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US Oil Sands Inc.

BEFORE THE UTAH WATER QUALITY BOARD

In the Matter of PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule No. WQ PR-11-001	**USOS'S OBJECTIONS TO TESTIMONY AND EXHIBITS OFFERED BY LIVING RIVERS**

U.S. Oil Sands, Inc. ("USOS") respectfully submits its objections to testimony and exhibits offered by Living Rivers.

Testimony/Exhibit	Objection
1. W. Johnson 1/20/12 Prepared Direct Testimony at p. 14, lines 10-22, p. 15, lines 1-2, attached hereto as Ex. 1. (This is marked as Exs. 1 and 2 to the 4/20/12 Johnson Dep. and as LR 200.) 2. Id. at p. 16, lines 15-21, attached hereto as Ex. 2.	This testimony purports to be based on alleged USOS measurements, but the measurements were not provided with the 1/20/12 testimony. The January 5, 2012 Stipulated Schedule, ¶ 8, provides that Living Rivers' pre-filed testimony "must include . . . all of the data on which such witness will rely for his or her testimony."
3. W. Johnson 3/16/12 Prepared Supp. Testimony at p. 28, lines 7-10, 16-20, p. 29, lines 3-10, attached hereto as Ex. 3. (This is marked as Exs. 1 and 2 to the 4/20/12 Johnson Dep. and as LR 201.) 4. Id. at p. 31, lines 7-8, attached hereto as Ex. 4. 5. W. Johnson 4/20/12 Dep. at p. 21, lines 19-25, p. 22, lines 1-2, attached hereto as Ex. 5. 6. W. Johnson 5/4/12 Dep. at 30, lines 18-25, p. 31, lines 1-16, attached hereto as Ex. 6.	The alleged measurements on which Prof. Johnson relies have never been provided, and USOS is unaware of the measurements to which Prof. Johnson refers. During his May 4, 2012 deposition, Prof. Johnson testified that the only USOS information he used "was information provided to counsel that they apparently were able to view it for a short time. They had notes on that. They showed me their notes. So I used the information they had on their notes to make the calculation." (5/4/12 Dep. of W. Johnson at 38, lines 21-24, p. 39, line 1, attached hereto as Ex. 17.) Living Rivers has never provided the notes on which Prof. Johnson relied, even after USOS's counsel asked for them. (Id. at p. 39, lines 8-12.) USOS would be unfairly prejudiced by the admission of this testimony. Living Rivers' failure to disclose on January 20, 2012, the information on which Prof. Johnson relied prevented USOS from having its witnesses verify the measurements and rebut in their February 29, 2012 reports Prof. Johnson's use of the measurements.

Testimony/Exhibit	Objection
7. W. Johnson 4/20/12 Dep. at p. 12, line 25 through p. 27, line 21, attached hereto as Ex. 7.	Under Utah Admin. Code R305-6-213(c)(i), "A witness for whom pre-filed testimony has been submitted shall be allowed to give a brief summary of that testimony, and shall then be made available for cross-examination." Prof. Johnson's testimony on these pages went well beyond a "brief summary" of his testimony. In fact, on page 13, line 5, through p. 16, line 12, Prof. Johnson provided previously undisclosed testimony regarding the volatility of d-limonene. Prof. Johnson admitted on page 39, lines 9-16 (attached hereto as Ex. 18), that his new testimony regarding the volatility of d-limonene is absent from his pre-filed testimony. In fact, the views Prof. Johnson expressed on April 20 were *contrary to* his January 20, 2012 pre-filed testimony at page 4, lines 9-11, attached hereto as Ex. 19.
8. W. Johnson 4/20/12 Dep. at 37, lines 16-25, and p. 38, lines 1-25, after the answer "Right," attached hereto as Ex. 8. 9. Id. at 55, lines 3-5, attached hereto as Ex. 9. 10. Id. at 57, lines 15-19, after the answer, "Yes, that's true," attached hereto as Ex. 10.	USOS moves to strike this testimony as non-responsive. This testimony was volunteered after Prof. Johnson had fully answered USOS's cross-examination question. USOS is unfairly prejudiced by this volunteered testimony, which interfered with, and was non-responsive to, USOS's cross-examination questions. The proper procedure would have been for Living Rivers to redirect Prof. Johnson to elicit this testimony.

Testimony/Exhibit	Objection
11. W. Johnson 5/4/12 Dep. at p. 14, lines 12-25, p. 15, lines 1-21, attached hereto as Ex. 11. 12. Id. at p. 41, lines 7-21, p. 42, lines 6-9, attached hereto as Ex. 12.	This testimony purports to be based upon an article that was neither identified nor provided until after the April 23, 2012 deadline for exchanging exhibits. The January 5, 2012 Stipulated Schedule, ¶ 11, provides that "Living Rivers' pre-filed rebuttal testimony must include all of the data on which the expert will rely for his or her rebuttal testimony." The article on which Prof. Johnson relies was not provided with his March 16, 2012 pre-filed testimony. In addition, ¶ 16 of the Stipulated Schedule provides, "On April 23, 2012, the parties will exchange their respective exhibits . . . pursuant to Rule 305-6-212(1)." The article was not provided or even identified until Living Rivers' cross-examination of USOS's expert, Ed Handl, on April 27, 2012. USOS would be unfairly prejudiced by the admission of this testimony because USOS was deprived of the ability to have its expert, Ed Handl, review the article prior to his deposition and rebut Prof. Johnson's use of it.
13. Ex. LR 208 – MacKay AA, and Gschwend, P.M., Enhanced Concentration of PAHs in Groundwater at a Coal Tar Site, Environmental Science Technology 35(7) (2001), attached hereto as Ex. 13. (This is also marked as Ex. 20 to the E. Handl Dep.)	This is the article that is referred to above in Objections 11 and 12. This article was neither identified nor provided to USOS until the cross-examination of USOS's expert, Ed Handl, on April 27, 2012. This article should be excluded for the same reasons that Prof. Johnson's testimony based upon this article should be excluded.
14. W. Johnson 5/4/12 Dep. at p. 37, lines 23-25, p. 38, lines 1-9, attached hereto as Ex. 14. 15. Id. at p. 40, lines 5-10, attached hereto as Ex. 15.	USOS moves to strike this testimony as non-responsive. This testimony was volunteered after Prof. Johnson had fully answered USOS's cross-examination question. This testimony should be stricken for the same reasons set forth in Objections 8, 9, and 10.

Testimony/Exhibit	Objection
16. E. Lips 3/16/12 Prepared Supp. Test. at p. 22, line 19 through p. 25, line 4, attached hereto as Ex. 16. (This is marked as Ex. LR 202.)	This testimony purports to be based on the "Hydrological Evaluation of Landfill Performance (HELP) [program] developed by the U.S. Army Corps of Engineers" and "the Ground Water Permit Application submitted to DWQ by Red Leaf Resources on December 20, 2011, for its Southwest #1 Project." First, this testimony is not proper rebuttal. It is not responsive to any testimony offered by either the Executive Secretary or USOS. Living Rivers could and should have offered this testimony in Mr. Lips' 1/20/12 testimony so that USOS and the Executive Secretary could have responded to it in their February 29, 2012 pre-filed testimony and expert reports. Second, Living Rivers failed to provide the data regarding the HELP program and the Red Leaf application. The Stipulated Schedule, ¶ 11, provides that "Living Rivers' pre-filed rebuttal testimony must include all of the data on which the expert will rely for his or her rebuttal testimony." Neither the HELP program nor the Red leaf application was included with Mr. Lips' 3/16/12 testimony. In addition, the HELP program and the Red Leaf application were neither listed nor provided on April 23, 2012, the deadline for disclosing exhibits under ¶ 16 of the Stipulated Schedule. The HELP program was never provided. The Red Leaf application was first provided on May 7, 2012. USOS would be unfairly prejudiced by the admission of this testimony. Living Rivers' failure to include it within Mr. Lips' 1/20/12 testimony deprived USOS of the ability to have its experts review and refute it in their February 29, 2012 reports. In addition, Living Rivers has never provided the HELP program.

Testimony/Exhibit	Objection
17. Ex. LR 209 – Utah Ground Water Discharge Permit Application for Red Leaf Resources, Inc. Southwest #1 Project Dec. 20, 2011. (This application is not attached because it exceeds 150 pages in length.)	This is the ground water application referred to above in Objection 16. This application was not included with Mr. Lips' 3/16/12 testimony, contrary to ¶ 11 of the Stipulated Schedule. This application should be excluded for the same reasons that testimony based upon this application should be excluded. In addition, this application is irrelevant. Utah R. Evid. 402. It deals with a different project involving a different operator and different processes. Also, whatever probative value this application may have, it is substantially outweighed by a danger of unfair prejudice, confusing the issues, undue delay, and waste of time. Utah R. Evid. 403. Again, this application deals with a different project.

Respectfully submitted this 9th day of May, 2012.

/s/ Christopher R. Hogle
Holland & Hart LLP
A. John Davis
Christopher R. Hogle
M. Benjamin Machlis

CERTIFICATE OF SERVICE

The undersigned hereby certifies that on this 9th day of May, 2012, a true and correct copy of the foregoing **USOS'S OBJECTIONS TO TESTIMONY AND EXHIBITS OFFERED BY LIVING RIVERS** was served via e-mail, as follows:

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EXHIBIT 1

In the Matter of

PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule

No. WQ PR-11-001

PREPARED DIRECT TESTIMONY

OF

WILLIAM P. JOHNSON, Ph.D

ON BEHALF OF

LIVING RIVERS

January 20, 2012

A. This demonstrates that d-limonene can be expected to increase the rate of transport of tar compounds by more than a factor of four ($R/R^* = 607/140 = 4.3$). This factor-of-four increase in the transport rate, along with the factor-of-1440 increase in the aqueous concentration of tar compounds in the presence of d-limonene, constitutes a major increase in the potential for exposure to these compounds via groundwater as a result of interaction with d-limonene residual.

Q. ARE THERE MEASUREMENTS PROVIDED BY THE COMPANY THAT CORROBORATE YOUR CALCULATIONS?

A. The reported reagent (TAI) content in the produced fines (averaging 1.8%) (provided to Living Rivers' attorneys by the company) and the reported water content in the produced fines (15.25%) yield a reagent concentration in the fluid equal to 118 mg of reagent per liter of fluid. This concentration is nearly ten times higher than the solubility of d-limonene in water (13.8 mg/L) assumed in the calculations above. This discrepancy suggests that the actual increase in tar compound solubility in water as result of mixing with the reagent will be ten times greater than the calculated factor of 1400, i.e, 14,000. Assuming that the reported % bitumen content of the "water" that is mixed with the ore is equivalent to the bitumen content of the residual fluid in produced waste sediment, the bitumen concentration of the residual fluid in the produced waste sediment is 900,000 μg/L. Using the normal water solubility (49.2 μg/L) of B(a)P, this represents a factor of 18,290 increase in the solubility of the tar compounds due to mixing with the reagent. This is a similar value to the expected factor of 14,000 increase observed in the "water" mixed with the ore. This agreement indicates that solubilization of tar compounds by reagent occurs as expected, and therefore the mobility of the tar compounds will increase as calculated.

Q. WHAT DID YOU CONCLUDE BASED ON YOUR CALCULATIONS?

A. The calculations show clearly that d-limonene enhances the solubility, and facilitates the transport, of tar compounds. It does so because the d-limonene is more soluble than the tar compounds; whereas, the tar compounds have a strong affinity for d-limonene. Although the specific partition coefficients can potentially be refined, the overall finding is correct: the residual d-limonene in the sand creates the potential for increased transport of carcinogenic tar compounds at higher concentrations.

Q. IS DWQ'S RELIANCE ON THE MSDS SHEETS FOR THE REAGENT APPROPRIATE?

A. The two MSDS sheets (d-limonene) provided to DWQ have information pertaining to workplace exposure, and are not specifically intended for assessment of environmental toxicity. However, there is sufficient concern expressed in these MSDS sheets regarding environmental dispersion of the reagent ("may be toxic to aquatic organisms") that additional investigation of potential deleterious consequences of environmental disposal should be investigated.

EXHIBIT 2

In the Matter of

PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule

No. WQ PR-11-001

PREPARED DIRECT TESTIMONY

OF

WILLIAM P. JOHNSON, Ph.D

ON BEHALF OF

LIVING RIVERS

January 20, 2012

Q. HAVE THE APPROPRIATE TESTS BEEN CONDUCTED TO ASSESS THE POTENTIAL FOR LEACHING OF PETROCHEMICALS FROM THE PROCESSED ORE?

A. Tests should be performed to assess the potential for leaching of tar and terpene compounds into water from the produced sediment. The test that was performed was extraction of non-volatile compounds from ore using hexane, which only assesses how much tar compound can be extracted using a non-polar solvent, and in no way addresses the question of how much tar compound would dissolve into water in contact with produced sediment. In the 2008 Demonstration, on page 10, the company makes the curious statement that "the absence of volatile or semi-volatile constituents in the processed material indicates that the organic compounds in the residual material are likely to be no more mobile than the *in situ* tar sands themselves." This statement completely ignores the fact that the addition of reagent terpenes alters the properties of the tar, as described above.

Q. WOULD YOU CHARACTERIZE THE PROCESSED SEDIMENT AS "DAMP-DRY"?

A. A comparison of the % water content in produced sands and fines (provided to Living Rivers by the company) indicates that approximately 511 tons of produced fluid exists in approximately 2763 tons of produced sediment (combined sand and fines). This ratio yields a volumetric ratio of 28.5% of fluid in the sediment, assuming a fluid specific gravity near unity and a sediment bulk density of 1.5 g/mL (reasonable values). This volumetric ratio is close to the expected 30% porosity of the sediment, indicating that the produced rock is saturated and will drain fluid to underlying soil, particularly with additional water added by precipitation.

EXHIBIT 3

In the Matter of

PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule

No. WQ PR-11-001

PREPARED SUPPLEMENTAL TESTIMONY

OF

WILLIAM JOHNSON

ON BEHALF OF

LIVING RIVERS

March 16, 2012

Q: What is your conclusion based on the analysis above?

Of course the specific values used in these calculations can be disputed, but what cannot be disputed is that the dissolution of bitumen compounds in the raffinate is promoted by the solid/liquid transition ($P^0(L)/P^0(S)$) and by solubilization into dissolved d-limonene ($\gamma^{sat}_{w}/\gamma_{raf}$).

Q: Are there any measurements that corroborate your calculations?

The above calculated effect of d-limonene on the concentration of bitumen compounds in the raffinate is corroborated by the values for percent bitumen content of return water (900,000 µg/L) measured by USOS, and reported in documents provided to Living Rivers. Johnson January 20, 2012 Testimony at 14.

Q: How do the values measured by USOS equate with Mr. Handl's analysis?

Such a high dissolved concentration of bitumen compounds is impossible to explain using Mr. Handl's analysis. Mr Handl's analysis states that the maximum concentration of combined bitumen compounds in the raffinate should be approximately 1.5 µg/L in the absence of d-limonene, and should decrease below that value as d-limonene is added to the system. In contrast, the USOS data shows a bitumen concentration in the raffinate that is nearly a factor of 400,000 (more than five orders of magnitude) higher than the representative concentration 1.5 µg/L chosen by Mr. Handl. Clearly Mr. Handl's analysis is greatly at odds with the data provided by USOS.

Q: Therefore, in addition to all of the other reasons stated above, is your analysis more in keeping with the USOS findings?

Yes. The data is explained by my analysis above. While my calculation estimated a factor of 2000 increase in bitumen compound concentration (far lower than the observed 400,000 increase), my calculation assumed that d-limonene interacted with bitumen similarly to octanol, which likely underestimates solubilization of bitumen compounds by d-limonene. Furthermore, to accurately estimate the full extent of solubilization, my calculations would need to include the mole fractions and vapor pressures of all bitumen compounds. The data provided by USOS supports my claim that d-limonene will greatly increase the concentration of bitumen compounds in water that comes into contact with the residual tar/d-limonene mixture.

Q: Is there some test that would actually determine the degree to which the bitumen compounds would dissolve into water in the presence of d-limonene?

Yes. Such tests exist. For this reason, it would be prudent for the State of Utah to require leach tests to be performed to quantify the potential for tar compounds to leach into WATER from the residual tar/d-limonene mixture in the processed sand. These measurements are not particularly difficult to perform, and would provide critical understanding of the behavior of the tar compounds should the residual extract come into contact with water. A leach test was previously performed using hexane; however, as recognized by DWQ, this test provides no insight regarding what concentration of bitumen compounds would be expected in water.

EXHIBIT 4

In the Matter of

PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule

No. WQ PR-11-001

PREPARED SUPPLEMENTAL TESTIMONY

OF

WILLIAM JOHNSON

ON BEHALF OF

LIVING RIVERS

March 16, 2012

Third, Mr. Handl fails to account for the differences in the behavior of tar without d-limonene (a semi solid) and the tar/d-limonene mixture (a liquid). This oversight further causes Mr. Handl's calculation to severely underestimate the increase in the concentration of bitumen compounds that will dissolve into water in the presence versus the absence of d-limonene. I showed these flaws using both Mr. Handl's ternary equilibrium approach as well as an approach using thermodynamic relationships.

