BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
REVISIONS TO RADIUM QUALITY STANDARDS: PROPOSED NEW 35 ILL. ADM CODE 302.307 and AMENDMENTS TO 35 ILL. ADM. CODE 302.207 and 302.525	)	R 04-21 (Rulemaking—Water)

NOTICE

TO: Dorothy Gunn, Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 W. Randolph Street, Suite 11-500
Chicago, Illinois 60601

SEE ATTACHED SERVICE LIST

PLEASE TAKE NOTICE that I have filed with the Office of the Pollution Control Board the Supplemental Information as agreed to at the hearing held on October 21 and October 22, 2004 on behalf of the City of Joliet, a copy of which is herewith served upon you.

Date: November 24, 2004

CITY OF JOLIET

By: [signature]
Roy M. Harsch

Roy M. Harsch
Gardner Carton & Douglas LLP
191 North Wacker Drive
Suite 3700
Chicago, Illinois 60606
(312) 569-1441

THIS FILING IS SUBMITTED ON RECYCLED PAPER

CH02/ 22352356.2

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

RECEIVED
CLERK'S OFFICE
NOV 2 4 2004
STATE OF ILLINOIS
Pollution Control Board

IN THE MATTER OF:	)	
	)	
REVISIONS TO RADIUM QUALITY	)	R 04-21
STANDARDS: PROPOSED NEW 35 ILL. ADM	)	(Rulemaking—Water)
CODE 302.307 and AMENDMENTS TO	)	
35 ILL. ADM. CODE 302.207 and 302.525	)	

SUPPLEMENTAL INFORMATION

NOW COMES the City of Joliet through one of its attorneys, Roy M. Harsch, and submits this Supplemental Information, as agreed to at the hearing held on October 21 and October 22, 2004, to the Illinois Pollution Control Board ("Board") and the participants listed on the Service List.

The City of Joliet is providing the following Supplemental Information:

1) Attachment 1. The Calculation of the Benefit to Public Costs in Dollars Per Person – rem for Land Application of Biosolids prepared by Mr. Dennis Duffield.

2) Attachment 2. A report entitled "Evaluation of Radium Removal Impacts to Study Handling at the Eastside and Westside Waste Water Treatment Facilities," prepared by Clark Dietz, Inc. and dated August 2004.

3) Attachment 3. A report entitled "Report of Survey at Westside Waste Water Treatment Plant in City of Joliet, Illinois," prepared by RSSI, and dated November 15, 2004.

4) Attachment 4. A report entitled "Report of RESRAD Dose Modeling for Waste Water Treatment Plant Sludge Applied to Land Currently Used for Agriculture," prepared by RSSI, and dated October 18, 2004.

WHEREFORE, the City of Joliet by one of its attorneys requests that these four attachments be included as Exhibits in the record of this procedure.

CITY OF JOLIET

By: ______________________
Roy M. Harsch

Roy M. Harsch
Gardner Carton & Douglas LLP
191 North Wacker Drive
Suite 3700
Chicago, Illinois 60606
(312) 569-1441

CERTIFICATE OF SERVICE

I, the undersigned, certify that I have filed with the Pollution Control Board and served the attached Supplemental Information upon the person to whom it is directed, by placing it in an envelope addressed to:

TO: Dorothy Gunn, Clerk
Illinois Pollution Control Board
James R. Thompson Center
100 W. Randolph Street, Suite 11-500
Chicago, Illinois 60601

SEE ATTACHED SERVICE LIST

And mailing it by First Class Mail from Chicago, Illinois on November 24, 2004, with sufficient postage affixed.

THIS FILING IS SUBMITTED ON RECYCLED PAPER

R 04-21 SERVICE LIST

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Exhibit 1

Calculation of the Benefit to Public Costs in Dollars Per Person – rem For Land Application of Biosolids

The Nuclear Regulatory Commission (NRC) gave recommendations of $2,000/person-rem in NUREG-1530 *Assessment of NRC's Dollar Per Person-Rem Conversion Factor Policy*, published in 1995.

The benefit to the public is that costs are saved by continued land application of biosolids(wastewater treatment plant sludge). The savings associated with land applications were calculated by Clark Dietz, Inc in the report entitled "Evaluation of Radium Removal Impacts on Sludge Handling at the Eastside and Westside Wastewater Treatment Plants" The report provides 20 year costs and must be adjusted to 25 years. Adjustments were made to the operating costs only.

