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BEFORE THE POLLUTION CONTROL BOARD
OF THE STATE OF ILLINOIS

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Pollution Control Board

IN THE MATTER OF:	)	
	)	
REVISIONS TO RADIUM WATER	)	
QUALITY STANDARDS: PROPOSED	)	R04-21
NEW 35 ILL. ADMIN. CODE 302.307	)	Rulemaking - Water
AND AMENDMENTS TO 35 ILL. ADMIN.	)	
CODE 302.207 AND 302.525	)	

PC #26

NOTICE OF FILING

To: See Attached Service List

Please take notice that on December 8, 2004, we filed with the Office of the Clerk of the Illinois Pollution Control Board an original and ten copies of the attached ***COMMENTS SUBMITTED BY THEODORE ADAMS, BRIAN ANDERSON AND CHARLES WILLIAMS,*** a copy of which is served upon you.

Respectfully submitted,

WATER REMEDIATION TECHNOLOGY, LLC

By: ______________________
One of its Attorneys

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SERVICE LIST

R04-21

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ORIGINAL

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December 7, 2004

A. Antoniolli
Illinois Pollution Control Board
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Suite 11-500
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Dear Hearing Officer Antoniolli,

I have been in attendance at the hearings on August 24, and October 21 and 22. I have also reviewed the prior testimony and the documents submitted by the Agency, the City of Joliet and the Metropolitan water reclamation District of Greater Chicago. Based on that review, I believe that there are several misunderstandings about radiation generally, and particularly the potential effects and exposure of radium in sludge.

The potency of radium particles and their behavior in POTWs

There appears to be a general lack of understanding about the toxicity of radium particles that are formed from the treatment of naturally occurring radium materials. These materials -- known as Technically Enhanced Naturally Occurring Radioactive Materials or TENORM - are not the same as they occur naturally. When the NORM are treated, such as with the HMO process, they become concentrated radium particles. These are the kind of particles that led to the clean-up costs in Ohio and Pennsylvania that I discussed in my August testimony. These are the kind of particles that the NRC [and subsequently the NRC-agreement states such as Illinois] banned from being placed into POTWs through the investigations and rulemaking activities I have discussed in my testimony and exhibits.

As an example, the concentration of radium on a particle from an HMO process likely is in the range of 10,000 pCi/g, to 70,000 pCi/g. These particulates will be in the sludge that is placed on the farm field, the parks and other public area where the sludge is used as a fertilizer. A small amount of these particles on a child's face or arm could produce as much as 320 mRem dose to that area in a 6-hour period. Every time the child goes out to play in the yard/field he/she is able to pick up these high activity radium particulates and be exposed to unnecessary and unwanted risks to skin cancer and lesions.

The exposure would be greater if the particle were ingested or inhaled. If a child ingested 2 grams of these particles he/she could be exposed to 350 mRem, which is 3.5 times the NRC allowable exposure to the public (100 mRem/yr), but obtained in only one exposure event. [See Attachment 1 to this comment].

Comments on the supplemental documentation submitted by the City of Joliet

These documents may be the reports relied upon by Dennis Duffield during his testimony on October 22. However, the reports are very fragmentary and do not appear to match, in at least one instance, the reports that he promised to provide. We have numerous questions about these documents, both as to their bases, their scientific acceptability and their completeness. The document appearing at Tab 3 regarding the Westside Treatment Plant does not appear to be the report on worker safety Mr. Duffield described in his testimony; it appears to relate to surveys and sampling of the WRT pilot plant and the Westside Treatment Plant. The report at Tab 4 ostensibly dealing with risks from exposure to soils that had been land-applied has several inaccuracies, and it does not disclose the basis for the input assumptions. Those inputs are quite different from those used by ISCORS analysis. And the analysis is cut off after 7 years - ostensibly because the resident will move in that period of time. But dermal exposure to high activity radium particles, such as digging in a garden or playing in a sludge augmented field/yard, as well as ingestion exposures, do not appear to have been taken into account.

My comments on the 4 documents are presented in Attachment 2. The relevance of these documents to this matter would have been much more clear had they been produced during the October hearings, allowing questions to be asked. Nothing in them causes me to believe that my prior testimony was not accurate for the issues addressed. And none of these documents address the effects of TENORM and exposures to particles of high radium activity.

Inaccuracies and observations relating to the documents submitted by Illinois EPA

At the August 24 hearing, IEPA presented three documents that were marked as exhibits. No one from the Agency testified in support of those documents. I was expecting an opportunity to explore those documents since they included some clear errors in calculations. Instead, we found that the one conclusion potentially relating to water quality was done by someone no longer with the Agency and no one at the Agency could vouch for his calculations [calculations which during the August hearing I stated my disagreement].

With respect to the issues raised by Tab 4 submitted by Joliet, and the assertions included in the Agency's document [Exhibit 11], I have noted several inconsistencies that are troubling.

First, I was surprised to find that there was a substantial amount of radiation unaccounted for between the total levels documented by IEPA's Exhibit 11, and the calculations done by Dr Port [Joliet, Tab 4]. Approximately .2 Curie per year is missing. That is a very large amount of radiation, about half of the level that created a major problem in the North-East Ohio Regional Sanitary District POTW. [See Attachment 3 to this comment]

Second, it appears that the Agency's calculations on the amount of acreage that Joliet should use to apply its sludge is 3 times greater than represented by the Agency.

Those calculations and their bases are in Attachment 4 to this comment.

Third, it appears that with the actual sludge levels sampled by the City of Joliet, that the Westside plant does not meet the 0.1 pCi/g standard contained in the IDNS/IEPA memorandum of agreement. Instead it appears that the sludge levels require twice as much land to meet the IDNS standard. Interestingly, the East Side plant - which has sludge levels of less 18 pCi/g does meet the IDNS standard; it may be that at the current application rates allowed by IEPA that any sludge with levels over about 25 pCi/g will exceed the 0.1pCi/g standard. See calculations in Attachment 5 to this comment.

Finally, I examined the effect on sludge levels of a 5 pCi/l concentration in the wastewater entering the Joliet treatment plants. Those calculations indicate that if the ONLY material incoming is compliant with the drinking water standard of 5 pCi/l, that the sludge will barely meet the 0.1 pCi/g limit in the IDNS-IEPA agreement. See Attachment 6. This would confirm that the filtrate from treating the groundwater for Joliet should not be discharged into the POTW, and certainly could not if the water treatment plant were licensed. Obviously, I believe that is the prudent engineering choice to make, for reasons completely apart from the relationship between the maximum allowable federal drinking water level, and the IDNS-IEPA soil application rule.

Further comments on the BDAC approach

There was not time to respond to the comments at the last hearing about the alleged conservatism of the BDAC approach. Dr Anderson has explained why the approach is not conservative from an ecological perspective. I have used the BDAC approach to give an example of what a water quality standard might be based on the formulas included there.

Since that last hearing I did one further calculation that I wanted to share. I applied the BDAC formula to the conditions at the lakes in Florida to see how it worked. I found that the Florida situation passed the BDAC screening criteria. Then I calculated the actual radioactive dose, and found that the actual radioactive dose in that situation exceeded the 1.0 Rad/day dose required by the DOE order. From this I must conclude that the BDAC methodology is not perfect in equating environmental conditions to the DOE standard, and that it may give a false sense of re-assurance. These calculations are included as Attachment 7.

Feedback from NEORSD and KISKI POTW Representatives

As part of my evaluation of the impacts to POTWs from insoluble radioactive particulates discharged to the sewers/drains, I contacted two of my clients who have been the recipients of 'radioactive solids' placed into their sewers. I contacted Mr. Robert Kossack; Director of the KISKI Valley Water Pollution Control Authority (KVWPCA) on what was his opinion of allowing radioactive particles to be released to the sanitary sewer/drains. His response was an emphatic 'NOT A GOOD IDEA!' (Approximately 10 years ago, the KWVPCA ended up with a lagoon full of uranium contaminated ash as a result of an NRC licensee discharging allowable quantities of insoluble uranium down the sewer and into the POTW. The issue has still not been resolved).

Mr. Kossack then went on to say that following his experience with the contaminated ash, the KVWPCA took immediate action under their Pretreatment Permit Program and instituted a 'No Radioactive Solids Down the Sewer' requirement on the NRC licensee. Rather than comply with the permit condition, the licensee disposed of their uranium material offsite.

I also contacted Mr. Thomas Lenhart from the Northeast Ohio Regional Sewer District (NEORSD). In 1991 the NEORSD discovered cobalt-60 contaminated ash on their Easterly Plant property and their Southerly Plant Property and dewatering lagoons. Remediation costs have exceeded $2M to date and the NEORSD is now required to be an Ohio Radioactive Materials Licensee.

Mr. Lenhart responded to my question by stating "The total amount of Co-60 in terms of physical quantity was a tiny fraction of an ounce, only a gram or two. This gram or two of material was mixed in hundreds of tons of ash and yet still posed a regulatory issue due to hot spots resulting from the cobalt high activity.. NEORSD has to date spent approximately $2M addressing the resulting issues."

He continued by stating, "The studies (ISCORS) suggest that while neither man-made radionuclides nor NORM are usually a problem for the POTWs, in certain circumstances levels of activity can be of regulatory concern, as happened at NEORSD. Furthermore, the cost of contaminating a POTW, even at extremely low levels, can be well into the millions."

Regarding water treatment technologies, Mr. Lenhart stated, "I do not endorse any particular technology or process. However, where there are inexpensive and effective processes available to avoid the disposal of radioactive materials into sanitary sewers, these processes or technologies should be considered."

Based on the responses from these POTW representatives who have experienced the financial impacts, potential liabilities, and concern over worker and public safety, the allowing of the discharge of radioactive particulates down the sewers by the IEPA/IEMA is inappropriate.

Conclusion

It appears that the IEPA is not conversant with the kinds of issues raised by control of radiation. Moreover, the NRC and the agreement states have had experience with the very issue that Illinois is confronting in this proceeding. I believe that what is done with the radium AFTER it is removed from the drinking water supply is very important and should not be trivialized. I urge Illinois to learn from what the NRC and other POTWs have learned. I urge Illinois to keep radioactive solids out of sanitary sewers and to not dispose of radium filtrate by putting it back into the environment.

Sincerely,

Theodore G. Adams /JH

Theodore G. Adams

ATTACHMENT 1: DOSE FROM DISCRETE RADIUM PARTICULATES

There are a number of best available and small system compliance treatment technologies available for removal of radionuclides (radium in our case) from drinking water. These technologies include, but are not limited to:

- Ion Exchange (IX)
- Reverse Osmosis (RO)
- Lime Softening
- Hydrous Manganese Oxide (HMO)

Some of the treatment technologies produce a relatively soluble radium effluent, while others like HMO produce a solid radium (i.e., spent resin) or particulate residual.

The Hydrous Manganese Oxide (HMO) treatment process produces two types of residuals:

Liquid - spent filter backwash water (contains high activity radium particulates and co-occurring contaminants)

Solid - spent filter media (contains radium and co-occurring contaminants and sludge)

It is the generation of the high activity radium particulates in the HMO spent filter backwash, the IEPA approved release of their particulates into the sanitary sewer/POTW plants, and the ultimate further concentration of high activity in the POTW sludge which is subsequently applied to local farmland as fertilization that is the greatest concern. Based on available process information, radium particles from the HMO process can range from 16,000 - 70,000 pCi/g (see attached memo from John Litz to Charles Williams)

Discrete radium particulates of this kind, with radium levels on solids of 10,000pCi/g to 70,000 pCi/g present a unique concern when they are part of sludge applied to a local farm, park, playground as fertilizer/soil augmentation.

Discrete Radioactive Particles (DRPs) or hot particles are a major concern in nuclear power plants. Radiation protection procedures/programs have been developed to address DRPs. A large amount of effort by both the National Council on Radiation Protection and Measurement (NCRP), the Nuclear Regulatory Commission (NRC), and other independent researchers have been expended in evaluating the overall human health effects (i.e., skin cancers) due to the exposure to these hot particles.

To gain an understanding of the potential dose impacts to individuals (i.e., children playing in fields, parks where sludge containing high activity radium particulates was applied) who might obtain several of radium particulates on their skin, a dose calculation was performed.

Details of the input, assumptions, and results of the calculation is presented in Calculation #6.

