine the background concentrations of Co-60, Cs-137, and uranium for the Oak Ridge sludge, samples of sludge from five other East Tennessee communities with no known sources of radionuclides—Lenoir City, Knoxville, Maryville, Morristown, and Sevierville—were collected and analyzed for gamma emitting radionuclides (Oak Ridge National Laboratory) and for total uranium (TMA Eberline, Oak Ridge).

No detectable levels of Co-60 were found in the sludges from these municipalities (minimum detectable activity ≈ 0.06 pCi/g-dry wt). Cs-137 was present in the sludges at concentrations ranging from 0.05 to 0.2 pCi/g-dry wt. with a mean of approximately 0.1. Low levels of uranium, presumably at natural ratios, were also present in the sludge samples. The mean value for uranium was approximately 3 ppm. Because the background levels were all well below 1% of the sludge limits in Table A-2, they were not considered in the land application dose assessment or the allowable plant loading calculations.

Table C-3. Model for limiting discharges of fissionable materials

q1= quantity in primary and secondary sludges (grams)

q2= quantity in digester sludges (grams)

I= input rate to WWTP (grams/day) (assumed to be constant)

Model differential equations: $dq_1/dt = I - k_1 q_1$ and $dq_2/dt = q_1 k_1 - k_2 q_2$

Solutions:

$q_1 = I/k_1(1-\exp(-k_1 t)) + q_1(0)\exp(-k_1 t)$

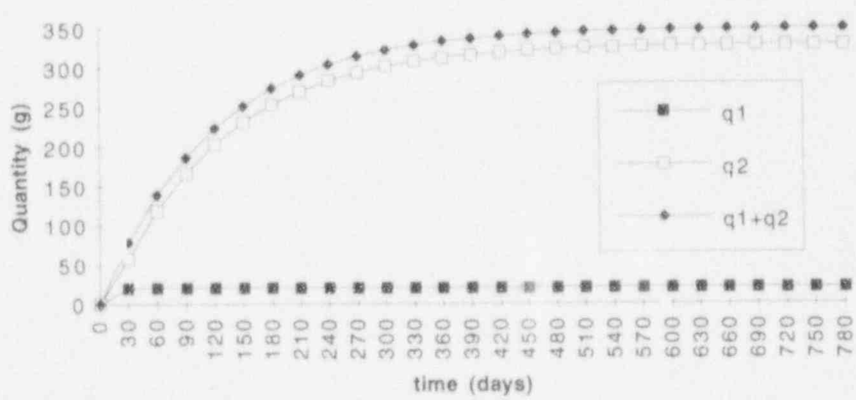
$q_2 = I/k_2(1-\exp(-k_2 t)) + ((q_1(0) k_1 - I)/k_2 - k_1)(\exp(-k_1 t) - \exp(-k_2 t)) + q_2(0)\exp(-k_2 t)$

Calculations for U-235: q1 + q2 ≤ 350 g

I (g/day) =	2.80	**Allowable plant loading, L = I/R(SFR)**
k1(1/day)=	1.37E-01	*I = constant input rate to WWTP (grams/day)*
k2 (1/day)=	8.50E-03	*R = fractional removal during treatment, 0.9 assumed*
q1(0)=	0.00	*SFR = safety factor reduction (0.75)*
q2 (0) =	0.00	**L (U-235)=2.3 g/day, L(2%-enr.U)=115 g/day (3450 g/mo)**

Demonstration:	time (days)	q1	q2	q1+q2
	0	0	0	0
	30	20	58	78
	60	20	119	139
	90	20	166	186
	120	20	203	223
	150	20	231	252
	180	20	253	274
	210	20	270	291
	240	20	284	304
	270	20	294	314
	300	20	302	322
	330	20	308	329
	360	20	313	333
	390	20	317	337
	420	20	320	340
	450	20	322	342
	480	20	323	344
	510	20	325	345
	540	20	326	346
	570	20	327	347
	600	20	327	348
	630	20	328	348
	660	20	328	349
	690	20	328	349
	720	20	329	349
	750	20	329	349
	780	20	329	349

Equilibrium Quantity of U-235 With Constant Input of 2.8 Grams/Day



REFERENCES

Stetar, E.A., H. L. Boston, I.L. Larsen, and M.H. Mobley (1993). The removal of radioactive cobalt, cesium, and iodine in a conventional municipal wastewater treatment plant; *Water Environ. Res.*, 65, 630-639.

