

**Workshop Report**  
**“Disposal of Arsenic-Bearing Water Treatment Residuals: Assessing the Potential  
for Environmental Contamination”**

**Rio Rico, Arizona**  
**February 12- 14, 2006**

The objective of this workshop was discussion of the most current scientific understanding of arsenic-bearing water treatment residuals' behavior in the environment in an effort to assess the potential for environmental contamination and human health risk posed by these wastes. The workshop reviewed the science, research, and modeling involved in predicting the potential contamination based on expected generation and disposal practices for arsenic-bearing residuals (ABR). The symposium was limited to consideration of ABR generated by drinking water treatment processes, but included insights into predicted arsenic behavior gained from a broad range of studies on arsenic cycling and landfill processes. The specific goal of the effort was to answer the following: "Is there a problem with disposing of ABR in non-hazardous landfills? If the answer is negative, how do we conclude and document the effort? If the answer is affirmative, what can be done? However, if it is determined that the question cannot be answered, then the critical question becomes: why not and what must be done to answer it?"

Attendance was limited to approximately 40 invited participants representing the National Institute of Environmental Health Science (NIEHS), the Environmental Protection Agency (EPA), state environmental quality agencies, academics, and selected additional experts in the field. The first day included five sessions in which invited speakers discussed key ABR-related issues with time allotted for questions and discussion. In order to gather information and motivate additional comment from the non-platform participants, the first day concluded with an open discussion of how to integrate the information and expertise into an overall assessment of the future potential threat posed by ABR. The second day consisted of a closed planning meeting involving a smaller group (approximately 30 participants) from NIEHS, EPA and academia with the purpose of defining and putting into action the next steps needed to assess the potential health impact of ABR landfill disposal.

It was emphasized that a shared sense of partnership among stakeholders was important to the success of this conference and to the follow-on activities that are determined to be appropriate. This workshop was the second in a series of conferences intended to examine appropriate management of ABR and possible ways to mitigate any public health issues that may arise from ABR disposal.

It is further emphasized that the opinions and statements made in this report should not be construed as reflecting the policies or opinions of EPA, NIEHS or any other agency. The opinions and statements are solely the responsibility of the individual participants at the workshop.

Finally, this report's purpose is to summarily document the presentations and discussions that transpired at the workshop. The report has undergone two rounds of review by all participants of the workshop. It is not intended to be a chronicle of the follow on discussions that have occurred since the workshop even though such discussions are very much a desired outcome of the workshop. A secondary objective of the report is to provide a useful summary of preceding efforts and discussions as a resource for participants in the workshop on "Arsenic and Landfills" planned for October, 2006 in Boston, Massachusetts. Toward this end, an update of discussions and thinking that has occurred since the Rio Rico workshop is useful. Thus, in order to capture post workshop discussion, immediately prior to the report's publication, two page statements were invited from participants for inclusion as un-reviewed appendices. The editor's statement is attached as Appendix A.

## **Sessions II-V: Presentations**

The Workshop began with several presentations covering the characteristics of ABR, current regulatory and management practices for wastes from drinking water treatment utilities, characteristics and management of different types of landfills, arsenic geochemistry, and other factors controlling arsenic behavior in landfills. The attached agenda (Appendix B) provides additional details. The following statements, data and findings summarize information provided in the presentations in the order in which the presentations were delivered. (One exception is made to this order, in that the Session IIb presentation is reported in Session II, despite being delivered, out of the agenda sequence, in Session V due a delay in the speaker's travel schedule.) In order to preserve a sense of context and the flow of the discussion, only those comments made by participants during or in the question and answer period immediately following a presentation are included with the presentation information. Related or similar comments made in later discussion sessions, even though often motivated by information in a particular presentation, are reported in the notes summarizing the later discussion sessions in which they occurred. Note on acronyms: Both ABR (arsenic-bearing residual(s)) and ABSR (arsenic-bearing solid residual(s)) are used in this report. The former refers to all arsenic-bearing wastes from drinking water treatment processes for arsenic removal, whereas the latter (ABSR) refers to only the solid phase wastes generated from drinking water treatment processes for arsenic removal. For instance, the arsenic containing brine waste from an anion exchange arsenic removal process is termed an ABR but not ABSR, whereas a spent arsenic sorbent such as spent activated alumina would be correctly termed both an ABR and ABSR.

### Session IIa: Characteristics of ABR and associated water treatment facilities

EPA is conducting two or three rounds of research comprised of 40 or more pilot projects on small water supply arsenic treatment technologies. Some initial findings related to ABR management and disposal from the Arsenic Demonstration Projects are:

- At the pilot project sites, 25 employ an adsorptive media technology, 5 employ coagulation/filtration (C/F), 6 employ iron removal, 2 employ anion exchange, 1

employs POU (point of use) and one employs coagulation/filtration system modification.

- Iron removal from water supply also removes arsenic, so the choice of arsenic removal method should first consider if iron removal is beneficial.
- Adsorptive media are used at pilot sites in the southwest and northeast, while C/F and iron removal are used at sites primarily in the northwest and north central United States.
- The primary ABR generated by the technology types are: arsenic bearing solid residuals (ABSR) from adsorptive media, mixed liquid and solid residuals from C/F, and liquid residuals from anion exchange and POU.
- Many States require certification by NSF International (a drinking water systems certification program) of any product that has contact with drinking water, and at the present time NSF won't recertify regenerated adsorptive media.
- All spent adsorbent media that were tested "pass" the TCLP test and TC regulatory value for arsenic used to determine whether or not a solid waste is a hazardous waste under current Federal regulations.
- For the pilot sites generating ABSR, 24 will send it to landfills and 1 will have it regenerated by the vendor. Of the sites generating mixed liquid/solid, most will use sanitary sewer discharge. The anion exchange brines may be treated to reclaim the water (with subsequent ABR disposal unspecified).
- Vendors generally overestimate the longevity of their adsorbent media. None have performed as advertised. Some may be regenerable.

#### Session IIb: Regulation of landfills and ABR disposal

Under the Resource Conservation and Recovery Act (RCRA), EPA's Office of Solid Waste regulates landfills and defines what wastes are eligible for disposal in the various types of landfills. Some issues relevant to this workshop:

- ABSR must be managed under RCRA regulations.
- Disposal of non-hazardous ABSR is allowed in municipal solid waste (MSW) or industrial non-hazardous landfills. Construction and Demolition Debris (C&D) landfills are not a legal disposal option.
- Most ABSR pass the Toxicity Characteristic (TC) regulation, which relies on the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP is the most widely-used leaching test to determine if an ABSR is classified as hazardous.
- The TC regulatory level for arsenic is based on a standard dilution attenuation factor of 100 and the old 50 ppb MCL standard, so the TC regulatory value of 5 mg/L doesn't reflect the new MCL level for arsenic of 10 ppb.
- Any solid waste that is a TC hazardous waste must be treated so it does not leach above the Land Disposal Restrictions (LDR) level of 5 mg/l for arsenic, and it must also meet regulations for underlying hazardous constituents.
- In a sample of 200 MSW landfills, the median arsenic concentration in the leachate was 20 ppb, the mean was 441 ppb, the 5<sup>th</sup> percentile was 4 ppb and the 95<sup>th</sup> percentile was 260 ppb.
- From a national regulatory perspective, it was stated that projected groundwater contamination from ABSR at one or two landfills only would not be considered a national problem.