CALCULATION OF DOSE TO SKIN FROM DISCRETE RADIUM PARTICULATES

The methodology for calculating the skin dose to the individual is provided.

CALCULATION #1
CALCULATION OF DOSE TO SKIN FROM DISCRETE RADIUM PARTICULATES

Given:

Particle Activity:	70,000 pCi/g
Exposure Area:	10 cm^2
Skin Thickness:	4 mg/cm^2 (child's neck, arm, face)
Skin Dose Rate Factor* for Radium-226:	5.9×10^{-4} Sv/yr per Bq/cm^2 or 0.25 Rem/hr per $\mu Ci/cm^2$
Exposure Time:	6 Hours
Activity:	Child playing in soil augmented with radium particulates containing 70,000 pCi/g
Distribution:	3 grams of soil containing 70,000 pCi/g or 210,000 pCi or 0.21 μCi on skin

D = A DFt/s

= $0.21\ \mu Ci \times 0.25\ Rem/hr/\mu Ci/cm^2 \times 6\ hrs/10\ cm^2$

= **0.03 Rem or 30 mRem per occurrence/event**

Where:

D = Hot Particle Skin Dose (Rem)
A = Particle activity (μCi)
DF = Skin Dose Factor (Rem/hr per $\mu Ci/cm^2$)
t = Residence Time on Skin (hr)
s = Area over which the dose is averaged (cm^2)

* *Health Physics, 53 Pages, 138-141, Kocher & Eckerman, 1987, Pergamon Journals, Limited*

Prior to April 5, 2002, the hot particle skin exposure was averaged over 1 cm^2 of the skin. Prior to this date, the NRC requested the NCRP evaluate this approach. NCRP issued Report No. 130 (NCRP 1999) and Statement No. 9 on March 30, 2001, which supported among other recommendations that the hot particle dose be averaged at 10 cm^2 rather than 1 cm^2. On April 5, 2002, the NRC revised the area to be averaged from 1 cm^2 to 10 cm^2.

If the pre-2002 NRC rule was still in effect, the skin dose to the child would be 0.32 Rem or 320 mRem! This dose would be for just one exposure event. Whether it is 30 or 300 mRem, every time the child goes out to play in the yard, he/she is able to pick up these high activity radium particulates and be exposed to unnecessary and unwanted radiation and unnecessary risk to skin cancer and lesions.

Dose Due to Ingestion of Radium Particulates

If a gram or two of these were ingested by a young child, which is not unreasonable, the results would be:

Given:

2 grams (140,000 pCi or 0.14 μCi) of Radium-226 was ingested.
All radium was retained in body (i.e., body burden of 0.14 μCi)
ALI for radium is 2 μCi (NRC 10 CFR 20, Appendix B)
Use internal dose methodology used for radiation worker.

CEDE = 5 Rem x I (μCi)/ALI (μCi)

= 5 Rem x 0.14 μCi/2 μCi

= **0.35 Rem or 350 mRem**

Where:

CEDE = Committed Effective Dose Equivalent (Rem)
I = Activity of Ingested Radionuclide (μCi)
ALI = Annual Limit on Intake (μCi)

The 350 mRem is 3.5 times the NRC allowable exposure to the public (100 mRem/yr), but obtained in only one exposure event.

ATTACHMENT 2:
REVIEW OF
CITY OF JOLIET SUPPLEMENTAL DOCUMENTS
DATED NOVEMBER 24, 2004

Based on our review of the following calculations/reports (provided as Tabs 1, 2, 3 and 4 of the City of Joliet supplemental documents) the following comments/questions are offered:

Calculations/Reports

- Calculation of the Benefit to Public Costs in Dollars per Person-Rem for Land Application of Biosolids (Author Unknown, Tab 1)
- Evaluation of Radium Removal Impacts to Sludge Handling at the Eastside and Westside Wastewater Treatment Facilities (Clark Dietz, Inc., August 2004, Tab 2)
- Report of Survey at Westside Wastewater Treatment Plant in City of Joliet, Illinois (RSSI, November 15, 2004, Tab 3)
- Report of RESRAD Dose Modeling for Wastewater Treatment Plant Sludge Applied to Land Currently Used for Agriculture (RSSI, October 18, 2004, Tab 4)

CALCULATION OF THE BENEFIT TO PUBLIC COSTS IN DOLLARS PER PERSON-REM FOR LAND APPLICATION OF BIOSOLIDS

COMMENTS

Specific

5. Paragraph 5:

   The paragraph should clarify that the 25 years doses are from the Eastside and Westside "Model 2 Applications."

6. The basis for three homes per acre is not given.
7.
8. It is not clear how the information in the first table, which shows capital and operating costs for the Eastside and Westside POTWs, relates to the "savings associated with land applications" in the Clark Dietz, Inc. report. There appears to be no existing operating or capital costs presented in the subject report.

9. The calculation of the cost of person-rem is incomplete. Please clarify/show costs per person-rem using the 2,500 per person-rem costs.

10. It is not evident how the number of persons was determined?

EVALUATION OF RADIUM REMOVAL IMPACTS TO SLUDGE HANDLING AT THE EASTSIDE AND WESTSIDE WASTEWATER TREATMENT FACILITIES

COMMENTS

Specific

1. Page 3, Section 2.1, Paragraph 1, Section 1:

   The daily flow of 14 mgd presented here conflicts with the 7.628 mgd presented by IEPA from the 2002 data from the DWPC database.

2. Page 3, Section 2.2, Paragraph 3, Section 1:

   "Westside" should be "Eastside." The "2,217.3 dry tons" presented here does not agree with the IEPA's 2,400 dry tons presented in the September 2003 Engineering Evaluation Report.

3. Page 5, Section 3.3, Paragraph 1:

   Sentence 1

   But the proposed water treatment technology (HMO) will produce concentrated radium particles in the sludge which will contain radium concentrations up to 70,000 pCi/g. (See attached memo from John Litz to Charles Williams).

   Section 2

   The test results of the sludge and farmer's field were not referenced. References and/or test results should be provided.

   However, the need for more drinking water due to population growth will require more water be pumped from deeper wells with higher concentrations of radium. This event cause increases in radium concentrations to occur in the sludge.

4. Page 6, Title: Analysis of Landfill of Alternative:

   Delete second "of."

5. Page 7, Section 4

General:

Dewatering the sludge will increase the radium concentration in the sludge. Care will need to be taken to maintain sludge concentrations within acceptable IEPA/IEMA and landfill operator limits.

Not all of the sludge will need to be disposed of in a landfill, only the radium contaminted water treatment residuals. The POTW sludge can be applied to the farmer's field, as is currently done.

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

COMMENTS

General

1. No page numbers are provided.

2. There were no purposes or objectives given for the survey and sludge sampling efforts. Please clarify.

3. No references are provided for field procedures used to perform the surface scan, exposure rate measurements, dose rate measurements, or the laboratory gamma spectroscopy analysis. Please provide copies of the procedures used to perform the three types of surveys and the gamma spec analysis of the sludge sample.

4. No mention was made of the use of a chain of custody procedure/form to control/maintain custody of the sludge samples.

5. No mention was made of the calibration status of the survey instrumentation used to perform the survey.

10. Testimony was provided by Mr. Duffield during the October 21-22, 2004 hearings that RSSI evaluated the production of radon within the Joliet Westside POTW. However, there is no description or discussion of this sampling effort or related results. This report does not appear to be the same equipment.

Specific

1. Page 1, Methodology, Paragraph 1:

   Please clarify that this survey was a "scan survey" as opposed to a "static survey" (i.e., one minute count in a particular location/spot).

2. Page 1, Methodology, Paragraph 1:

   "Surface of the surface." Suggest deleting "surface and."

3. How much of the surface area tank(s) were scanned?

4. Page 1, Methodology, Paragraph 2, Sentence 5:

"Located" should be "locate."

5. Page 1, Methodology, Paragraph 2, Sentence 6:

Do not understand the relevance of this statement and the overall objective of the survey. Please see General Comment 2.

6. Page 1, Paragraphs 2 and 3:

How many exposure rate measurements were obtained?

7. Page 1, Paragraph 4:

How many dose rate measurements were obtained?

8. Page 2, Bulk High Resolution, Gamma Spectroscopy, Paragraph 1, Sentence 1:

Marinelli beakers are not typically used for sampling purposes due to th econcern of contamination of the outside of the container and the counting system. They are usually used for counting purposes. Please clarify.

Please clarify who counted the sludge samples and at what location/facility.

Was the sample counted utilizing an approved field/lab procedure, trained lab technician, and under an approved Quality Assurance Plan? Please provide documentation.

9. Page 2, Results, Paragraph 1, Sentence 1:

Where were the background level determinations made for each instrument? Were they performed in accordance with an approved and documented field procedure? Please provide documentation.

10. Page 2, Results, Paragraph 1, Sentence 2:

The survey described in the Methodology, Direct Reading section was a scanning survey. Therefore, one would expect a range of readings/results for the surface scan screening survey (i.e., 40-80 cpm with a high of 80 cpm, a low of 40 cpm, and an average of 60 cpm). The section states, "the surface tanks were 40 cpm approximately. Please clarify.

11. Typically, drawings of the item(s) surveyed (i.e., tank, vehicle, floor) are provided with locations of each survey point shown on the drawing. Completed survey measurements/results can then be correlated with the location of the item where the measurement/reading was taken. It is recommended that a drawing of the tank(s) be shown and a table with the specific survey results (i.e., exposure rates, dose rates, and scan results) be provided to correlate these results.

12. Page 3, Bulk High Resolution Gamma Spectroscopy, Paragraph 1, Sentence 1:

    It is not clear based on statements made on page 2 whether the sludge sample was dried first and then counted, or the sample counted as soon as it was collected with no drying.

    Was the 17 gram, which resulted after drying, counted in the Marinelli container or the gamma spec system? How was counting geometry controlled?

13. Page 3, Bulk High Resolution Gamma Spectroscopy:

    Typically, an analytical result for a sample is reported with its standard error (i.e., 95%). The results reported in the RSSI report are shown without their associated standards errors. Please clarify.

14. Page 3, Conclusions, Bullet 7:

    What is the relevancy of the second sentence in the first bullet, the second bullet, and the third bullet to the objectives (or lack thereof) of the survey?

REPORT OF RESRAD DOSE MODELING FOR WASTEWATER TREATMENT PLANT SLUDGE APPLIED TO LAND CURRENTLY USED FOR AGRICULTURE

COMMENTS

General

1. There are no page numbers.

Specific

1. Page 1, Paragraph 1, Sentence 5:

   Ra-228 is not an alpha emitter, it is a beta emitter.

2. Page 1, Paragraph 2, Sentence 1:

   "Usually has" run on.

3. Page 1, Paragraph 4, Sentence 2 and Paragraph 5, Sentence 3:

   Statements are not true.

   "Drinking water studies in Ontario, Canada, Illinois/Iowa, and in Wisconsin previously have found the association between osteosarcoma and elevated radium levels in drinking water." (NDHSS News Release, 9/19/03.)

   "When exposure estimates were categorized in terms of total radium cancer potency, expressed as equivalents of Radium-228, the resulting incidence rate among those exposed at ≥ 4 pCi/L was 90% higher than those whose tap water had less than 0.5 pCi/L. The elevated incidence of osteosarcoma was entirely associated with males.

   For males in areas receiving water with ≥4 pCi/L and 2.0 - 3.9 pCi/L, compared to those receiving <0.5 pCi/L, the rate ratios were 3.4 (95% CI 1.5, 6.7), and 3.1 (95% CI 1.3, 6.0), respectively. For males 25 and over, rate ratios were 6.2 (95% CI 2.0, 14) and 5.5 (95% CI 1.8, 1.3), respectively. ("Radium in Drinking Water and the Incidence of Osteosarcoma," DHSS, 9/19/03.)

   In other words, even at the 2 - 3.9 pCi/L Ra-228 equivalent, the rate of osteosarcoma was 3.4 (3.4 times higher) for ≥4 pCi/L and 3.1 for 2.0 - 3.9 pCi/L. For males over 25, it was 6.2 and 5.5 higher.

4. Page 1, Paragraph 6, Sentence 1:

   Inconsistency with IEPA information. Range from IEPA calculation, September 2003 Engineering Report was 8.1 - 17.2 pCi/L radium, average 13.3 pCi/L for Joliet water supply.