I also showed that Mr. Handl's approach led to results that were not consistent with USOC's own data and that my analysis more accurately reflect these company-provided results.

Finally, I stated that there are tests readily available that would determine the potential for tar compounds to leach into water from the residual tar/d-limonene mixture in the processed sand. I concluded that DWQ should order that such tests be run, reported and analyzed before the agency permits the PR Spring mining operations.

Q: Does this conclude your testimony for now?

Yes.

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EXHIBIT 5

Tempest℠
REPORTING

COMPRESSED
CERTIFIED TRANSCRIPT

BEFORE THE UTAH WATER QUALITY BOARD

In the Matter of	:
PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule	: Videotaped Testimony of: **WILLIAM JOHNSON, Ph.D.**
No. WQ PR-11-001	:

Place: TEMPEST REPORTING, INC.
175 South Main Street, #710
Salt Lake City, Utah 84111

Date: April 20, 2012
9:06 a.m.

Reporter: Vickie Larsen, CSR/RPR

Tempest Reporting, Inc.
801-521-5222 / Fax 801-521-5244
Post Office Box 3474 / Salt Lake City, UT 84110

(09:26:16-09:27:04)

From now on, please refer to your report if you need to refresh your memory, okay?

THE WITNESS: Sure. Sure. It's just a matter of framing the response, it's not an important aspect.

MS. WALKER: Yeah, no, I don't think it's important.

THE WITNESS: So there's two reasons why the addition of d-limonene to the tar changes the behavior of the tar compounds.

As I said before, you were taking what was a solid or a semi-solid, and you're turning it into a liquid. It's going to behave as a liquid, and therefore, the solubility is greatly increased with water.

The second is that the d-limonene itself is much more soluble than the tar compounds in water. And so the d-limonene will be present in the water, and the d-limonene, I think we all agree, is a very good solvent for the tar compounds. So if it exists in the water, it will act as a carrier for the tar compounds to come into the water.

Q. BY MS. WALKER: Okay. So I just want to -- you to provide your basis for that first reason.

A. Well, the -- there's two ways to get at

(09:27:26-09:28:15)

this. But in my initial testimony what I used were so-called partition coefficients that represent the distribution of tar compounds between this organic mixture and water. And those are available in the literature from any similar compounds, and so I used those partition coefficients.

Q. And with those coefficients, what were you able to do?

A. Well, you can combine those coefficients to predict what the concentration would ultimately be of the tar compounds in water. And I chose a representative tar compound, benzo(a)pyrene.

Q. And is this the typical way in your profession to do such calculations?

A. Sure.

MR. HOGLE: I'm going to interpose another objection. I think this is getting beyond a summary. I don't want to keep repeating it, Joro, so if you want to let me have a continuing objection that this goes beyond the scope of a proper summary, I won't bring it up any more.

MS. WALKER: Okay.

MR. HOGLE: I mean, I won't waive it, but I won't have to keep interposing the same objection.

MS. WALKER: Fine. It seems to me that

(09:28:33-09:30:01)

it's a summary of his report.

MR. HOGLE: Well, he gave a summary of his report in the first pages of his testimony. That's a typical summary, and he's going well beyond that.

MS. WALKER: Well, that may be your understanding of a summary of a report, but my understanding of a summary of a report is to actually explain it, and given how technical it is, it's very difficult to explain. And I think the ALJ will appreciate his efforts to explain it.

Okay. So -- but I understand you're going to have an ongoing objection that he's talking too much.

So would you kindly read back his last response.

(The previous answer and pending question were read.)

Q. BY MS. WALKER: So do you want to answer that question, please.

A. Yes. This is a typical way to address that problem. This kind of approach is substantiated in a staple -- in a textbook that's a staple in environmental engineering curriculum.

Q. Okay. And did you actually calculate the increase in concentration of tar in water?

(09:30:12-09:31:14)

A. Yes, I did, for a representative compound.

Q. And what was that?

A. It was three orders of magnitude. It came out to be about 1600 -- or 1400, something like that. Three orders of magnitude.

Q. So can you explain what an order of magnitude is?

A. Factor of ten. So this would be a factor of a thousand.

Q. And why, in your mind, is that significant?

A. Well, that's significant because if you increase the concentration that you'd expect in water by a factor of a thousand, then you increase the potential toxic dose by a factor of a thousand.

Q. And did you find further support for your conclusion?

A. Yes, I did. I was shown some data from U.S. Oil Sands that showed concentrations of polycyclic aromatic hydrocarbons in their process water. And the concentrations that were in that water were a factor of something like 20,000 higher than you'd expect, according to their normal water solubility. So that agrees with my calculation that

(09:31:36-09:32:28)

you greatly enhance the dissolution -- the dissolving into water.

Q. Is there a way to verify whether the presence of d-limonene in the residual mixture will increase the concentration of --

THE REPORTER: I'm sorry. Is there a way to verify whether the presence of the...

Q. BY MS. WALKER: -- d-limonene in the residual mixture will increase the concentration of tar compounds in the water?

A. Certainly. All that's needed is a leech test to equilibrate to put in contact the residual with water and monitor the concentration of these kinds of compounds in the water over time.

Q. And did you see any such test in the record?

A. Not that test. There was a leech test, but it was done with hexane instead of water. And so they took the residual material and they equilibrated with hexane and measured the polycyclic aromatic hydrocarbon compound concentration in the hexane.

Now, what they found were extremely high concentrations of the polycyclic aromatic hydrocarbons, which is -- if that were water you'd be alarmed. But it was hexane, and you'd expect that

(09:32:42-09:33:46)

from hexane, because hexane is acting like d-limonene. It's extracting the tar compounds.

And so the apparent conclusion that was drawn is that hexane was the inappropriate solvent to test to represent water, which is correct, but then there was no follow up.

Q. Okay. And did you submit further testimony in this case?

A. Yes. I submitted a supplemental testimony in response to comments by Mr. Handl.

Q. And is that testimony dated March 16th, 2012?

A. I believe it is. Can I look at your copy?

Q. Yeah.

A. Would there be an objection?

Yes.

Q. And in most general terms, what's this report about?

A. So this was -- I wrote this in response to Mr. Handl's criticisms of my testimony. What they -- what those criticisms boiled down to was that the d-limonene has no effect on tar compound dissolution into water. And so I wrote a response to demonstrate that that criticism was incorrect and that

(09:34:00-09:34:52)

in fact d-limonene has a major effect on tar compound dissolving into water.

Q. And does this report represent your expert opinion on that subject?

A. Yes.

Q. And does it still represent your expert opinion on that subject?

A. Yes.

MS. WALKER: So I'd like to move to enter that as an exhibit, please.

MR. HOGLE: No objection.

MS. WALKER: And this would be Exhibit 2.

(Exhibit 2 was marked for identification.)

Q. BY MS. WALKER: So what materials did you review to address that second point? Mr. Handl's testimony.

A. Yeah, Mr. Handl's testimony.

Q. I didn't mean to answer the question for you. I meant -- okay.

And what I meant is what -- it's fine.

Okay. So can you briefly summarize Mr. Handl's analysis that you were responding to?

A. Yeah. His analysis is that the d-limonene simply dilutes the mixture, okay. The residual organic mixture is comprised of tar compounds

(09:35:12-09:36:17)

and d-limonene, or in his terminology, bitumen compounds and d-limonene. And his assertion is that that is simply a dilution of the tar compounds, and therefore any tar compounds that would dissolve into water would be lower than their normal water solubility, according to Raul's, which is the equation that he used.

Q. Okay. And your response to this analysis was?

A. That it's incorrect because it's missing two very important terms when you do a more complete thermodynamic analysis.

Q. And can you explain that a little bit more --

A. Sure.

Q. -- fully?

A. If you -- if you -- if you go back to the basic thermodynamics and solve for the change in the, basically the ratio of the concentration of the tar compound in the water, pure water, versus water that has d-limonene as a result of being in contact with this residual, then you can calculate the ratio of those two concentrations, and a value that is -- I don't want to confuse things because I'm changing the -- let me put it this way:

EXHIBIT 6

*********************ROUGH DRAFT***********************

*****************WILLIAM JOHNSON PhD*****************

THE VIDEOGRAPHER: One moment please. We are going on the record. The time is 2:02. This is the videotaped deposition of William Johnson taken in the matter of PR Spring Tar Sand project groundwater discharge permit by rule before the Utah Water Quality Board.

This deposition is being held at 175 South Main, Salt Lake City, Utah on April 4, 201. My name is Max Nelson from the firm of Tempest Reporting with offices at 175 South Main Salt Lake City, Utah. I am the video specialist. The reporter is Denise Kirk from Tempest Reporting.

Counsel will now state their appearances for the record and the witness will be sworn.

MR. DUBUC: Today's date is May 4th, 2012. You said April.

MS. WALKER: This is Joro Walker and Rob Dubuc on behalf of Living Rivers.

MR. McCONKIE: Paul McConkie on behalf of the executive secretary.

MR. HOGLE: Chris Hogle and Benjamin Machlis. And we have Barclay Cuthbart here who is a representative of U.S. Oil Sands.

It dissolves to some extent. That's why we have an issue. But it doesn't dissolve completely. So it's partially I am miscible. Mr. Handl was unwilling to use that term last time because it states in his own reference per ease handbook which he calls the bible for chemical engineers, it states there that an partially miscible solution with suffer nonidealities, okay? Which goes against his assumption of an ideal solution, okay? They're clearly partially miscible. Partial miscibility can lead to nonideality.

It says that in Perry's Handbook. There's this continuum then from completely immiscible which doesn't actually exist to partially immiscible to completely immiscible and there's this transition from ideal to nonideal.

So that's how the two terms relate to one another. Does that clarify that well enough?

Q. Yes, thank you. I just had another clarifying point. So when you were showing us those two factors that the one that accounts for northern

ideality and the one that accounts for phase change, were you assuming then in that situation that the solutions were nonideal?

A. No, there's no -- I don't have to assume anything to develop that. That equation is diagnostic to (anthropomorphite) right? It's got no (word) assumptions built in.

What those terms do is if the activity coefficient ratio ends up larger than one, that means there's nonideality that drives the compound into solution which is indeed what I found to be the case when I did the calculations for a representative compound. But there's no assumption (ipari) that's that the case.

Q. Okay. Then finally, was there any evidence that you saw, so hard evidence, that supports your calculations?

A. Yes. The U. S. Oil sands own results with I forget the place where they did the pilot study but they had material from there that they had monitored. So they were looking at the residual extract, the extract that's in the processed sand.

They quantified that, they quantified the petroleum hydrocarbons that are present in the processed water, which apparently gets returned back

into the process.

And so I think that's probably the most illuminating in terms of what ends up in the water. And the numbers that they gave showed that the amount of petroleum hydrocarbons which you'd expect to be dominated by is polycyclic aromatic hydrocarbons in the asphaltines and the other components of the tar, those concentrations were a factor of something like 10,000, much higher than what I had predicted. And so they are strong indicator that the processes that we're concerned about are occurring.

So again, that is in a way a leach test, okay? They have their own data that demonstrates that there is a large amount of these compounds that will go into the water once you add d-limonene to the system.

Now, I believe what's needed is a more controlled leach test, you know, done by a reputable group, consultant or academic group or what have you, but somebody who can do these leach tests and it's not difficult to do to get to the truth of how much is going to be in the water.

Q. Okay. Thank you.

A. You bet.

MR. HOGLE: Let's take a break, okay.

THE VIDEOGRAPHER: We're going off the record, the time is 2:54.

(Brief recess.)

THE VIDEOGRAPHER: One moment please. We're going back on the record. The time is 319.

EXAMINATION

BY MR. HOGLE:

Q. Dr. Johnson, we've met before. I'm Chris Hogle. Just a few questions. Nowhere near like last time.

There was some discussion about bitumen, whether it's a solid or a liquid or both. If it's in

EXHIBIT 7

Tempest REPORTING

COMPRESSED
CERTIFIED TRANSCRIPT

BEFORE THE UTAH WATER QUALITY BOARD

In the Matter of

PR Spring Tar Sands Project,
Ground Water Discharge
Permit-by-Rule

No. WQ PR-11-001

Videotaped Testimony of:
WILLIAM JOHNSON, Ph.D.

Place: TEMPEST REPORTING, INC.
175 South Main Street, #710
Salt Lake City, Utah 84111

Date: April 20, 2012
9:06 a.m.

Reporter: Vickie Larsen, CSR/RPR

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(09:15:05-09:16:02)

on -- on those documents, because I'm bringing new information into this.

Q. Okay. Let me rephrase the question a little bit.

A. Sure.

Q. So were there other documents that you reviewed that were provided by the applicant or U.S. Oil Sands?

A. Yes.

Q. And what would those be?

A. Well, I can't remember exactly the titles, but there was other information related to U.S. Oil Sands in different reports that were provided to me.

Q. Okay.

A. I can look that up if it helps.

Q. No, I think that's fine.

Okay. So I just want to make sure we're clear on terms. When you speak of the residual mixture, what do you mean by that?

A. The residual mixture is the organic mixture that's remaining in the process sands. That's a mixture of the bitumen that's extracted from the process sand and the d-limonene or the solvent they're using to extract the bitumen.

Page 11

(09:16:19-09:17:32)

Q. Okay. And when you talk about bitumen, do you call that something else often?

A. Yeah, we often call that tar, you know, so I use tar as the catch-all term for the compounds that comprise the bitumen.

Q. Okay. And can you just give us an idea of what those compounds are?

A. Sure. There's a range of compounds in that. Asphalting is a compo- -- predominant component. Polycyclic aromatic hydrocarbons are another component. These are all related organic compounds.

Q. Okay. So why are you in a position to address this issue?

A. Well, my doctoral research concerned the solubilization and transport of polycyclic aromatic hydrocarbons by agents that will increase their solubilizing into water. And the particular agent I was looking at was natural organic mater, which shares significant properties with d-limonene.

Q. And so as a result of your evaluation or calculations, what did you conclude?

A. I concluded that the d-limonene would enhance the solubility of the tar compounds in water that's in contact with the residual mixture. And I

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(09:17:51-09:18:52)

concluded that the transport of the organic -- the tar compounds would be facilitating, would be increased, the mobility would be increased by the presence of d-limonene.

Q. And why is that a concern?

A. It's a concern because if this material were to come into contact with water, and if that water had a potential receptor of these compounds, you know, a number of scenarios could be envisioned, but if there were a receptor, whether that's something in the ecosystem or whether that's a human ingesting the water for some reason, then that would be a toxic concern. Toxicological concern.

Q. And why do we care about an increase in concentration?

A. Because the toxicity's directly proportioned to the concentration. So the dose encountered by a receptor is increased with increased concentration.

Q. And is there anything about tar that makes it a matter of concern?

A. Sure, yeah. The polycyclic aromatic hydrocarbons, a significant number of those compounds are highly carcinogenic.

Q. But now I'd like to delve a little deeper

Page 13

(09:19:07-09:20:14)

into your testimony.

You said that you were testing an -- an assertion. Would you just repeat that assertion that -- made by oil sands?

A. The predominant one is that the d-limonene will vaporize readily from the residual -- from the process sands.

Q. And what are the consequences if the d-limonene doesn't evaporate readily?

A. So the addition of the d-limonene changes the tar. First the tar is in a solid form, or a semi-solid form. It's not mobile in its natural state. It's been there a long, long time because it doesn't dissolve readily into water, it doesn't flow on its own. But when you extract this tar compound with d-limonene, now you've turned it into a liquid mixture, and that changes its properties.

And the property that I focussed on is its -- its dissolution or dissolving into water, okay. And so the d-limonene enhances that dissolution into water.

And so now -- I'm not sure I answered your question, because I think maybe you were focussing on the vaporization.

Q. No, no. You answered my question.

Page 14

(09:20:32-09:21:48)

So in -- so is there an additional reason for why -- the effect that d-limonene would have if it didn't evaporate? You talked about the solidity of the tar.

A. Right. So it -- now you're dealing with a liquid mixture, okay, and that greatly -- the solubility of the tar compound in a liquid form is much, much greater than in a solid form. And so that increases the concentration of those compounds in water and the transport is, therefore, affected by that as well.

Q. Okay. And in your opinion was it reasonable for the company to assert that the d-limonene would evaporate quickly?

A. They -- no. And -- and they didn't support that assertion. There was a statement that was made that -- that had no backing and it -- it -- d-limonene's not a particularly volatile compound. It has a relatively high boiling temperature, it has a vapor pressure that's ten times lower than that of water. Which means that it would -- its propensity to vaporize is ten times lower than water, and therefore, it's not going to be rapidly removed from the residual -- residual mixture.

Q. And are there any physical reasons that

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(09:22:00-09:23:06)

you believe that the d-limonene won't evaporate readily?