APPENDIX D

Radioactive Materials Questionnaire

Attach additional sheets as needed.

1. Indicate which of the following radiation protection criteria your firm is subject to:

   State of Tennessee Standards for Protection Against Radiation (SRPAR) ____________

   Nuclear Regulatory Commission ____________

   Department of Energy (DOE) Orders ____________

   Other, specify ____________

2. List all radioactive materials related licenses/permits:

Permit Name and No.	Issuing Agency

   Do any of these permits contain limits (other than those specified in the above radiation protection criteria) for discharges of radioactive materials to the sewer?

   [ ] Yes [ ] No

   If yes, please list these limits in the space provided or attach a copy:

Radioactive Material	Limit (include units)

3. Indicate the types, forms, and quantities of radioactive materials that are typically present at your facility/facilities:

Radioactive Material	Form (Solid, Liquid, Gas)	Quantity (Ci)

4. Briefly describe each process that involves radioactive material:

____

____

____

____

____

____

5. Does your firm discharge measurable amounts of radioactive material (including samples containing radioactive material) into the sewer?

[ ] Yes [ ] No

If Yes, indicate the quantities discharged on a monthly basis for the last two years:

Month/Year	Radioactive Material	Quantity Discharged (μCi)

6. Is your wastewater treated to remove radioactive materials prior to discharge to the sewer?

[ ] Yes [ ] No

If Yes, describe the treatment processes used and attach drawings of your existing treatment facilities.

7. Describe any safeguards that are in place at your facility to prevent inadvertent releases of radioactive materials to the sewer.

APPENDIX E

X_1 : Quadrex Monthly Co-60 (µCi)

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
68.046	65.214	14.582	4252.846	95.837	20
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
0	215.6	215.6	1360.93	173410.597	6

X_2 : Quadrex Monthly Cs-137 (µCi)

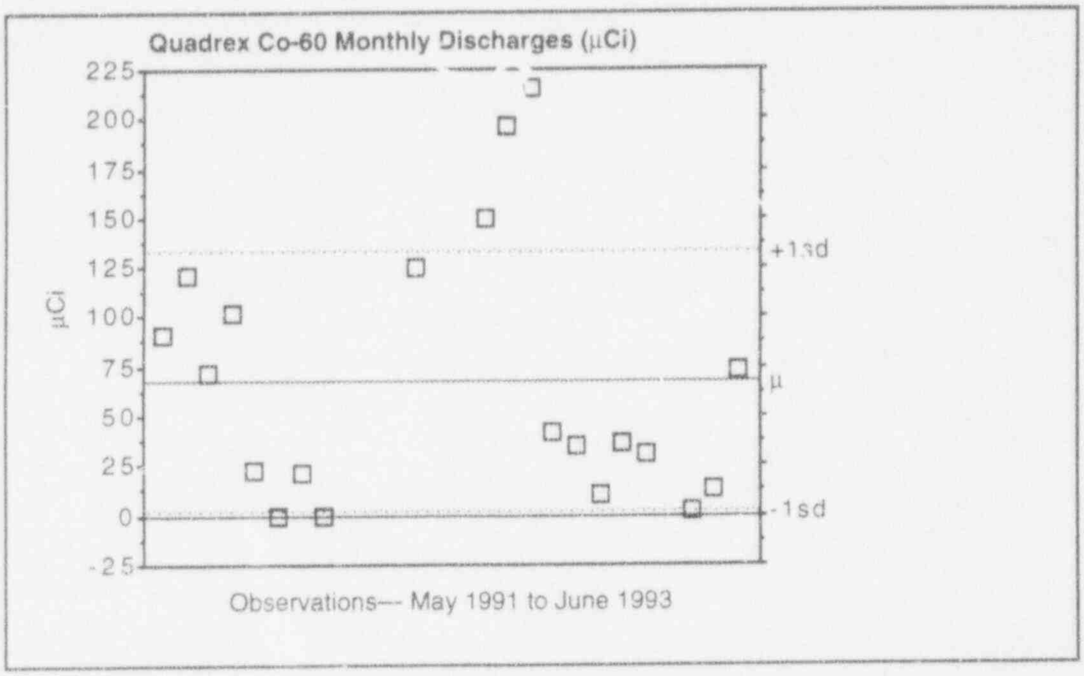
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
12.253	16.306	3.646	265.881	133.073	20
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
0	62.31	62.31	245.066	8054.625	6