- At this stage there is no absolute, categorical answer as to whether ABR disposal in landfills will cause groundwater contamination, despite it not being classified as RCRA hazardous. Indicators that it may potentially impact groundwater resources include the likelihood that the TCLP under predicts arsenic leaching from ABSR and the TC regulation is out of sync with the new MCL. Indicators that it may not are that: a) ABSR are a low volume waste, b) ABSR must be landfilled, and c) current regulations require MSW landfills to either have liners and leachate collection or otherwise demonstrate no migration potential, unless exempted from modern MSW landfill design requirements promulgated by EPA in 1991.
- Leaching from a waste does not mean that groundwater contamination will occur – only that it may occur.

### Session IIIa: Landfill types and behavior and landfill leachate fate

The following points were made to describe general landfill operations and metal-bearing waste disposal in landfills.

- Landfills are of three basic types: hazardous waste landfills, municipal solid waste landfills and other (construction& demolition debris (C&D) and industrial waste) landfills.
- Modern municipal landfills are typically constructed with a single “composite” liner comprised of a geosynthetic membrane (e.g., 60 mil thick HDPE liner) placed above and in direct contact with a minimum 2 foot thick layer of compacted soil (hydraulic conductivity  $< 10^{-7}$  cm/sec), where leachate is actively collected above this liner system (ref: CFR 40 Part 258; i.e., RCRA Subtitle D facilities; specifically municipal landfills).
- Many landfills truck their collected leachate to off-site wastewater treatment plants, some directly pipe it to off-site wastewater treatment plants, some landfills treat/dispose their collected leachate on-site, and some landfills recirculate leachate through the fill zone (i.e., bioreactors).
- Landfill design and operation promotes rainwater runoff away from the landfill cover to minimize leachate.
- Hazardous waste landfills (i.e., RCRA Subtitle C facilities) have two liner systems, with a second leachate collection (i.e., “leak detection”) system placed between the two liner systems.
- About half the States have a liner requirement for Construction & Demolition Debris (C&D) landfills (Note: current regulations prevent the disposal of ABSR of water treatment processes in C&D landfills).
- It is important to remember that most landfills stay “dry”.
- Waste stabilization in landfills is characterized by four phases: a preliminary aerobic phase, an anaerobic acid forming phase, an anaerobic methane forming phase, and a final aerobic phase.
- The potential problems posed by landfill disposal of metal-bearing waste are: groundwater contamination (primarily an unlined landfill issue), impact on leachate quality, impact on gas quality (e.g., Hg), and long-term operation issues.

- Some of the key factors to be considered in evaluating potential problems are: leachability, rainfall and amount of leachate, and fraction of waste in the landfill.
  - Most workshop participants agreed that the highest potential for groundwater contamination is expected to be from disposal of ABSR in the smaller, "grandfathered" unlined landfills. The fraction of operating MSW landfills which are unlined and subject to potential releases is not currently well characterized. [It was noted in later discussion that from a regulatory perspective all currently operating MSW landfills are required to implement active groundwater monitoring and are subject to associated corrective action requirements.]

#### Session IIIb: Estimating the leaching behavior of ABSR

Laboratory research has been conducted to quantify and understand the mechanisms controlling the leaching of arsenic from ABSR if disposed under mature (methanogenic) MSW landfill conditions. The following points were made regarding estimated ABSR production, laboratory research results and projected black-box modeling.

- About 4000 water treatment plants (WTPs) (95% of which are small) are impacted by the revised MCL.
- Assuming 75% will have to treat for arsenic (rather than blend or find new supplies), it can be projected that about 24,000 lb of arsenic (as As) will be removed annually and require disposal. This arsenic mass will be contained in an estimated 6-24 million pounds of ABSR generated annually, indicating a projected average waste stream concentration entering landfills of 1000 to 4000 ppm.
- Nearly all ABSR pass the TCLP and are expected to be disposed in municipal solid waste (MSW) landfills.
- Under California regulations, the Waste Extraction Test (WET) and/or the Total Threshold Limit Concentration (TTLC, which is 500 mg/ kg for arsenic) will probably bar most ABSR from MSW landfills in that state.
- Mature landfill simulation column studies indicate iron sorbents undergo reductive dissolution and the iron sorbent leaches initially faster than the arsenic leading to a delayed spike in arsenic leaching.
- The studies indicate particle and colloid associated transport of arsenic is a dominant mobilization mechanism, as are also microbial reductive dissolution of the sorbent matrix and the microbial reduction of oxidized arsenic to more soluble reduced arsenite. These mechanisms are not simulated in the TCLP test.
- Based on laboratory studies attempting to simulate, a wet, mature landfill, about 50% of the arsenic in GFH ABSR leached within 900 days. GFH is a common, iron-based arsenic sorbent used for drinking water treatment. In similar bench-scale studies, about 75% of the arsenic in an amorphous iron sludge ABSR leached within one year. Amorphous iron sludge ABSR are produced during iron removal, enhanced coagulation microfiltration, iron amended filtration, and iron salt coagulation operations used to remove arsenic from water.

- A simple Mass Balance Model for arsenic in a landfill raises a potential concern with ABSR disposal in MSW landfills. It suggests that if one assumes, based on laboratory column studies, that arsenic release would reach a steady-state after several years so that the rate that arsenic is disposed into the landfill on ABSR is equal to the rate at which it is released into the leachate, and that 100% of the populace served by the landfill receives drinking water from a public water system (PWS) that is removing arsenic and sending the ABSR to the landfill, then the steady-state concentration in the leachate from the ABSR contribution alone would be 0.36 - 27 ppm. For comparison the toxicity characteristic (TC) for designation of a waste as hazardous is 5.0 ppm. The model used the following estimates which were derived from published EPA frequency and occurrence data or published peer-reviewed literature values: 2.24 g<sub>As</sub>/capita/year (average mass of arsenic removed from water per capita per year by a PWS impacted by the new MCL), 560 kg<sub>waste</sub>/capita/year (average mass of MSW landfill waste generated per capita per year in the U.S.), and 0.15-11 L<sub>leachate</sub>/kg<sub>waste</sub> (volume of leachate produced per mass of waste deposited in an MSW landfill). There was not general consensus as to whether or not a Mass Balance model could appropriately model ABSR associated arsenic in a MSW landfill.
  - A participant suggested that it would not be typical for the all of the populace served by a given landfill to be served by PWS that are removing arsenic and, therefore, the ABSR loading going to the landfill would be less.
  - The presenter responded that this was correct and that the concentration of arsenic predicted in the leachate is linearly proportional to the fraction of the landfill populace that is served by impacted PWSs. So if only 25% of the populace contributing waste to the landfill also received water from an impacted PWS, then the leachate concentration would be predicted to be 25% of that shown, or 0.09 – 6.7 ppm.
  - A participant also commented that the assumption of an infinite source of arsenic, as would be needed to reach such a steady state, is not representative of the ABSR disposal scenario under consideration.
  - The presenter responded that this is not an equilibrium model, but a steady state model, so an infinite source of arsenic is not assumed, but merely that the rate that arsenic arrives in the landfill is equal to the rate that arsenic is released into the leachate.

#### Session IVa: Geochemistry of arsenic

The geochemistry of arsenic and the surrounding environment determines its release from natural and manmade solids and its subsequent fate and transport. Important findings regarding arsenic mobilization and stability in the natural environment which bear on understanding the behavior of arsenic after disposal on ABSR were presented.