A. Yeah. In addition to just considering vapor pressures, there's physical processes that you would expect to occur.

So if you have this liquid mixture of d-limonene and tar compound, the tar compounds will not vaporize and they will accumulate, and they will accumulate typically on the interface between the air and the liquid mixture. And so they'll form kind of a rind that will inhibit the vaporization of d-limonene, and we can expect that based on studies that have been done looking at organic mixtures dissolving into water. The same processes have been documented.

Q. And are there any issues with the handling of the waste that may affect the evaporation of d-limonene?

A. Yeah, possibly. I mean, I didn't focus on how the waste is disposed of, but if it's being piled you would expect that you'll inhibit the vapor transport from the interior of the pile.

And furthermore, the vapor density is fairly high, about -- almost five times higher than -- than air. And so it will tend to accumulate over the organic liquid, and that will further inhibit

Page 16

(09:23:17-09:24:27)

d-limonene vaporization.

Q. Okay. Is there any way to test whether d-limonene will evaporate quickly?

A. Oh, yeah, that's -- that's very simple. All they need to do is do this themselves or just have university or a consulting company do this, but they can simply have a chamber in which they put residual material and monitor the vaporization of the d-limonene.

Q. And in your review of the record did you see any such test?

A. No, there's no such test.

Q. So you gave two reasons as to why in the presence of d-limonene tar will dissolve to a greater extent in water. Do you recall the first of these? Just to repeat it so that we can provide context for the discussion we're going to have.

A. Sure. If -- so the two -- the two issues that fall out of d-limonene and tar compounds being mixed together are the -- now, I'm sorry, I've got to take a quick break. I got to look back at my notes.

MS. WALKER: Okay.

MR. HOGLE: Should we take a break?

MS. WALKER: Yeah.

THE VIDEOGRAPHER: We're going off the

Page 17

(09:25:08-09:26:00)

record, the time is 9:25.

(There was a discussion held off the record.)

THE VIDEOGRAPHER: We're going back on the record, the time is 9:26.

Q. BY MS. WALKER: Okay. I asked you to recall or restate the first reason that, in your expert opinion, you determined that the presence of d-limonene will dissolve tar into water -- or will cause the tar to dissolve into water at a greater extent?

A. Okay. So --

MR. HOGLE: Let me interpose an objection here.

The witness refreshed his recollection with something, I don't know if I've ever seen before. It didn't look like he was looking at his report. I'm entitled to see what he's refreshing his recollection with. I'm entitled to a copy. And furthermore, if it's not in his report, I'm not sure why he's looking at it anyway. This is supposed to be a summary of his testimony, and it seems like we're going well beyond that.

That's my objection.

MS. WALKER: Okay. Well, he won't refer to that any more.

(09:26:16-09:27:04)

From now on, please refer to your report if you need to refresh your memory, okay?

THE WITNESS: Sure. Sure. It's just a matter of framing the response, it's not an important aspect.

MS. WALKER: Yeah, no, I don't think it's important.

THE WITNESS: So there's two reasons why the addition of d-limonene to the tar changes the behavior of the tar compounds.

As I said before, you were taking what was a solid or a semi-solid, and you're turning it into a liquid. It's going to behave as a liquid, and therefore, the solubility is greatly increased with water.

The second is that the d-limonene itself is much more soluble than the tar compounds in water. And so the d-limonene will be present in the water, and the d-limonene, I think we all agree, is a very good solvent for the tar compounds. So if it exists in the water, it will act as a carrier for the tar compounds to come into the water.

Q. BY MS. WALKER: Okay. So I just want to -- you to provide your basis for that first reason.

A. Well, the -- there's two ways to get at

(09:27:26-09:28:15)

this. But in my initial testimony what I used were so-called partition coefficients that represent the distribution of tar compounds between this organic mixture and water. And those are available in the literature from any similar compounds, and so I used those partition coefficients.

Q. And with those coefficients, what were you able to do?

A. Well, you can combine those coefficients to predict what the concentration would ultimately be of the tar compounds in water. And I chose a representative tar compound, benzo(a)pyrene.

Q. And is this the typical way in your profession to do such calculations?

A. Sure.

MR. HOGLE: I'm going to interpose another objection. I think this is getting beyond a summary. I don't want to keep repeating it, Joro, so if you want to let me have a continuing objection that this goes beyond the scope of a proper summary, I won't bring it up any more.

MS. WALKER: Okay.

MR. HOGLE: I mean, I won't waive it, but I won't have to keep interposing the same objection.

MS. WALKER: Fine. It seems to me that

(09:28:33-09:30:01)

it's a summary of his report.

MR. HOGLE: Well, he gave a summary of his report in the first pages of his testimony. That's a typical summary, and he's going well beyond that.

MS. WALKER: Well, that may be your understanding of a summary of a report, but my understanding of a summary of a report is to actually explain it, and given how technical it is, it's very difficult to explain. And I think the ALJ will appreciate his efforts to explain it.

Okay. So -- but I understand you're going to have an ongoing objection that he's talking too much.

So would you kindly read back his last response.

(The previous answer and pending question were read.)

Q. BY MS. WALKER: So do you want to answer that question, please.

A. Yes. This is a typical way to address that problem. This kind of approach is substantiated in a staple -- in a textbook that's a staple in environmental engineering curriculum.

Q. Okay. And did you actually calculate the increase in concentration of tar in water?

(09:30:12-09:31:14)

A. Yes, I did, for a representative compound.

Q. And what was that?

A. It was three orders of magnitude. It came out to be about 1600 -- or 1400, something like that. Three orders of magnitude.

Q. So can you explain what an order of magnitude is?

A. Factor of ten. So this would be a factor of a thousand.

Q. And why, in your mind, is that significant?

A. Well, that's significant because if you increase the concentration that you'd expect in water by a factor of a thousand, then you increase the potential toxic dose by a factor of a thousand.

Q. And did you find further support for your conclusion?

A. Yes, I did. I was shown some data from U.S. Oil Sands that showed concentrations of polycyclic aromatic hydrocarbons in their process water. And the concentrations that were in that water were a factor of something like 20,000 higher than you'd expect, according to their normal water solubility. So that agrees with my calculation that

(09:31:36-09:32:28)

you greatly enhance the dissolution -- the dissolving into water.

Q. Is there a way to verify whether the presence of d-limonene in the residual mixture will increase the concentration of --

THE REPORTER: I'm sorry. Is there a way to verify whether the presence of the...

Q. BY MS. WALKER: -- d-limonene in the residual mixture will increase the concentration of tar compounds in the water?

A. Certainly. All that's needed is a leech test to equilibrate to put in contact the residual with water and monitor the concentration of these kinds of compounds in the water over time.

Q. And did you see any such test in the record?

A. Not that test. There was a leech test, but it was done with hexane instead of water. And so they took the residual material and they equilibrated with hexane and measured the polycyclic aromatic hydrocarbon compound concentration in the hexane.

Now, what they found were extremely high concentrations of the polycyclic aromatic hydrocarbons, which is -- if that were water you'd be alarmed. But it was hexane, and you'd expect that

(09:32:42-09:33:46)

from hexane, because hexane is acting like d-limonene. It's extracting the tar compounds.

And so the apparent conclusion that was drawn is that hexane was the inappropriate solvent to test to represent water, which is correct, but then there was no follow up.

Q. Okay. And did you submit further testimony in this case?

A. Yes. I submitted a supplemental testimony in response to comments by Mr. Handl.

Q. And is that testimony dated March 16th, 2012?

A. I believe it is. Can I look at your copy?

Q. Yeah.

A. Would there be an objection?

Yes.

Q. And in most general terms, what's this report about?

A. So this was -- I wrote this in response to Mr. Handl's criticisms of my testimony. What they -- what those criticisms boiled down to was that the d-limonene has no effect on tar compound dissolution into water. And so I wrote a response to demonstrate that that criticism was incorrect and that

(09:34:00-09:34:52)

in fact d-limonene has a major effect on tar compound dissolving into water.

Q. And does this report represent your expert opinion on that subject?

A. Yes.

Q. And does it still represent your expert opinion on that subject?

A. Yes.

MS. WALKER: So I'd like to move to enter that as an exhibit, please.

MR. HOGLE: No objection.

MS. WALKER: And this would be Exhibit 2.

(Exhibit 2 was marked for identification.)

Q. BY MS. WALKER: So what materials did you review to address that second point? Mr. Handl's testimony.

A. Yeah, Mr. Handl's testimony.

Q. I didn't mean to answer the question for you. I meant -- okay.

And what I meant is what -- it's fine.

Okay. So can you briefly summarize Mr. Handl's analysis that you were responding to?

A. Yeah. His analysis is that the d-limonene simply dilutes the mixture, okay. The residual organic mixture is comprised of tar compounds

(09:35:12-09:36:17)

and d-limonene, or in his terminology, bitumen compounds and d-limonene. And his assertion is that that is simply a dilution of the tar compounds, and therefore any tar compounds that would dissolve into water would be lower than their normal water solubility, according to Raul's, which is the equation that he used.

Q. Okay. And your response to this analysis was?

A. That it's incorrect because it's missing two very important terms when you do a more complete thermodynamic analysis.

Q. And can you explain that a little bit more --

A. Sure.

Q. -- fully?

A. If you -- if you -- if you go back to the basic thermodynamics and solve for the change in the, basically the ratio of the concentration of the tar compound in the water, pure water, versus water that has d-limonene as a result of being in contact with this residual, then you can calculate the ratio of those two concentrations, and a value that is -- I don't want to confuse things because I'm changing the -- let me put it this way:

Page 26

(09:36:31-09:37:41)

A ratio of the -- so if we have a high concentration of the tar compound in the water in the presence of d-limonene, versus a relatively low concentration in water in the absence of d-limonene, then that ratio will be very high, okay.

And so we can solve for that ratio. And what we find is that, going back to the basic thermodynamics, is that in addition to the typical Raul's law term in that expression that Handl had, there are two additional terms.

One is the ratio of the activity coefficients of the tar compounds in water without versus with d-limonene. And the other is the ratio of the vapor pressures of the tar compound in the solid versus the liquid form, which represents that change that occurs in response to turning that tar compound into a liquid, as opposed to its solid, natural state.

Q. And did you believe that these terms were significant?

A. Yeah, they're significant. Both of those terms are much greater than one, and so they contribute anywhere between the factor of 10 to 100, each of those terms, to increase the concentration of the d-limonene in the water.

Q. So what happens when you correctly

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(09:37:56-09:38:50)

account for those terms?

A. Then you show that the d-limonene increases the solubility of the tar compounds in water by about three orders of magnitude.

In this case I calculated a factor of 2,000, pretty close to the factor of six -- or 1400-ish that I calculated using a different method.

Q. So do you believe in the absence of those terms that Handl's analysis showed the effect of d-limonene on the dissolving of tar in water?

A. No, it absolutely does not.

Q. And is your analysis more accurate?

A. Yes.

MS. WALKER: Okay. That concludes my -- my questions. Thank you.

MR. HOGLE: Okay.

MS. WALKER: Want to take a break?

THE WITNESS: I'm good.

MR. HOGLE: Dr. Johnson, I'm Chris Hogle. I'm going to ask you some questions about your work in this case.

CROSS-EXAMINATION

BY MR. HOGLE:

Q. You indicated that generally your report

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(09:39:15-09:40:13)

is about performing some calculations to show that d-limonene in the residual from the tar processing, tar sand processing, will enhance the dissolution of the tar compounds in the water?

A. Right.

Q. And the concern there, I mean, the ultimate concern is that the -- the -- that process, the increasing the solubility of the tar compounds, might lead to groundwater, which somebody or some animal may get to, and the tar compounds contain a carcinogen, right? Is that a fair summary?

A. Not quite. Because I'm not speaking to the likelihood of this reaching groundwater.

Q. Okay.

A. I'm speaking to the possible -- what would happen if this comes into contact with water.

Q. Right. But -- but in order for your concern to materialize, it has to come into contact with groundwater?

A. No. It has to come into contact with water. And whether it's surface water or groundwater, I don't know specifically how they plan to manage all this at the site.

Q. But if it doesn't come into contact with groundwater, doesn't -- it's not going to be ingested

Page 29

(09:40:22-09:41:16)

by a human or animal?

A. It could be if it's coming into contact with surface water that's in contact --

Q. Okay.

A. -- that has a receptor.

Q. Do you know of any information that it's going to come into contact with surface water?

A. Again, I'm not speaking to the likelihood of contact with surface water or groundwater.

Q. So let's set aside surface water, all right? If it -- if it doesn't come into contact with groundwater, then your concern is a nonissue, true?

A. If it doesn't come into contact with water, my concern is a nonissue.

Q. Okay. And if it doesn't come into contact with usable amounts of water, water that somebody or some animal's going to use, your concern is a nonissue?

A. If it doesn't come into contact with a receptor downgrading, it's a nonissue.

Q. "Receptor" is usable amount of water?

A. Well, I wouldn't define it that way.

Q. How would you define it?

A. Some organism that would be dosed with the polycyclic aromatic hydrocarbons as a result of

EXHIBIT 8

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BEFORE THE UTAH WATER QUALITY BOARD

In the Matter of

PR Spring Tar Sands Project,
Ground Water Discharge
Permit-by-Rule

No. WQ PR-11-001

Videotaped Testimony of:
WILLIAM JOHNSON, Ph.D.

Place: TEMPEST REPORTING, INC.
175 South Main Street, #710
Salt Lake City, Utah 84111

Date: April 20, 2012
9:06 a.m.

Reporter: Vickie Larsen, CSR/RPR

Tempest Reporting, Inc.
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Post Office Box 3474 / Salt Lake City, UT 84110

(09:46:39-09:47:40)

to do that, and then I've added -- you know, I've, in addition to that, raised the issue that d-limonene itself is not -- does not have a high vapor pressure.

Q. Okay.

A. Does not readily vaporize.

Q. And that's -- that's an important part of your work in this case, right?

A. Well, I would say that if d-limonene vaporizes out of that mixture quickly, then the mixture reverts back to the original tar mixture, which is not, by itself, a concern.

Q. Okay. Could you go to Exhibit 1, please. And turn to Page 4.

All right. And you see you -- there's a question and an answer on Lines 8 through 11, right?

A. Uh-huh.

Q. And the question is: "Can you briefly describe d-limonene?" That's correct, right? I read the question correctly?

A. Yes.

Q. And your answer is:

> "Based on the properties listed in Appendix B, d-limonene is a small molecule that is readily transported to air. Therefore d-limonene by

(09:47:52-09:48:33)

> itself will likely vaporize/volatilize readily to the atmosphere."

That was your testimony, was it not?

A. That was my testimony, but that statement comes out of the NOI. That's U.S. Oil Sands' statement.

Q. You don't reference NOI -- the NOI in that statement?

A. No, that's true. That's a mistake on my part, but that's where it comes from.

Q. But I -- I read the complete answer to the question on Line 8, Page 4, did I not?

A. Yes.

Q. And that was your testimony?

A. Yes. But --

Q. And your testimony was under oath, was it not?

A. Well, I don't know. Was it under oath?

MS. WALKER: Yes.

THE WITNESS: Okay. So, yes, it was.

Q. BY MR. HOGLE: You don't know. Okay.

A. But my point is that I -- I was not focussing on d-limonene in this testimony. I was focussing on the effect of d-limonene on tar

(09:48:49-09:50:04)

compounds. And so to me I did not emphasize the properties of d-limonene itself. That was not the issue I was addressing.

Now on further, you know, understanding of the properties of d-limonene, I've realize that in fact d-limonene itself does not readily vaporize.

Q. You said in your answer on Page 4, Line 9, you said your answer is based on the properties listed in Appendix B, correct?

A. Yes, properties.

Q. You wrote that.

And Appendix B is on Page 31 of Exhibit 1, correct?

A. Yes.

Q. Okay. And these properties of d-limonene, there's no reference to the NOI, is there?

A. No. And so again --

Q. In fact your references are References 1, 2, and 3, which are listed on Page 34, correct?

A. Page 34. Yes.

Q. Okay. Reference Number 1 is to what?

A. Reference Number 1 is to a USEPA document.

Q. Okay. Reference Number 2?

A. Is to a Chemical Safety document.

(09:50:15-09:51:23)

Q. Not the NOI?

A. Correct, not the NOI.

Q. And Reference Number 3?

A. Reference Number 3 is a National Toxicology Program document.

Q. Okay. Again, not the NOI?

A. Not the NOI. But I didn't reference the NOI because that document was obvious throughout all this. I was bringing new information, aside from the NOI, that's why I referenced those documents, not the NOI.

Q. But your answer on Page 4 says based on the properties listed in Appendix B, d-limonene is a small molecule that is readily transported to air, correct?

A. Right. But again, that is -- what my intent was with this statement is that I'm not going to focus on d-limonene, okay. What I'm interested in is the issue of dissolution of the tar compound in the water and how d-limonene affects that, okay.

I wasn't at that -- in this testimony focussing on the issue of d-limonene evaporation itself. And I did raise the point that you would form a rind of these polycyclic aromatic hydrocarbon compounds on that organic mixture. And that was the

(09:51:40-09:52:58)

statement that I was making that substantiated my concern that d-limonene would not readily vaporize, okay.