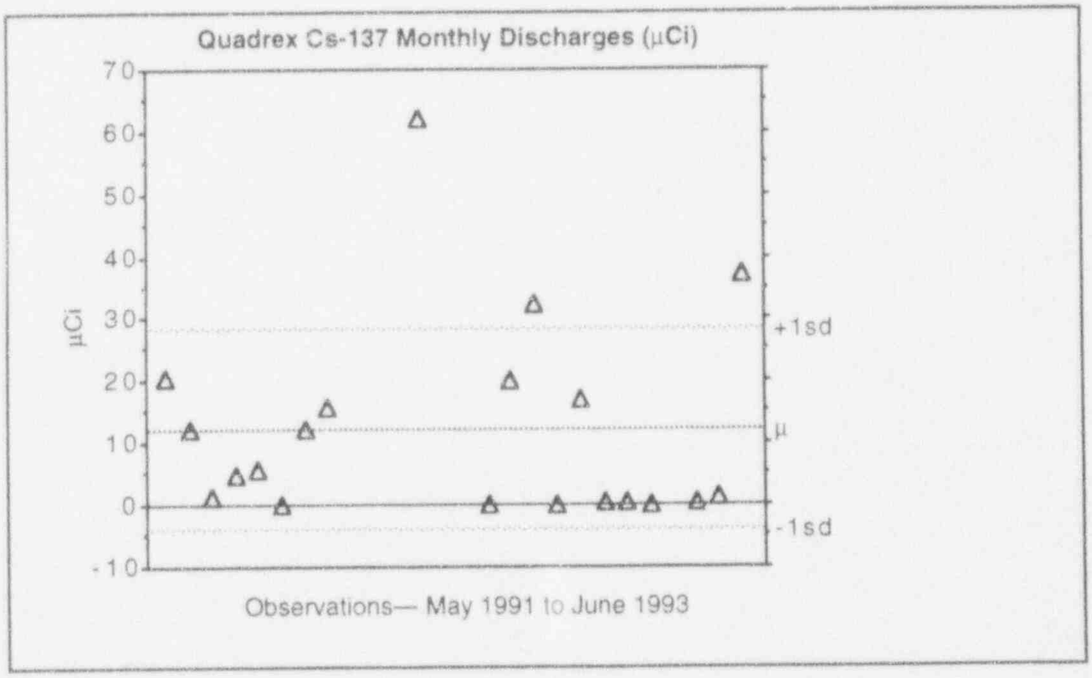
X_3 : MSC Monthly Uranium (g)