	Joliet Eastside	Joliet Westside	Total
Capital	$4,050,000.00	$3,645,000.00	$7,695,000.00
20 year operating increase	$15,647,933.55	$11,804,581.45	$27,452,515.00
20 year total	$19,697,933.55	$15,449,581.45	$35,147,515.00
25 year total	$22,543,836.32	$17,596,490.56	$40,140,326.88

The costs to the public are the cost associated with additional radiation exposure. The Nuclear Regulatory Commission published costs in 1995 of $2,000 per person-rem. This cost inflates to $2,500 per person-rem in 2004 using the consumer price index.

Using the radiation dose for 25 years from the RSSI Study entitled" REPORT OF RESRAD MODELING FOR WASTEWATER TREATMENT PLANT SLUDGE APPLIED TO LAND CURRENTLY USED FOR AGRICULTURE" The 25 year doses are as follows"

	Joliet Eastside		**Joliet Westside**		**Total**	
	50.19000	mrem	120.58	mrem	170.77	mrem
convert to rem	0.00100	rem/mrem	0.00100	rem/mrem	0.00100	rem/mrem
	0.05019	rem	0.12058	rem	0.17077	rem

Acres receiving biosolids	705.00	405.00	1,110.00
homes per acre	3.00	3.00	3.00
homes	2,115.00	1,215.00	3,330.00

Exhibit 2

Evaluation of Radium Removal Impacts to Sludge Handling at the Eastside and Westside Wastewater Treatment Facilities

Prepared for:

City of Joliet

Clark Dietz, Inc.
1817 South Neil Street, Suite 100
Champaign, IL 61820

August 2004

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1 INRODUCTION

1.1 Project Background and Objective

The City of Joliet currently owns and operates two wastewater treatment facilities which treat the City's wastewater. The Eastside WWTP, located on the east side of the River, has the capacity to treat an average daily flow of 18 MGD, while the Westside WWTP has the capacity to treat an average daily flow of 14 MGD. In addition, a third wastewater treatment plant, located on the far western edge of the City in Kendall County, is currently under construction, which has the capacity to treat 3.2 MGD.

The Eastside and Westside treatment facilities consist of the secondary treatment activated sludge process with primary settling upstream of the aeration tanks. The clarified effluent is sent directly to the receiving streams. The waste biosolids from the activated sludge process, as well as the primary sludge, is sent to the anaerobic digesters for stabilization. After sludge stabilization, the stabilized sludge is stored in holding tanks to be land applied on local farmers' fields.

As part of the City's continued population growth, the City is currently in the process of providing upgraded and expanded water treatment facilities. Regulations require the City to remove radium from the water supply. Due to the type of radium removal equipment, concentrated discharges of filter backwash from the co-precipitation of radium with hydrous manganese oxides will be discharged to the sewer system, causing radium to accumulate in the biosolids. The radium accumulation in the biosolids will be similar to the radium accumulation occurring at the present time. The waste sludge to be land applied may exceed the allowed amounts radium and may require that the waste sludge is disposed of in a landfill rather than continuing with the current practice of land application.

The purpose of this report is to review the costs, as well as advantages and disadvantages, of changing from the practice of land application of biosolids to disposal of the biosolids in a landfill.

2 EXISTING SLUDGE HANDLING AND DISPOSAL METHODS

2.1 Westside Wastewater Treatment Plant

The Westside Wastewater Treatment Plant was designed for an average daily flow of 14 MGD and a peak flow of 28 MGD. The plant consists of an influent pump station which pumps the flow to an influent channel where it flows by gravity through a Parshall flume to the grit removal tanks. The wastewater then flows to the primary clarifiers for primary treatment and then on to the aeration tanks for removal of CBOD and ammonia from the wastewater. After secondary clarification, the treated wastewater is discharged to the Des Plaines River.

The primary sludge from the primary clarifiers, and the waste sludge from the secondary clarifiers, are both sent to anaerobic digesters for sludge digestion. The digested sludge is then transferred to sludge storage tanks where it is held in storage until it can be land applied to local farm fields. There are no thickening process units prior to the sludge storage tanks. It is estimated that the sludge storage tank decant system will allow the operator to thicken the sludge to the 6 to 8 percent range while in storage.

Based on the records from the City of Joliet Land Application Program for 2003, the amount of biosolids produced by the Westside WWTP and land applied was 895.3 dry tons. This amounted to a liquid volume of sludge of 8.69 million gallons.