5. Page 2, Paragraph 1, Sentence 2:

   Please clarify the meaning of "some other form." Is "other form concentrated radium particles up to 16,000 - 70,000 pCi/g?" There is no mention of concentrated particles.

6. Page 2, Paragraph 2, Sentence 1:

   Confusing. Should read something like, *"Joliet currently 'discharges' the radium initially in the water supply to the POTW where it is concentrated in the sludge or released to the Fox River."*

7. Page 3, Paragraph 3, Sentence 2:

   "planed"

8. Page 3, Footnote 1:

   "RASRAD" should read *"RESRAD."*

9. Page 4, Paragraph 1, Sentence 2:

   "by the Joliet?"

10. Page 8, Paragraph 1, Sentence 1:

    No reference to HPS position statements is provided (it is August 2004).

11. Page 8, Paragraph 2, Sentence 2:

    No reference.

12. Page 8, Paragraphs 3 and 4, Sentence 1:

    No reference.

13. Page 8, Paragraph 5, First Word:

"Joliet"

14. Input Parameters, Page 4:

See Table 1, Comparison of Input Parameters between RESRAD, ISCORS, and Joliet (document number WRT001.wpd).

Dimension of Field

150 acres x 4,047 m2/acre = 607,050 m^2 (**not** 590,000 m^2)

Contaminated Zone Hydraulic

4,310 m/yr vs 210 m/yr conductivity

Contaminated Zone b Parameters

9.075 vs 2.895 or 5.3

Watershed for Nearby Stream

2,589,988 m^2 vs 1,000,000 m^2

Saturated Zone Hydraulic Conductivity

4,310 m/yr vs 10 or 100

Saturated Zone b Parameters

9.075 vs 5.3

Model for Water Transport

Non-dispersion, but RESRAD printout says Mass Balance.

Has no thickness for unsaturated zone.

Exposure duration - not used for dose calculations only risk.

General Joliet RESRAD analysis not consistent with input parameter in ISCORS RESRAD analysis, i.e., shutting off plant food, meat, milk, aquatic foods, soil ingestion, and drinking water.

15. Page 6:

3.5 tons x 1,016 Kg/ton x 1,000 g/Kg = 3.56 x 10^6 g/acre

not 3.2 x 10^6 g/acre

16. Page 6, Table Radium in Soil Field:

Eastside Plant: 0.028 pCi/g + 0.031 pCi/g = 0.059 pCi/g

Westside Plant: 0.058 pCi/g + 0.091 pCi/g = 0.15 pCi/g

0.15 pCi/g > 0.1 pCi/g IEPA / IEMA limit.

ATTACHMENT 3

COMPARISON OF ILLINOIS ENVIRONMENTAL PROTECTION AGENCY AND RSSI ESTIMATES OF RADIUM ACTIVITY IN THE CITY OF JOLIET'S SLUDGE

A comparison of the amount of radium activity reported to be in the city of Joliet's sludge by the Illinois Environmental Protection Agency (IEPA) (T.G. Adams Supplemental Testimony, Attachment G, dated October 8, 2004) and RSSI (R.M. Harsch Supplemental Testimony, Attachment 3, November 24, 2004) was performed. The information and methodology used to perform the comparison is presented in Calculation #3. The methodology incorporates data from the IEPA, RSSI, and Clark Dietz documents provided as supplemental testimony.

The comparison of the IEPA and RSSI/Clark Dietz calculations related to radium activity in the city of Joliet's sludge identified the following:

- Total Annual Radium Activity in Sludge

0.294 Ci/yr	IEPA
0.093 Ci/yr	RSSI (using IEPA annual sludge production rates)
0.2 Ci/yr	

0.294 Ci/yr	IEPA
0.085 Ci.yr	RSSI (using Clark Dietz sludge production rates)
0.21 Ci/yr	

0.2 Ci/yr $\cong$ 0.21 Ci/yr

The basic question is where did the rest of the radium go? If it is assumed that all of the radium in the raw well water went into the sludge, then the annual radium activity should be shown to be approximately 0.294 Ci/yr for both the IEPA and RSSI calculations. Instead, there is a large discrepancy (0.2 Ci) between the IEPA results and the RSSI/Clark Dietz results. Once again, where did the radium go?

Thus, the attempt to develop a reasonable mass balance for the Joliet POTWs using the IEPA and RSSI/Clark Dietz was unsuccessful.

Given: Information from IEPA Calculation and RSSI Report

- Radium Concentrations (pCi/g) in Sludge [1]

Westside Plant	**47.2**
Eastside Plant	**18.7**

CALCULATION #3
COMPARISON OF ILLINOIS ENVIRONMENTAL PROTECTION AGENCY AND RSSI ESTIMATES OF RADIUM ACTIVITY IN THE CITY OF JOLIET'S SLUDGE

- Activity (annual production)

Westside Plant **0.047 Ci**

47.2 pCi/g [(1)] x 988 dry tons/yr [(2)] x 1,016 Kg/ton x 1,000 g/Kg = 4.74 E10 pCi
(using IEPA annual sludge production rate)

47.2 pCi/g [(1)] x 895.3 dry tons/yr [(3)] x 1,016 Kg/ton x 1,000 g/Kg = 4.29 E10 pCi
(using Clark Dietz annual sludge production rate)

Eastside Plant **0.046 Ci**

18.7 pCi/g x 2,400 dry tons/yr x 1,016 Kg/ton x 1,000 g/Kg = 4.56 E10 pCi
(using IEPA annual sludge production rate)

18.7 pCi/g x 2,217.3 dry tons/yr x 1,016 Kg/ton x 1,000 g/Kg = 4.21 E10 pCi
(using Clark Dietz annual sludge production rate)

- Total Activity in Sludge (annual production) [(1)]
  0.093 Ci/yr (IEPA)
  0.085 Ci/yr (Clark Dietz)

- Total Activity in Raw Water Supply [(2)]
  0.294 Ci/yr (IEPA)

and hence sludge (i.e., assume 100% of radium in water goes to sludge

- **Where did the Radium go?**

0.294 Ci/yr - 0.093 Ci/yr = 0.2 Ci/yr (IEPA)

0.294 Ci/yr - 0.085 Ci/yr = 0.21 Ci/yr (Clark Dietz)

0.2 $\cong$ 0.21

ATTACHMENT 4

AMOUNT OF APPLICATION AREA (ACREAGE) REQUIRED TO ALLOW PLACEMENT OF JOLIET POTW SLUDGE ON LOCAL FARM FIELDS

A review of the IEPA calculations/analysis of the application area (acres) required to allow placement of the sludge from Joliet's POTWs (East Plant and West Plant) on local farm fields was performed. The IEPA analysis is presented in Attachment G of T.G. Adams supplemental testimony dated October 8, 2004. The IEPA/IEMA agreed upon radium concentration of 0.1 pCi/g (refer to IEPA/IEMA Memorandum of Agreement dated September 13, 1984) was utilized as a limit for the radium/soil field mixture.

The review identified two major errors in the IEPA's calculations. The first error occurs in the IEPA's calculation of the "radium loading" for the Westside and Eastside plants. The values of 52.065 g/ft^2 and 70.809 g/ft^3 should be multiplied not divided by the radium concentrations (98.40 pCi/g and 94.53 pCi/g), respectively, in the radium/sludge mix.

Hence, the radium loading should be:

Westside Plant

98.40 pCi/g x 52.065 g/ft^2 = 5,123 pCi/ft^2

not the 1.89 pCi/ft^2 calculated by the IEPA.

Eastside Plant

94.53 pCi/g x 70.809 g/ft^2 = 6,693.5 pCi/ft^2

not the 1.335 pCi/ft^2 calculated by the IEPA.

The second error occurs in the IEPA's calculation of the "assumed soil weight" for the farm fields. A density of 120 #/ft^3 is the density of rock (i.e., granite) and is not realistic. A more reasonable density value would be 78 #/ft^3, which is the density for soil (see RSSI RESRAD Report, Attachment 4, R.M. Harsch Supplemental Testimony, dated November 24, 2004). The RSSI report used a value of 1.25 g/cm^3 or 78 #/ft^3.

Hence, the assumed soil weight for the farm fields should be:

78 #/ft x 453.5924 g/# = 35,397 g/ft^3

not the 54,531.09 g/ft^3 calculated by the IEPA.

The overall impacts due to the IEPA calculation errors are:

- Radium/soil field mix concentration is much higher

Westside Plant	**0.29 pCi/g vs 6.94 E-5 pCi/g**
Eastside Plant	**0.38 pCi/g vs 4.9 E-5 pCi/g**

- Application area is increased

Westside Plant	1,146 acres vs 395.2 acres
Eastside Plant	2,682 acres vs 705.9 acres

Thus, the amount of acreage required to allow application of the Westside Plant sludge is 2.9 times (i.e., 1,146 acres) more than the amount calculated by the IEPA. The amount of acreage required to allow application of the Eastside Plant sludge is 3.8 times (2,682 acres) more than the amount calculated by the IEPA.

In summary, the total amount of acreage required to allow placement of the sludge from both the Eastside and Westside POTW plants in compliance with the 0.1 pCi/g IEPA/IEMA limit is 3,828 acres, not the 1,100 acres as calculated by the IEPA.

Details of the corrected IEPA calculations are presented in Calculations #4-A and #4-B.

CALCULATION #4-A
RADIUM/SOIL FIELD MIX - WESTSIDE PLANT

Given: From IEPA Calculations [(1)] (and T.G. Adams corrections) *

Westside Plant

- Sludge
  8.963 E8 g

- Proportionate Radium
  88.2 E9 pCi

- Radium/Sludge Mix
  98.40 pCi/g

- Sludge Loading
  52.065 g/ft^2

- Radium Loading
  5,123 pCi/ft^2

98.40 pCi/g x 52.065 g/ft^3 = 5,123 pCi/ft^2 (instead of 1.89) *

- Soil Weight
  35,380 g/ft^3

78 $\#/ft^3$ x 453.594 g/# = 35,380 g/ft^3 (instead of 54,431) *

- Plow Down
  0.5 ft

- Radium/Soil Field Mix
  0.29 pCi/g

5,123 pCi/ft^2/35,380 g/ft^3 (0.5 ft) = 0.29 (instead of 6.94 E-5) *

- Application Area
  1,146 acres *

IEPA calculated 395.2 acres, but with corrected Radium/Soil Field mix, need 2.9 times the acreage (395.2) or 1,146 acres to comply with the 0.1 pCi/g IEPA/IEMA limit (e.g., 0.29/0.1 = 2.9).

CALCULATION #4-B
RADIUM/SOIL FIELD MIX - EASTSIDE PLANT

Given: From IEPA Calculations [(1)] (and T.G. Adams corrections) *

- Sludge
  2.177 E9 g

- Proportionate Radium
  205.79 E9 pCi

- Radium/Sludge Mix
  94.53 pCi/g

- Sludge Loading
  70.809 g/ft^2

- Radium Loading
  6,693.5 pCi/ft^2

94.53 pCi/g x 70.809 g/ft^3 = 6,693.5 pCi/ft^2 (instead of 1,335) *

- Soil Weight
  35.380 g/ft^3

78#/ft^3 x 453.594 g/# = 35,380 g/ft^3 (instead of 54,431) *

- Plow Down
  0.5 ft

- Radium/Soil Field Mix
  0.38 pCi/g

6,693.5 pCi/ft^2/35,380 g/ft^3 (0.5 ft) = 0.38 (instead of 4.9 E^{-5}) *

- Application Area
  2,682 acres *

IEPA calculated 705.9 acres, but with the corrected Radium/Soil Field mix, need 3.8 times the acreage (705 acres) or 2,682 acres to comply with the 0.1 pCi/g IEPA/IEMA limit (e.g., (0.38/0.1 = 3.8).

<u>Total Acreage Required</u>

CALCULATION #4-B
RADIUM/SOIL FIELD MIX - EASTSIDE PLANT

Westside Plant	1,146	
Eastside Plant		2,682
	Total	3,828 acres (not 1,100 acres as IEPA calculated)

(1) IEPA Calculation (T.G. Adams Supplemental Testimony, Attachment G, October 8, 2004)

ATTACHMENT 5

EVALUATION OF RADIUM/SOIL FIELD MIX UTILIZING RSSI APPLICATION RATE AND RADIUM CONCENTRATIONS

An evaluation was conducted of the radium/soil field mix (pCi/g) that was calculated by utilizing an application rate of 3.5 dry tons/acre and radium concentrations of 48 pCi/g and 18 pCi/g for Joliet's Westside and Eastside plants, respectively, as documented in the RSSI report (R.M. Harsch Supplemental Testimony, Attachment 4, dated November 24, 2004).