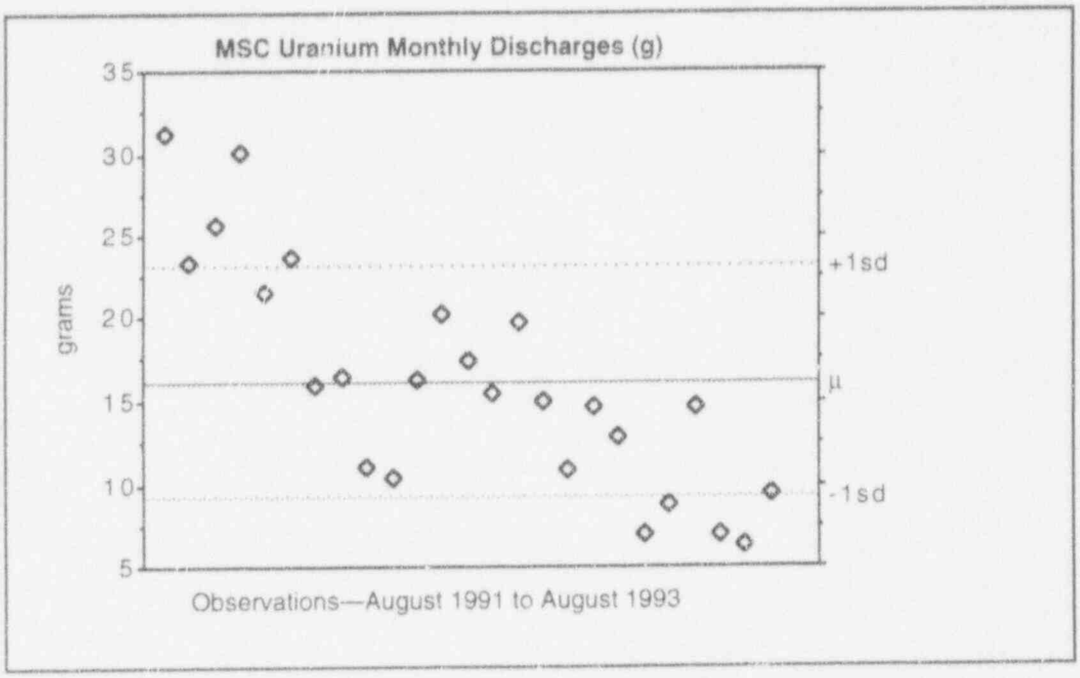
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
16.212	6.928	1.386	47.995	42.732	25
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
6.329	31.176	24.847	405.302	7722.658	1

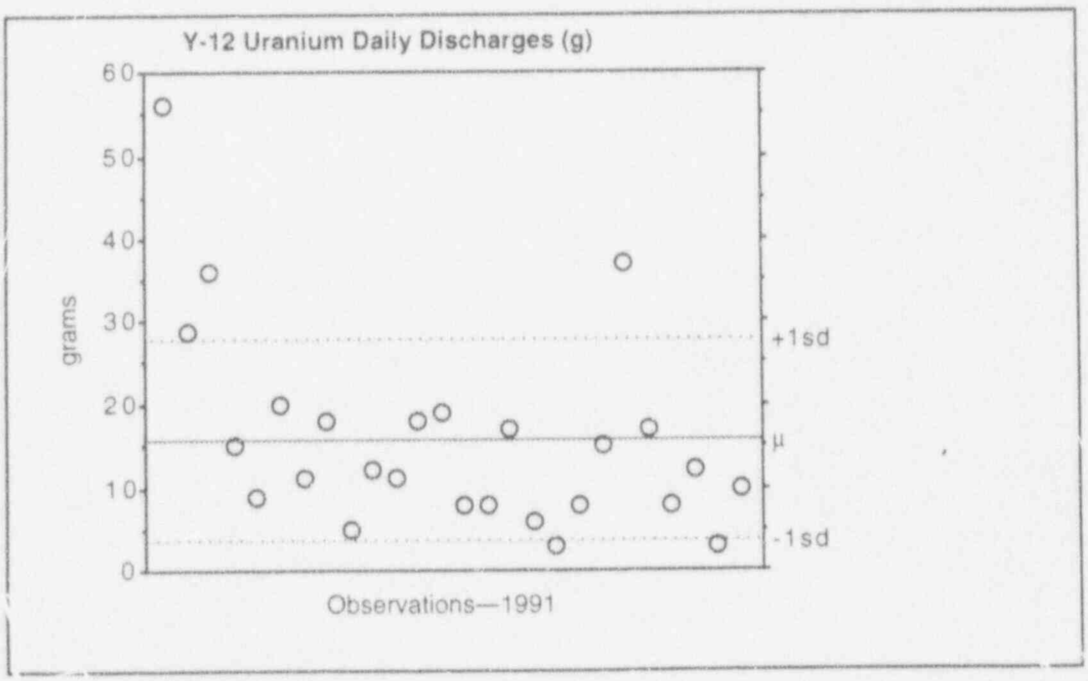
X_4 : Y-12 Daily Uranium (g)

Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
15.808	12.047	2.363	145.122	76.207	26
Minimum:	**Maximum:**	**Range:**	**Sum:**	**Sum of Sqr.:**	**# Missing:**
3	56	53	411	10125	0


Quadrex Co-60 Monthly Discharges (µCi)
225
200
175
150
125
100
75
50
25
0
-25
µCi
+1sd
µ
-1sd
Observations— May 1991 to June 1993


Quadrex Cs-137 Monthly Discharges (µCi)
70
60
50
40
30
20
10
0
-10
µCi
+1sd
µ
-1sd
Observations— May 1991 to June 1993


MSC Uranium Monthly Discharges (g)
35
30
25
20
15
10
5
grams
+1sd
μ
-1sd
Observations—August 1991 to August 1993


Y-12 Uranium Daily Discharges (g)
60
50
40
30
20
10
0
grams
+1sd
μ
-1sd
Observations—1991

X_1 : Quadrex Monthly Co-60 (μCi)

# < 10th %:	10th %:	25th %:	50th %:	75th %:	90th %:
2	1.47	17.36	39.305	111.55	172.95

# > 90th %:					
2					

X_2 : Quadrex Monthly Cs-137 (μCi)

# < 10th %:	10th %:	25th %:	50th %:	75th %:	90th %:
0	0	.677	5.184	18.59	34.93

# > 90th %:					
2					

X_3 : MSC Monthly Uranium (g)

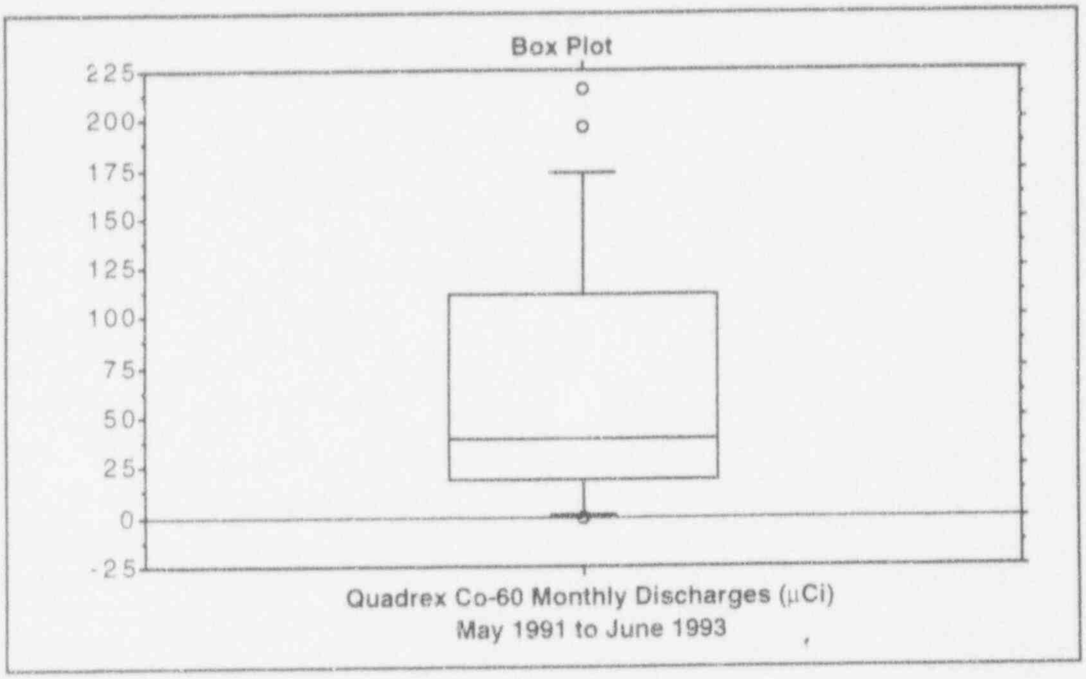
# < 10th %:	10th %:	25th %:	50th %:	75th %:	90th %:
2	6.916	10.797	15.52	20.534	25.722