So this -- this small, two sentence piece of this larger testimony wasn't the focus, okay. And so now as a result of more time passing and having, you know, examined the issue further, what I've learned is that d-limonene itself is not a particularly small molecule and it is -- or actually let's look at the structure of it in the appendix.

Its properties that actually are relevant here are not so much size, but the fact that it -- it's -- it's large enough that it isn't going to readily move into the vapor phase from its own organic mixture, okay. It has Van der walls forces holding those molecules together that they have to break free from in order to move into the vapor phase, okay. And it's a large enough molecule that that process is going to be slow, okay.

So regardless of whether we focus on the properties of d-limonene itself or the fact that you'll accumulate polycyclic aromatic hydrocarbons on the air/water interface of this residual mixture, there are good arguments for why we wouldn't expect d-limonene to leave that mixture as readily as the NOI

(09:53:13-09:54:33)

seems to state.

MR. HOGLE: Move to strike as nonresponsive everything after the answer to the question, which was "right."

Q. Where in your testimony do you say that -- that d-limonene by itself is not likely to vaporize/volatilize readily to the atmosphere?

A. I'm sorry, could you repeat that.

Q. Sure. Where in your testimony did you say what you're now saying, that d-limonene is not a small molecule -- molecule that is readily transported to air?

A. I did not say that in my testimony.

Q. Okay. How about in your March testimony?

A. I did not address that in my March testimony.

Q. All right. So in your initial testimony and both your supplemental testimony, you relied on textbook Schwarzenbach RP? It's Reference Number 5 on Page 34.

A. That's right.

Q. And it's the, according to the reference here, a 1993 publication?

A. Yes, the edition I used was 1993.

Q. Okay. And you consider that to be

(09:54:42-09:55:30)

authoritative in this area?

A. Uh-huh, yes.

Q. The title of it is Environmental Organic Chemistry?

A. That's right.

Q. And do you teach using that?

A. I do. Not that edition, but I teach.

Q. Which edition do you use when you teach?

A. There's a newer edition, I forget the year. But it's harder to get the older edition, so the students need to buy the newer one.

Q. Okay. Is it 2003?

A. Possibly. I don't remember off the top of my head.

Q. I'm handing you a book we checked out of the library, and can you -- can you identify that for us?

A. Sure. This is apparently the same textbook that I referenced.

Q. Okay. And how long is that?

A. How long?

Q. Yeah.

A. How long is the book?

Q. Yeah, easy question.

A. Well, I don't have it memorized so I'm

(09:55:45-09:56:37)

going to look, and it's 680 pages.

Q. Okay. You don't identify a single page in any -- either of your testimony, do you, out of that book?

A. No, but I could easily do so.

Q. Okay. Maybe we'll get to that.

But you also don't attach to your testimony the pages from that book on which you rely. That's true, right?

A. That's true.

Q. Okay.

A. Quite true.

Q. So it's not clear, from your testimony anyway, which portions of the text you're relying on, right?

A. Sure.

Q. All right. And then if we go to Page 6 of Exhibit 1. The question on Page 6 -- the question on Page 6:

"How did you go about substantiating these concerns..." it goes on.

Do you see that question?

A. Sure.

Q. And then you have an answer that starts in the bottom of Page 6 and goes to close to the

EXHIBIT 9

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COMPRESSED
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BEFORE THE UTAH WATER QUALITY BOARD

In the Matter of PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule No. WQ PR-11-001	Videotaped Testimony of: **WILLIAM JOHNSON, Ph.D.**

Place:	TEMPEST REPORTING, INC. 175 South Main Street, #710 Salt Lake City, Utah 84111
Date:	April 20, 2012 9:06 a.m.
Reporter:	Vickie Larsen, CSR/RPR

Tempest Reporting, Inc.
801-521-5222 / Fax 801-521-5244
Post Office Box 3474 / Salt Lake City, UT 84110

(10:49:43-10:50:54)

A. Cosolvent effect?

Q. Yes.

A. No.

Q. But you do opine in your testimony that the presence of d-limonene increases by a factor of over 1440 the concentration of BAP, right?

A. Yeah, I calculated a factor of 1440.

Q. Okay. And it's the d-limonene that causes that -- that increased concentration of BAP, right?

A. Yes.

Q. And you would agree with me, wouldn't you, that the most -- the maximum amount of d-limonene that can exist in water is 13.8 milligrams per liter?

A. That is the solubility that I found, I can't even remember the source, but it's in the testimony, but yes. But that -- I wouldn't call that the maximum amount, but that is the normal water solubility of d-limonene.

Q. Okay. At room temperature?

A. Yes, I believe it was room temperature.

Q. Okay. And you would agree with me, wouldn't you, that 13.8 milligrams per liter is less than ten percent by concentration, by volume?

A. By volume. I would agree with you that 13.8 milligrams per liter is less than ten percent by volume.

(10:51:11-10:52:23)

But I need to clarify that the ten percent is irrelevant, because I'm not speaking to a cosolvent effect.

MR. HOGLE: Okay. Move to strike everything following the answer that I got.

Could we mark the excerpt of the Schwarzenbach textbook at Exhibit 3, please. And I move for the admission of Exhibit 3.

MR. McCONKIE: No objection.

MS. WALKER: No objection.

(Exhibit 3 was marked for identification.)

Q. BY MR. HOGLE: Dr. Johnson, I'm handing you a document that's entitled Environmental Research Brief Solubility, Sorption and Transport of Hydrophobic Organic Chemicals in Complex Mixtures. Do you see that?

A. Yes.

Q. Is this the type of publication that you rely on?

A. It's the type, but this concerns cosolvent effects, and that is not what I'm addressing in my testimony.

Q. Okay. But this is the type of -- of publication that you rely on in the course of your -- of your -- of your work, your profession?

(10:52:37-10:53:42)

A. This is one of a million.

Q. Okay. And you rely on publications like these in your -- in your regular work, right?

A. Sure. Yeah.

Q. Could you go to Page 11, please. All right, and I'm going to read from -- well, before I get there, I'd like to mark this as Exhibit 4 and move for its admission.

MS. WALKER: Do you have a copy?

MR. HOGLE: Oh, I'm sorry.

(Exhibit 4 was marked for identification.)

MS. WALKER: Thank you. Say the page again.

MR. HOGLE: 11. But I guess I would mark that Exhibit 4 and move for its admission, if there's any objection.

MR. McCONKIE: No objection.

MR. HOGLE: Unless there's an objection.

MR. DUBUC: No objection.

Q. BY MR. HOGLE: All right. If we go to Page 11, just under the graph there's a sentence. Tell me when you're there.

A. I'm there.

(10:53:54-10:55:10)

Q. Okay. There's a sentence that says:

> "Our data and model calculations suggest that solubility enhancement for most organic contaminants is likely to be small (less than 20% Increase) as long as cosolvent concentrations in pore water are less than 2% by volume (or about 20,000 milligrams per liter)."

Do you see that?

A. Yes, I do see that statement.

Q. Okay. And it's true, isn't it, that the d-limonene in a water solution would be less than two percent by volume?

A. Yes, that's true. But this document concerns very different compounds than the polycyclic aromatic hydrocarbons that I was examining. And so this generalization is for compounds that are much more soluble in water.

MR. HOGLE: Okay. Move to strike everything after "Yes, that's true."

Q. All right. Switching gears a little bit here. What you did -- if you look at Page 7 of Exhibit 1, your initial testimony.

A. Uh-huh.

EXHIBIT 10

Tempest℠ REPORTING

COMPRESSED
CERTIFIED TRANSCRIPT

BEFORE THE UTAH WATER QUALITY BOARD

In the Matter of	:	
PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule	:	Videotaped Testimony of: **WILLIAM JOHNSON, Ph.D.**
No. WQ PR-11-001	:	

Place:	TEMPEST REPORTING, INC. 175 South Main Street, #710 Salt Lake City, Utah 84111
Date:	April 20, 2012 9:06 a.m.
Reporter:	Vickie Larsen, CSR/RPR

(10:49:43-10:50:54)

A. Cosolvent effect?

Q. Yes.

A. No.

Q. But you do opine in your testimony that the presence of d-limonene increases by a factor of over 1440 the concentration of BAP, right?

A. Yeah, I calculated a factor of 1440.

Q. Okay. And it's the d-limonene that causes that -- that increased concentration of BAP, right?

A. Yes.

Q. And you would agree with me, wouldn't you, that the most -- the maximum amount of d-limonene that can exist in water is 13.8 milligrams per liter?

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Q. Okay. At room temperature?

A. Yes, I believe it was room temperature.

Q. Okay. And you would agree with me, wouldn't you, that 13.8 milligrams per liter is less than ten percent by concentration, by volume?

A. By volume. I would agree with you that

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But I need to clarify that the ten percent is irrelevant, because I'm not speaking to a cosolvent effect.

MR. HOGLE: Okay. Move to strike everything following the answer that I got.

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MR. McCONKIE: No objection.

MS. WALKER: No objection.

(Exhibit 3 was marked for identification.)

Q. BY MR. HOGLE: Dr. Johnson, I'm handing you a document that's entitled Environmental Research Brief Solubility, Sorption and Transport of Hydrophobic Organic Chemicals in Complex Mixtures. Do you see that?

A. Yes.

Q. Is this the type of publication that you rely on?

A. It's the type, but this concerns cosolvent effects, and that is not what I'm addressing in my testimony.

Q. Okay. But this is the type of -- of

(10:52:37-10:53:42)

publication that you rely on in the course of your -- of your -- of your work, your profession?

A. This is one of a million.

Q. Okay. And you rely on publications like these in your -- in your regular work, right?

A. Sure. Yeah.

Q. Could you go to Page 11, please. All right, and I'm going to read from -- well, before I get there, I'd like to mark this as Exhibit 4 and move for its admission.

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MR. HOGLE: 11. But I guess I would mark that Exhibit 4 and move for its admission, if there's any objection.

MR. McCONKIE: No objection.

MR. HOGLE: Unless there's an objection.

MR. DUBUC: No objection.

Q. BY MR. HOGLE: All right. If we go to Page 11, just under the graph there's a sentence. Tell me when you're there.

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A. Yes, that's true. But this document concerns very different compounds than the polycyclic aromatic hydrocarbons that I was examining. And so this generalization is for compounds that are much more soluble in water.

MR. HOGLE: Okay. Move to strike everything after "Yes, that's true."

Q. All right. Switching gears a little bit here. What you did -- if you look at Page 7 of Exhibit 1, your initial testimony.

A. Uh-huh.

EXHIBIT 11

*********************ROUGH DRAFT***********************
*****************WILLIAM JOHNSON PhD******************

THE VIDEOGRAPHER: One moment please. We are going on the record. The time is 2:02. This is the videotaped deposition of William Johnson taken in the matter of PR Spring Tar Sand project groundwater discharge permit by rule before the Utah Water Quality Board.

This deposition is being held at 175 South Main, Salt Lake City, Utah on April 4, 201. My name is Max Nelson from the firm of Tempest Reporting with offices at 175 South Main Salt Lake City, Utah. I am the video specialist. The reporter is Denise Kirk from Tempest Reporting.

Counsel will now state their appearances for the record and the witness will be sworn.

MR. DUBUC: Today's date is May 4th, 2012. You said April.

MS. WALKER: This is Joro Walker and Rob Dubuc on behalf of Living Rivers.

MR. McCONKIE: Paul McConkie on behalf of the executive secretary.

MR. HOGLE: Chris Hogle and Benjamin Machlis. And we have Barclay Cuthbart here who is a representative of U.S. Oil Sands.

bitumen compounds, benzo(a)pyrene being a representative, and the d-limonene is low enough that they don't affect one another. They act as molecules just bouncing off one foot they even find one another as so-called hard spheres. They don't change on e another's properties in water, okay? That's an so-called ideal solution.

Mr. Handl assumed that to be the case and he assumed it to be the case because the solution is dilute, okay? The problem is dilute is a vague term. And handle admits that it's a vague term in his testimony -- is that the term for it last week -- he admitted that there's a continuum of diluteness. And that the transition from ideal to non-ideal solution is along this continuum without a clearly defined threshold.

So that's the problem is he has assumed that it's ideal and there is a lot of well there's empirical data and there are other reasons to believe it's not ideal. And non-ideality is important and I want to explain that a little bit more.

But before I do that, this relates to my previous testimony, my previous recorded testimony on video where it was brought up that the text Schwarzenbach Gschwend and Imboden states that the threshold for non-ideal solution, okay, for a co-solute effect is another way to put a nonideal solution, and the molecules are affecting one another, that that threshold should be .001 volumes for volumes, that is volume of molecules and interest in the solution per volume of water.

I made the point that this is an overgeneralization, okay? Mr. Handl has made the point that it's not an overgeneralization, okay? But it is. And there's two reasons I can give you right now that it is.

First of all, there is a significant number of publications in the literature in peer reviewed journals that show that for agents not exactly d-limonene but acting the same way as d-limonene in water increase the solubility of compounds such as bitumen compounds in water significantly, even when they're at concentrations far lows below the zero.

One specific paper is the one by Mackay and Gschwend, and Gschwend is the second author on the textbook that states that, but he published an paper showing that in fact natural organic matter, which can act as a co-solute just like d-limonene can, increases the solubility of tar compounds by factors of between

I think it was ten to 50. Something in that range.

And this is published in environmental science and technology. That is the top scientific particular journal for this field. So that author who made that statement, he was responsible for that portion of the text, actually published results that show that that .001 is isn't over generally saying and when you talk about highly like the. Polycyclic aromatic hydrocarbons, that you can have a cosolute effect well below that threshold and in fact what they saw for natural organic matter which is actually going to have less cosolvency power or cosolute power than d-limonene because they are more compatible with water and obviously I'd have to lecture on this a while to make that clearer.

But the natural organic matter would not be as effective as d-limonene and yet they saw the solubility enhancement in only four milligrams per liter in solution. Far lower than the 13 point 18 of d-limonene that's expected in the water, okay? So there's lots of empirical evidence for this effect.

The other thing I'd like to do is clarify how in my testimony I showed to show from first principles from very basic equation is how ideal solution in phase change are accounted for. Before

I'd written that the concentration in water -- can I go out to here? Concentration in water is equal to the mole fraction of the you compound in the ex extract and I'm not going to label it because this can be

EXHIBIT 12

********************ROUGH DRAFT***********************

*****************WILLIAM JOHNSON PhD******************

THE VIDEOGRAPHER: One moment please. We are going on the record. The time is 2:02. This is the videotaped deposition of William Johnson taken in the matter of PR Spring Tar Sand project groundwater discharge permit by rule before the Utah Water Quality Board.

This deposition is being held at 175 South Main, Salt Lake City, Utah on April 4, 201. My name is Max Nelson from the firm of Tempest Reporting with offices at 175 South Main Salt Lake City, Utah. I am the video specialist. The reporter is Denise Kirk from Tempest Reporting.

Counsel will now state their appearances for the record and the witness will be sworn.

MR. DUBUC: Today's date is May 4th, 2012. You said April.

MS. WALKER: This is Joro Walker and Rob Dubuc on behalf of Living Rivers.

MR. McCONKIE: Paul McConkie on behalf of the executive secretary.

MR. HOGLE: Chris Hogle and Benjamin Machlis. And we have Barclay Cuthbart here who is a representative of U.S. Oil Sands.

A. Yeah. My testimony doesn't go there but that's true.

Q. Okay, that's all I have.

A. But one thing issued mention is that permeability is a tricky matter. Hydrologists know that when water moves through the subsurface it's not moving through that matrix porosity, it's moving through fractures and things that transport things much much fast other.

Q. Move to strike as nonresponsive. No further questions.

MR. McCONKIE: I have no questions.

MS. WALKER: I have a few questions.

MS. WALKER: I have a few questions.

FURTHER EXAMINATION

BY MS. WALKER:

Q. So Chris was asking -- I'm sorry Mr. Hogle was asking you about this 13.8 to the minus sixth and you were relating it to four milligrams per liter. Could you just explain that because he moved to strike it so I'd like you to explain it to me?

A. The point made here is that 1.38 times ten to the minus fifth is a volume/volume fraction and much lower, almost two orders of magnitude lower than

that .001 threshold, okay?

By the way, in that same text, in that same section they show that for volume volume fraction is lower than that .001 there's significant solubility enhancement so even the remainder of that paragraph recognition that that's a rough threshold. Okay?

Now, there's empirical evidence that shows that the zero .001 doesn't apply for hide phone I can compounds. One nice piece of empirical evidence is this publication by Allison Mackay and Phil Gschwend. Phil is an environmental engineer at MIT, he's well known in the field of contaminate transport especially related to hydrophobic organic compounds being solubilized, being carried into the water by cosolutes, okay?

And what they saw, this is empirical, it was at a coal tar site, where they saw that natural organic matter at an concentration of other only four milligrams per liter caused factors of ten to 50 increases in the solubility. You can't see that can you?

THE VIDEOGRAPHER: Yes.