Details of the subject calculations for both the Westside and Eastside plants are shown in Calculation #5.

The results of the calculations show that for an application rate of 3.5 dry tons/acre and the radium concentration of 48 pCi/g and 18 pCi/g for the Westside and Eastside plants, respectively, the 0.1 pCi/g IEPA/IEMA limit will be exceeded by the Westside Plant (0.198 pCi/g vs 0.1 pCi/g IEPA/IEMA limit).

CALCULATION #5
RADIUM/SOIL FIELD MIX USING JOLIET DATA

Radium in Sludge

Westside Plant	**48 pCi/g**
Eastside Plant	**18 pCi/g**

Westside Plant

- Sludge Loading **72.9 g/ft²**

3.5 dry tons/acre x 2,000 #/ton x 453.592 g/# / 43,560 ft^2/acre = 72.9 g/ft^2

- Radium Loading **3,499 pCi/ft²**

48 pCi/g x 72.9 g/ft^2 = 3,499 pCi/ft^2

- Soil Weight **35,380 g/ft³**

78 $\#/ft^3$ x 453.594 g/# = 35,380 g/ft^3

- Plow Down **0.5 ft**

- Radium/Soil Field Mix **0.198 pCi/g**

3,499 pCi/ft^2 / 35,380 g/ft^3 (0.5 ft) = 0.198 pCi/g

Note: 0.198 pCi/g > 0.1 pCi/g IEPA / IEMA limit.

Eastside Plant

- Sludge Loading **72.9 g/ft²**

CALCULATION #5
RADIUM/SOIL FIELD MIX USING JOLIET DATA

3.5 tons/acre x 2,000 #/ton x 453.592 g/# / 43,560 ft^2/acre = 72.9 g/ft^2

CALLATION #5

RADIUM/SOIL FIELD MIX USING JOLIET DATA

(continued)

- Radium Loading
  1,312 pCi/ft²

$18 \text{ pCi/g} \times 72.9 \text{ g/ft}^2 = 1{,}312 \text{ pCi/ft}^2$

- Soil Weight
  35,380 g/ft³

- Plow Down
  0.5 ft

- Radium/Soil Field Mix
  0.07 pCi/g

$1{,}312 \text{ pCi/ft}^2 / 35{,}380 \text{ g/ft}^3 (0.5 \text{ ft}) = 0.07 \text{ pCi/g}$

Note: 0.07 pCi/g < 0.1 pCi/g IEPA / IEMA limit.

ATTACHMENT 6

EVALUATION OF RADIUM/SOIL FIELD MIX FROM JOLIET'S WESTSIDE AND EASTSIDE POTW SLUDGE AT A RADIUM CONCENTRATION OF 5 pCi/L IN THE INFLUENT TO THE PLANTS

An evaluation was conducted of the radium/soil field mix from Joliet's Westside and Eastside POTWs utilizing information from the IEPA analysis of Joliet's water and wastewater plants. The radium effluent concentration from the Joliet water treatment plant was limited to 5 pCi/L, the USEPA drinking water limit.

The details of the calculations are presented as Calculations #6-A and #6-B.

The results of the calculations show that with a water treatment effluent radium concentration of 5 pCi/L, and assuming all radium in treated drinking water goes to the POTWs, the radium/soil field mix for either the Westside or Eastside plants will meet the 0.1 pCi/g IEPA/IEMA limit.

CALCULATION #6-A

RADIUM/SOIL FIELD MIX - WESTSIDE PLANT

(5 pCi/L in water supply)

Given: From IEPA Calculations[1] (and 5 pCi/L water supply)

Westside Plant

Sludge	**8.963 E8 g**
Average Radium Concentration	**5 pCi/L**
Radium Production	**1.1 E11 pCi/yr or .11 Ci/yr**

16 mgd x 3.785 L/gal = 60.56 E6 L/day
60.56 E6 L/day x 5 pCi/L = 302.8 E6 pCi/day
302.8 E6 pCi/day x 365 days/yr = 1.1 E11 pCi/yr or .11 Ci/yr

Proportionate Radium (30%) — **3.33 E10 pCi**

1.1 E11 pCi x .30 = 3.33 E10 pCi

Radium/Sludge Mix — **37.2 pCi/g**

3.33 E10 pCi/8.963 E8 g = 37.2 pCi/g

Sludge Loading — **52.065 g/ft^2**

2.5 dry tons/acre x 2,000 #/ton x 453.5924 g/# / 43,560 ft^2/acre = 52.065 g/ft^2

Radium Loading — **1,937 pCi/ft^2**

37.2 pCi/g x 52.065 g/ft^2 = 1,937 pCi/ft^2

Soil Weight — **35,380 g/ft^3**

78 #/ft^3 x 453.594 g/# = 35,380 g/ft^3

CALCULATION #6-A
<u>RADIUM/SOIL FIELD MIX - WESTSIDE PLANT</u>
(5 pCi/L in water supply)
(continued)

Plow Down	**0.5 ft**
Radium/Soil Field Mix	**0.11 pCi/g**

1,937 pCi/ft^2 / 35,380 g/ft^3 (0.5 ft) = 0.11 pCi/g

Note: Meets/comes close to meeting 0.1 pCi/g IEPA/IEMA limit. Will meet limit when taking into consideration not all radium will go to sludge.

(1) IEPA Calculation (T.G. Adams Supplemental Testimony, Attachment G, October 8, 2004)

CALCULATION #6-B
RADIUM/SOIL FIELD MIX - EASTSIDE PLANT
(5 pCi/L in water supply)

Given: From IEPA Calculations (and 5 pCi/L water supply)

Eastside Plant

Sludge	**2.177 E9 g**
Average Radium Concentration	**5.0 pCi/L**
Radium Production **(see calculation for Westside Plant)**	**1.1 E11 pCi/yr or .11 Ci/yr**
Proportionate Radium (70%)	**7.77 E10 pCi**

1.11 E11 pCi x .70 = 7.77 E10 pCi

Radium / Sludge Mix	**35.7 pCi/g**

7.77 E10 pCi/2.177 E9 g = 35.7 pCi/g

Sludge Loading	**70.809 g/ft^2**

3.4 dry tons/acre x 2,000 #/ton x 453.5924 g/ft / 43,560 ft^2/acre = 70.809 g/ft^2

Radium Loading	**2,528 pCi/ft^2**

35.7 pCi/g x 70.809 g/ft^3 = 2,528 pCi/ft^2

Soil Weight	**35,380 g/ft^3**

78 #/ft^3 x 453.5924 g/# = 35,380 g/ft^3

CALCULATION #6-B
<u>RADIUM/SOIL FIELD MIX - EASTSIDE PLANT</u>
(5 pCi/L in water supply)
(continued)

Plow Down **0.5 ft**

Radium / Soil Field Mix **0.14 pCi/g**

$2{,}528\ \text{pCi/ft}^2 / 35{,}380\ \text{g/ft}^3\ (0.5\ \text{ft}) = 0.14$

Note: Meets/comes close to meeting 0.1 pCi/g IEPA/IEMA limit. Will meet the limit when taking into consideration not all radium will go to the sludge.

CALCULATED DOSE RATES USING DATA FROM FLORIDA STUDY AUGUST 2000

ATTACHMENT 7:

COMMENTS ON "CONSERVATISM" OF DOE BIOTA DOSE METHODOLOGY

The IEPA provided testimony that the DOE Biota Dose Assessment Committee (BDAC) methodology was overly conservative and did not provide realistic assumptions and/or limits in which to evaluate the effort(s) of radionuclides (radium) ~~on aquatic organisms and~~ riparian animals (limiting organism for radium).

As will be demonstrated in the subsequent paragraphs and accompanying dose calculations, this statement is not correct (for a more detailed presentation of the DOE BDAC and the related DOE Standard 1153-2002, please refer to T.G. Adams Supplemental Testimony, Attachment B, dated October 8, 2004).

To demonstrate that the DOE BDAC methodology can at times be less than conservative, a comparison was made between the results of a standard biota dose determination using the RESRAD Biota model and a manual calculation used in determining the dose to an aquatic organism (i.e., a mussel).

Information from a study on the effects of Radium-226 in several central Florida lake ecosystems[(1)] (see T.G. Adams Supplemental Testimony, Attachment D, dated October 8, 2004) was used as input data for both approaches.

The following input data from the study was used:

Medium	Ra-226 Concentration (pCi/L or pCi/g)
Lake Water (Round Lake)	1.6 pCi/L
Sediment (Round Lake)	12.2 pCi/g
Mussels (Round Lake)	205 pCi/g

Inserting the Ra-226 values for water (1.6 pCi/L) and sediment (12.2 pCi/g) from the Florida study into the RESRAD Biota Dose computer model resulted in the model concluding that the Ra-226 concentrations in the water and sediment did not exceed the established respective radium Biota Concentration Guide (BCG) for water (4.0 pCi/L) or sediment (101 pCi/g). Thus, the DOE Biota Dose model concluded that the radium water and sediment concentrations were less than their respective BCGs and hence resulted in the sum of the fractions of less than 1.0.

$$1.6/4.0 + 12.2/101 = .4 + .12 = .52 < 1$$ **(See RESRAD Table 1)**

Furthermore, the Dose to the aquatic and reprian animals calculated by the RESRAD Biota Dose model were 1.58E-1 and 5.13E-2 RAD/day, respectively, which is less than the 1.0 and 0.1 RAD/day DOE limits (See RESRAD Table 2).

Therefore, based on the results above, the DOE established biota protection limit of 0.1 Rad/day for the limiting organism, the riparian animal or 1.0 Rad/day for aquatic organisms was not exceeded.

In comparison, the same information from the Florida study was used to determine the dose to an aquatic organism (i.e., mussel) applying the methodology used by Blaylock et al, September 1993.[(2)] The details of the determination of the dose (both internal and external) due to the radium in the Florida lake ecosystem is presented in Calculation #7.

Results of the calculation show that the most contributing internal dose comes from the alpha emitters (Ra-226 and related daughters). The contribution of external dose from radium related alpha, beta, or gamma emitters were negligible. Most importantly, however, was the fact that the internal dose calculated for the mussels was 1.68 Rad/day. This dose is greater than the 1.0 Rad/day limit for aquatic organisms established by the DOE standard to protect biota. This dose is also comparable to the 5.5 Rad/day determined by Hazardous Substance and Waste Management Research, Inc., in their August 2000 study[(1)] (T.G. Adams Supplemental Testimony, Attachment D, dated October 8, 2004).

Thus, contrary to the IEPA's contention, the DOE Biota Dose approach can be less than conservative under certain conditions.

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(1) Hazardous Substance and Waste Management Research, Inc., Human Health Risk Assessment and Preliminary Ecological Evaluation Regarding Potential Exposure to Radium-226 in Several Central Florida Lake Ecosystems, August 2000

(2) Blaylock, et al, Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment, ES/ER/TM-78, September 1993

CALCULATION #7
CALCULATED DOSE RATES USING DATA FROM FLORIDA STUDY AUGUST 2000

Given: Information from Human Health Risk Assessment and Preliminary Ecological Evaluation Regarding Potential Exposure to Radium-226 in Several Central Florida Lake Ecosystems, Hazardous Substance and Waste Management Research, Inc., August 2000

Round Lake Radium-226 concentrations in:

Sediment:	**12 pCi/g, dry**
Water:	**1.6 pCi/L**
Mussel:	**205 pCi/g, dry**

Mussel Activity

205 pCi/g x 1,000 g/kg x 1 Bq/27 pCi = 7,593 Bq/kg (dry) x .75 = 5,695 Bq/kg (wet)

Sediment Activity

12 pCi/g x 1,000 g/kg x 1 Bq/27 pCi = 444 Bq/kg (dry) x .75 = 333 Bq/kg (wet)

Water Activity

1.6 pCi/L x 1 Bq/27 pCi = 0.06 Bq/L

Dose Rates to Mussels from Ra-226 *

Given: Isotopes	**Ra-226 and short-lived progeny**
Geometry	**Mussels**
Activity in Organism	**5,695 Bq of Ra-226/kg (wet weight)**
Water Activity	**0.06 (Bq/L)**
Sediment Activity	**333 Bq of Ra-226/kg (wet weight)**

Ra-226 is a member of the U-238 decay chain and has a series of progeny with short half-lives. It is reasonable to assume that because of their short half-lives, these progeny will be present at the same activity level as Ra-226. However, Ra-226 decays to Rn-222, which is a gas with a 3.8 day half-life. Rn-222 produced in water or surface sediment would escape to the atmosphere; therefore, the succeeding progeny would not be present in surface sediment or water unless other sources were available. In this calculation, it is assumed that 30% of the Rn-222 produced within a mussel remains in the mussel tissue so that the activity level of the succeeding progeny will also be 30% of the Ra-226.