2.2 Eastside Wastewater Treatment Plant

The Eastside Wastewater Treatment Plant was designed for an average daily flow of 18.2 MGD and a peak flow of 45 MGD. The plant consists of an influent pump station which pumps the flow to an influent channel where it flows by gravity to the grit removal tanks. The wastewater then flows to the primary clarifiers for primary treatment and then on to the aeration tanks for removal of CBOD and ammonia from the wastewater. After secondary clarification, the treated wastewater is discharged to the Des Plaines River.

The primary sludge from the primary clarifiers, and the waste sludge from the secondary clarifiers, are both sent to anaerobic digesters for sludge digestion. The digested sludge is then transferred to sludge storage tanks where it is held in storage until it can be land applied to local farm fields. A gravity belt thickener thickens the waste activated sludge and the digested sludge.

Based on the records from the City of Joliet Land Application Program for 2003, the amount of biosolids produced by the Westside WWTP and land applied was 2217.3 dry tons. This amounted to a liquid volume of sludge of 17.03 million gallons.

2.3 Land Application of Sludge

Both the Eastside and Westside wastewater treatments use land application as the ultimate disposal option for the wastewater sludge generated by the treatment process. The sludge is stored onsite in large sludge storage tanks and is taken to local farm fields by contract sludge haulers.

The City currently uses about 23 different land application sites with a total area of approximately 1287 acres. All of these sites are located in Will County, Illinois. The biosolids are applied during approximately six months out of the year. A total of 25.7 million gallons of biosolids were applied in 2003.

The local farmers agree to take the biosolids in order to provide the nitrogen required for the crops. There is a substantial difference between the biosolids generated by the Eastside plant and the biosolids generated by the Westside plant. The Eastside biosolids are lower in nitrogen and therefore require more volume per acre (approximately 32,300 gal/acre). The Westside biosolids are able to meet the crop nitrogen requirements with approximately 21,400 gals/acre. The plant personnel attempt to obtain 6 to 8% solids in the sludge storage tanks in order to reduce transportation costs and allow for more nutrient value per gallon of biosolids.

The site application life for the farm fields is based on total phosphorus applied and is generally limited to five years. The application of sludge to a field may not occur over five consecutive years, but may be applied over 10 or more years. Application to a specific field during a year depends on the crops planted, harvest time, rainfall, and other factors. The sludge is applied to the farm field using chisel plows that inject the sludge 6" to 8" under the surface.

The sludge from both plants consistently meets Class B requirements for sludge disposal by land application. The anaerobic digestion process provides enough detention time and a high enough temperature to control pathogenic microorganisms. The majority of the biosolids are injected below the soil surface to allow nutrients to be readily available to the crop roots.

2.4 Current Costs for Land Application

The City bids out for the hauling services to haul the biosolids to the farm fields for land application. The cost for hauling and disposal at the farm fields has historically ranged from 2 to 2.4 cents per gallon according to City records. This results in an approximate annual cost of $617,000 based on the 2003 volumes of sludge removed from the wastewater treatment plants. The City does not charge the landowners for the biosolids.

3 IMPACT OF WATER TREATMENT RESIDUALS

3.1 Radium Removal Requirements

The Safe Drinking Water act requires the removal of radium from drinking water supplies down to the level of 5 picocuries per liter. The City of Joliet's water supply contains naturally occurring radium at a level above the required 5 picocuries per liter limit. The City is in the process of evaluating water treatment technology to be installed at the new water treatment facilities for the removal of radium from the water supply.

3.2 Proposed Water Treatment Technology

The radium removal technology being considered at present is hydrous manganese oxide technology. The backwash from the regeneration cycle will contain concentrated forms of radium which can be discharged to the City's wastewater collection system, and eventually, to the treatment facilities downstream. While the concentration of radium in the backwash stream will be higher than the naturally occurring radium levels, the mass loading of radium to the wastewater treatment plants is not expected to change due to the mechanisms by which radium is absorbed.

3.3 Current Radium Levels in Existing Sludge

The proposed water treatment technology is not expected to increase the amount of radium in the sludge. Tests on the sludge and the farmers' fields have indicated radium levels that have not exceeded background levels of radium.

Since the mass loading of radium is not expected to change, the quantity of radium in the waste sludge from the plant is not expected to change from the current levels. Therefore, the amount of radium currently being applied with the biosolids to farm fields will not be increased due to the installation of new water treatment technology.