A. In the solubility of polycyclic aromatic hydrocarbons. Now, that's really important because this is well well below and we don't have, for natural

organic matter we don't have an molecular weight and I don't have a density. I'd have to guesstimate an density.

But the point is comparing them only a mass basis, these are -- this is much lower, okay? And it's having a large effect. And so Gschwend who is the second author on that textbook that states the zero .001 rule of thumb recognition that it's only an rule of thumb. It's not hard and fast. Okay?

Q. And then what were you saying about rocks and mobility?

A. Well, when you talk about permeability of rocks, it's not the permeability of the rock itself that matters, okay? So I do know that a significant component of the lithology at the site is limestone, for example. Limestone related rocks. Okay?

Well, when you've got surface and you are concerned about some kind of source of water at the surface, let's say rainfall, going down to the subsurface to the water table, how it gets there is not by flowing through the pour spaces in the rocks unless it's something like a sand.

But when you are talking about hard rock lithology like lime stones where it's flowing in fractures, okay, and the transport can be very rapid

in fractures.

And so the question of the permeability of the limestones is really immaterial to the potential for transport. Okay? The question is fracture density, the site has springs nearby so there's clearly places where the groundwater, at least from what I've read in U.S. Oil Sands NOI, it appears there's places where groundwater is close to the

EXHIBIT 13

Environ. Sci. Technol. **2001,** *35,* 1320–1328

Enhanced Concentrations of PAHs in Groundwater at a Coal Tar Site

ALLISON A. MACKAY* AND
PHILIP M. GSCHWEND

Ralph M. Parsons Laboratory, 48-415, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

Concentrations of polycyclic aromatic hydrocarbons (PAHs) in groundwater at a coal tar site were elevated by factors ranging from 3 (pyrene) to 50 (indeno[1,2,3-*cd*]-pyrene) over purely dissolved concentrations. Air–groundwater surface tension measurements (70.6 ± 3 dyn/cm) were not sufficiently different from air–pure water measures (72.2 ± 0.1 dyn/cm) to ascribe the observed enrichments to either cosolvents or surfactants in the groundwater. Excess pyrene was associated with colloids that passed an ultrafilter at ambient pH but became ultrafilterable when the groundwater pH was lowered to 1. This suggested pyrene association with humic acids. Given the decrease in groundwater total organic carbon (TOC) of 4 $\mathrm{mg_C/L}$ upon acidification and ultrafiltration, a partition coefficient of 10^5 $\mathrm{L/kg_C}$ was estimated for this pyrene association. Use of the results for pyrene and scaling for the differences in PAH hydrophobicities enabled good predictions of the observed enrichments of less water-soluble PAHs in the groundwater. This is strong field evidence indicating colloid-facilitated transport of HOCs in groundwater. Assuming that humic-bound PAHs were as mobile as the dissolved PAHs, the fluxes of individual PAHs (e.g., benzo[*a*]pyrene) from the tar source were as much as 20 times greater than estimates based solely on tar–water partitioning predictions.

Introduction

The total masses of hydrophobic organic compounds (HOCs) that are mobile in groundwater may include both dissolved and colloid-associated species. Dissolved forms may include HOC molecules solvated by water or mixtures of water and nonaqueous solvents. Colloid-associated species include HOC molecules carried in water-borne media such as macromolecular humic substances, biogenic exudates, micelles, microorganisms, and nanometer-to-micrometer-sized suspended mixed-phase solids (e.g., organic-coated kaolinite.) To the extent that various species are important relative to the fully water-solvated species, "facilitated" subsurface HOC transport may occur. As a result, sensitive receptors, such as groundwater wells and surface water bodies, may receive HOCs sooner, and the HOC fluxes may be greater than would be expected in the absence of such "facilitating" species. Indeed, efforts to cleanup subsurface sites using surfactant-generated micelles are cases of promoting facilitated transport.

In order for facilitated transport *by colloids* to be important: (i) colloids must be present, suspended in the groundwater; (ii) HOCs must associate with these colloids sufficiently to enhance the mobile load; and (iii) the colloids must be substantially transportable through the subsurface (*1*). Evidence for each of the three conditions has been found at various field sites and in focused laboratory studies. Laboratory studies have shown that various colloidal materials may increase the total aqueous concentrations of HOCs. These include humic substances (*2–4*), organic matter-coated mineral particles (*5*), anthropogenic surfactants/micelles (*6, 7*), microorganisms (e.g., bacteria; *8*), and microbial exudates (*9, 10*). Enhanced mobilization of HOCs in the presence of these agents has been demonstrated through the use of miscible displacement experiments with laboratory soil columns (*4, 6, 8, 10, 11*). [Note that the mass fraction of mobile HOC that is colloid associated is a function of both the HOC colloid–water partition coefficient and the abundance of colloids (*12*).]

Several field studies also suggest the potential facilitated transport of HOCs in contaminated aquifers. Polycyclic aromatic hydrocarbon (PAH) concentrations in groundwater from a coal tar site were greater than levels estimated from the tar composition using Raoult's law (*13*). In this case, it was suggested that colloids were present in the groundwater; however, the colloid phase was not isolated or characterized. Colloids, capable of binding HOCs, have been verified in groundwater from a crude oil site (*14*) and a sewage plume (*15*) by spiking hydrophobic compounds into groundwater samples. However, no evidence was obtained for "enhanced" HOC groundwater concentrations or fluxes at these sites. Colloid-associated PAHs were quantified in size-separated samples from two creosote-contaminated sites (*16*). In this case, it was suggested that the hydrophobic compounds were associated with clays and quartz- and iron-containing colloids. Colloid-associated polychlorinated biphenyls (PCBs) and PAHs have also been quantified in size-separated samples from a landfill leachate plume (*17*). In that instance, most of the contaminant mass was associated with particles greater in size than 1 μm. Consequently, it seems unlikely that these particles were substantially mobile under the ambient groundwater gradient at this site. Thus, while other studies of varied sites have shown some evidence for enhanced HOC transport due to colloids, no field observations have shown conclusive evidence by simultaneously demonstrating enhanced in situ mobile HOC concentrations and the presence of substantially mobile colloidal species, which may facilitate HOC tranport.

The purpose of this study was to assess whether colloid-associated species contributed significantly to the mobile PAH load in groundwater at a coal tar site. Aqueous PAH concentrations were evaluated using both calculations based on the site's tar composition and tar–water equilibrations in the laboratory. These dissolved concentrations were then compared with total PAH levels in groundwater samples carefully collected by prolonged slow pumping at the site. Fractionated extractions of groundwater were used to determine in situ colloid-associated PAHs after further prolonged settling (5 months) and again after precipitating humic acids using acidification and ultrafiltration. Colloid–water partition coefficients were quantified using these fractionated extractions and by fluorescence quenching in the raw groundwater. The results were used to estimate the effect of colloid-facilitated transport on PAH fluxes away from the coal tar source.

Methods

Chemicals. Solvents used for extraction of groundwater and dissolution of compounds were methanol, methylene chlo-

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10.1021/es0014786 CCC: $20.00

ride, and hexane (OmniSolve, EM Science). Internal standards of deuterated phenanthrene, *p*-terphenyl, and *m*-terphenyl were obtained from Ultra Scientific (North Kingstown, RI). External PAH standards were obtained as EPA 525 Mix A (Supelco, Bellefonte, PA). Pyrene was obtained from Aldrich (Milwaukee, WI). Other compounds included sodium sulfate (Fisher Scientific, Fairlawn, NJ), silica gel (100–200 mesh, EM Science), potassium hydrogen phthalate (Sigma, St. Louis, MO), hydrochloric acid (Fisher), and phosphoric acid (Mallinckrodt, Paris, KY). Purified water (18 MΩ·cm) was from an Aries purification system (Vaponics, Rockland, MA).

Sample Collection. The groundwater samples were collected from a shallow, water-bearing unit composed of anthropogenic fill materials at a mid-Atlantic coal tar site. As is typical of such sites (*18*), the tarry deposits occur in land adjacent to a surface water body. Seven stainless steel multi-level wells with 0.6-m-long stainless steel screens (0.05-cm slots) were installed in December 1994 using hollow-stem auger drilling with no drilling fluids. Groundwater samples were collected during five field campaigns between December 1995 and September 1996. Slow pumping techniques, with continuous monitoring of sample turbidities, were employed to minimize entrainment of immobile particles in groundwater samples (*13*). Packers were used to isolate the 60-cm screens from the overlying standing water. The pump flow rate (25–35 mL/min) was set so that the well screen withdrawal velocity did not exceed the local groundwater velocity. After prolonged purging, 2-L samples were collected in amber bottles for total (dissolved + colloid-associated) PAH analysis. Groundwater was also collected in all-glass biological oxidation demand (BOD) bottles for organic carbon analysis. Groundwater (0.5–2 mL, followed by 10 mL of purified water rinse) was also filtered through 30-nm poresize Nuclepore (Pleasanton, CA) filters for microscopic analysis of groundwater particles. Well W40M consistently showed the greatest PAH concentration enhancements. Therefore, replicate samples were collected from this well in September 1996 in foil-wrapped BOD bottles for fluorescence quenching studies and fractionation efforts aimed at elucidating the in situ pyrene speciation. These duplicate samples were stored undisturbed (i.e., allowing particle settling) at 4 °C for 5 months before use.

Ancillary Data. Groundwater turbidity, conductivity, pH, and E_H were measured in the field. Conductivity (HI8333, Hanna Instruments), pH (Orion), and redox potential (platinum electrode, Orion) were monitored continuously during pumping. Turbidity was measured periodically by redirecting the pumped flow through another flow-through cell and a calibrated turbidimeter (DRT-15CE, HF Scientific, Inc.) Dissolved oxygen and sulfide were measured periodically using colorimetric assays (Chemettes, Chemetrics, Calverton, VA).

Levels of inorganic ions in the groundwater were determined by ion chromatography (Dionex Ion Chromatograph 16.) A 1-mL sample was transferred to the AS4A-SC column (Dionex) and eluted with 3 mM sodium bicarbonate/2.4 mM sodium carbonate buffer flowing at a rate of 2 mL/min. Ions were quantified using response factors determined with external standards. Metal concentrations were determined by graphite furnace atomic absorption spectrometry using a Perkin-Elmer 4100ZL instrument. Standards were made up in Q-water (Millipore, Bedford, MA). Alkalinity titrations were performed by Gran titration with 20 mM HCl and an Orion pH electrode/meter.

PAH Analyses. Groundwater PAH concentrations were quantified by liquid–liquid extraction and gas chromatographic separation. Immediately after sample collection, an internal recovery standard of deuterated phenanthrene in methanol was added to each sample. Methylene chloride (100 mL) was then added to the bottles to begin the extraction process and to preserve the samples during transportation. At the laboratory, a second recovery standard of *p*-terphenyl in methanol was added without disturbing the methylene chloride layer. A total of three methylene chloride extractions (100 mL each) were made, combined, and dried with anhydrous sodium sulfate. The extract was reduced to a small volume in a Kuderna–Danish concentrator and then transferred into hexane for further concentration to 1 mL under a stream of nitrogen. A PAH fraction was isolated by silica gel chromatography [2 g of fully activated SiO_2, eluted with 24 mL of hexane, 5 mL of 8:1 hexane:methylene chloride, and finally 15 mL of 3.4:1 hexane:methylene chloride (*19*)]. The PAHs were quantified by capillary gas chromatography using a flame ionization detector (FID) (Carlo Erba, HRGC, on-column injection, 30 m DB5-MS column, 0.32 mm i.d., 0.25 μm film thickness, J&W Scientific, Folsom, CA). An injection standard of *m*-terphenyl was added just prior to analysis to quantify the final volume of the extract. The temperature program began at 70 °C with a ramp of 12 °C/min to 120 °C, followed by a ramp of 3 °C/min to 175 °C, a ramp of 8 °C/min to 300 °C, and a final hold time of 5 min at 300 °C. Compounds were quantified by using response factors from contemporaneous injections of known external PAH standards. Phenanthrene and anthracene concentrations were corrected with deuterated phenanthrene recoveries, and all other PAHs were corrected for recovery with *p*-terphenyl, a hydrophobic internal standard (log $K_{ow} = 6.03$; *20*) that could be detected by FID.

Tar–Water Equilibrations and Tar Analysis. A sample of free-flowing tar was pumped from W40M in April 1996. PAH concentrations in this tar were quantified by gas chromatography, as described above (start temperature 35 °C), after diluting an aliquot of tar into methylene chloride. This tar sample was assumed representative of all the wells sampled, as the greatest distance between any well and W40M was only 18 m. This was ultimately borne out as PAH concentrations in other tar samples obtained 1 (A. A. MacKay, unpublished results) and 30 m (*21*) from W40M differed by less than 10% from levels found in the W40M tar.

Tar (3 mL) was also mixed with 2 L of purified water containing sodium chloride (1 g/L) to match the site groundwater conductivity and mercuric chloride (1 mg/L) to inhibit compound biodegradation. The two phases were mixed with a stir bar for 2 days, and the dispersed tar droplets were allowed to settle for 2 months before sampling. The aqueous phase was carefully siphoned into a separatory funnel using aluminum tubing, primed with purified water. This sample was spiked with deuterated phenanthrene and *p*-terphenyl and extracted as outlined above.

Fractionated Extractions of Groundwater. Pyrene was quantified in a series of fractions of the W40M groundwater. First, solids were allowed to settle from solution over a 5-month standing period. (Assuming Stokes settling and a particle density of 1.05 g/cm^3, all particles greater than 1.2 μm in diameter would have settled in this time.) Next, the supernatant was gently siphoned from the BOD bottle, leaving a small, undisturbed volume of water containing the settled solids. (The siphon tube was a piece of aluminum tubing primed with purified water, introducing less than 8 mL to the 270 mL transferred volume.) The small volume of water remaining in the original sample bottle was spiked with an internal standard of *p*-terphenyl and extracted in the bottle with methylene chloride. This extract was denoted the "settled solids + walls" fraction and contained pyrene associated with settled solids and any pyrene species that may have adhered to the glass walls, including tar-associated pyrene.

The siphoned supernatant contained the dissolved species plus any pyrene associated with stable colloids. This fraction (initially at pH 5.6) was acidified to pH 1 with hydrochloric acid. The sample was allowed to stand for 3 days while acid-

TABLE 1. Physical and Chemical Groundwater Parameters from Several Wells at a Coal Tar Site in September 1996[a]

parameter	well id W20M	W20S	W40M	W40S	W100D	W100M	W100S
pH	5.4	5.5	5.6	5.4	5.3	5.5	5.6
turbidity (NTU)	1.4	2.3	0.5	1.6	7.2	7.8	4.3
conductivity (mS)	1.95	1.37	1.76	1.32	1.50	2.23	2.44
redox potential (mV, H° scale)	−51	−82	−31	−110	−16	29	−76
dissolved oxygen (μM)	<1	<0.3	<0.3	6	<6	5	<0.5
alkalinity (meq/L)	27.2	15.7	19.2	14.6	15.4	18.6	15.1
nonpurgeable organic carbon (mg/L)	45	34	34	28	33	33	40
$S^{2-}{}_{total}$ (μM)	<80	1600	<80	1600	<80	<80	800
$SO_4{}^{2-}$ (μM)	2000	300	<1	1400	na	20	1400
Al_{total} (μM)	30	20	4	7	17	31	80
$Al_{dissolved}$ (μM)	1	1.4	2	1	9	2	10
Fe_{total} (μM)	13	37	40	5	100	370	83
$Fe_{dissolved}$ (μM)	3	70	3	3	12	4	7
Si_{total} (μM)	na	na	1500	na	na	na	1600
$Si_{dissolved}$ (μM)	na	na	1000	na	na	na	1300

[a] na indicates samples that were not analyzed.

precipitated material settled out. The siphoning procedure was then repeated. The remaining volume was spiked, extracted, and referred to as the "pH 1 precipitate" fraction. The second siphoned supernatant contained dissolved pyrene and any colloids not precipitated under acidic conditions. This volume of water was also spiked with *p*-terphenyl and extracted with methylene chloride. This fraction was called the "pH 1 dissolved" fraction. The methylene chloride extracts were transferred to hexane and analyzed by capillary gas chromatography, as described above.

Fluorescence Quenching. Fluorescence quenching (*15, 22*) measurements were made with water samples siphoned from the collection vessels to include only the colloids stable over a 5-month period. Fluorescence of an added pyrene probe was measured with a Perkin-Elmer LS50B luminescence spectrometer. The excitation wavelength was 334 nm (slit width 4 nm), and the emission wavelength was 373 nm (slit width 4 nm). The absorbances at these two wavelengths were measured on a Beckman DU 640 spectrophotometer to correct for the inner filter effect (*22*). The linearity of a Stern–Volmer plot was verified by a dilution series (minimizing coagulation artifacts that might have occurred with a colloid concentration approach). Subsequently, single-point measurements were made at only one quencher concentration. Background fluorescence readings of a 3-mL water sample were taken before pyrene addition. Four 50-μL aliquots of a pyrene in methanol stock solution were sequentially added to the cuvette. The cuvette was allowed to stand for 10 min after each addition before fluorescence measurements were made. In all cases, fluorescence response was linear, suggesting that the relatively high carrier solvent concentration did not change the probe partition coefficient. Thus, the maximum error that would result from this approach was estimated from the 1.6% methanol in water solution (i.e., 50 μL of stock aliquot) and found to underestimate the colloid–water partition coefficient by 20% (*12*). Fluorescence response was quantified as the slope of a plot of background-subtracted fluorescence versus added-pyrene concentration. A duplicate sample with 3 mL of oxygen-free (<0.3 μM, Chemettes, Chemetrics, Calverton, VA) purified water was treated identically to quantify pyrene fluorescence in the absence of O_2 quenching. All sample manipulations were made in an argon or nitrogen atmosphere.