* ***Based on "Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment," B.G. Blaylock et al, ES/ER/TM-78, September 1978.***

CALCULATION #7
CALCULATED DOSE RATES USING DATA FROM FLORIDA STUDY AUGUST 2000

Alpha Emitters

Using average energies from Table A.2, the internal " dose rates for Ra-226 and its short-lived progeny are calculated as follows:

$D_{\alpha} = 5.76 \times 10^{-4} E_{''} n_{''} C_o$		_Gy h^{-1}
Ra-226 $D_{''} = (5.76 \times 10^{-4})(4.86)(5{,}695)$	= 15.9	_Gy h^{-1}
Rn-222 $D_{''} = (5.76 \times 10^{-4})(5.59)(5{,}695 \times 0.30)$	= 5.5	_Gy h^{-1}
Po-218 $D_{''} = (5.76 \times 10^{-4})(6.11)(5{,}695 \times 0.30)$	= 6.0	_Gy h^{-1}
Pb-214 $D_{''}$ = no alpha		
Bi-214 $D_{''}$ = no alpha		
Po-214 $D_{''} = (5.76 \times 10^{-4})(7.83)(5{,}695 \times 0.30)$	= 7.7	_Gy h^{-1}
Total Internal " Dose Rate	= 35.1	_Gy h^{-1}

35.1 _Gy/hr x .0001 Rad/_Gy x 20 Rem/Rad = 0.07 Rem/hr

0.07 Rem/hr x 24 hrs/day = 1.68 Rem/day _1.68 Rad/day

1.68 Rem/day > 1.0 Rad/day DOE Biota Limit

Gamma Emitters

The internal dose rate from the _ emitters with the highest energies is calculated as follows:

$D_{\_} = 5.76 \times 10^{-4} E_{\_} n_{\_} {}_{\_} C_o$		_Gy h^{-1}
Pb-214 $D_{\_} = (5.76 \times 10^{-4})(0.248)(0.009)(5{,}695 \times 0.30)$	$= 2.19 \times 10^{-3}$	_Gy h^{-1}
Bi-214 $D_{\_} = (5.76 \times 10^{-4})(1.46)(0.007)(5{,}695 \times 0.30)$	$= 1.00 \times 10^{-3}$	_Gy h^{-1}
Total Internal _ Dose Rate	$= 3.20 \times 10^{-3}$	_Gy h^{-1}

CALCULATION #7
CALCULATED DOSE RATES USING DATA FROM FLORIDA STUDY AUGUST 2000

3.2×10^{-3} _Gy h^{-1} x 0.0001 Rad/_Gy x 24 hrs/day = 7.7×10^{-6} Rad/day

CALCULATION #7
CALCULATED DOSE RATES USING DATA FROM FLORIDA STUDY AUGUST 2000

Beta Emitters

The internal dose rate from the _ emitters with the highest energies is:

$D\_ = 5.76 \times 10^{-4}\ E\_\ n\_\ \_\ C_o$		$\_Gy\ h^{-1}$
Pb-214 $D\_ = (5.76 \times 10^{-4})(0.291)(1)(5{,}695 \times 0.30)$	= 0.29	$\_Gy\ h^{-1}$
Bi-214 $D\_ = (5.76 \times 10^{-4})(0.648)(1)(5{,}695 \times 0.30)$	= 0.64	$\_Gy\ h^{-1}$
Total Internal _ Dose Rate	= 0.93	$\_Gy\ h^{-1}$

Conclusion

As shown above, the internal _ dose rate is more than an order of magnitude greater than the internal dose rates from the _ and _ emissions. Additionally, the relative biological effectiveness of _ radiation is 20 times greater than _ or _ radiation; consequently, the main concern for internal dose to the mussels from Ra-226 would be from the _ dose.

Notes

Alpha Emitters

- $D_{''}$ = Dose rate for alpha emitters (Rem/day)
- $E_{''}$ = Energy of alpha particle (MeV)
- $n_{''}$ = Proportion of transitions producing an alpha particle
- C_o = Concentration of radionuclides (Bq/kg, wet weight)

Beta Emitters

- $D\_$ = Dose rate for beta emitters (Rad/day)
- $E\_$ = Average energy of _ particle (MeV)
- $n\_$ = Proportion of transitions producing _ particle of energy Ec (MeV)
- _ = Absorbed fractions (Fig A-4)
- C_o = Concentration of radionuclide (Bq/kg, wet weight)

Gamma Emitters

- $D\_$ = Dose rate for gamma emitters (Rad/day)
- $E\_$ = Photon energy (MeV)
- $n\_$ = Proportion of disintegrations producing a gamma ray
- _ = Absorbed fractions (Fig A-1)

In addition to calculating the internal dose to the Florida mussels for completeness,

external doses to the mussel were also determined.

CALCULATION #7

CALCULATED DOSE RATES USING DATA FROM FLORIDA STUDY AUGUST 2000

External Radiation Dose Rates

External Alpha and Beta Radiation Dose Rates from Water and Sediment

External alpha and beta radiation dose rates from water and sediment would be insignificant because the mussel's shell would serve as an effective shield.

External Gamma Radiation Dose Rate from Water

D_ = 5.76×10^{-4} E_ n_ (1-_) C_w

Pb-214 = 5.76×10^{-4} (0.248) (1-.009)(0.06)

= $(8.6 \times 10^{-6})(.991)$

= 8.5×10^{-6} _Gy/hr

8.6×10^{-6} _Gy/hr x 0.0001 Rad/_Gy x 24 hrs/day = 2.0×10^{-8} Rad/day

Bi-214 = 5.76×10^{-4} (1.46) (1-.007)(0.06)

= 5.0×10^{-5} _G/hr

5.0×10^{-5} _G/hr x 0.0001 Rad/_Gy x 24 hrs/day = 1.2×10^{-7} Rad/day

External Gamma Radiation Dose Rate from Sediment

D_ = 5.76×10^{-4} E_ n_ (1-_) C_s R

Pb-214 = 5.76×10^{-4} (0.248) (1-.009)(.333)(1)

= 4.7×10^{-5} _Gy

4.7×10^{-5} _Gy/hr x 0.0001 Rad/_Gy x 24 hrs/day = 1.13×10^{-7} Rad/day

Bi-214 = 5.76×10^{-4} (1.46) (1-.007)(.333)(1)

= 2.8 E^{-4} _Gy/hr

2.8 E^{-4} _Gy/hr x 0.0001 Rad/_Gy x 24 hrs/day = 6.7×10^{-7} Rad/day

CALCULATION #7
CALCULATED DOSE RATES USING DATA FROM FLORIDA STUDY AUGUST 2000

Conclusion

The external doses to the mussel as a result of alpha, beta, or gamma radiation from Ra-226 daughters (Pb-214 and Bi-214) were determined to be insignificant.

Notes

D_	=	**Dose rate for gamma emitters (Rad/day)**
E_	=	**Photon energy (MeV)**
n_	=	**Proportion of disintegrations producing gamma ray**
_	=	**Absorbed fractions (Fig A-4)**
C_w	=	**Concentration of radionuclides in water (Bq/L)**
C_s	=	**Concentration of radionuclides in sediment (Bq/kg, wet weight)**
R	=	**Amount of time organism is in contact with sediment (1)**

Table 1: Aquatic BCG Report for Level 2

Sum of Total Ratio: 5.13E-01

Sum of Water Ratio: 3.93E-01

Sum of Sediment Ratio: 1.21E-01

	Water			
Nuclide	Concentration (pCi/L)	BCG (pCi/L)	Ratio	Limiting Organism
Ra-226	1.60E+00	4.08E+00	3.93E-01	Riparian Animal
	Sediment			
Nuclide	Concentration (pCi/g)	BCG (pCi/g)	Ratio	Limiting Organism
Ra-226	1.22E+01	1.01E+02	1.21E-01	Riparian Animal

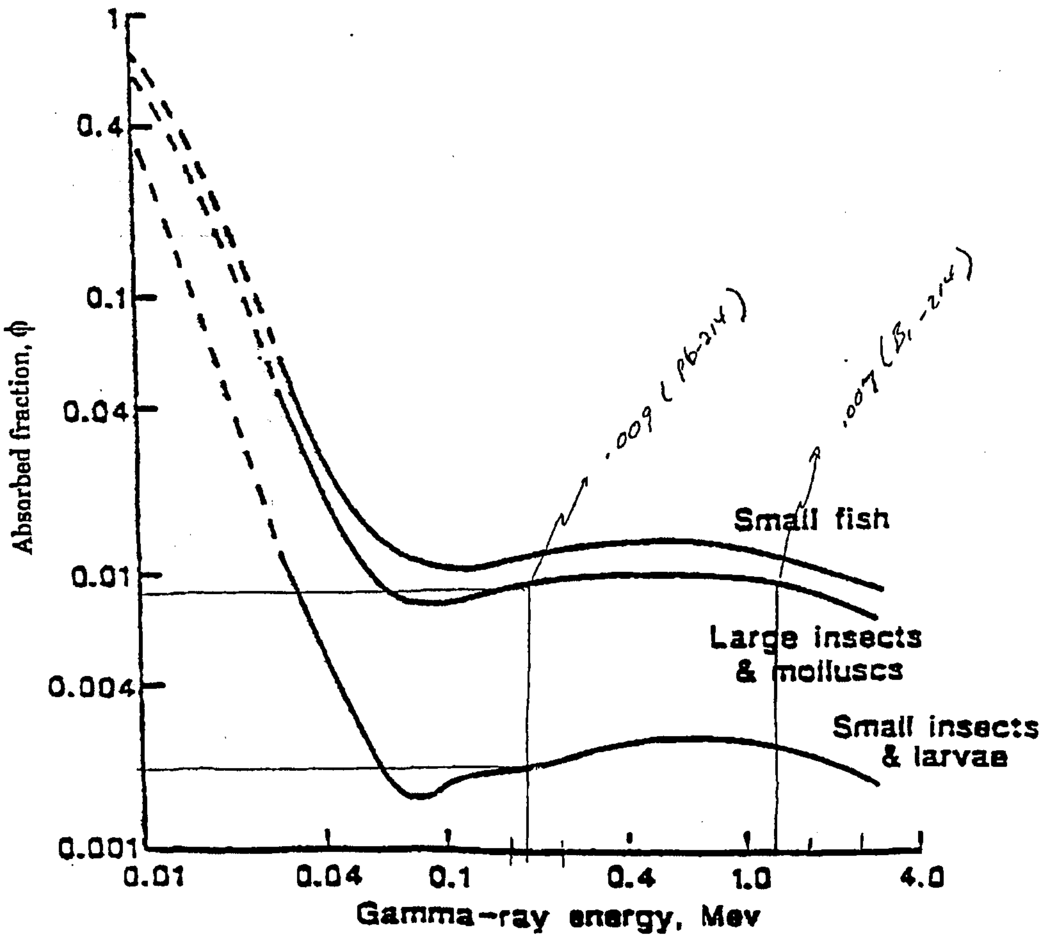
Table 2: Aquatic Dose Report for Level 2 in rad/d

Aquatic Animal				
Nuclide	Water	Soil	Sediment	Summed
Ra-226	1.57E-01	0.00E+00	8.42E-04	1.58E-01
Summed	1.57E-01	0.00E+00	8.42E-04	1.58E-01

Riparian Animal				
Nuclide	Water	Soil	Sediment	Summed
Ra-226	3.93E-02	0.00E+00	1.21E-02	5.13E-02
Summed	3.93E-02	0.00E+00	1.21E-02	5.13E-02