- Key geochemical parameters controlling arsenic mobilization and transport: amount of labile iron, amount of sulfur available for oxidation/reduction, pH and Eh (local and gradients), and the role of nitrogen species.
- Both arsenite and arsenate strongly partition with solid iron hydroxides/oxides.
- Iron ( $\text{FeCl}_3$ ) addition has been effective in removing arsenic from solution in the Haiwee Reservoir in Owens Valley, CA to the reservoir sediments through iron hydroxide coprecipitation and adsorption.
- In the high iron, low sulfur case, arsenic is immobile if the environment remains oxidizing. If high carbon is present causing a reducing environment, reductive dissolution of sorbent  $\text{Fe}(\text{OH})_3$  releases As. As(V) reduced to As(III) may remain sorbed dependent on pH, competitive sorbates and available sorbents.
- A high sulfate and reducing environment (created by high carbon) at the Bay Rd. Site, East Palo Alto, CA shows natural attenuation of arsenic.
- In the low iron, high sulfur case, arsenic is immobile if the environment remains reducing as arsenic precipitates with sulfide as  $\text{AsS}$  and  $\text{As}_2\text{S}_3$ .
- The biotic and abiotic reaction rates become key issues as to arsenic stabilization and the problem simulation requires a kinetic modeling approach.
- In one case stabilizing arsenic with Portland cement slowed down the leaching process adequately to protect from short-term leaching problems. In this case arsenate was incorporated into the crystalline sulfate phases.
- Key issues in assessing the potential for arsenic mobilization from ABSR are:
  - Rates of Fe(III) and Fe(II/III) hydroxide dissolution and potential release of sorbed As
  - pH dependent desorption and competitive effects (sulfate, phosphate, silica)
  - Rates of sulfate reduction and production of arsenic-bearing sulfides as well as the rates of reoxidation
  - Influence of N species on As-Fe-S redox rates
  - Cost/benefit of amendment stabilization
  - Reactive transport models must be validated by accurate coupling of biogeochemical and hydrological processes.

#### Session IVb: Biological transformations of arsenic

Biological transformations of arsenic (reduction, oxidation, methylation) are ubiquitous throughout the environment. The role and importance of microbial processes in arsenic mobilization were summarized in the following points.

- Arsenite ( $\text{As}(\text{III})\text{O}_3^{3-}$ ) is more toxic and mobile than arsenate ( $\text{As}(\text{V})\text{O}_4^{3-}$ ).. Methylated arsenicals are less common in typical environments than arsenite or arsenate.
- Extensive leaching of arsenic could be inhibitory to the organisms responsible for methanogenesis at landfills, due to arsenite toxicity at concentrations of about 350 ppb. This may destroy the natural degradation processes of a landfill. This is perhaps a significant issue that could impact the release of other toxicants from landfills, if these natural, chemical-degrading microbes are eliminated by arsenic leachate toxicity.

- Arsenate may be reduced by microbes for either detoxification or respiration (as an energy source).
- Numerous microbes are capable of arsenite oxidation to arsenate. Anoxic denitrification can efficiently oxidize arsenite to arsenate.
- Laboratory column work indicates that in about one year, 15% of the arsenic will leach from spent GFH, a commercial, iron-based solid sorbent in a wet, methanogenic, up-flow landfill simulation. Most arsenic mobilized is as As(III). Both iron and arsenic reducing microbes play significant roles in the mobilization.
- In a biologically active laboratory column containing an activated alumina ABSR, 37% of the arsenic was released in 257 days. 17.4% of the arsenic was released as soluble (less than 0.2  $\mu\text{m}$  filtered) arsenic. Most arsenic mobilized is as As(III).
- If arsenic is in a matrix with Fe or Al solids and low sulfate then it will be stable in aerobic, but not anaerobic environments. If arsenic is in a matrix with sulfide minerals it will be stable in anaerobic, but not aerobic environments.

#### Session Va: Case studies of abandoned and active landfills

SBRP investigators and others have studied arsenic in groundwater at several Superfund NPL sites including the Winthrop Landfill in Maine and the Coakley Landfill in New Hampshire, and work continues at over one hundred closed landfills in the Northeast.

This current research indicates:

- Arsenic mobilization from old landfill sites is: 1) coupled with iron mobilization; 2) tied to carbon sources at the sites; and 3) varies regionally dependent on the amount of iron associated arsenic in the soil.
- Naturally occurring arsenic in soils/sediments under landfill sites can be mobilized by landfill leachate.
- Following capping of the Coakley Landfill Superfund Site, NH, the concentrations of groundwater cationic metals decreased, but arsenic increased.
- Arsenic and iron concentration in the groundwater at the landfill sites studied was inversely proportional to ORP (oxidation reduction potential) and directly proportional to carbon.
- At the Winthrop Landfill site in Maine, arsenic levels in the groundwater rose after capping while DMF (dimethyl formamide) concentrations dropped.
- Arsenic is found in groundwater at concentrations as high as 300 to 1000 ppb at these sites. Sulfide and carbonate precipitation may limit arsenic solubility at some sites.
- Particulate associated arsenic (with iron flocs) is a major factor in seeps where subsurface water impacted by the landfill's presence emerges at the ground surface.
- Arsenic and benzene/other VOCs are statistically highly correlated at NPL sites. 419 of the 555 Superfund sites with arsenic contamination also have aromatic hydrocarbon contamination, while 42 of the 45 NPL sites in the northeast with arsenic also have VOCs.
- Only seven of the estimated 150 old landfills in Region 3 have been sampled.
- Chloride can be used as a conservative tracer for leachate strength and mixing.



### Session Vb: 3MRA modeling of ABSR in landfills

Prior to the Workshop, initial modeling efforts to simulate MSW landfill disposal of ABSR were undertaken by the Center for Exposure Assessment Modeling of EPA's ORD. EPA's multimedia risk assessment model, 3MRA (Multimedia Multipathway Multireceptor Risk Assessment), was used to estimate potential impacts to the environment and the public health as a result of the disposal of the ABSR in MSW landfills. 3MRA generates a probabilistic risk assessment which estimates the maximum concentrations in waste entering the landfill at which specified risk levels would not be exceeded by selected percentiles of human and ecological receptors (e.g., 99%), at selected percentiles of probability (e.g. 95%), at a selected % of sites across the country (e.g. 95%). The focus of the modeling exercise was to predict impacts from ABSR disposal in unlined landfills on a national-scale, and used an equilibrium partitioning,  $K_d$ , approach to characterize the landfill source term. The 3MRA landfill module is based upon the well known Jury model with enhancements that allow for: 1) incremental deposition of wastes (cell by cell construction) over the operational period of each landfill (assumed to be 30 years in this analysis), and 2) a finite length subsurface soil column.

Important assumptions and values used in the model and the 3MRA predictions generated follow.