Organic Carbon Measurements. Total organic carbon (TOC) in water samples was determined with a high-temperature Shimadzu TOC-5000 organic carbon analyzer. Samples were acidified to pH 3 with phosphoric acid and bubbled with nitrogen or argon for 10 min to remove inorganic carbon. Triplicate TOC measurements were made, and the high temperature oxidation system was externally calibrated with potassium hydrogen phthalate standards.

For the W40M groundwater with pH 1, acid-precipitated material was separated from acid-stable organic carbon by centrifuge ultrafiltration. Centricon 3 (Amicon, Beverley, MA) filter cartridges were used to separate organic carbon with a nominal cutoff of 3000 Da (*23*). Before use, the filters were washed with methanol, followed by repeated washes with purified water until the TOC of the filtrate was indistinguishable from purified water. Acidified samples were ultrafiltered by centrifuging for 2 h at 800*g*. Subsequent TOC measures of the filtrate were made as described above.

Surface Tension. Groundwater surface tension measurements were made by the falling drop method (*24*). Measurements of purified water surface tension were made to verify this method. A value of 72.2 ± 0.1 dyn/cm ($n = 5$) was calculated for purified water and compares reasonably with the reported value of 71.97 dyn/cm at 25 °C (*25*).

Calculation of Partition Coefficients. Partition coefficients of colloidal materials were calculated from enhancement factors:

$$E = \frac{C_T}{C_w} = 1 + \sum[\text{colloid}]K_{\text{colloid}} \qquad (1)$$

where E is the enhancement factor, C_T (mg/L) is the total compound concentration in a bulk (dissolved + colloid-associated) water sample, C_w (mg/L) is the dissolved concentration as measured by tar–water equilibration, [colloid] (kg/L) is the colloid concentration, and $K_{colloid}$ (L/kg) is the colloid–water partition coefficient. In the case of fluorescence quenching, the total compound concentration was assumed proportional to the background-subtracted fluorescence of a supernatant after the colloid phase had been removed (F_0). The dissolved concentration was assumed proportional to the background-subtracted fluorescence in the colloid-containing sample (F_1) and assuming the colloid-associated probe is fully quenched.

Results and Discussion

Groundwater Characteristics. Groundwater, pumped slowly on five dates from seven wells at the site, exhibited a range of properties (Table 1). Some parameters were fairly invariant between wells; for example, pH values only ranged from 5.3 to 5.6, electric conductivities only varied from 1.32 to 2.44 mS, alkalinities were between 15 and 27 mM, and non-

TABLE 2. Aqueous and Tar Concentrations of Polycyclic Aromatic Hydrocarbons[a]

		equilibrium aq concn (mg/L)		Apr. 10, 1996, groundwater concn (mg/L)	
compd and abbrev	tar concn (mg/L)	calcd	measd	W40S	W40M
phenanthrene, PH	19 700	0.11	0.073	0.063 ± 0.0007	0.12
anthracene, AN	5 000	0.027	0.012	0.011 ± 0.001	0.02
fluoranthene, FL	6 500	8.7×10^{-3}	3.3×10^{-3}	$3.8 \times 10^{-3} \pm 5 \times 10^{-4}$	0.015
pyrene, PY	9 300	6.4×10^{-4}	1.4×10^{-3}	$2.5 \times 10^{-3} \pm 5 \times 10^{-4}$	0.011
benz[*a*]anthracene, BA	3 900	6.9×10^{-4}	7.7×10^{-4}	$3.8 \times 10^{-4} \pm 5 \times 10^{-5}$	7.9×10^{-3}
chrysene, CH	3 600	9.6×10^{-4}	6.8×10^{-4}	$4.2 \times 10^{-4} \pm 3 \times 10^{-5}$	6.3×10^{-3}
benzo[*b*&k]fluoranthene	4 300	*b*	2.4×10^{-4}	$1.8 \times 10^{-4} \pm 5 \times 10^{-5}$	3.4×10^{-3}
benzo[*e*]pyrene	3 700	*b*	1.9×10^{-4}	$1.4 \times 10^{-3} \pm 1.4 \times 10^{-3}$	3.4×10^{-3}
benzo[*a*]pyrene, BaP	3 600	1.1×10^{-4}	3.5×10^{-4}	$1.7 \times 10^{-4} \pm 9 \times 10^{-4}$	5.8×10^{-3}
indeno[123-*cd*]pyrene, IP	1 200	*b*	6.2×10^{-5}	$7 \times 10^{-5} \pm 4 \times 10^{-5}$	2×10^{-3}
benzo[*ghi*]perylene, BP	1 200	6×10^{-5}	1.6×10^{-4}	$6 \times 10^{-5} \pm 3 \times 10^{-5}$	2×10^{-3}

[a] W40S groundwater concentrations are the average and standard deviation of 3 samples obtained over a 36-h period. [b] Experimental solubility not available.

purgeable organic carbon varied between 28 and 45 mg_C/L. [Note that while these organic carbon concentrations appear large in comparison to pristine aquifers (*26*), 8−11 mg/L reflect dissolved coal tar components, primarily naphthalenes.] Generally, the groundwater was reducing (+29 down to −110 mV), and oxygen was very low or absent (≤ 6 μM). Sulfide was present (>800 μM) in the three wells screened nearest the water table, but this reduced sulfur species was not detected in the corresponding deeper groundwater (<80 μM). Sulfate was found in the water at every well except W40M.

Some parameters suggested the presence of colloidal phases suspended in these water samples (Table 1). Although the groundwater samples were always "clear" to the naked eye after many hours of slow pumping, light scattering above instrument background (ca. 0.1 NTU) was always seen. This scattering was as low as 0.5 NTU in well W40M and as high as 7−8 NTU in wells W100D and W100M. Well-to-well variations in turbidity or total scattered light likely resulted from differences in the composition of colloidal materials at the different wells. For example, filterable iron was 2−10 times higher in wells W100D and W100M than in well W40M (Table 1). Scanning electron microscopy observations of particles collected on Nuclepore filters revealed colloids with mean diameters (number average) between 300 and 700 nm and a range of diameters from about 100 to 4000 nm. Filterable aluminum, iron, and silicon (total minus dissolved concentrations, Table 2) ranged from a few micromolar to 70 μM_{Al}, 370 μM_{Fe}, and 500 μM_{Si}, respectively. These observations indicate that inorganic colloidal phases were present, suspended in these groundwaters, at levels between 1 and 40 mg/L.

Enhanced Groundwater Concentrations. Residual tar was observed to be distributed throughout the subsurface solids recovered during well installation (*19*). Thus, we expected groundwater concentrations of dissolved PAHs in this area to exhibit equilibrium with nonaqueous phase liquid tar. Equilibrium aqueous PAH concentrations can be estimated theoretically, via application of Raoult's law with knowledge of the tar composition. One may also evaluate these aqueous concentrations empirically by experimental equilibration of the site's tar with water. Expected equilibrium dissolved PAH concentrations were determined using both of these approaches. First, using results of our measurements of the tar composition, we calculated dissolved concentrations of PAHs in water at equilibrium, assuming a sufficiently large tar-to-water ratio that tar concentrations were not depleted by PAH partitioning into the water. This calculation required knowledge of compound subcooled liquid solubilities (*27*), the tar "molecular" weight (160 g/mol; *21*), and the compound activity coefficient in tar (1; *19*, *28*, *29*). Although each of the compounds we examined occur in the tar at concentrations greater than 1000 mg/L tar, their hydrophobicities result in an expected range of groundwater concentrations from about 10^{-1} down to less than 10^{-4} mg/L water (Table 2).

We also made experimental determinations of water concentrations in equilibrium with tar using incubations in the laboratory. In general, the values calculated from tar compositions were the same as the measured ones within a factor of 3 (measured/calculated = 1.4 ± 1.0, $n = 8$ compounds). Since the measured values do not require any assumptions about PAH compatibilities with the tar mixture or mean tar molecular weight, in subsequent discussion we will assume that *the measured concentrations reflect the dissolved species in equilibrium with the site's tar.*

To ascertain whether the site's groundwater concentrations only reflected the presence of the dissolved-in-water PAH species, we compared measured tar−water equilibrium values with levels we measured in slow-pumped samples from the site (Figure 1). In many wells (e.g., W20M, W40S, W100D, W100M), concentrations of PAHs observed in slow-pumped groundwater from this coal tar site appeared to reflect equilibrium dissolution from the coal tar. However, some monitoring wells had groundwater concentrations of PAHs distinctly in excess of tar−water equilibrium values. For 7 of 25 well/date sample combinations, at least 50% of the PAH compounds monitored exhibited groundwater concentrations more than 3 times greater than measured by tar−water equilibration. Benzo[*a*]pyrene concentrations were observed up to 16 times higher than tar−water equilibrium, and indeno[1,2,3-*cd*]pyrene concentrations were up to 50 times higher. Well W40M always showed such PAH enrichments (Figure 2). Notably, in all of those cases, the ratio of observed-to-equilibrium concentrations increased with increasing compound hydrophobicity. This trend suggested the presence of dissolved or suspended materials in some of the groundwater at this site, which enabled the concentrations of PAHs in the water to exceed levels reflecting only dissolved-in-water species in equilibrium with coal tar.

For several reasons, we believe that this enhanced load of groundwater PAHs was truly mobile and not an artifact of our sampling procedure. First, in all cases the turbidity levels had reached asymptotic values (<1.5 NTU), as determined by long-term (5−9 days) slow pumping. Also, only particles less than 4 μm in diameter were obtained on filters. Finally, no correlation was seen between the occurrence of enhanced PAH concentrations and observations of tar in monitoring wells (only 10−100 μg of tar entrained in a 1-L groundwater sample would be needed to explain our observed PAH concentrations) (*19*). Convinced that our observations did not result from sampling artifacts, we

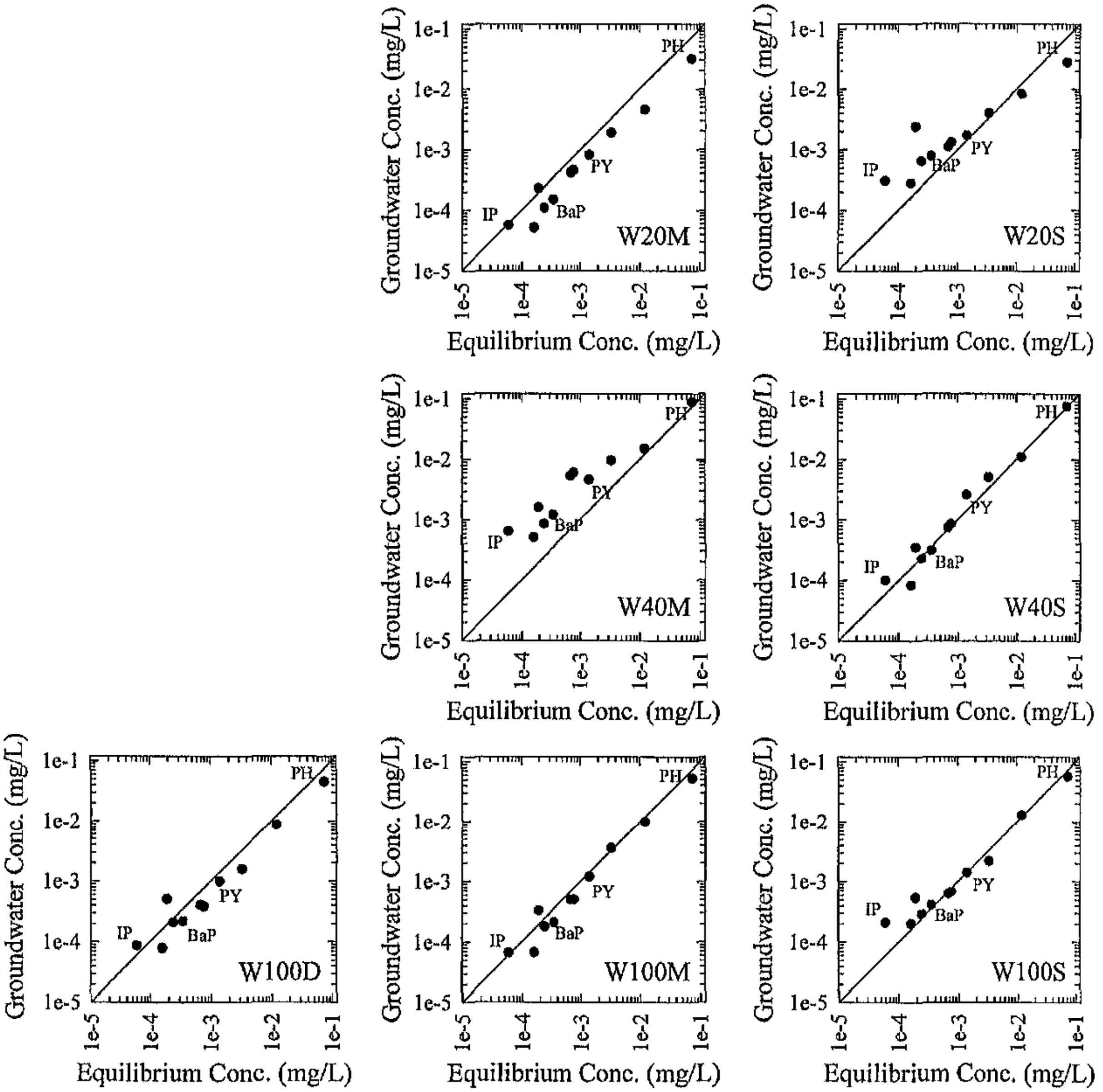

FIGURE 1. Comparison of observed groundwater PAH concentrations to measured aqueous tar–water equilibrium concentrations. Slow-pumped groundwater samples were collected from all wells in September 1996. Compound abbreviations are given in Table 2.

investigated possible mechanism(s) for enhanced solubilization of hydrophobic PAHs using samples from well W40M.

Cosolvents and Surfactants. Cosolvents or surfactants in the groundwater could enhance PAH solubilities over the measured tar–water equilibrium values (*6*, *7*, *30*). If such materials were present at concentrations sufficient to have a detectable concentration-enhancing effect, we would expect to observe lower groundwater–air surface tensions. We measured the surface tension of the groundwater samples from W40M to be 70.6 ± 3 dyn/cm ($n = 5$). Within the measurement variability, this value did not differ from the surface tension measured for purified water. Water that has been equilibrated with tar has a surface tension that is not significantly different from purified water (*31*), indicating that tar constituents do not lower aqueous surface tension values. The much greater variability observed for the groundwater samples than the purified water may suggest the presence of surface active species in the groundwater pumped from this well. Indeed humic substances present at 5–10 mg/L, as were observed in this groundwater (see Colloidal Materials discussion below), may lower surface tensions by 1 dyn/cm (*32*, *33*).

The magnitude of this surface tension effect on the solubility of benzo[*a*]pyrene was estimated with (*12*)

$$\log \frac{C_{\mathrm{mix}}^{\mathrm{sat}}}{C_{\mathrm{w}}^{\mathrm{sat}}} = \frac{N(\sigma_{\mathrm{air:H_2O}} - \sigma_{\mathrm{air:gw}})(\mathrm{HSA})}{2.303\,RT} \qquad (2)$$

where C_{mix} and C_{w} (mg/L) are the aqueous concentrations in the presence and the absence, respectively, of any surface active agent; N is Avogadro's number; $(\sigma_{\mathrm{air:H_2O}} - \sigma_{\mathrm{air:gw}})$ (dyn/cm) is the difference in surface tensions between the two water samples; R (erg mol^{-1} K^{-1}) is the gas constant; T (K) is the temperature; and HSA (cm^2) is the molecule hydrophobic surface area, here approximated as 250 Å^2 (*12*).