FIGURE A.1

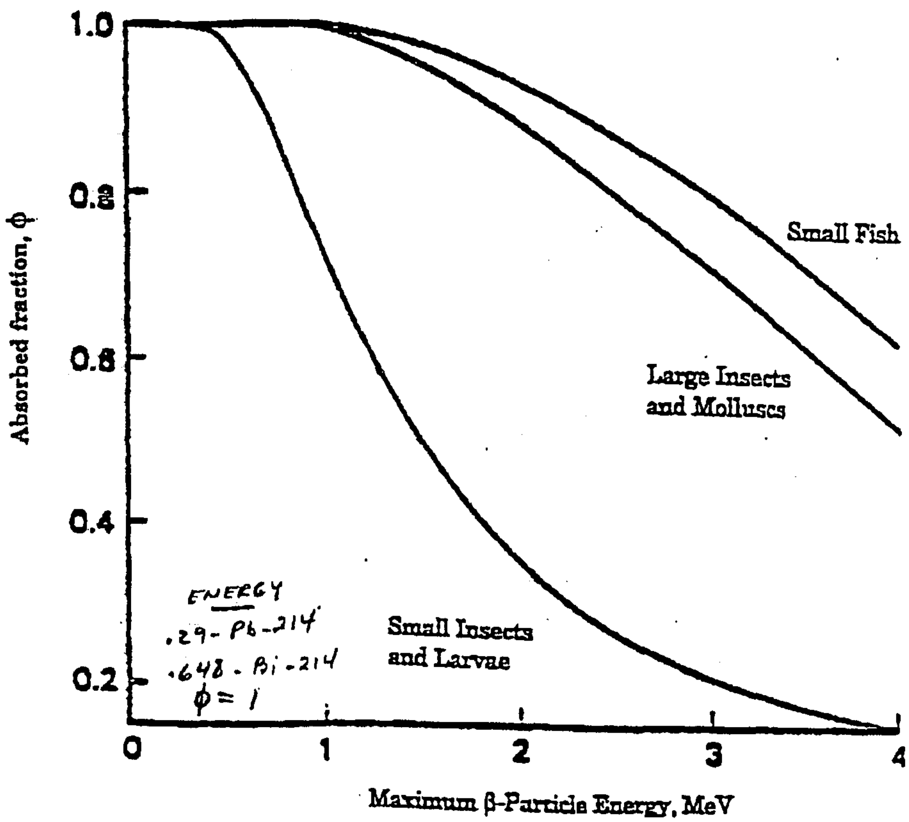
DERIVED ABSORBED FRACTIONS AS A FUNCTION OF γ-RAY ENERGY
(SMALL FISH, LARGE INSECTS AND MOLLUSCS, AND SMALL INSECTS AND LARVAE)



From: B.G. Blaylock et al, Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment, ES/ER/TM-78, September 1993

FIGURE A.4

ABSORBED FRACTION AS A FUNCTION OF Β-PARTICLE ENERGY FOR THREE SMALL GEOMETRIES



From: B.G. Blaylock et al, Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment, ES/ER/TM-78, September 1993

TABLE A.2

Element	Biological Concentration Factor*	Radiological Half-life	Average alpha & alpha recoil (MeV)	Maximum beta energy^ (MeV)	Average beta energy (MeV)	Average gamma energy (MeV)
Uranium Series						
Uranium-238	10	4.51E+09 y	4.26E+00		1.00E-02	1.36E-03
Thorium-234	100	24.1 d	--		5.92E-02	9.34E-03
Protactinium-234m	10	1.17 m	--	2.29E+00	8.20E-01	1.13E-02
Uranium-234	10	2.47E+05 y	4.84E+00		1.32E-02	1.73E-03
Thorium-230	100	7.7E+04 y	4.74E+00		1.46E-02	1.55E-03
Radium-226	50	1.62E+03 y	4.86E+00 *		3.59E-03	6.47E-03
Radon-222		3.823 d	5.59E+00 *		1.09E-05	3.98E-04
Polonium-218	50	3.05 m	6.11E+00 *		1.42E-05	9.12E-06
Lead-214	300	26.8 m	--	6.70E-01	2.91E-01 *	2.48E-01 *
Astatine-218 (.02% yield)		2 s	6.82E+00		4.00E-02	6.72E-03
Bismuth-214	10	19.7 m	--	3.26E+00	6.48E-01 *	1.46E+00 *
Polonium-214	50	164 µs	7.83E+00 *		8.19E-07	8.33E-05
Lead-210	300	22.3 y	--		3.80E-02	4.81E-03
Bismuth-210	10	5.01 d	--	1.16E+00	3.89E-01	--
Polonium-210	50	138.4 d	5.40E+00		8.18E-08	8.50E-06
Actinium Series						
Uranium-235	10	7.04+08 y	4.47E+00		4.80E-02	1.54E-01
Thorium-231	100	25.5 h	--		1.63E-01	2.55E-02
Protactinium-231	10	3.28E+04 y	5.04E+00		6.28E-02	4.76E-02
Actinium-227		21.77 y	6.90E-02		1.56E-02	2.31E-04
Thorium-227	100	18.7 d	5.95E+00		4.57E-02	1.06E-01
Radium-223	50	11.43 d	5.75E+00		7.46E-02	1.33E-01
Radon-219		4.0 s	6.88E+00		6.30E-03	5.58E-02
Polonium-215	50	1.78 ms	7.52E+00		8.30E-06	1.76E-04
Lead-211	300	36.1 m	--	1.36E+00	4.54E-01	5.03E-02
Bismuth-211	10	2.15 m	6.68E+00			
Thallium-207	10000	4.79 m	--	1.52E+00	4.93E-01	2.21E-03

From: B.G. Blaylock et al, Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment, ES/ER/TM-78, September 1993

From: B.G. Blaylock et al, Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment, ES/ER/TM-78, September 1993

Dr. Brian D. Anderson
33 Taft Drive
Rochester, IL 62563

December 7, 2004

A. Antoniolli
Illinois Pollution Control Board
State of Illinois
Suite 11-500
100 W. Randolph
Chicago, IL 60601

Dear Hearing Officer Antoniolli,

The Illinois Environmental Protection Agency's proposal to eliminate the General Water Quality Standard and Lake Michigan Water Quality Standard for radium is not acceptable based on the risk radium poses to aquatic life, as well as risk to municipal infrastructure, POTW workers, and human and wildlife health at sites where radium contaminated sewer sludge is land applied. This risk is well documented in the record before the Illinois Pollution Control Board. It appears the Agency's response is to try and cast doubt on nationally and internationally accepted standards and methodologies for protecting biota from the impacts of radiation, which became the focus of supplemental testimony offered by IEPA staff on 21 October 2004; testimony which raised more questions and concerns that it purported to address.

The agency's biologist, Robert Mosher, related a conversation wherein he discussed the application of the DOE standard with Stephen Domotor, Chair of the BDAC. He claimed Mr. Domotor cautioned him against use of DOE Standard-1135-2002 (hereafter, the DOE Standard) in the development of a Water Quality Standard because it "might be too conservative." While the introduction to Module 3 emphasizes the conservatism of the graded approach, the conservatism the authors are referring to is in the context of site-specific remediation. The question that should be asked is whether the screening criteria are too conservative to have any application in development of a Water Quality Standard. In a site-specific remediation, the opportunity exists to do a detailed investigation of on-site receptors and available pathways of exposure. That is certainly not the context of a General Water Quality Standard. The intent of a Water Quality Standard is to be protective of all flora and fauna. As expressed in Module 3 on page 1 of the DOE Standard, "Since the screening limits would be chosen to protect "all biota everywhere" they would, by their nature, be restrictive, and in many circumstances conservative with regards, to specific environments." Since General Water Quality Standards are meant to be applied in all waters and protect all species, the DOE Standard is, therefore, directly applicable. And since, if a Water Quality Standard is repeatedly exceeded the party can go to IPCB for an exemption based on site-specific data, this process is directly analogous to the graded approach around which the DOE Standard is built. Furthermore, in Table 3.1, Module 1, pages 22-23 of the DOE Standard, compliance with the Clean Water Act is even identified as one of the potential uses of the DOE Standard, along with Superfund Risk Assessments and Natural Resource Damage Assessments, among others.

Mr. Mosher also testified that the underlying assumptions of the DOE Standard are not met by any "riparian animal" that he could think of other than the manatee, which spends 100% of its time in the water. He argued that since the manatee does not occur in Illinois, the DOE Standard is not applicable. On page 2 of Module 3 the DOE Standard points out that: "A fourth [category of organisms], riparian animal, was added after recognizing that the riparian pathways of exposure combine aspects of both the terrestrial and aquatic systems." Notice that this acknowledges that there are "terrestrial pathways" for exposure. The organism doesn't have to be immersed in the contaminated water or the contaminated sediments to be exposed, flooding for example, can redistribute contaminated sediments in riparian soils, and organisms can physically redistribute contaminated media. Besides, the manatee is actually a threatened aquatic (not riparian) mammal with a very limited range. The DOE Standard clearly states that it was developed to be applicable at any DOE-operated facility, as well as to be employed in the context of Superfund clean-ups. In other words, the DOE Standard explicitly states that it is intended to be widely applicable. Logic therefore dictates the rejection of Mr. Mosher's argument. While the default value for the screening criterion is based on the assumption of a one hundred percent residence time for the riparian animal, for small mammals with limited home ranges like mice, voles, and shrews, this criterion is fully met. Some larger mammalian species like muskrats, beaver, otter, and mink can also meet this criterion; as can many species of birds with high affinities for riparian areas like wading birds and waterfowl. In all these cases the entire diet of these species comes from the river or stream, which also brings them into direct contact with potentially contaminated sediments. In fact, on page 5 of Module 3, in a discussion about how external dose coefficients were calculated the DOE Standard points out that: "...only penetrating radiation (photons [gamma] and electrons [beta]) are of concern, and non-penetrating radiation (i.e., alpha particles) need not be considered." Clearly the IEPA's contention that the DOE Standard assumes a riparian animal must spend 100% of its time in the water, is a misinterpretation. Since radium 226 is an alpha emitter no external dose coefficient is used in the calculation of the BCG for riparian animals for radium 226. That number is based almost entirely on the ingested dose (there are a few short lived beta emitters in the decay series that may have been included in the calculation). This obviously indicates that BDAC's definition of "riparian animal" is not as narrow as suggested by Agency staff. The actual assumption built into the DOE Standard for radium 226 is that 100% of an animal's food and water is taken from within the riparian corridor (or stream). This is an assumption that holds for nearly all species occurring in the riparian corridor, the only exceptions would be things like raccoons and foxes, where some individuals may feed part of the time in uplands.

IEPA staff also fail to acknowledge that the screening criteria derived using the DOE Standard are very liberal in that they reflect the dose below which no population level effects have been observed. Impacts to individuals at exposures well below the screening criterion are statistically probable. Consequently, the screening criterion does not meet the requirements of the Illinois Endangered Species Protection Act to protect individuals of listed species. The General Water Quality Standards are supposed to be designed to protect all aquatic use by wildlife, not just protect populations of whole groups of species (for example all small mammals) from extirpation due to reproductive impairment.

The DOE standard is very liberal when compared to the standard being employed to protect human health. In testimony before the IPCB a health physicist with Metropolitan Sanitary District of Greater Chicago, testified that the federal MCL for drinking water of 5 picoCuries/L resulted in an exposure of 4 millirems/year to humans, while the BDAC standard for radium resulted in an exposure of 42 millirems/hour to riparian animals. The calculated BDAC screening limit for radium is clearly not "overly conservative" as Mr. Mosher testified.

Mr. Mosher also argued before the IPCB that since the discharge of concentrated radium will be to flowing water, aquatic animals would not suffer from continuous exposures to radiation from radium released to rivers or streams. He argued that releases would be "intermittent" and therefore the exposure assumptions inherent in the DOE standard would not apply. This ignores the fact that the impacts of radiation exposure are cumulative not threshold-based like chemical pollutants. This line of reasoning also ignores the likelihood of sediment contamination with radium and the fate of that sediment. The Florida Study as noted in my prior testimony and attached graphs documents that radium levels are likely to dramatically increase through time. Everyone who is familiar with the dynamics of Illinois' sediment-strangled waterways should be aware of the propensity of sediment to accumulate in slower moving parts of our rivers and streams and in sensitive, historically productive, backwaters. Where such sediments concentrate, so too will the radium. Furthermore, the intermittent exposure argument totally ignores food chain impacts, which are substantial given the bio-concentration factor of 3200 for radium. The Agency criticized using data from groundwater-enhanced lakes in Florida because they are not flowing systems, while failing to acknowledge that the IEPA's proposal would eliminate the Lake Michigan Water Quality Standard for radium as well and that the General Water Quality Standard which is applicable to all waters, including lakes and impounded streams and rivers.