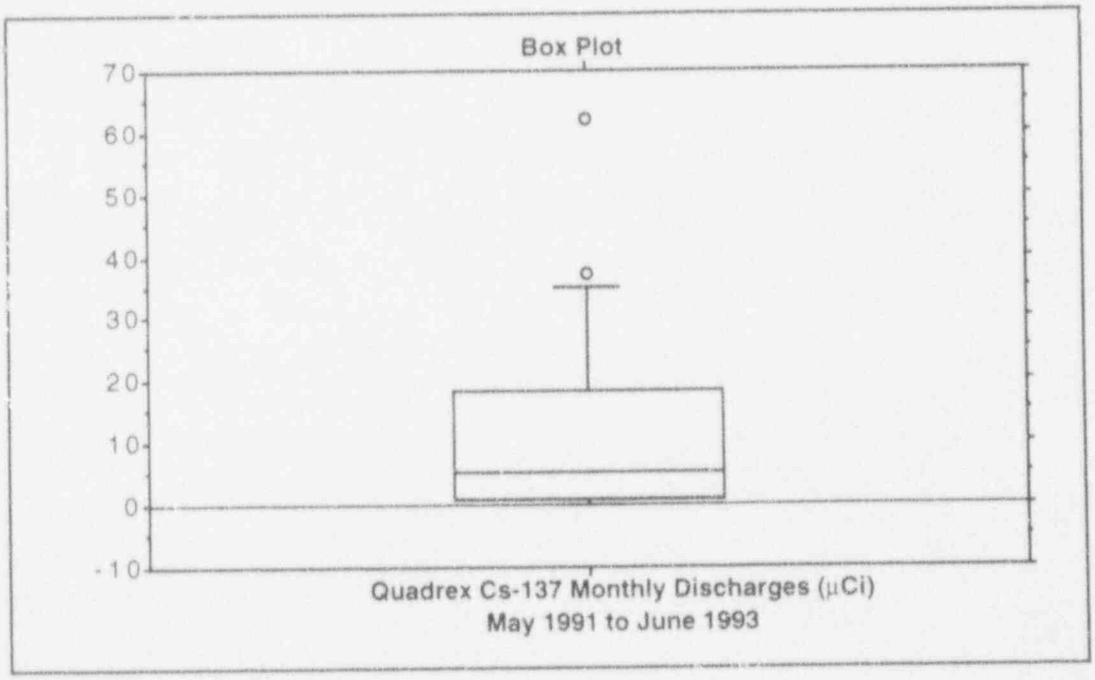
# > 90th %:					
2					

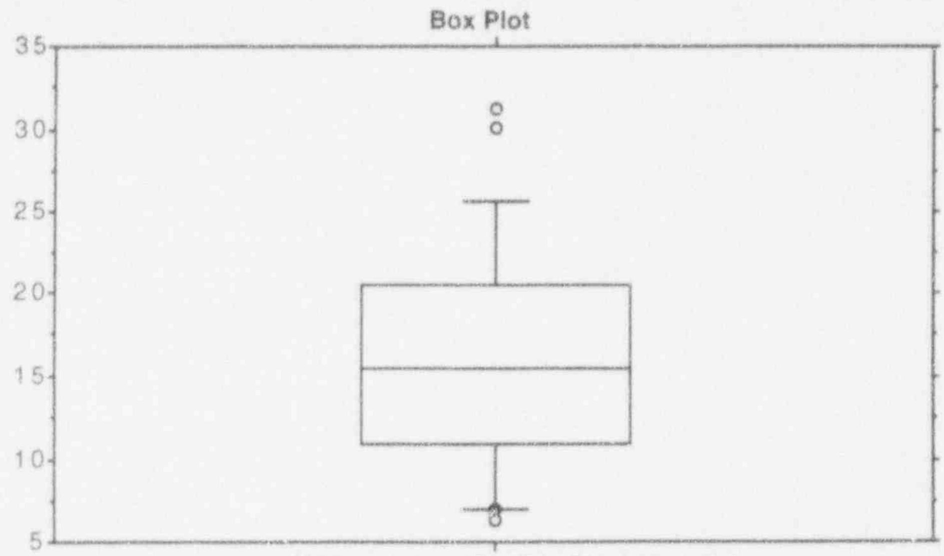
X_4 : Y-12 Daily Uranium (g)

# < 10th %:	10th %:	25th %:	50th %:	75th %:	90th %:
3	5.1	8	12	18	35.3

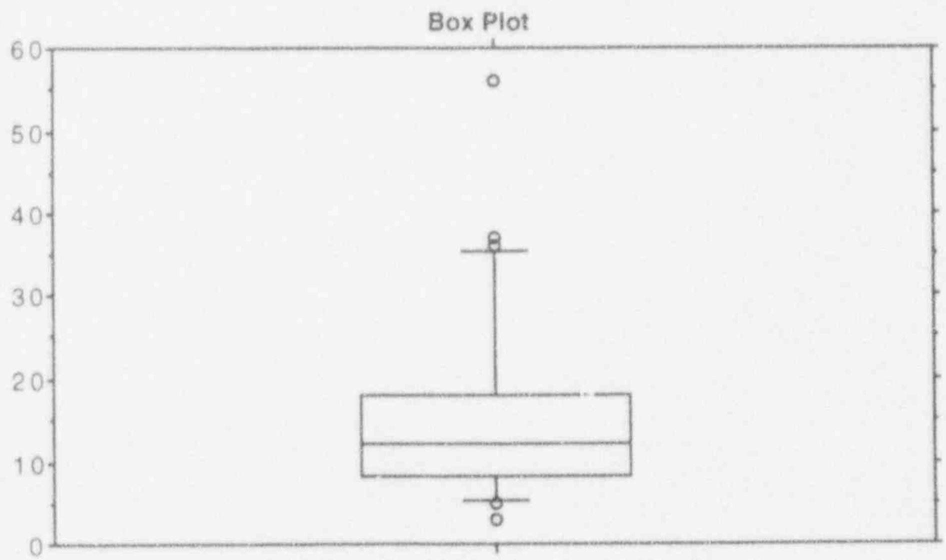
# > 90th %:					
3					


Box Plot
225
200
175
150
125
100
75
50
25
0
-25
Quadrex Co-60 Monthly Discharges (μCi)
May 1991 to June 1993


Box Plot
70
60
50
40
30
20
10
0
-10
Quadrex Cs-137 Monthly Discharges (μCi)
May 1991 to June 1993



MSC Uranium Monthly Discharges (g)
August 1991 to August 1993



Y-12 Uranium Daily Discharges Uranium
(grams)

THE FOLLOWING COPYRIGHTED STUDIES ARE RETAINED ON THE OFFICIAL RULEMAKING DOCKET AS PART OF COMMENT NUMBER 19, COMMENT OF THE CITY OF OAK RIDGE:

1. DISCOVERY OF A ^{137}Cs HOT PARTICLE IN MUNICIPAL WASTEWATER TREATMENT SLUDGE

2. THE REMOVAL OF RADIOACTIVE COBALT, CESIUM AND IODINE IN A CONVENTIONAL MUNICIPAL WASTEWATER TREATMENT PLANT, PUBLISNED IN VOL. 65, NO. 5, WATER ENVIRONMENT RESEARCH (JULY/AUGUST 1993)