- The  $K_d$  distribution used was developed in part based on the Ghosh et.al. (2004) paper, as well as on unpublished data from subsequent column studies by the same researchers. Other model input distributions that were used to reflect the likely ABSR waste characteristics and disposal conditions were the landfill fill mass fraction (i.e., the fraction of all waste in the MSW landfill that is ABSR), and the dry bulk density and water content of the ABSR.
- Based upon the national input distributions of the analysis, the initial 3MRA modeling indicated that overall there was a very low potential for risk in unlined landfills at equivalent risk levels used to develop the new 10 ppb MCL. A statistical sample of 56 industrial landfills is in the national database for 3MRA and was used in the study.
- The study assumed unlined landfill conditions; liners would provide a greater degree of protection to groundwater resources.
- Based on data originally provided by other researchers attending the workshop, a triangular distribution for the arsenic solid partitioning coefficient (i.e.,  $K_d$ ) of 35, 1000, 3500 L/kg was used in the study. Estimates of moisture content and dry bulk density of ABSR materials were also made from this data source.
- Based on an assumption of deposition in facilities ranging from 50 to 400 TPD (representing small to moderate-sized landfills), and estimates of ABSR generation rates and As concentrations, a waste mass fraction ( $F_{wmu}$ ) of ABSR (i.e., % ABSR by volume *in situ*) was estimated, represented as a uniform distribution ranging from 0.00002 to 0.0002.
- Regarding deposition of ABSRs, with 95% confidence, 3MRA estimated protection of 99% of humans at 95% of all sites for the following associated

cancer risk levels, health hazard levels, and waste stream concentrations (i.e., exit levels = level below which deposition is deemed protective):

Risk Category	Risk Level	Exit Level (ppm)
Cancer	$<7.5 \times 10^{-7}$	220
Cancer	$<2.5 \times 10^{-6}$	250
Cancer	$<7.5 \times 10^{-6}$	760
HQ	$<0.5$	$>10,000$
Cancer	$<5 \times 10^{-5}$	$>10,000$

- At  $5 \times 10^{-5}$  cancer risk level, bounding the new MCL standard of 10 ppb, deposition of ABSRs at all levels up to 10,000 ppm were observed to be protective for 95% of humans at 100% of sites studied in the analysis.
- For comparison, simulations were also run with a constant Fwmu of 1 (i.e., representing a unrealistic concept of 100% ABSR loading to all facilities nationwide).
- For Fwmu = 1 (i.e., if the landfill contained nothing but ABSR), the model predicted 95% of sites would be protective, with a confidence of 95%, for an ABSR concentration of 0.136 ppm or less. This latter scenario essentially asks the question what arsenic level in the ABSR would 3MRA predict to be safe (i.e., not exceed the risk criteria) if every municipal landfill nationwide were completely filled with ABSRs.

Extensive discussion arose in response to the 3MRA modeling presentation. Most of the discussion focused on modeling of the source term. Significant concern was expressed by several geochemists that the Kd values specifically, and in general, the partitioning model approach didn't accurately reflect the landfill environment. The geochemists argued that kinetic models would be more reliable and could be formulated for modeling release, but acknowledged that a better source term model does not currently exist. As well, it was acknowledged as general consensus that additional work could be done to further evaluate uncertainty in parameterization of arsenic Kd values. However, a participant noted that the model does not account for loss of sorbent, so in their opinion the most important variable is unaccounted for in the model. In response the presenter opined that the arsenic release due to loss of sorbent could be captured by appropriate parameterization. One participant favored the use of  $K_d = 0$  (i.e., immediate release of all landfilled arsenic), where others expressed the view that the distribution of values should be reduced (e.g., T(0, 1, 10), T(1, 10, 100), etc.) to more accurately reflect potential in situ time-scales of biotic reduction of sorbents anticipated. There was not general consensus as to whether or not a Kd model could appropriately model ABSR associated arsenic in a MSW landfill. By the end of discussion, however, most participants felt that Kd models could be useful and informative of ABSR disposal risk. As well, longer term strategies involving the development of enhanced biogeochemical modeling abilities would be of considerable value in improving the accuracy of the models overall, and should be a long-term research priority.

**Sessions VI - IX: Open Discussion: Approaching an integrated assessment of the potential risks from ABSR landfill disposal and the next steps in assessing ABR impact.**

Four sessions were scheduled for developing an assessment of our current understanding as to whether or not ABSR landfill disposal presents an unacceptable risk and, to the degree needed, determining next steps that should be taken in improving this assessment. However, the discussion in the various sessions largely overlapped one another and issues arising in one session were typically re-examined and discussed in later sessions. This wide-ranging discussion covered many of the inter-dependent processes involved in generation and management of ABSR, as well as disposal practices and the ultimate fate of the arsenic in these wastes. The comments expressed in the session fell loosely into six topical areas: 1) modeling ABSR and arsenic behavior, 2) regulations, 3) life cycle management of arsenic, 4) operational considerations regarding arsenic removal technology choices and landfill management, 5) determination if ABSR represent a potential 'national' problem, and 6) other considerations. Consequently, the reporting of the subsequent workshop proceedings is not organized by workshop session but by topical area. That is to say, the comments and opinions, which follow, may have occurred in any or several of the sessions and the discussion has been grouped into the listed topic areas for purposes of clarity. It must be emphasized that the statements reported are the opinions expressed by various individual participants and, unless otherwise stated, are not consensus statements from the workshop participants or positions necessarily held by more than the individual commenter.

1) Modeling ABSR and arsenic behavior

As noted above, several geochemists commented that current models don't work for arsenic, because 3MRA and other models don't reflect the unique geochemistry of arsenic, while at the same time acknowledging that no better, single model currently exists. Some of participants stated the partitioning coefficient (Kd) approach such as used in 3MRA is inherently flawed for the case of modeling arsenic release from waste ABSR and that a kinetic approach was needed to account for processes such as reductive dissolution of sorbents, microbial activity, rate limited transformations in redox gradient zones and precipitation rates. One participant indicated that the "standard" equilibrium models are not accurate for arsenic in certain cases, particularly those involving sulfur species. Another participant responded that the fate and transport codes in 3MRA represent well established legacy codes, where 3MRA has undergone extensive, module-level and system-level peer reviews, and has been recommended by EPA's Science Advisory Board (SAB) as an appropriate tool for informing national-scale risk assessments regarding waste management disposal problems.

Some participants argued that model simulations should capture the worst case for arsenic disposal, since that was their understanding of the original rationale for the TCLP, i.e. a plausible, or realistic, worst case situation for the leaching potential of a material to be disposed in a landfill. The notion as to what was the realistic, worst case situation for ABSR disposal generated considerable discussion and no agreed upon consensus, although it was generally agreed that the worst case would not be filling a landfill solely

with ABSR and would entail co-deposition of both organics and ABSR. Simulations were conducted by EPA for demonstration purposes at ABSR loads of 100% and were compared to the national-scale ABSR deposition scenario considered in the primary modeling effort, which itself considered realistic ABSR to landfill volume ratios. Both exercises assumed release of arsenic using the  $K_d$  partitioning mechanism and input values developed based on the Ghosh et al. paper and in conjunction with the workshop organizers, to estimate releases of As.

Disposing ABSR in a landfill with organic waste is considered representative of the worst case, because, eventually, through reductive dissolution the arsenic will be released from the ABSR. It was noted that not all of the arsenic may be released, for example due to zonation in the landfill, and other re-adsorption mechanisms in the landfill that are not accounted for in the model formulation. This would be a new level of detail and sophistication for landfill modeling, and 3MRA cannot simulate all of the details of microbially mediated reductive dissolution of arsenic as it is presently configured; in fact, there currently is no well known model that represents this process. 3MRA input distributions can be set to characterize release rates of arsenic via equilibrium partitioning and sequenced exchange volumes of infiltration. This is what the EPA research team attempted to do before the meeting, in collaboration with the workshop organizers who assisted in providing data used in the initial analysis. While it would be highly desirable to have an alternate, more sophisticated modeling capability in place today, a model addressing detailed geochemical mechanisms simply is not currently available. There is also a lack of adequate data to supply quantitative parameterization for such a model if it did exist.

There was a general consensus that it is a high priority to develop models that are arsenic specific, but there was not general agreement as to whether 3MRA, using its present approach, was capable of achieving this objective. All of the modelers and the geochemists felt that additional consultation would be helpful in arriving at a better understanding of how best to parameterize existing modeling capabilities, particularly for the release term, but also for the groundwater transport modeling. Several participants suggested that modeling should focus on case studies, particularly those where research has reasonably characterized the release, transport and rate terms, as a means to validate model functioning for arsenic simulation before focusing on national or general assessments. Several participants considered that while case studies may provide useful information for understanding the mechanisms of ABSR leaching and the field parameters that can significantly affect it (and thereby improve our modeling capabilities), case studies are inherently incapable of responding to the question of whether ABSR landfilling is a national concern.