There is also an assumption built into the DOE Standard which the Agency has tried to ignore. Notice on page 5 of Module 3 at the very end, when talking about the External Dose Coefficients the DOE Standard states: "This assumption results in reasonably realistic estimates of dose rates for radionuclides ***which are dispersed in the source medium*** (emphasis added). Later when talking about the underlying assumptions in the Internal Dose Coefficients on page 16 of Module 3 : "The radionuclides were presumed to be ***homogeneously distributed*** in the tissue." In other words, the screening criteria calculated using the DOE Standard are not protective **AT ALL** if radioactive particulates are allowed into the stream (or POTW's then streams). If an organism picks up a single particle it could receive an acute exposure! If there are many particles present, whole populations and species could be wiped out. And with a half-life of 1600 years it is difficult to anticipate where radium particulates will eventually turn up.

So, to protect aquatic life uses of our rivers and streams some way must be found to limit radioactive particulates from getting into streams (or POTW's then streams). If we prohibit discharge of radioactive particulates, a DOE Standard-calculated screening criteria may be protective. However if discharge of radioactive particulates is not prohibited, the current standard of 1 picoCurie/L of radium 226 (which is really 2 picoCurie/L, radium 226 and 228 combined), should be left in place. POTW's that can't meet that standard could still seek an Adjusted Standard.

Perhaps the most alarming supplemental testimony given by the Agency was that acknowledging the Agency has never monitored its agreement with the Division of Nuclear Safety regarding land application of radionuclide-contaminated sludge. The Agency testified it had asked POTW's land applying sludge to voluntarily test their sludge for radioactivity for the first time this past March. This revelation also begs the question of whether POTW's from Illinois' radium belt are meeting the radiological guidelines for sludge disposal in landfills. The Agency testified that radiation levels from 1.3 picoCuries/g. to 47 picoCuries/g. have been reported so far. The latter is very close to the 50 picoCurie/g. limit imposed by the IDNS/IEPA memorandum of agreement for land application (the same limit in place for landfill disposal), and this is <u>without</u> concentrating the radium to meet the new federal MCL for drinking water. A Chicago Tribune article which followed the 21 October 2004 hearing indicated that the Agency had sent warning letters to five communities land applying sludge, something the Agency failed to disclose to the Board. NRC licensees and DNS licensees are no prohibited from discharging radioactive particulates, yet because there is presently no prohibition against water companies dumping radium particulates down the drain, radiological contamination of wastewater facilities, landfills, and farmland beyond federally allowable limits may, in fact, be occurring. It is unfathomable why the Agency, with such data in hand, would propose to eliminate the General Water Quality and Lake Michigan Water Quality Standards for radium.

The Agency's testimony continues to demonstrate a pervasive, dismissive attitude toward the potential heath and environmental effects of a known carcinogen and mutagen that has been demonstrated to bioaccumulate in the environment. Taken together with IEPA's supplemental testimony that they filed this proceeding without knowing what the levels already were in sewage treatment sludge in affected areas of the state, that they don't actually know how many POTWs are affected by radium contaminated discharges from water treatment plants, and that they do not know the radioactive concentrations in the Technologically Enhanced Naturally Occurring Radium (TENORM) (which could be 10,00 to 70,000 PicoCuries/g or if the TENORM will contaminate the POTW's receiving it.. Reliance on the Agency's recommendation to eliminate the radium standards could easily be characterized as arbitrary and capricious, and would not likely be upheld should such a decision be appealed.

Finally, it is important to recognize that elimination of the General Water Quality Standard for radium opens the door to other potential discharges of radium into Illinois' waters. Radioactive groundwater from a Superfund cleanup could be discharged to a stream without the radium standard in place (not only from radium clean-ups, like those at Ottawa, IL, but also from any thorium or uranium-contaminated site, since radium isotopes would be present as decay products).

Based on these considerations I recommend the Board reject the Agency's proposal.

Sincerely,

Brian D. Anderson/JH

Dr. Brian D. Anderson

December 7, 2004

A. Antoniolli
Illinois Pollution Control Board
State of Illinois
Suite 11-500
100 W. Randolph
Chicago, IL 60601

Dear Hearing Officer Antoniolli,

Several questions were raised by the Report of Survey at the Westside Waste Water Treatment Plant in City Of Joliet, Illinois: by RSSI Dated November 15, 2004 which I would like to address.

First WRT, from the beginning, has monitored the radium content and emissions from its radium removal system. The pilot plant system is representative of the operation and related exposures of the full scale treatment system. The municipal workers in a full scale plant are exposed to only a small increase above background and will be trained and advised of that exposure. The expected exposure to a municipal worker is estimated to be approximately three millirem per year, assuming that one person does all of the monitoring task which is unlikely. (see attached excerpt from IDNS application) The three millirem exposure represents only 3 percent of the maximum exposure allowed to a member of the general public from a licensed facility. Most importantly we will be monitoring the exposure to workers and will know if an exposure problem occurs.

In contrast, according to the testimony, no exposure estimates have been made for water treatment personnel for exposures resulting from the HMO or the ION Exchange process. Testimony from Ted Adams and Brian Anderson clearly demonstrates the exposure to workers and biota from unrestrained disposal of radium to our streams and sewers can clearly lead to exposures that may be harmful to both human and biota. The failure of both the IEPA to even be aware of the levels of radiation that could occur on the radioactive solids from a HMO process is disappointing.

RSSI conclusion that the WRT process will need three to four stages in the full scale plant is incorrect. The typical full scale design calls for a minimum depth of 6 feet of media per stage compared to a pilot plant that has only two feet of media per stage. Therefore, the typical stage in a full scale system has three times the media for a given flow rate than the pilot plants. Each of the WRT plants is designed for the specific application.

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Joliet's assertion that there may be a radon problem with our process is disingenuous when their own results after six months of testing by Joliet personnel of our system shows there is no evidence that radon is any higher after our system than before. (See RSM Extended Pilot- WRT Radon Results, provided by Joliet.)

Also attached are Joliet's results of the Joliet Pilot Plant which indicates that the radium in the feed averaged 13.5 pCi combined Ra 226 and Ra 228 and had a high of 16.4 pCi Ra combined while the discharge after the WRT pilot plant was average 0.28 pCi Ra combined with a high of 0.8 pCi Ra combined. Recovery was 98% of the contained radium.

Removing radium from the water and concentrating the radium into a concentrated form prior to disposal is a fundamental change from simply passing the radium through the system as has been historically occurring. While the total amount of radium may be unchanged the form of that radium is entirely different. In the case of HMO the particulates of very high radium content will be discharged to the land and stream intact, and may very well have significant consequences to both the aquatic and land based biota. Most surprising of all is the fact that this rule change is being requested without the studies that demonstrate no impact and in the face of studies and real life examples such as the Florida lakes and Elliot Lake, Canada where a very real impact has been measured.

I would like to thank the Illinois Pollution Control Board for the opportunity of expressing our opinion on this very important issue.

Sincerely,

Charlie Williams
President Water Remediation Technologies

RSM Extended Pilot

WRT Radon Results, provided by Joliet

Strand Associates, Inc.
City of Joliet

Wisconsin Radium Effluent Lab Testing

All results in pCi/L

		Well 9-D Raw					WRT									
		Gross α	Gross β	Ra - 226	Ra- 228	Combined Radium	Gross α		Gross β		Ra - 226		Ra- 228		Combined Radium	
		Result	Result	Result	Result	Result	Result	% Removed	Result	% Removed	Result	% Removed	Result	% Removed	Result	% Removed
Day 1	Thursday, 6/3/04	30	29.5	7.9	3.4	11.3	1.2	96.00	8.9	69.83	0.12	98.48	0.2	94.12	0.32	97.17
Day 5	Wednesday, 6/9/04	25	27	8.1	4.9	13	0.9	96.40	10.5	61.11	0.01	99.88	0.2	95.92	0.21	98.38
Day 7	Friday, 6/11/04	26	27.4	7.6	5.6	13.2	1.1	95.77	11.4	58.39	0.15	98.03	0.1	98.21	0.25	98.11
Day 10	Wednesday, 6/16/04	33	32.6	7.8	5.8	13.6	2	93.94	13.4	58.90	0.14	98.21	0	100.00	0.14	98.97
Day 12	Friday, 6/18/04	24	28	7.8	5	12.8	1.9	92.08	11.5	58.93	0	100.00	0.1	98.00	0.1	99.22
Day 15	Wednesday, 6/23/04	30	30.6	7.8	5.5	13.3	2.1	93.00	12	60.78	0.1	98.72	0.1	98.18	0.2	98.50
Day 17	Friday, 6/25/04	25	28	7.3	5.6	12.9	1	96.00	12	57.14	0.15	97.95	0	100.00	0.15	98.84
Day 20	Wednesday, 6/30/04	26	25.8	8.6	5.4	14	2.2	91.54	11.7	54.65	0.08	99.07	0.1	98.15	0.18	98.71
Day 22	Friday, 7/2/04	32	31.3	7.6	5.2	12.8	1.1	96.56	11.7	62.62	0.08	98.95	0	100.00	0.08	99.38
Day 25	Wednesday, 7/7/04	30	31.8	7.1	8.1	15.2	1.3	95.67	10	68.55	0.7	90.14	0.1	98.77	0.8	94.74
Day 27	Friday, 7/9/04	23	26	8.4	8	16.4	0.6	97.39	12	53.85	0.47	94.40	0.3	96.25	0.77	95.30
Day 30	Wednesday, 7/14/04	21	25.4	8.4	5.1	13.5	0.9	95.71	12.6	50.39	0.18	97.86	0	100.00	0.18	98.67
	AVG	27.08		7.87	5.63	13.50	1.36				0.13		0.10		0.28	98.00
	MIN	21.00		7.10	3.40	11.30	0.60				0.00		0.00		0.08	
	MAX	33		8.6	8.1	16.4	2.2				0.47		0.3		0.8	

Strand Associates, Inc.
City of Joliet
Pilot Study

RSM Extended Pilot - WRT Radon Results

	Well 9-D pCi/L ± 20	WRT pCi/L ± 20	
Friday, 6/18/04	130	120	
Wednesday, 6/23/04	130	110	
Friday, 7/2/04	140	150	
Wednesday, 7/7/04	150	130	
Monday, 9/27/04		180	Before pressurization
Monday, 9/27/04		190	After pressurization
Thursday, 9/30/04		160	
Friday, 10/1/04	110	120	
Monday, 10/11/04	140	140	
Monday, 10/18/04	140	120	
Monday, 10/25/04	160	190	
Monday, 11/1/04	140	130	
Monday, 11/8/04			
Monday, 11/15/04			
Monday, 11/22/04			

30-day vendor pilot

	Well 9-D Raw Result pCi/L ± 20	WRT Result pCi/L ± 20
Friday, 6/18/04	130	120
Wednesday, 6/23/04	130	110
Friday, 7/2/04	140	150
Wednesday, 7/7/04	150	130

Table 22-2

Full Scale Radium Removal System
Estimated Annual Dose to Operators

Illinois –
Typical Treatment Systems

- 1,000 gpm well with two 15-ton stages of media
- Maximum total-radium activity of Stage 1 = 3,000 pCi/g, 1,500 pCi/g each Ra-226 and Ra-228
- 3-year media life
- Estimated average dose rate is for the last year prior to exchange of Stage 1 media
- The annual dose is based on one person performing all the tasks

Task	Distance from Tank (m)	Task Duration (min)	Task Frequency	Total Task Time (hr/yr)	Estimated Dose Rate (mrem/hr)	Estimated Annual Dose (mrem/yr)
Utility Operators:						
Inspect/record flow and pressure readings	3.0	3	5 days/wk	13.0	0.023	0.3
General equipment inspection	1.5	4	5 days/wk	17.3	0.055	1.0
Inspect/service external filter	1.5	10	every 2 weeks	4.3	0.055	0.2
Take radiation survey meter readings	1.0	3	2 times/mo	1.2	0.082	0.1
Collect inflow/discharge water samples	3.0	4	2 times/mo	1.6	0.023	0.04
Miscellaneous task time within tank area	1.5	5	5 days/wk	21.7	0.055	1.2
Miscellaneous task time within treatment room	4.0			30.0	0.015	0.5
Total and/or Average				89.1	0.037	3.3

Notes:

1. Based on instrumentation and remote readout for pressures and flows
2. Utility operators will not handle treatment media
3. Source of estimated dose rates - MFG, Inc. Dose Rate Calculator

Exhibit 22-1

MEMORANDUM

consulting scientists and engineers

MFG PROJECT: 181050

TO: Duane Bollig
Environmental Manager
Water Remediation Technology. LLC.