A decrease of 1.4 dyn/cm in surface tension from that in pure water would enable a benzo[*a*]pyrene concentration increase of a factor of about 3 in the groundwater relative to pure water. The observed BaP enhancement factor at W40M

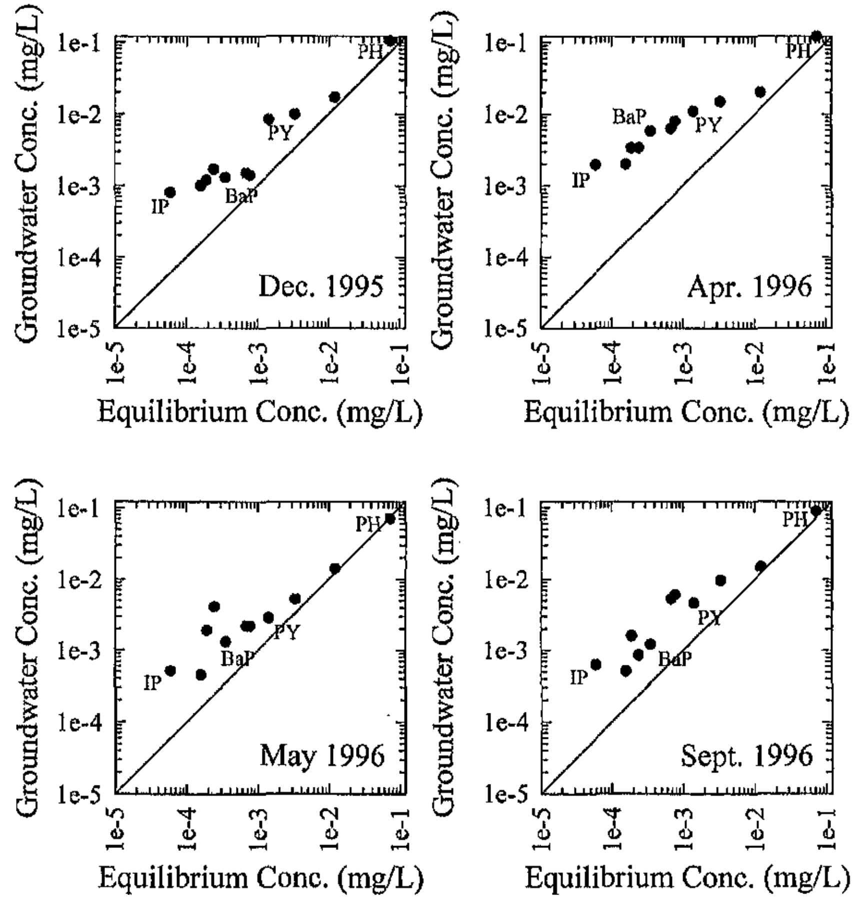

FIGURE 2. Comparison of observed groundwater PAH concentrations to measured aqueous tar–water equilibrium concentrations from well W40M.

TABLE 3. Distribution of Pyrene in Fractionated W40M Groundwater

fraction	pyrene concn (mg/L)	vol of extract (L)	mass of pyrene (μg)	fraction of total pyrene after correction for carryovers (%)
settled solids + walls	0.044	0.010	0.44	36
pH 1 precipitate	0.0071	0.039	0.28	28
pH 1 dissolved	0.0013	0.230	0.3	36
bulk groundwater	0.0036	0.279	1.02	100

[a] Bulk groundwater values are the sum total from each of the separated fractions.

was 14 in September 1996 when the surface tension was measured. A polar, methanol-like cosolvent would need to be present at gram per liter quantities to explain this enhancement (*12, 31*); however, only 34 mg/L of organic carbon was measured in the groundwater. On a carbon-basis, synthetic surfactants and biosurfactants can elevate compound solubilities at milligrams per liter concentrations but not without dramatic decreases in surface tension (*9*). Thus, surface active species did not appear to be important contributors to the enhancement of groundwater PAH concentrations at this site.

Colloidal Materials—In Situ Pyrene Distribution. Pyrene concentrations were elevated above dissolved concentrations in both the settled solids + walls and the pH 1 precipitate fractions of W40M groundwater (Table 3). The masses in each fraction were summed to give the pyrene concentration that would have been obtained by an extraction of the bulk water sample. This concentration (0.0036 ± 0.001 mg/L) was consistent with the concentration of pyrene (0.0046 ± 0.0013 mg/L) determined in 2 L of fresh W40M groundwater, indicating no compound degradation over the 5-month storage period. While the separation of the colloid fractions in W40M groundwater was likely not perfect because gravitational settling and siphoning were used for separation, the pyrene concentration (0.0013 mg/L) in the final pH 1 dissolved fraction was in agreement with the dissolved concentration in equilibrium with coal tar (0.0014 mg/L). Concentration agreement between the pH 1 dissolved fraction and the expected equilibrium with tar indicated that fulvic acids, organic materials that would remain suspended even at pH 1, were not important colloidal phases for pyrene sorption in this groundwater. Thus, all colloid-associated pyrene appears to have been removed by the settling and pH 1 precipitation steps.

The relative importance of settled solids-plus-tar and acid-precipitated organic matter on the enhancement of groundwater pyrene concentrations was calculated. In order not to suspend settled particles between successive siphon steps, a measurable volume of water was left behind at each stage. Thus, dissolved and stable organic colloid-associated pyrene was also extracted with the settled solids and walls; likewise, dissolved pyrene was in the pH 1 precipitate. The portion of the pyrene mass (reported in Table 3) for the settled solids-and-walls that originated from the inclusion of dissolved and organic colloid-associated pyrene in this volume was calculated to be 15%. In the case of the pH 1 precipitate, 18% of the pyrene mass extracted was actually dissolved and not colloid-associated. With these corrections, about 40% of the pyrene in the original water sample was associated with the

TABLE 4. Pyrene Fluorescence in W40M Groundwater after Various Treatments to Remove Organic Colloids

sample	fluorescence response (intensity units/unit of pyrene added)	TOC (mg_C/L)
purified water	3.1 ± 0.1, 3.2 ± 0.1	1.9 ± 0.4
unaltered W40M groundwater	2.2 ± 0.1	19 ± 1.5
ultrafiltered W40M groundwater	2.4 ± 0.1	17 ± 0.02
pH 1 W40M groundwater	not measured	20 ± 0.9
ultrafiltered pH 1 W40M groundwater	3.4 ± 0.2	13 ± 0.4

bottle walls or settled solids, about 30% of the pyrene was associated with colloids that were stable over 5 months, and the remaining mass was dissolved-in-water pyrene.

Colloidal Materials—Fluorescence Quenching. The presence of stable colloids in W40M groundwater was supported by observations of fluorescence quenching of pyrene added to groundwater samples. Increases in fluorescence due to pyrene additions to W40M groundwater were clearly less than corresponding responses from pyrene amendments of purified water (Table 4), indicating the presence of a quenching colloid phase in the groundwater. Ultrafiltration (3000 D) did not remove substantial amounts of the quenching phase: the pyrene fluorescence was slightly greater than in the unaltered groundwater, but the fluorescence did not approach that of pyrene in purified water. Thus, the quencher was able to pass through a nominal 3000 D filter. However, when the groundwater sample was acidified to pH 1 and then ultrafiltered, the fluorescence with pyrene additions did approach the levels of fluorescence in colloid-free water. The organic carbon concentration also decreased to 13 mg_C/L (Table 4). Acidification of the water sample would cause humic acids to precipitate and be more efficiently removed from solution by ultrafiltration. Thus, the fluorescent probe measurements also indicate that pyrene concentrations in the excess of tar–water equilibrium concentrations result from the association of pyrene with stable colloids which can be acid-precipitated.

Changes in the groundwater absorbance at 280 nm with sample manipulation also support the hypothesized presence of humic acid-like colloids. The absorbance at 280 nm decreased from 0.73 for ultrafiltered groundwater to 0.50 for pH 1 ultrafiltered groundwater. Water that was equilibrated with tar in the laboratory incubation had an absorbance of 0.45 (280 nm), and thus the groundwater absorbance after acidification and ultrafiltration likely resulted from dissolved aromatic hydrocarbons. The molar absorptivity of the 4 mg_C/L organic carbon removed by acidification was calculated to be 690 M_C^{-1} cm^{-1}. This molar absorptivity is of the same magnitude as reported for humic materials (*34, 35*) and is much less than the molar absorptivity of polycyclic aromatic hydrocarbons (cf., benz[*a*]anthracene absorptivity of 10^4 M_C^{-1} cm^{-1}; *12*). Thus, the change in absorbance upon acidification and ultrafiltration is consistent with colloids of a humic nature rather than a tar nature.

Coupled with the results indicating pyrene in excess of tar-equilibrated concentrations occurred in situ, this is strong field evidence for association of hydrophobic organic compounds with small (< nominal 3000 Da) organic colloids in groundwater. Previous laboratory studies have demonstrated that humic substances isolated from soil (*36*) and aquatic systems (*2, 37–39*) can enhance the solubility of added HOCs. In our study, colloid-associated PAH concentrations were measured directly by increased groundwater concentrations above tar–water solubility and in extracts of separated colloid fractions. Previous fractionated extractions of contaminated groundwater have not identified humic materials as important facilitating phases (*16, 17*). HOC association with organic groundwater colloids has been inferred in other contaminant plumes through the addition of hydrophobic probes (*14, 15*). Our probe additions were consistent with in situ pyrene distributions that showed organic colloids to be important facilitating phases under certain conditions at this coal tar site.

An organic colloid–water partition coefficient for pyrene was estimated from the fluorescence quenching results. Using eq 1 and values of F_0 and F_1 taken from the ultrafiltered pH 1 groundwater and the unaltered, ultrafiltered groundwater, respectively, an enhancement factor of 1.4 ± 0.1 was calculated. The decrease in TOC concentration of 4 mg_C/L between the ultrafiltered groundwater and the pH 1 ultrafiltered groundwater (Table 1) was assumed to indicate the concentration of sorbent colloids. With this colloid concentration and an enhancement factor of 1.4, a colloid–water partition coefficient of 10^5 mL/g_C was calculated for pyrene using eq 1. The magnitude of this partition coefficient is greater than observed for pyrene association with aquatic humic substances ($10^{4.3}$–$10^{4.5}$; *40*) but is of a comparable magnitude to pyrene partitioning to soil humic substances ($10^{4.9}$–$10^{5.5}$; *22, 41*). The source of colloidal organic matter at this site is unknown; however, degradation of many organic materials in the fill solids, including wood, tar, and natural organic matter (*19*), could contribute to the high dissolved organic carbon concentrations observed in the groundwater.

Predicted PAH Concentration Enhancements. Pyrene partitioning was used to calculate the expected concentration enhancements of other PAHs above tar–water equilibrium in the W40M groundwater. Compound concentrations in the bulk groundwater will be increased by PAH association with stable humic acid-like organic colloids and the material that was operationally labeled settled solids + walls in our fractionated extractions. The overall enhancement factor for a given compound in groundwater can be estimated using

$$E = \frac{C_T}{C_w} = 1 + \begin{bmatrix}\text{organic}\\ \text{colloids}\end{bmatrix} K_{\text{colloid}} + \begin{bmatrix}\text{settled}\\ \text{solids}\end{bmatrix} K_{\text{solids}} + [\text{tar}]K_{\text{tar}} \quad (3)$$

where [*i*] (kg/L) is the concentration of the colloidal phase as indicated and K_i values (L/kg) are the corresponding colloid–water partition coefficients. A tar–water partitioning term has been included in eq 3 because some of the pyrene lost to walls in the fractionation steps may have been associated with tarry colloids that have a different colloid–water partition coefficient than the settled solids. Since we found that the fractionated in situ pyrene mass distribution indicated that the settled solids-plus-walls terms are about the same magnitude as the organic colloid term (Table 3), we modified eq 3 to be

$$E^{\text{PY}} = \frac{C_T}{C_w} \approx 1 + 2\begin{bmatrix}\text{organic}\\ \text{colloids}\end{bmatrix} K_{\text{colloid}} \quad (4)$$

K_{colloid} values for other PAHs were estimated from the pyrene K_{colloid} value, assuming that they scaled according to the compounds relative octanol–water partition coefficients (i.e., $K_{\text{colloid}}^{\text{PAH}}/K_{\text{colloid}}^{\text{PY}} = K_{\text{ow}}^{\text{PAH}}/K_{\text{ow}}^{\text{PY}}$) (Table 5). An organic colloid concentration of 4 mg_C/L was used in the calculations. The calculated solubility enhancements (eq 4) matched closely the observed enhancements calculated by the ratio of PAH concentrations in bulk groundwater extractions to tar–water equilibrium concentrations (Table 5). As expected, less water-soluble PAHs were more susceptible to colloid enhancement. With the concentrations of colloidal materials observed, the mass of pyrene that can be transported in the groundwater

TABLE 5. Expected PAH Solubility Enhancement Factors

compd	log K_{ow}[a]	log $K_{colloid}$	calcd E	obsd E[b]
phenanthrene	4.57	4.39	1.2	1.2 ± 0.5
fluoranthene	5.22	5.04	1.9	2.4 ± 0.9
pyrene	5.18	5	1.8	2.9 ± 1.1
benz[*a*]anthracene	5.91	5.73	5.3	3.7 ± 1.4
chrysene	5.79	5.61	4.2	3.6 ± 1.4
benzo[*a*]pyrene	5.98	5.8	6	7.2 ± 2.8

[a] Ref *27*. [b] Calculated from $E = C_{groundwater}/C_w$, where $C_{groundwater}$ is the concentration in a 2-L sample collected at the same time as the fractionated samples, and C_w is the concentration from the laboratory tar–water equilibration.

is increased by a factor of 2–3 over the dissolved hydrated mass; however, over 80% of the mass of benzo[*a*]pyrene, a more hydrophobic PAH, is associated with colloidal materials, increasing the mobile benzo[*a*]pyrene mass by a factor of 6–7 times.

Environmental Significance. The results of this research may be coupled with colloid generation and transport models to predict the enhanced flux of PAHs away from the coal tar source. The low groundwater turbidities and small colloid particle sizes suggest that the PAHs observed in the bulk groundwater were mobile, at least in the vicinity of our sampling wells; however, we have no data characterizing the colloid attachment and detachment rates for the subsurface solids and colloids at this site from which to develop a colloid transport model. As an upper, conservative (i.e., fastest transport) bound, a retardation factor (R) in the presence of colloids was estimated assuming (i) linear equilibrium partitioning of the colloids to the solid phase; (ii) linear equilibrium partitioning of the PAHs between colloid and solid phases; and (iii) a constant colloid concentration (*42*):

$$R = 1 + \frac{r_{sw}K_d}{1 + \sum[\text{colloid}]K_{\text{colloid}}} \qquad (5)$$

where r_{sw} (kg/L) is the solid-to-water ratio and K_d (L/kg) is the solid–water partition coefficient. This model is applicable to organic matter colloids, which have a lesser tendency to partition to the immobile solid phase than do PAHs (*4*). For PAHs, the product of the solid-to-water ratio and the partition coefficient is generally much greater than 1, so the retardation factor for these compounds in colloid-containing groundwater is reduced by a factor of $1 + \Sigma[\text{colloid}]K_{\text{colloid}}$ ($= E$), relative to a system with no colloids. We observed enhancement factors for benzo[*a*]pyrene between 4 and 16 at this coal tar site. Thus, the retardation factor for benzo[*a*]pyrene would be reduced by a factor of 4–16, relative to predictions assuming no colloids and assuming no pore exclusion effects (*43*).

For a typical natural aquifer ($f_{oc} = 10^{-3}$ kg$_C$/kg), the benzo[*a*]pyrene retardation factor would decrease from about 1000 to about 100 with the magnitude of colloid-enhanced solubilization observed at this coal tar site. The resultant colloid-impacted retardation factor for benzo[*a*]pyrene is still high, but if the industrial site that was the source of this groundwater contamination had been in operation for over 100 years, as is common for many coal tar and industrial sites, sufficient time may have elapsed for benzo[*a*]pyrene to have been transported to sensitive receptors, even with a retardation factor of 100. Certainly, other colloid partition coefficients measured in other anthropogenically impacted aquifers exhibited much greater capacities to sorb HOCs than colloids sampled from pristine locations outside of the zone of contamination (*14*, *15*).

Ideally, characterization of the colloidal materials at this coal tar site would enable a water quality parameter (e.g., acid filtered organic carbon) to be used to delineate solubility enhancements as a surrogate for direct organic contaminant analysis. No bulk water quality parameters that we measured (TOC, turbidity, total or filtered Fe, Al, Si) correlated with the concentration enhancement factors of hydrophobic compounds such as benzo[*a*]pyrene for the suite of wells sampled here. Thus, knowledge of the source and composition of the groundwater colloids is required to enable predictions of spatial and temporal colloid distributions at this coal tar site and to enable predictions of their occurrence at other similar sites.

Acknowledgments

Funding for this research was provided by an anonymous industrial sponsor and the U.S. Department of Energy under Contract DE-FG07-96ER14712. The authors gratefully acknowledge John MacFarlane, Freddi-Jo Eisenberg, and Chris Swartz for field sampling support. The authors also thank four anonymous reviewers who provided valuable comments on this manuscript.

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ES0014786

EXHIBIT 14

********************ROUGH DRAFT**********************

*****************WILLIAM JOHNSON PhD*****************

THE VIDEOGRAPHER: One moment please. We are going on the record. The time is 2:02. This is the videotaped deposition of William Johnson taken in the matter of PR Spring Tar Sand project groundwater discharge permit by rule before the Utah Water Quality Board.