4 ANALYSIS OF LANDFILL OF ALTERNATIVE

4.1 Design Objective and Approach

In evaluating the range of feasible alternatives for the ultimate disposal of sludge, if land application is not available due to radium issues, the options that are available to the City are limited. Since there is a limiting constituent in the sludge (radium), options such as composting and eventual use as soil amendment will have the same limitations as land application. Therefore, the only option available for ultimate disposal is disposing of the sludge in a landfill.

In order to decrease the amount of solids to the landfill, additional processes such as incineration can be considered. Due to the high capital cost, significant increase in operation and maintenance costs, and the air pollution control considerations, the option of incineration will not be considered at this time. Instead, landfill disposal preceded by dewatering of the sludge will be evaluated.

Landfill disposal will require additional dewatering of the sludge in order produce a cake like product without any free water. Belt filter press dewatering facilities will be required to accomplish the required dewatering.

Belt filter presses can typically achieve between 18 to 25 percent cake solids. In order to be conservative in the amount of sludge dewatered and disposed of in the landfill, the cake solids will be assumed to be 16% in the dewatered sludge. This will produce a somewhat higher volume of dried sludge for landfill disposal. The estimated sludge production from the wastewater treatment plants, based on design capacity flow rates, is as follows:

Eastside Plant

Daily Production at 6% Solids (wet)	40,000	gpd
Annual Production at 6% solids (wet)	14,600,000	gal
Annual Production at 16% solids (wet)	5,475,000	gal
Annual Solids Production	47,487,960	lbs

Westside Plant

Daily Production at 6% Solids (wet)	34,000	gpd
Annual Production at 6% solids (wet)	12,410,000	gal
Annual Production at 16% solids (wet)	4,653,750	gal
Annual Solids Production	40,364,766	lbs

Therefore, the total solids requiring landfill disposal is approximately 43,927 tons. This amount of material will require hauling from the plant and disposal at the landfill.

4.2 Capital Costs for New Sludge Dewatering Facilities

New sludge dewatering facilities will consist of the following components at each of the wastewater treatment plants:

New building: A new building will be required to house the dewatering equipment.

Dewatering equipment: The dewatering equipment will consist of belt filter presses, sludge feed pumps, sludge conditioning equipment, polymer mixing and feeding facilities, conveyor belts, sludge hoppers and truck loading areas.

Dried sludge storage: In order to account for scheduling of trucks to haul sludge to the landfill, some type of dried sludge storage facilities will be needed. This will most likely consist of a large pole barn type building.

Odor control facilities: The sludge dewatering building and the sludge storage building will be the source of significant odors. Therefore, extensive odor control facilities will be required to remove the required air changes per hour and treat the air for odors from these two buildings.

Site piping: Significant piping modifications will be required in order to route digested sludge from the digesters to a new dewatering building.

Electrical: The new dewatering facilities and odor control equipment will require that new electrical be routed from the existing MCC's to the new buildings.

The capital costs for new sludge dewatering and odor control facilities are estimated as follows:

Eastside Plant

New Building	$750,000
Dewatering Equipment	$500,000
Odor Control	$750,000
Dried Sludge Storage	$450,000
Electrical	$200,000
Site Piping	$250,000
Site Restoration	$50,000
Miscellaneous	$50,000
Construction Cost Sub-Total	$3,000,000

Contingency	$600,000
Non-Construction Cost	$450,000
Project Total	$4,050,000

Westside Plant

New Building	$750,000
Dewatering Equipment	$500,000
Odor Control	$550,000
Dried Sludge Storage	$350,000
Electrical	$200,000
Site Piping	$250,000
Site Restoration	$50,000
Miscellaneous	$50,000
Construction Cost Sub-Total	$2,700,000
Contingency	$540,000
Non-Construction Cost	$405,000
Project Total	$3,645,000

4.3 Annual O & M Costs for New Sludge Dewatering Facilities

In addition to the capital costs discussed above, there will be ongoing annual costs to operate and maintain the facilities, as well as the hauling and disposal costs for the dried sludge. The annual O & M costs, for both the Eastside and Westside plants, are estimated as follows:

Operation of presses (Power, staff, polymer)		$400,000
Odor control facilities		$350,000
Hauling costs at $7.00 per ton (44,000 tons)		$308,000
Disposal costs at $30.00 per ton		$1,320,000
	Total	$2,378,000

Therefore, the estimated annual cost for operating new sludge dewatering facilities and for hauling and disposing the dried sludge at a landfill is approximately $2,400,000 per year. This is a significant increase in operating costs for the City of Joliet. This annual amount has a present worth value over 20 years at the current rate of inflation is approximately $37 million dollars.