It was agreed by all present that development of a biogeochemical model would be of considerable value in improving the accuracy of the models overall, and should be a long-term research priority. It was also generally agreed that this could not be done in the short-term, although there were short-term, useful modeling efforts that should be undertaken. A number of participants expressed interest and willingness in participating in these efforts.

## 2) Regulations

A participant observed that there are no regulatory efforts envisaged that would change the present rules controlling ABSR disposal and that there will be no sense of urgency to change regulations unless new modeling and projections indicate risk of sufficient national significance to warrant the effort and resources necessary to make such regulatory changes. The participant added that current modeling and projections do not demonstrate this significance. Another approach discussed was whether there were non-regulatory approaches that could be utilized, such as EPA guidance to address this issue, if the science were to show that an issue exists. EPA responded that national guidance was almost as difficult to issue as a regulation, which is prohibitive in the short term. State representatives were asked about what independent authority they had beyond the Federal requirements to address this arsenic issue without an EPA regulation. The State participants generally responded that they had very little authority or motivation to go beyond what is in their regulations (and these are typically based on federal regulations). It was also noted by a participant that some states, such as California, may go their own way on such issues due to their regionally specific factors and concerns.

## 3) Life cycle management

The discussion was opened with a participant's perspective that liners in landfills aren't the answer to ABSR disposal. The suggestion was made that risk assessment should focus on how leachate is handled and what happens to arsenic in the leachate so that downstream negative consequences do not occur. This preamble to life cycle management of arsenic represented a recurring theme of many discussions. The desire by some participants to investigate this concept as an ultimate risk management strategy arose as a key outcome of discussions that could guide the purpose and scope of future research, workshops, collaborations, and partnerships.

This life cycle management approach was a part of discussions concerning the disposal of landfill leachate that contains arsenic and the mobilization of naturally occurring arsenic. The point being, that arsenic and metals, in general, are not degraded and may continue to cycle through the environment; that is, the same issue arises in the management of all metal-bearing wastes. For example, if landfill leachate is taken to a wastewater treatment plant the arsenic will either: 1) be reloaded onto biosolids and returned to the landfill or a land application unit, or 2) be released to surface waters. Thus, argued some participants, the arsenic problem must ultimately be viewed in the context of its use and disposal through time, treatment settings, and the environment. They believed that ultimately, it would be desirable to identify ABSR management actions that will minimize the potential for environmental contamination from arsenic through all post-disposal transformations, relocations and media transfers it may undergo. Many participants expressed a viewpoint that this should involve preventing the inter-media transfer of arsenic from ABSR unless such transfer is consistent with what has been determined to be the most cost-effective and protective ultimate fate for the arsenic. It was agreed that this is a difficult endeavor. Further, a participant noted, that any attempt to generalize such an approach to waste

management would be difficult and resource-intensive, and implementing it would require significant restructuring of current regulatory programs.

The current management scheme does not necessarily keep the arsenic in ABSR from entering the leachate and leaving its fate to be determined by how the leachate is managed. One participant noted that if ABSR are disposed in a bioreactor landfill, the arsenic could accumulate in landfill leachate until, eventually, it may potentially have to be disposed as a hazardous waste or reach a concentration at which the microbial processes in the landfill are adversely affected. Another potential scenario of concern raised was that if the leachate is disposed to a wastewater treatment plant it may increase the biosolids' arsenic loading to a level that would preclude land application in the current manner or rates now practiced. It was noted by another participant that regulations are in place that govern such wastewater treatment plant situations. Biosolids from POTW treatment may be land applied under the 40 CFR Part 503 program, which restricts metals levels and prohibits the land application of hazardous wastes. One participant stated the opinion that land applied biosolids will experience oxidizing conditions and may be stable in surface soils for many years. Any biosolids that are hazardous waste are required to be treated and landfilled in accord with RCRA Subtitle C (hazardous waste disposal) requirements.

Another issue that arose related to arsenic life-cycle management was that ABSR is not the only source of arsenic in landfills. The participant noted that there are many sources of arsenic going into landfills and that it is unwise to base a determination as to the appropriateness of disposal of a single arsenic waste source on whether or not that source is alone sufficient to cause the landfill leachate to reach a hazardous or undesirable arsenic concentration level. It was suggested that it is most likely that it will be the combination of contributions from several arsenic waste sources, which cause problems, rather than the fault of a single source. It was suggested that the arsenic sources should be considered as to which are most readily mitigated for the greatest net effect in avoiding a problematic concentration of As in the leachate being reached. It was noted that in terms of mass of arsenic alone, ABSR may not be the largest arsenic source in a landfill. For instance, the predicted mass of arsenic in chromated copper arsenic (CCA) treated timber due to be disposed in the near future is much greater than that in ABSR. However, because the current research suggests the arsenic in ABSR is readily and fairly quickly released and because some participants felt there seem to be feasible and affordable means to avoid having ABSR contribute to a landfill's arsenic leachate load, then the current strategy for disposing of ABSR is a legitimate concern. It was suggested that ABSR are low hanging fruit when trying to pick how to avoid potential problems with excess arsenic in MSW leachate. Other participants thought ABSR were unlikely to pose groundwater contamination problems, and that any suggested action await a well substantiated demonstration that ABSR is likely to be a problem.

#### 4) Operational considerations (technology choices and landfill management)

It was recognized that water treatment utilities are not likely to undertake additional costs to stabilize the arsenic in ABSR without additional motivation. The discussion included potential technological solutions to this issue, i.e. how can we extend the residence time

of arsenic in landfill solids, so it doesn't leach so quickly into groundwater or the leachate treatment environment? Is encapsulation in Portland cement a possibility? This has been considered in research on arsenic leaching both in the U.S. and abroad and the results are varied as to effectiveness - some work showing enhanced stabilization, while other suggests poorer arsenic retention than for the unencapsulated case. There may be other technologies for stabilizing arsenic in ABSR, but they all entail some additional costs for small drinking water utilities, so none are expected to be widely used unless concern for liability is high enough to warrant such additional costs. Further, there is not general agreement that this will be necessary.

It was noted by a participant that another option for managing the ultimate fate of arsenic is leachate recirculation (i.e., onsite bioreactors). Rather than removing arsenic in landfill leachate and transferring it to wastewater treatment plant sludge and effluent or some other leachate management site, it may be better in the long run to recycle it back into the landfill environment. Several issues would have to be considered in this scenario as a recommendation for alternate leachate management to achieve desired "life-cycle" management. Another participant stated that bioreactors themselves present several additional problems, which can in some cases outweigh the benefits associated with management of arsenic fate in this manner.

Based on economic drivers, ABSR are most likely to be disposed in MSW landfills near the areas where they are generated. While these landfills are currently constructed with single liner systems with leachate collection, designed to contain and remove the leachate, some small unlined MSW landfills were grandfathered in under these regulations, and remain in operation today. An undetermined number of these unlined landfills may conceivably receive ABSR, though the degree to which this may occur is not currently well-defined. The number and characteristics of "grandfathered" unlined MSW still in operation today, which may conceivably receive ABSR, is not well quantified. These landfills likely present the most immediate concern for arsenic leaching into groundwater due to potential ABSR deposition. Concerns were raised about the unlined landfills and whether or not it is possible to determine how many there are and where they are located. Chartwell is a private company that has likely the best available data on unlined landfills in the US, which could be used to shed additional light on this aspect of the ABSR management problem. Another option proposed by one participant was to go directly to the States to inquire how many unlined MSW landfills exist and where they are. It was cautioned that States may not have that information in an accessible form.