This deposition is being held at 175 South Main, Salt Lake City, Utah on April 4, 201. My name is Max Nelson from the firm of Tempest Reporting with offices at 175 South Main Salt Lake City, Utah. I am the video specialist. The reporter is Denise Kirk from Tempest Reporting.

Counsel will now state their appearances for the record and the witness will be sworn.

MR. DUBUC: Today's date is May 4th, 2012. You said April.

MS. WALKER: This is Joro Walker and Rob Dubuc on behalf of Living Rivers.

MR. McCONKIE: Paul McConkie on behalf of the executive secretary.

MR. HOGLE: Chris Hogle and Benjamin Machlis. And we have Barclay Cuthbart here who is a representative of U.S. Oil Sands.

A. So specifically gravity is how it's listed here is .84. So that's one milliliter of d-limonene per zero .84 grams of d-limonene. Right?

Q. Right.

A. So -- okay. So now we have millimeters of d-limonene per liter of water, right so we want to get those in equivalent units so we simply need to recognize that one liter of water is one thousand milliliters of water and that will of milliliters of d-limonene per milliliter of water. Which gives us our fraction.

MR. CUTHBART: You need your conversion between milligrams, if I might add that.

A. That wouldn't have been a good number for you anyway. Grams down there. So one gram of d-limonene per ten to the third milligrams. Of d-limonene. Right?

So there's ten to the sixth as the denominator just to make this easy let's call that one, okay? So it's 13 -- woops -- 13.8 -- well milliliters of d-limonene -- 13.8 times ten to the minus sixth milliliters of d-limonene per milliliter of water.

Q. Okay. Thanks.

A. Okay.

Q. So that's a very small fraction. Okay? That concentration of d-limonene is much larger than the four milligrams per liter that resulted in significant solubilization of polycyclic aromatic hydrocarbons by natural organic matter. That was the agent here.

My point being that, yes, it's below that .001 threshold, but even the author of that textbook that in fact would be responsible for that statement, for that threshold has published papers showing there's a significant effect of low concentrations for hydrophobic compounds.

Q. Move to strike as nonresponsive the testimony after he answered my question with the 13.8 times ten to the sixth.

I wanted to ask you where you got the information that you provided in your testimony -- in your testimony from before, you indicated that you relied on some U.S. Oil Sands information or that you said some U.S. Oil Sands information supported your conclusion?

A. Right.

Q. Could you identify that for us?

A. Well, I can tell you that it was information provided to counsel that they apparently were able to view it for a short time. They had notes on that. They showed me their notes.

So I used the information they had on

EXHIBIT 15

********************ROUGH DRAFT**********************

*****************WILLIAM JOHNSON PhD*****************

THE VIDEOGRAPHER: One moment please. We are going on the record. The time is 2:02. This is the videotaped deposition of William Johnson taken in the matter of PR Spring Tar Sand project groundwater discharge permit by rule before the Utah Water Quality Board.

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MR. HOGLE: Chris Hogle and Benjamin Machlis. And we have Barclay Cuthbart here who is a representative of U.S. Oil Sands.

their notes to make the calculation.

Q. Okay.

A. What the note showed is petroleum hydrocarbon concentration in the process water.

Q. Okay.

A. I think it might have been called return water. I can't remember off the top of my head.

Q. I would make a request to see the notes that he utilized and relied on and, you know, you don't have to tell me now whether you'll let me see that. I think I'm entitled to see that because he used it. Any other information that you received that was company information?

A. I don't believe so.

Q. Okay. All right. One final question: Solubility is different than mobility, true?

A. They're related but they're different.

Q. Okay. And mobility being the propensity of something to transport, right depends in part at least on the -- what it has to transport through, correct?

A. Correct.

Q. So a factor in determining the mobility in this case is the permanent I can't built of the subsurface material at the project sight, wouldn't you

say that that's accurate?

A. Yeah. My testimony doesn't go there but that's true.

Q. Okay, that's all I have.

A. But one thing issued mention is that permeability is a tricky matter. Hydrologists know that when water moves through the subsurface it's not moving through that matrix porosity, it's moving through fractures and things that transport things much much fast other.

Q. Move to strike as nonresponsive. No further questions.

MR. McCONKIE: I have no questions.

MS. WALKER: I have a few questions.

MS. WALKER: I have a few questions.

FURTHER EXAMINATION

BY MS. WALKER:

Q. So Chris was asking -- I'm sorry Mr. Hogle was asking you about this 13.8 to the minus sixth and you were relating it to four milligrams per liter. Could you just explain that because he moved to strike it so I'd like you to explain it to me?

A. The point made here is that 1.38 times ten to the minus fifth is a volume/volume fraction and much lower, almost two orders of magnitude lower than

that .001 threshold, okay?

By the way, in that same text, in that same section they show that for volume volume fraction

EXHIBIT 16

In the Matter of

PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule

No. WQ PR-11-001

PREPARED SUPPLEMENTAL TESTIMONY

OF

ELLIOTT W. LIPS

ON BEHALF OF

LIVING RIVERS

March 16, 2012

A. Bayer (pg. 6) claims that in my direct testimony I: 1) overlooked or disregarded the combined volume of tailings and overburden and their capacity to absorb excess water, and 2) ignored the effect of revegetation and resultant evapotranspiration in excess of precipitation. Bayer's claims are without basis. First, the volume of the tailings and overburden and their capacity to absorb excess water simply affects how long it will take for water to infiltrate through the tailings – a point I made clear in my direct testimony. Second, as I explained in my direct testimony (and supported by references to published literature and field evidence), excess precipitation is sufficient under current conditions to infiltrate into the subsurface and recharge ground water and thus is sufficient to seep through the tailings and backfill material.

Q. YOU STATED EARLIER IN YOUR TESTIMONY THAT DWQ'S ASSUMPTION THAT OPERATIONS WILL NOT GENERATE LEACHATE FROM THE TAILINGS IS UNSUPPORTED BY ANY ANALYSIS. WOULD YOU PLEASE EXPLAIN THIS?

A. USOS failed to conduct, and DWQ failed to require, an analysis of the seepage of water through the tailings in the dumps or pits. Without analysis, there is no basis for the assumption that the operations will not generate leachate from the tailings.

Q. ARE THERE ACCEPTED METHODS FOR CONDUCTING SUCH ANALYSES?

A. There are computer programs designed specifically to evaluate seepage of precipitation through material placed in landfills and dumps. One such program is the Hydrologic Evaluation of Landfill Performance (HELP) developed by the U.S. Army Corps of Engineers. HELP is a hydrologic model for conducting water balance analysis of landfills, cover systems, and other solid waste containment facilities. The model accepts weather, soil and design data, and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, and leakage through soil.

Q. WHAT INFORMATION WOULD THE HELP PROGRAM PROVIDE?

A. The program would conduct water balance calculations through various layers and can be tailored to input material properties and thicknesses in order to be specific to varying designs. As such, HELP could be used to evaluate the seepage of water through various layers of material in the dumps and backfilled pits. Ultimately, the model provides a valuable result – the amount of water that seeps from the base of a dump or pit. As I described in my direct testimony, this is the seepage water that will come into contact with the underlying soils and/or bedrock. In fact, HELP could evaluate the seepage of water into these materials (inputs to the program) and, in the case of the dumps, determine whether the seepage water will infiltrate into the underlying geologic materials or will flow from the toe of the dumps and discharge to surface water.

Q. ARE YOU AWARE OF ANY RECENT GROUND WATER PERMIT APPLICATIONS SUBMITTED TO DWQ THAT EVALUATED SEEPAGE OF PRECIPITATION WITH THE HELP PROGRAM?

A. Yes, the Ground Water Permit Application submitted to DWQ by Red Leaf Resources on December 20, 2011 for its Southwest #1 Project contained an analysis of the infiltration and seepage of precipitation using the HELP program.

Q. WHERE IS THE RED LEAF SOUTHWEST #1 PROJECT?

A. It is an oil shale project located in the southern Uinta Basin approximately 15 miles north of the PR Spring project site.

Q. WOULD YOU SUMMARIZE THE RESULTS OF THE SEEPAGE ANALYSIS CONDUCTED FOR THE RED LEAF PROJECT USING THE HELP PROGRAM?

A. The results of the analysis indicated that excess precipitation would infiltrate through a 1-foot thick vegetated topsoil layer, a 2-foot thick overburden layer, and a 3-foot thick layer of a layer of bentonite amended soil with a permeability of $1x10^{-7}$ cm/sec.

Q. BASED ON THESE RESULTS, DO YOU HAVE AN OPINION ON THE SEEPAGE OF EXCESS PRECIPITATION AT THE PR SPRING PROJECT SITE?

A. The results indicate that in this area, there is enough excess precipitation to infiltrate through a layer of material that will have much less permeability than the tailings at the PR Spring project, and therefore, I conclude that there is sufficient excess precipitation to infiltrate through the tailings and into ground water.

Q. IN YOUR OPINION, SHOULD USOS HAVE EVALUATED THE SEEPAGE OF WATER THROUGH THE TAILINGS USING THE HELP PROGRAM?

A. Yes. This program is designed specifically to analyze this very question, and it has been used by engineers for this purpose in support of a ground water permit application submitted to DWQ. It is unclear why DWQ did not require the use of a generally accepted and commonly used methodology to evaluate seepage of water through the tailings at PR Spring. Furthermore, DWQ is aware that the results of the seepage analyses for a nearby project indicate that there is sufficient excess precipitation in this area for seepage to occur (acknowledging differences in the details of the two projects). I would expect DWQ to apply this knowledge and question USOS's assumption that seepage will not occur through the tailings at the PR Spring project and require USOS to conduct seepage analyses.

Q. DOES THIS CONCLUDE YOUR TESTIMONY FOR NOW?

A. Yes.

Elliott W. L

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(801) 599-2189
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EXHIBIT 17

********************ROUGH DRAFT**********************

*****************WILLIAM JOHNSON PhD*****************

THE VIDEOGRAPHER: One moment please. We are going on the record. The time is 2:02. This is the videotaped deposition of William Johnson taken in the matter of PR Spring Tar Sand project groundwater discharge permit by rule before the Utah Water Quality Board.

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My point being that, yes, it's below that .001 threshold, but even the author of that textbook that in fact would be responsible for that statement, for that threshold has published papers showing there's a significant effect of low concentrations for hydrophobic compounds.

Q. Move to strike as nonresponsive the testimony after he answered my question with the 13.8 times ten to the sixth.

I wanted to ask you where you got the information that you provided in your testimony -- in your testimony from before, you indicated that you relied on some U.S. Oil Sands information or that you said some U.S. Oil Sands information supported your conclusion?

A. Right.

Q. Could you identify that for us?

A. Well, I can tell you that it was information provided to counsel that they apparently were able to view it for a short time. They had notes on that. They showed me their notes.

So I used the information they had on

their notes to make the calculation.

Q. Okay.

A. What the note showed is petroleum hydrocarbon concentration in the process water.

Q. Okay.

A. I think it might have been called return water. I can't remember off the top of my head.

Q. I would make a request to see the notes that he utilized and relied on and, you know, you don't have to tell me now whether you'll let me see that. I think I'm entitled to see that because he used it. Any other information that you received that was company information?

A. I don't believe so.

Q. Okay. All right. One final question: Solubility is different than mobility, true?

A. They're related but they're different.

Q. Okay. And mobility being the propensity of something to transport, right depends in part at least on the -- what it has to transport through, correct?

A. Correct.

Q. So a factor in determining the mobility in this case is the permanent I can't built of the subsurface material at the project sight, wouldn't you

say that that's accurate?

EXHIBIT 18

Tempest℠ REPORTING

COMPRESSED
CERTIFIED TRANSCRIPT

BEFORE THE UTAH WATER QUALITY BOARD

In the Matter of PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule No. WQ PR-11-001	Videotaped Testimony of: **WILLIAM JOHNSON, Ph.D.**

Place:	TEMPEST REPORTING, INC. 175 South Main Street, #710 Salt Lake City, Utah 84111
Date:	April 20, 2012 9:06 a.m.
Reporter:	Vickie Larsen, CSR/RPR

Page 38

(09:51:40-09:52:58)

statement that I was making that substantiated my concern that d-limonene would not readily vaporize, okay.

So this -- this small, two sentence piece of this larger testimony wasn't the focus, okay. And so now as a result of more time passing and having, you know, examined the issue further, what I've learned is that d-limonene itself is not a particularly small molecule and it is -- or actually let's look at the structure of it in the appendix.

Its properties that actually are relevant here are not so much size, but the fact that it -- it's -- it's large enough that it isn't going to readily move into the vapor phase from its own organic mixture, okay. It has Van der walls forces holding those molecules together that they have to break free from in order to move into the vapor phase, okay. And it's a large enough molecule that that process is going to be slow, okay.

So regardless of whether we focus on the properties of d-limonene itself or the fact that you'll accumulate polycyclic aromatic hydrocarbons on the air/water interface of this residual mixture, there are good arguments for why we wouldn't expect d-limonene to leave that mixture as readily as the NOI

Page 39

(09:53:13-09:54:33)

seems to state.

MR. HOGLE: Move to strike as nonresponsive everything after the answer to the question, which was "right."

Q. Where in your testimony do you say that -- that d-limonene by itself is not likely to vaporize/volatilize readily to the atmosphere?

A. I'm sorry, could you repeat that.

Q. Sure. Where in your testimony did you say what you're now saying, that d-limonene is not a small molecule -- molecule that is readily transported to air?

A. I did not say that in my testimony.

Q. Okay. How about in your March testimony?

A. I did not address that in my March testimony.

Q. All right. So in your initial testimony and both your supplemental testimony, you relied on textbook Schwarzenbach RP? It's Reference Number 5 on Page 34.

A. That's right.

Q. And it's the, according to the reference here, a 1993 publication?

A. Yes, the edition I used was 1993.

Q. Okay. And you consider that to be

Page 40

(09:54:42-09:55:30)

authoritative in this area?

A. Uh-huh, yes.

Q. The title of it is Environmental Organic Chemistry?

A. That's right.

Q. And do you teach using that?

A. I do. Not that edition, but I teach.

Q. Which edition do you use when you teach?

A. There's a newer edition, I forget the year. But it's harder to get the older edition, so the students need to buy the newer one.

Q. Okay. Is it 2003?

A. Possibly. I don't remember off the top of my head.

Q. I'm handing you a book we checked out of the library, and can you -- can you identify that for us?

A. Sure. This is apparently the same textbook that I referenced.

Q. Okay. And how long is that?

A. How long?

Q. Yeah.

A. How long is the book?

Q. Yeah, easy question.

A. Well, I don't have it memorized so I'm

Page 41

(09:55:45-09:56:37)

going to look, and it's 680 pages.

Q. Okay. You don't identify a single page in any -- either of your testimony, do you, out of that book?

A. No, but I could easily do so.

Q. Okay. Maybe we'll get to that.

But you also don't attach to your testimony the pages from that book on which you rely. That's true, right?

A. That's true.

Q. Okay.

A. Quite true.

Q. So it's not clear, from your testimony anyway, which portions of the text you're relying on, right?

A. Sure.

Q. All right. And then if we go to Page 6 of Exhibit 1. The question on Page 6 -- the question on Page 6:

"How did you go about substantiating these concerns..." it goes on.

Do you see that question?

A. Sure.

Q. And then you have an answer that starts in the bottom of Page 6 and goes to close to the

EXHIBIT 19

In the Matter of

PR Spring Tar Sands Project, Ground Water Discharge Permit-by-Rule

No. WQ PR-11-001

PREPARED DIRECT TESTIMONY

OF

WILLIAM P. JOHNSON, Ph.D

ON BEHALF OF

LIVING RIVERS

January 20, 2012

Additionally, I will discuss: 1) why it was inappropriate for DWQ to rely on the MSDS sheets provided by the company in determining the toxicity of the reagent; 2) that DWQ did not require the company to conduct the appropriate tests to assess the potential for leaching of petrochemicals from the processed ore to water; and, 3) that it was inappropriate for DWQ to conclude that the processed sediment is "damp-dry" because it is, in fact, saturated with fluid based on water contents provided by the company.

Q. CAN YOU BRIEFLY DESCRIBE D-LIMONENE?

A. Based on the properties listed in Appendix B, d-limonene is a small molecule that is readily transported to air. Therefore d-limonene by itself will likely vaporize/volatilize readily to the atmosphere.

Q. CAN YOU DESCRIBE UTAH TAR SANDS COMPOUNDS?

A. Based on information regarding Utah tar sand compounds provided in Appendix C, these compounds likely include polycyclic aromatic hydrocarbons (PAH) which are known human carcinogens. The tar exists as a semi-solid, and so has no significant propensity to migrate into the subsurface as a phase. By themselves, the PAH compounds and aliphatic chains comprising the tar are highly insoluble in water, and so despite the significant carcinogencity of at least some of these component compounds, they are not expected to undergo significant transport in site runoff or site groundwater, greatly limiting the possibility of exposure to these compounds.

Q. WHY ARE YOU CONCERNED ABOUT THE CARCINOGENCITY OF UTAH TAR SANDS COMPOUNDS WITH THE PR SPRING MINE?