4.4 Other Costs

In addition to the capital and O & M costs listed above, there are a number of other costs due to switching to landfill disposal, some of which are not as easily quantified. These costs include the following:

Use of available landfill space: The amount of sludge to be disposed of in a landfill is approximately 44,000 tons per year. By using this available landfill space for sludge disposal it reduces the capacity available for normal domestic waste disposal. Normal domestic solid waste generation is estimated to be approximately 4.4 lbs per person per day. At this rate, and considering each household to consist of 3.5 persons, disposal of waste sludge at a landfill will use the equivalent capacity of over 15,000 households each year.

It is getting more and more difficult each year to site and permit landfills. Therefore, this disposal alternative does have a significant impact on the available landfill capacity.

Nutrient value of sludge: The sludge which is currently land applied provides a substantial nutrient benefit to the local farmers who participate in the program. The nutrient components of the existing biosolids consist of nitrogen, phosphorus, potassium, copper, zinc and manganese. The fertilizer value of the applied biosolids has been estimated at $30.28 per acre in the first year of the program and at $44.65 per acre in the fourth year of the program. On the average, the fertilizer value is $37.47 per acre. Based on a total acreage in the program of 1287 acres, the current benefit to the local farmers is a cumulative annual savings of approximately $48,000.

If the City is required to switch to landfill disposal, the local farmers will have this added cost due to the required purchase of fertilizer for their fields.

Abandonment of existing facilities: The existing sludge storage facilities would no longer be required if the biosolids were disposed of in a landfill. These facilities consist of large sludge storage tanks as well as mixing and transfer pumping systems. There are very few equipment items from these systems that can be used in the new dewatering facilities. Therefore, these facilities will be abandoned and the capital investment will be returning no value as the facilities sit in a mothballed state.

The construction cost of the existing sludge storage infrastructure at the Eastside Wastewater Treatment Plant was $2,964,330. The construction cost of the existing sludge storage infrastructure at the Westside Wastewater Treatment Plant was $4,075,000. Therefore, the total cost of existing infrastructure that would be abandoned by going to landfill disposal is approximately $7,000,000.

5 RECOMMENDATION

Based on the costs required to switch to landfill disposal of the sludge, the landfill disposal option of the sludge is not cost effective. The costs are summarized as follows:

Parameter	Proposed Landfill	Existing Land Application
Planning Period, years	20	20
Inflation Rate, %	2.5	2.5
Capital Cost	$7,695,000	$0
Installation Cost	$0	$0
Present Value Capital Cost	$7,695,000	$0
Operating Costs per Year	$2,378,000	$617,000
Present Value Operating Cost	$37,071,028	$9,618,513
Total Life Cycle Cost - Present Value	$44,766,028	$9,618,513

As can be seen from the above table, the present value life cycle cost is over $44 million dollars, versus under $10 million dollars for the existing land application practice. This does not account for the cost of abandoning facilities, the nutrient value of the sludge, or the landfill space taken up by landfill sludge disposal.

Therefore, since landfill disposal of sludge is not required for environmental reasons, it is recommended that the current practice of land application of the sludge on local farmers' fields be continued as it is the most cost effective option for ultimate sludge disposal.

Exhibit 3

REPORT OF SURVEY
AT
WESTSIDE WASTE WATER TREATMENT PLANT
IN
CITY OF JOLIET, ILLINOIS

PERFORMED FOR

DEPARTMENT OF PUBLIC WORKS AND UTILITIES
CITY OF JOLIET, ILLINOIS

BY

RSSI
6312 W. OAKTON STREET
MORTON GROVE, ILLINOIS

November 15, 2004

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INTRODUCTION

On October 15, 2004, RSSI performed a survey and a sludge sample was collected at the Joliet Westside Waste Water Treatment Plant (WWTP) to measure the dose rate at the surface of sludge tanks and for analysis for the radium concentration in the sludge.

METHODOLOGY

Direct Reading

Radiation levels were measured at the surface of sludge storage tank no. 4 to determine if areas of elevated radiation were present. The measurements were made using a Ludlum Model 3 survey meter with a 44-9 pancake probe. The probe was moved slowly approximately 1 centimeter from the surface of the surface and the tank between 3 to 6 feet above the base.