FROM: Jan Johnson, Ph.D.
Craig Little, Ph.D.
MFG, Inc.

DATE: September 20, 2004

SUBJECT: Calculation of Water Treatment Tank Exposure Rate – 3-year media life case

---

The dose rates from a water treatment tank at full capacity were calculated assuming a receptor at the surface of the tank and at several distances from the surface of the tank. The calculated dose rates are based on very conservative assumptions and simplifications that result in uncertainty in the numerical values of the estimates. These estimates are provided in order to project the upper limit of potential doses to workers. The estimated doses should not be construed as representing the actual doses that workers may incur from the WRT water treatment technology. When the equipment is in operation, doses to workers and members of the public will be determined using area gamma exposure rate measurements and personal dosimeters.

Dose at Specific Distances from the Tank Surface

Calculation of dose rates from point sources, line sources, and plane sources can be done by employing standard equations. However, estimation of the dose rate from a solid source with finite dimensions such as the water treatment tank is not a straightforward calculation but one that requires making some simplifying assumptions. Our approach to this problem is consistent with the recommendations of standard texts. For example, the following is an excerpt from a recent health physics textbook.

"Many radiation sources can, with ease and utility, be represented as a point or an approximate point source; however, many real-world situations cannot: for example, long pipes or tubes (typical of a line source), contaminated areas (representative of a disc or infinite planar source), and various volume sources. Fortunately, various practical calculations, some of which are fairly complex, can be used to determine the photon flux, which can then be applied in the usual way to calculate radiation exposure. Such calculations are generally conservative in that they tend to overestimate exposure, but considerable simplification of the calculations is obtained and errors in the estimates are not large."....."Volume sources such as large drums or tanks of radioactive material produce scattered photons due to self-absorption by the medium in which they are produced. ....good information can be obtained for such geometries by dividing them up into several point-source subdivisions and summing the contributions of each." (From "Physics for Radiation Protection", James E. Martin, Wiley and Sons, 2000.)

Our calculation method for the radium removal tank system takes such an approach. Based on information provided by WRT, the tank was assumed to be a cylinder 11 feet in diameter and 20 feet tall with two chambers, a lower stage (Stage 1) and an upper stage (Stage 2). Each stage contains 15 tons of treatment media. Typically, for a fully-utilized water well, WRT expects a stage of media to have approximately a two-year life before requiring exchange. The following example models a somewhat more conservative scenario in which a well is only partially utilized, resulting in a longer life for a stage of media – three years. This scenario also results in a slightly higher average activity in both stages of the media during the last year prior to the exchange of media. The fully-loaded media stage in the tank was assumed to be changed out on a three-year schedule (one of the two stages in a tank is exchanged every 1.5 years). At the time of each exchange, the lower stage (Stage 1) will be removed and the upper stage contents (Stage 2) physically moved to the lower chamber becoming the new Stage 1 of the treatment column. Fresh media will be installed in Stage 2.

The maximum radium loading was assumed to be achieved in Stage 1 after three years of operation. Based on results from WRT's pilot-scale testing at municipal well sites, it's reasonable to expect the media in Stage 1 to adsorb at least 1.5 times the amount of radioactive material adsorbed by Stage 2 during the same period of time, under steady-state conditions. At the time of the exchange of Stage 1, when its activity is assumed to be at the proposed maximum of 3,000 pCi/g total radium, the maximum loading in Stage 2 would be approximately 40 percent of maximum loading,

The maximum concentrations in the tank would occur at the end of the third year of operation in each cycle. For this dose-rate estimate, the activity concentration in Stage 1 at the start of the third year was assumed to be 60 percent of the maximum loading and 100 percent at the end of the year. The average loading in Stage 1 would then be approximately 80 percent of the maximum or 2,400 pCi/g. The activity concentration in Stage 2 at the start of the third year was assumed to be approximately 13 percent of the maximum loading and 40 percent at the end of the year for an annual average of approximately 27 percent (800 pCi/g). Average dose rates were estimated for the third and last year before the media in Stage 1 is exchanged.

As noted above, the calculation of exposure rate from a source such as the water treatment tank is not straightforward. For the purpose of these calculations, each stage was assumed to be configured into six cylindrical disk elements, each 1 foot thick, stacked vertically. The disc elements were assumed to have an inside radius one foot smaller than the outside radius (the radius of the tank). The gamma radiation emitted by the loaded media at a depth greater than one foot into the tank was assumed to be negligible, such that the remainder of each disc was ignored for the purposes of this calculation. Self-shielding would reduce the dose contribution for the remainder of each disk to less than 1% of the total. Each disc was divided into 16 segments. The receptor was assumed to be located at specific distances from the surface of the tank, ranging from 0.5 meters to 3 meters, at a height of 3 feet above the bottom surface of the adsorber in the tank. Only the segments of the disc facing the receptor were assumed to contribute to dose.

The gamma emission rate from each of the segments in each stage was calculated based on the total mass of the material in the segment and the assumed activity concentration, 2,400 pCi/g Ra-226 and Ra-228 for Stage 1 and 800 pCi/g for Stage 2.

For the purpose of calculating the emission "flux" at the receptor attributable to each of the segments or elements in the disc, the total activity in each element was assumed to be contained in a point source at the center of the surface of the element. The "flux" (d/s per cm^2) from each element at the receptor was estimated by dividing the total disintegration rate by the surface area of a sphere with a radius equal to the distance from the center surface of each element to the receptor. The total activity was calculated by multiplying the mass of material in the element by the activity concentration.

"Flux" = $A/4\pi d^2$ where: A = activity in the segment in d/s
d = distance from the segment to the receptor in cm

Activity = mass of the element x the average activity concentration for the stage

The distance from each element or source to the receptor was calculated using trigonometric relationships as described in the attached Excel spreadsheets and the Figures. It should be noted that this is not a true gamma flux, because each disintegration of Ra-226 and Ra-228 results in emission of several gammas. However, this is a convenient way of expressing the amount of electromagnetic energy in the form of gamma radiation that passes through an area of 1.0 cm^2, per second.

The dose rate was calculated by multiplying the ratio of the calculated flux from the water treatment tank to the flux from a point source of 1 MBq of Ra-226 or Ra-228 by the literature value (Handbook of Health Physics and Radiological Health) for the dose rate from a point source of 1 MBq of Ra-226 or Ra228. The decay products of Ra-228 and Ra-226 were assumed to be in equilibrium with the parent, that is, the activity concentration of each of the decay products is equal to the activity concentration of the parent. This is a reasonable assumption since equilibrium would be reached for both radium isotopes within a few weeks of radium adsorption onto the media.

Dose rate (tank) (D):
D = [(flux from tank at receptor)/(flux from 1MBq at 1m)][dose rate at 1m from 1MBq]

The calculations are given in the attached Excel spreadsheets.

Dose Rate At the Surface of the Tank

In contrast to the calculation of dose rate at one meter from the surface of the tank, the dose rate at the surface can be estimated by simply assuming that the tank is an infinitely thick, infinite plane source. The annual average dose rate at the surface of Stage 1 was calculated assuming an annual average Ra activity concentration of 2,400 pCi/g (1,200 pCi/g Ra-226 and 1,200 pCi/g Ra-228). A reasonable approximation of the dose rates can be obtained from the values given for these isotopes and their decay products in EPA Federal Guidance No. 12 that contains dose conversion factors for external radiation.

The dose rate from an infinitely thick, infinite plane source of Ra-226 and its decay products in equilibrium is 1.3 microrem per hour per pCi/g. The value for Ra-228 in equilibrium with its decay products is 1.8 microrem per hour per pCi/g. These values were calculated for contaminated soil. However, they are probably reasonably applicable to the media in the water treatment tanks.

The total dose at the surface of an unshielded source with these two radium isotopes at activity concentrations of pCi/g each would be as follows:

Ra-226 dose rate = (1,200 pCi/g)(1.3 uR/hr/pCi/g) = 1.56 mrem/hr
Ra -228 dose rate = (1,200 pCi/g)(1.8 uR/hr/pCi/g) = 2.16 mrem/hr

The total average annual unshielded dose rate would be approximately 3.72 mrem/hr. Assuming a shielding factor of approximately 0.8 for the tank wall, the dose rates for Ra-226 and Ra-228 for would be approximately 1.2 mrem/hr and 1.7 mrem/hr respectively for a total of 2.9 mrem/hr. The shielding factor was obtained from Ra-226 transmission curves in the Handbook of Health Physics and Radiological Health (1999). The activity concentration in Stage 1 (lower stage) of the tank was used in the surface dose calculation as the worker is more likely to contact the ground level stage than the upper stage and it is the most conservative assumption.

Dose Rates at Intermediate Distances

The dose rates at distances less than 1 meter from the surface of the tank should not be calculated in the same manner as the dose rates at 1 meter because the uncertainty resulting from the assumptions that were required to be used in the calculations would have a much greater impact on the estimated dose than for the 1.0 meter calculation. The closer to the source the receptor is placed the greater the error in the calculation. One approach could be to interpolate between the calculated surface dose rate and the estimated 1.0 meter dose rate. A second approach would be to use inverse square law to calculate the dose at distances less than 1 meter.

Summary of Dose Rates

The calculated or estimated annual average dose rates from the tank assuming an average total radium activity concentration in Stage 1 during its last year in the treatment tank of 2,400 pCi/g and 800 pCi/g in Stage 2, both equally divided between Ra-226 and Ra-228 are given below:

Table 1: Estimated Dose Rates at Specified Distances from the Surface of the Water Treatment Tank

Distance	Ra-226 Dose Rate (mrem/h)	Ra-228 Dose Rate (mrem/h)	Total Dose Rate (mrem/h)
Surface	1.25	1.73	2.98
0.5 m[1]	0.639	0.890	1.53
0.5 m[2]	0.124	0.204	0.328
1.0 m	0.031	0.051	0.082
1.5 m	0.021	0.034	0.055
2.0 m	0.015	0.024	0.039
2.5 m	0.011	0.018	0.029
3.0 m	0.009	0.014	0.023

[1]Interpolated value
[2]Inverse square value based on calculated 1.0 m dose

Potential Doses to Workers

Workers will be equipped with personal dosimeters at least until the negligible doses calculated above are verified by the dosimetry data. Workers will be instructed not to linger in the vicinity of the tank. Radiation doses to workers and members of the public will be kept As Low As Reasonably Achievable (ALARA).

The maximum allowable dose rate in areas where members of the public might have occasional access is 2 mrem per hour. The estimated distance at which this would occur at the average media loading for the second year of operation is approximately 0.5 meters. The maximum dose rate at the end of the second year of operation would be 10 percent higher than the loading used in calculating the dose to a worker. However, this would not change the estimated distance at which the allowable dose rate to a member of the public would be exceeded, 0.5 meters. This distance will be verified using measured exposure rates. As noted above, exposure rates in the treatment facility and at the surface of the tank will be measured at least monthly after the treatment facility goes into operation..

The estimated dose rate at the surface of the tank is 3.3 mrem/hour. This does not exceed the dose rate at which posting as a Radiation Area is required; however it does exceed the dose rate that is acceptable for members of the public. Therefore, the water treatment operators must be considered radiation workers even though the estimated annual dose to the worker is below the allowable annual dose to a member of the public. This means that all workers who have access to the treatment facility must be appropriately trained and the facility must develop and implement a program to keep radiation doses As Low As Reasonably Achievable (ALARA). The Radiation Safety Officer (RSO) for Water Remediation Technology (WRT) will serve as the RSO for each facility using its equipment. If the measured doses to all individual workers at the treatment facility are below 500 mrem per year, no individual dose tracking will be required.

Schematic Representation of Water Treatment Tank