The operative question is "What is the likelihood of existing unlined landfills receiving significant quantities of ABSR waste in the future? How many landfills, how much ABSR? It was noted by EPA that the current presentation of modeling efforts focused on unlined landfills, and these would again be considered by EPA in reformulating any alternate parameterizations of the initial study conducted. Further, any existing unlined landfills would have been "grandfathered" into continued operation more than 12 years ago, and in all likelihood had been operating for several years before that, at a minimum.

These landfills may well be nearing the end of their operational life, and may receive ABSR for only a few years.

After considerable discussion a majority of the participants agreed to the statement that it is not prudent to dispose of ABSR in unlined landfills.

EPA OW is compiling MCL compliance data from the States. EPA is encouraging the States to allow more time for implementation of the Arsenic MCL. It was reported by one EPA participant that 16 states will be receiving waivers that will delay arsenic MCL implementation (and generation of ABR) by 3 to 9 years, further reducing potential risks from any remaining unlined landfills. Follow up with EPA OW and individual states should indicate if all of the states with high levels of arsenic contamination in drinking water are included in that group and what fraction of the water systems in a state are likely to receive waivers.

With any proposed solutions to the problems posed by the workshop, however, one must consider what motivates the market to respond. Other than liability management (i.e., the desire to not become a Superfund PRP), which can be significant, important, and quite effective, there are no apparent financial incentives for the market (i.e., ABSR generators and technology vendors) to spend additional resources and make additional efforts to prevent arsenic leaching from ABSR. The present regulatory and market incentives do not encourage vendors to do anything more with ABSR than send them to landfills, since no more is legally required, and there is currently not a compelling case that more is necessary for liability management. A participant suggested that it may be possible, through the dissemination of information to landfill owners to motivate them to test the ABSR being received more aggressively, since at that point, it is the landfill operator that will bear the added cost if the landfill leachate reaches arsenic concentrations precluding its normal disposal. Another view was expressed that information dissemination may motivate the various stakeholder groups, even without immediate financial incentive, to take actions to limit the potential for environmental contamination.

##### 5) Is ABSR landfill disposal a national issue?

There was a discussion as to whether ABSR disposal is likely to be a national issue, or a more narrowly focused regional or local problem. In general the distinction for classifying this as a national or local problem is the number of landfills receiving ABSRs that are estimated would subsequently contaminate the environment with arsenic as a result of the ABSR disposal. One perspective voiced was that based on the assessments provided at the meeting it appears unlikely that more than a small handful of landfills will contaminate ground water and drinking water wells as a result of accepting ABSRs for disposal. Based on this consideration the speaker concluded that ABSR disposal is therefore likely to be a local problem only, if it does prove to be a problem (as represented by those few landfills) and not a national waste management problem. Another perspective voiced was that because at this time, based on a life cycle and cumulative impact perspective, there is evidence suggesting that disposal of ABSR may cause environmental contamination or unexpected economic burdens (i.e., on landfill



operators, wastewater treatment plants), then it should be considered a national issue until it can be clearly demonstrated that this disposal will only have isolated local impacts.

Several participants suggested that exceptional conditions at a few sites is not a basis for establishing a national regulation or alarm. It is important to determine conditions under which significant arsenic exposure and risk could occur. Regarding the sole issue of consensus regarding the caution with respect to deposition in unlined landfills, notably, new survey data should become available (e.g., Chartwell Information) in the next year which could be used to better characterize these types of facilities on a national scale. It was not discussed if or by whom a study to evaluate this data would be undertaken.

#### 6) Other considerations

One of the more important conclusions from the arsenic work to date is that the TCLP test (i.e., hazardous waste determination) does not appear to serve well its intended purpose with respect to ABSR disposal in MSW landfills.

Several participants noted a concern of the single liner systems of new MSW failing and causing groundwater contamination. In the case of failed liners for ABSRs, an EPA participant stated that these situations would present concern at only a few sites and that liners that fail still provide greater protection than would be found in the same landfill if unlined. Further, appropriate regulatory mechanisms are in place to deal with these situations (i.e., groundwater monitoring detection, assessment, and corrective action requirements). As such, the concern of failed liners would not warrant concern for change in national-scope policies currently associated with management of ABSR.

Some additional background information on existing Superfund sites was also discussed. Over 500 Superfund sites have arsenic contamination, and over 200 of these sites are municipal or industrial disposal sites with arsenic as a contaminant of concern. Arsenic is already a significant issue in landfills in the Northeast according to some participants. A commenter stated that residents in these states would likely be concerned about more arsenic going to their landfills – particularly in a form that is considered likely to release the arsenic in a relatively short period of time.

At various times participants suggested alternative management strategies for ABSR rather than simple disposal in MSW landfills. Several participants stated that there are inexpensive measures that could be taken, with the most commonly voiced being that ABSR should be separated from organic matter. This could be done by placing the ABSR in industrial-lined landfills or sequestering them in separate cells in MSW landfills. Stabilization techniques such as encapsulation and mineralogic aging were also mentioned.

## **Sessions IX - X: Open Discussion: Next steps and communications.**

The final two sessions of the conference were open discussion sessions dealing with communication of information on ABR management and on the next steps that are needed in assessing ABR impacts. Some discussion on these topics occurred in earlier sessions, but is consolidated here where the bulk of the discussion occurred.

### Communication

A recurring theme for some participants was what and how best to communicate what the current science indicates and, equally importantly, what are the uncertainties within the science and modeling. The challenge expressed by several participants is to communicate the current science concerning the release of arsenic from ABSR under MSW landfill conditions and, more generally, the problems with arsenic related to MSW landfills, while simultaneously conveying the significant uncertainties as to the environmental risk this implies and without creating undue alarm. Other participants thought issuance of any statement is premature, given the results of the 3MRA modeling assessment, and the overall uncertainty about whether ABSR disposal is likely to be problematic, and if a problem, the likely magnitude of the problem. The remaining uncertainties in the current science and modeling make it impossible to prove or disprove that placing ABSR in MSW landfills will create a human or environmental risk that is of concern at the national level.

Further discussion on information dissemination was believed to be indicated by some participants, while it was considered premature by others. A number of participants felt that due to implementation logistics of enforcing the new MCL treatment rule and the time lag between implementing a drinking water treatment technology and having resultant ABSR ready for disposal, that there is adequate time for more informed analysis of this problem and communication beyond the above noted statement (to caution against disposal in unlined landfills) would be premature and possibly cause unnecessary, unsubstantiated alarm. Other participants advised that a more immediate, precautionary communication approach be taken. The reasoning was that ABSR are currently now being sent to MSW landfills, albeit at a lesser rate than projected several years hence, and that non-regulatory guidance and information should be communicated as to alternatives for treatment and disposal that would lessen releases of arsenic from ABSR in landfills and, more generally, avoid potential broader ramifications (e.g., to wastewater treatment plants, landfill leachate handling). These participants suggested that guidance and information is needed now since it is now that drinking water providers are in the process of selecting and costing out their arsenic removal strategies and, consequently, the type and disposal method of their ABR.

A variety of stakeholder groups were suggested as potential audiences to whom to communicate information on this issue and supporting research – e.g. ASTSWMO (Association of State and Territorial Solid Waste Management Officials), SWANA (Solid Waste Association of North America), ITRC (Interstate Technology Regulatory Council), AWWA (American Water Works Association). Another suggestion was to set up a website of the relevant studies and materials for others to access and become familiar

with the issue, concerns and possible fixes. It was also mentioned that EPA ORD has other tools for disseminating information. They include issuing scientific reports and issue papers, which, if co-authored by EPA, go through standard EPA peer-review and clearance procedures.