Exposure rate measurements were made at the surface of columns in a Water Remediation Technology, LLC (WRT) demonstration project. The demonstration project removes radium from a water flow of approximately one gallon per minute (gpm). The removed radium is retained in four columns through which the water flows in series. The exposure rate measurements were made using a Ludlum Model 3 survey meter with an Eberline HP-270 probe. The probe was moved slowly approximately 1 centimeter from the surface of the columns to located the areas of highest exposure rate for each column. At 1 gpm much less radium is removed than would be removed by a production unit.

The Ludlum Model 3 is a general-purpose portable survey instrument. It is used with a Ludlum Model 44-9 pancake type Geiger-Mueller (GM) detector or an Eberline HP-270 energy compensated GM detector. The Model 44-9 is sensitive to charged particle radiation, such as alpha and beta radiation, and has limited sensitivity to photons. The HP-270 is energy compensate, having a flat exposure rate response between 70 keV and 1.3 MeV. With its beta shield closed it is insensitive to particulate radiation.

Dose rates were measured using a Health Physics instrument (HPI) model 1010 survey meter. Dose rates were measured at the surface of the tank in the same areas as the radiation levels were measured. The HPI Model 1010 is a portable survey meter with a soft tissue equivalent gas multiplication chamber. It measures deep dose and deep dose rates from photons and penetrating particles in continuous or pulsed radiation fields. The reading in mrad/hour is multiplied by the quality factor to obtain the dose equivalent in mrem/hour. The quality factor for beta and gamma radiation is one.

Bulk High Resolution Gamma Spectroscopy

A 535 grams sludge sample was collected by a city employee in 500 ml Marinelli beaker and counted for 48 hours in a Nucleus PCA II Analyzer. The Nucleus PCA II analyzer is a PC based 8k channel multichannel analyzer (MCA). It is used with an Ortec GEM-30185 high purity germanium (HPGe) detector, an Ortec 456 high voltage power supply, and a Canberra Model 2021 spectroscopy amplifier. Data are reduced using Quantum Technology gamma spectroscopy software. This system performs qualitative and quantitative analysis of spectra from the HPGe detector, identifying radionuclides and the quantities present in samples.

The sludge sample was analyzed for the presence of the naturally occurring uranium, thorium and actinium series and for potassium-40 using GDR software. Radium 228 is in the thorium series and emits no significant photons. Radium 226 is in the uranium series and has only one low abundance photon at 186 keV.

The concentrations of surrogates with more abundant high energy photons usually represent the concentration of Ra-228 and Ra-226. Actinium-228, in the thorium series, is frequently used as a surrogate for Radium-228. Lead-214, in the uranium series, is frequently used as a surrogate for Radium-226. These surrogates are in equilibrium with the radium isotopes after one month in-situ.

RESULTS

Instrument Surveys

Background radiation levels at the WWTP were between 50 and 60 counts per minute (cpm). Radiation levels at the surface of the tanks were approximately 40 cpm. The background dose rate was 8 μrad/hr. The dose rate at the surface of the tank was 5 μrad/hr.

Exposure rates at the surfaces of the columns in the WRT demonstration project are below.

Column Number	Exposure Rate (mR/hr)
1	2.0
2	1.3
3	0.6
4	< 0.1

Bulk High Resolution Gamma Spectroscopy

The 535 gram sludge sample dried to 17 grams. It was analyzed when collected and reanalyzed after being held 30 days to permit ingrowth of the radium daughters. High Resolution Gamma Spectroscopy results follow.

Isotope	Initial (pCi/g)	Final (pCi/g)
Ac-228	19.0	28.0
Pb-214	14.5	20.1
Total*		48.1

* Ra-226 and Ra-228 by surrogates

The changes in the activity of both surrogates are due to disequilibrium in the thorium and uranium series when the sample was collected. The lower initial concentration of Ac-228 suggests that the sample had a lower initial concentration of Ac-228 than of Ra-228. The ingrowth of Pb-214 occurs when a disturbance of equilibrium results from the release of radon-222.

CONCLUSIONS

- Radiation levels and dose rates at the surface of tank no. 4 lower than background are expected because the tank and its contents shielded the instrumentation from background radiation. Significant concentrations of radium would have raised the radiation levels and dose rates.
- The exposure rates at the surface of the WRT demonstration columns would be scaled up for radium removed from a two stage system at higher flow rates.
- The presence of significant radium in at least three stages of the WRT demonstration indicate that at least three stages, and probably four stages, may be required in a production operation to prevent breakthrough of radium.