It was suggested that the research translation project leaders for the SBRP programs at the University of Arizona, Columbia University and Dartmouth College should have a conference call to discuss how this issue should be communicated to the relevant stakeholders. These science communication experts may be able to advise on how best to disseminate the state of the science without unnecessarily causing alarm.

### Next Steps

Future research topics were identified for possible follow up:

- Another possible approach to assess the priority of this threat would be to research where ferric chloride has been used as a coagulant and its residuals sent to MSW landfills. Is there arsenic groundwater contamination found there? Are there MSW landfill sites that could be identified to assess whether or not arsenic has leached into the groundwater?
- A comparison of biotic and abiotic rates for ABSR dissolution could improve simulations in landfills.
- What are the implications of arsenite build-up on the inhibition of methanogenic activity in landfills? Under what conditions would this occur in the field? Has this ever occurred in the field?
- Gathering and scrutinizing for data quality specific case studies for insight into the ABSR disposal issue and for revising and ground-truthing of the model approaches such as 3MRA.

There was discussion of a need for a follow-up meeting with those interested in arsenic geochemistry to help EPA determine if, how, and in what time frame the 3MRA model could be revised to address the arsenic release and mobility issues raised at the workshop. This included discussion along several lines: a) addressing parameterization of  $K_d$  in the existing 3MRA formulation, b) investigating possibilities for direct enhancement of the source term module to better account for underlying geochemical reaction mechanisms, and c) construction of a thermodynamic or an enhanced model including both equilibrium and kinetic capabilities. The EPA groundwater research lab in Ada, OK could help in this effort, as could a number of the academic participants at the workshop.

Enhancement of the 3MRA model would not realistically be feasible to address by the next workshop. Conceptually, it was determined to convene interested researchers in the interim. It was also mentioned that the US Army Corps of Engineers' reactive transport model that has been applied to the Vineland, New Jersey Superfund site, which involves arsenic contamination and cleanup, should be looked at.

The next Arsenic Workshop is tentatively planned for New England, presumably Boston, in fall 2006. In addition to an update on the ABSR disposal in MSW landfill issue, it will more thoroughly address other broader arsenic and landfill issues. The participants recommended retaining the presentation and open discussion format used in this

Workshop, but allowing more discussion time after each presentation. The conference should include the EPA New England Regional office (Regional Managers, Bill Brandon, Dick Willie, Ed Hathaway, Chris Ryan, etc.), States, landfill operators, technology vendors, and drinking water treatment utilities. Conference agenda topics need to be thoroughly considered, but in addition to an update of the topics covered in this workshop, the next workshop agenda probably should include health effects of arsenic exposure, ABSR generated by those removing arsenic from water supplied by private wells, remediation of arsenic-contaminated landfills, case studies of risk assessments and clean up decisions at arsenic-contaminated landfills, and ABSR and other sources of arsenic going to landfills. Additionally, another follow-on workshop is suggested on a much narrower focus of a comprehensive review of the biogeochemistry issues involved in ABSR and other arsenic-bearing wastes' disposal. Such a workshop should evaluate approaches for incorporating this science into our current modeling efforts.

### Conclusions

The specific question asked at the outset of the workshop was: "Is there a problem with disposing of ABSR in non-hazardous landfills? Overall the conclusion by the majority of participants at the conference was that the question could not be confidently answered yes or no. The risks likely to be posed by ABSR disposal were as yet "uncertain" as to the extent of the public health risk and environmental contamination from disposal of ABSR in MSW unlined landfills. The issue deserves more follow up in preparation for the next arsenic conference to address the uncertainties regarding the public health impact. However, it was agreed by the majority of participants that a statement can be made that it is not prudent to dispose of ABSR in unlined landfills.

## List of Workshop Participants

Souhail Al-Abed	EPA ORD (Cincinnati, OH)
Beth Anderson	NIEHS
Justin Babendreier	EPA ORD (Athens, GA)
Ben Bostick	Dartmouth College
John Calkins	AZ Dept Environ. Quality
Steve Chillrud	Columbia University
Dave Dzombak	Carnegie Mellon University
Jim Field	University of Arizona
Jay Gandolfi	University of Arizona
Joe Graziano	Columbia University
Patrick Gurian	Drexel University
Josh Hamilton	Dartmouth College
Edward Hansen	NM Dept Environ. Protection
Greg Helms	EPA OSW
Bruce Holmgren	NV Dept Environ. Protection
Rudi Hon	Boston College
Mark Kaminski	NV Dept Environ. Protection
Gerry Laniak	EPA ORD (Athens, GA)
Karla Nuñez	University of Arizona SBRP
Peggy O'Day	University of California Merced
Karen Palmer	University of Arizona SBRP
Robert Puls	EPA ORD (Ada, OK)
Monica Ramirez	University of Arizona SBRP
Larry Reed	NIEHS Contractor
Eduardo Sáez	University of Arizona
Sally Safioles	WA Dept of Ecology
Malcolm Siegel	Sandia Natl. Lab
Tom Sorg	EPA ORD (Cincinnati)
Charles Thomas	NM Dept Environ. Protection
Tim Townsend	University of Florida
Larry Whitson	NIEHS Contractor
Corey Yep	CA Dept Toxic Substance Control

## Appendix A - Organizer's Statement

As hoped by the organizers, considerable excellent discussion was generated before, during and after the workshop. This probing evaluation is much needed as there are large areas of scientific uncertainty and important unanswered questions regarding the significance, ramifications and next steps to be taken in addressing ABR disposal issues. The uncertainty in and differences of opinion as to what actions are needed are accentuated because the ABR disposal discussion is now largely a proactive, rather than the much more common, reactive environmental effort. It is only as of January, 2006 that compliance with the new arsenic in drinking water standard became mandatory. Evaluating the question as to how to properly dispose of ABR is not a study of what has happened, but a prediction of what will happen. Thus, it is an opportunity to avoid negative environmental consequences, to the degree that they may occur, rather than a need to remediate past shortcomings. However, this also means that evidence on which the analysis rests is almost entirely derived from laboratory or model simulations or from predicted similarities to other similar, but not identical, geochemical processes that have been studied in the field. There is no direct field evidence currently available of the different disposal alternatives, and by the time there is, the opportunity will have been lost for preventing what, if any, negative economic or environmental consequences may eventuate. That said, it was generally agreed by workshop participants that the greatest risk of immediate environmental contamination caused by ABSR, non-hazardous landfill disposal is for the case of disposal in still operative, unlined landfills. This coupled with recent scientific evidence that assessment protocols underestimate the release of arsenic from ABSR, and that arsenic may remain mobile through subsurface media in the presence of landfill leachate plumes, led the majority of participants to agree with the advice that it is imprudent to dispose of ABSR in unlined landfills. This is not to say, that immediate regulatory changes are indicated or that this necessarily impacts a large number of landfills, but merely that it is low cost, reasonable, precautionary guidance in light of the evidence and uncertainties.

Considerable workshop discussion focused on the question of how significant a potential problem ABSR disposal is. A pivotal point in this discussion is the fact that ABSR is a low volume waste stream compared, for instance, to the volume of waste entering MSW landfills annually or to the volume of other arsenic waste sources such as CCA treated timber. Annually, several hundred million tonne of solid waste goes to MSW landfills and about 500 tonne of arsenic (as As) is predicted to be put into landfills (monofill, C&D and MSW) from CCA treated timber disposal, while ABSR will contribute only about 14 tonne of arsenic (as As). It was pointed out in the workshop, however that this seeming insignificance of ABSR volume hides a critical factor - that it is the combination of the rate of arsenic release and the mass deposited in the landfill that dictates the final leachate concentration, not simply the mass deposited. Laboratory simulations of wet landfill behavior presented from two different studies indicated annual arsenic release from ABSR ranged from 15-70% of the disposed arsenic mass, while disposed CCA treated timber releases 0.05-0.1% of its arsenic mass per year. Consequently from the perspective of their contribution to the arsenic concentration in the leachate, 14 tonne of arsenic in ABSR is the equivalent of 2,000-20,000 tonne of

arsenic in CCA treated timber. By the same token the enormous volume of total solid waste is of consequence only in that it contributes to the leachate production rate, contributes to the organic matter mass that constitutes the carbon source and electron donor for microbial reduction processes of iron and arsenic, and some constituents of it may act as sinks for arsenic released into the leachate, although the significance of this latter process has not yet been demonstrated or quantified.

Early in the first open discussion session of the workshop, a participant noted that if you assume that all arsenic in the ABSR disposed in MSW lined landfills remains contained in the landfill or the landfill leachate, the key issue becomes how is the leachate from landfills handled? This comment was representative of a commonly voiced theme; simply finding whether or not arsenic released to the leachate percolates into the groundwater underlying the landfill, does not answer the question if landfill disposal of ABSR presents an environmental problem. Several potential problems were enunciated even if landfill liners work as designed and all leachate is contained, monitored and disposed of appropriately. For instance, evidence was presented that if the leachate arsenite concentration reaches a ppm level, methanogenic activity may be severely retarded and normal landfill waste decomposition inhibited. If the landfill leachate arsenic level increases so that the leachate is classified as hazardous, then normal leachate disposal is precluded and the landfill must bear the management and cost of hazardous waste disposal. Alternatively, if the landfill leachate is pumped in intermittent bursts and disposed to sewer as is common practice, then the wastewater treatment plant will receive slugs of arsenic-bearing water which may impact the treatment plants normal operation, ability to reclaim water and/or biosolids land application practices. The likelihood and extent of none of these domino effects is as yet studied, yet their plausibility suggests that even if current landfill practices limit direct arsenic migration to groundwater, plausible eventualities exist that may well have negative economic and practical impacts. The bottom line is that the wisdom of ABSR disposal cannot be simply judged by the likelihood of direct groundwater contamination, although this should be the highest priority immediate concern. ABSR disposal must be judged by the whole-life, economic and environmental impact on the landfill and the downstream leachate processes. This implies that the ultimate fate of the arsenic in the water treatment residuals should be identified for all feasible ABSR disposal strategies and associated media transfers. Subsequently, the strategy should be recommended, which provides the most cost-effective, environmentally protective whole-life solution.

Finally, dissemination of the information regarding potential issues; current uncertainties; and prioritized research, modeling and data collection needs should be more widespread and open, due to the breadth of potentially impacted sectors (i.e., water treatment, solid waste disposal, wastewater treatment), the seeming lack of widespread awareness of the issue, and the fact that water providers are currently still making large economic decisions as to what technologies to employ and residuals disposal practices to adopt. The workshop organizers believe workshops such as the currently reported effort can play an important role in this effort by providing a forum for a broad group of interested parties from academia, state and federal regulatory agencies, and practitioners to share information and discuss future work.

## Appendix B - Workshop Agenda

### Agenda

#### Day One (Monday, February 13)

**Breakfast** (Served in the Catalina Room) [7:30-8:15am]

[All Sessions held in the Patagonia/Santa Rita Rooms]

**Session I.** Welcome and Introduction [8:20-9:10am]

- a. Welcome  
[J. Gandolfi, – 5min]
- c. Public health research and environmental programs collaboration  
[B. Anderson – 25min]
- c. Problem statement and workshop goals  
[W. Ela – 20min]

**Session II.** What are the character, concentration and generation rates of the ABR that will be generated and how will they be disposed?  
[E. Sáez, Moderator] [9:15-10:15am]

- a. Review of types, volumes, arsenic loadings, geographical distribution, and disposal strategies of ABR  
[T. Sorg – 30min]
- b. Review of regulation of landfills and ABR disposal  
[G. Helms – 30min]

**Break** [10:15-10:30am]

**Session III.** How and how well do we assess ABR and understand landfills?  
[S. Al-Abed, Moderator] [10:30-11:30am]

- a. Landfill types and behavior and landfill leachate fate  
[T. Townsend – 30min]
- b. Estimating leaching behavior of ABR  
[W. Ela – 30min]

**Lunch** (Served in the Sierra Madre Room) [11:30am-12:30pm]



**Session IV.** What are the character and conditions of likely arsenic transformations in and out of landfills? [J. Hamilton, Moderator] [12:30-1:20pm]

- a. Geochemistry of arsenic  
[P. O'Day – 25min]
- b. Biological transformations of arsenic  
[J. Field – 25min]

**Session V.** What can we learn from existing landfills' behavior and model simulations?  
[J. Graziano, Moderator] [1:30-2:45pm]

- a. Case studies of abandoned and active landfills  
[S. Chilrud, B. Bostick, R. Hon – 35min]
- b. 3MRA Model capabilities, limitations and case studies  
[J. Babendreier, G. Laniak – 40min]

**Break** [2:45-3:00pm]

**Session VI.** Panel Discussion Part I: How do we get to an integrated assessment of the potential threat from ABR landfill disposal?  
[W. Ela, Moderator] [3:00-3:55pm]  
[Panelists: D. Dzombak, S. Al-Abed, T. Townsend, G. Laniak, E. Sáez, B. Bostick]

- a. What would be an ideal approach and data set?
- b. What are the biggest sources of uncertainty from the perspective of model sensitivity?
- c. What do we need to do to address uncertainties and evaluate sensitivity?
- d. What are appropriate criteria by which to judge the potential threat?

**Session VII.** Panel Discussion Part II: How do we get to an integrated assessment of the potential threat from ABR landfill disposal?  
[W. Ela, Moderator] [4:05-5:05pm]  
[Panelists: J. Graziano, J. Calkins, D. Dzombak, J. Babendreier, G. Helms, B. Bostick]

- a. How do we ground truth model simulations?
- b. How localized does an assessment need to be?
- c. Are there other arsenic sources that need to be incorporated?
- d. How can downstream paths and receptors be identified and evaluated?
- e. Who needs to do what and how will it be supported?

**Summary and Closing of Day One**  
[L. Reed] [5:15-5:20pm]

**Day Two** (Tuesday, February 14)

**Breakfast** (served in the Catalina Room) [7:15am-7:55am]

[All Sessions held in the Patagonia/Santa Rita Rooms]

**Session VIII.** Open Discussion: Conceptual Next Steps in Assessing ABR Impact  
(if money and time were not objects)

[G. Laniak, W. Ela, Moderators] [8:00-9:10am]

**Session IX.** Open Discussion: Pragmatic Next Steps in Assessing ABR Impact

[L. Reed, G. Helms, Moderators] [9:20-10:30am]

- a. Prioritizing and supporting follow-on work
- b. Expectations for achievable levels of certainty
- c. Timelines for outcomes

**Session X.** Open Discussion: Reporting Progress and Dissemination of Findings

[L. Whitson, Al-Abed, Moderators] [10:40-11:30am]

- a. What?
- b. How?
- c. When?