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MEMORANDUM

August 3, 2012

To: Michelle Cagley, Tennessee Valley Authority

Subject: Response to Comments from Industrial Economics, Incorporated (IEc), on behalf of Tennessee Valley Authority, on the *Toxicological Profiles* — Arsenic

ARCADIS, on behalf of the Tennessee Valley Authority (TVA), has reviewed and respectfully submits the following responses to the comments made by IEc in the memorandum dated June 20, 2012. The memorandum provided comments, on behalf of Tennessee Valley Authority, on the *Toxicological Profiles* report prepared by ARCADIS, dated November 11, 2011.

IEc's comments and our responses are as follows:

GENERAL COMMENTS

Proposed Additions To The Arsenic Toxicity Section

The effects of arsenic on natural resources are influenced by a number of factors, including, the form of arsenic, species and/or species group, and organism life stage (Irwin 1997). For example, inorganic arsenic is more toxic than organic arsenic, and trivalent arsenite compounds are more toxic than pentavalent arsenate compounds. Generally, plants are more sensitive to arsenic than animals (Lindsay and Sanders, 1990, as cited in Irwin 1997), and early life stages are more sensitive than adult stages. Examples of the toxicity of arsenic to plants, invertebrates, fish, amphibians and reptiles, birds, and mammals are summarized below.

Plants are moderately susceptible to arsenic toxicity (Lindsay and Sanders, 1990, as cited in Irwin 1997). The sorption of arsenate ions in the soil by iron, zinc and aluminum greatly restricts the exposure of arsenic to plants (Walsh 1977, as cited in Irwin 1997). In addition, bioavailability is affected by soil pH; texture; and organic matter, phosphorus and calcium content (Woolson 1975, as cited in Irwin 1997). Once absorbed, arsenic is mainly accumulated in the roots. According to the Texas State Soil and Water Conservation Board,[1] arsenic levels in soils higher than 7 ppm affect sensitive plants and concentrations higher than 17 ppm kill newly established vegetation (as cited in Irwin 1997). Furthermore, a study by Panaullah *et al*. (2009) showed a decrease in rice yields of 16 percent at arsenic water concentrations of 0.13 ppm. A review by Eisler (2004) identified adverse effects to terrestrial vegetation at water concentrations ranging from 3-28 ppm.

In invertebrates, arsenic intoxication can result in decreased reproduction and/or survival. Adsorption of arsenic to the exoskeleton of invertebrates appears to be an important accumulation mechanism (Mason *et al.* 2000). Bartell (1970, as cited in Irwin 1997) calculated the effect concentration to 50 percent of organisms (EC_{50}) of *Daphnia magna* at 4.3 ppm in water after four days. Biesinger and Christensen (1972, as cited in Irwin 1997), exposed *Daphnids* to 0.52 and 1.4 ppm of arsenate in water for three weeks, which resulted in a 16 and 50 percent decrease in reproduction, respectively.

In fish, acute arsenic intoxication can cause immediate death, often due to a corresponding increase in mucus leading to suffocation. Chronic exposures result in accumulation of the metalloid to toxic levels, affecting the liver and resulting in morphological alterations. A study by Sorensen (1976) looked at the

[1] The Texas State Soil and Water Conservation Board is the state agency that administers Texas' soil and water conservation law and coordinates conservation and nonpoint source pollution abatement programs throughout the State.

effects of sodium arsenate on green sunfish, reporting lethality to 50 percent of the population (LC_{50}) at water concentrations of 500 ppm and 100 ppm after 17 and 46 hours of exposure, respectively. Furthermore, a study by Richardson (1992, as cited in Irwin 1997) calculated an EC_{50} for fathead minnow of 141 ppm arsenic in water after 96 hours of exposure.

In amphibians and reptiles, effects of arsenic include mortality and/or malformations in developing embryos. Chen *et al.* (2009) exposed leopard frogs from post-hatch stage through metamorphosis to water concentrations ranging from 0.01 to 1 ppm for 113 days. At these concentrations body burdens varied from 0.6 to 5.31 ppm dry mass. The study reported significantly decreased tadpole swimming speeds, but no effects on survival, growth, percent metamorphosis, or sex ratio. In contrast, a study by the USEPA (1985, as cited in Eisler 2004) found LC_{50} values for developing embryos of the narrow-mouthed toad at As^{3+} water concentrations of 0.04 ppm after seven days of exposure.

Arsenic intoxication in birds results in ataxia, reduced growth, muscular incoordination, debility, slowness and seizures (Moore et al. 1990, as cited in Irwin 1997). For example, Albert (2006) looked at the effect of an arsenic-based pesticide on Zebra finches. After 14 days, adult zebra finches showed significant less body mass when dosed with 24 and 72 ppm body weight/day (bw/d) of Monomethylarsonic acid (MMA (V)). Albert (2008) showed a greater effect of MMA (V) on zebra finch nestlings: doses of 36 and 72 ppm bw/d resulted in complete mortality, suggesting that nestlings are more sensitive to arsenic toxicity than adults. Furthermore, a review by Eisler (2004) identified lethal doses to 50 percent of organisms (LD_{50}) at oral doses ranging from 17-48 ppm bw.

Arsenic intoxication effects in mammals include muscular incoordination, debility, slowness and seizures. These are similar to the effects on birds and might be induced by other toxicants. Arsenic is a carcinogen that can traverse placental barriers and result in fetal deaths and malformations in many species of mammals (Eisler 2004). Santra et al. (2000) showed the effects of arsenic exposure on the livers of mice by exposing them to water containing 3.2 ppm of arsenic acid, which resulted in hepatic fibrosis and loss in hepatic function after one year. A review of multiple toxicological studies on mammals by Eisler (2004) identified LD50s at oral doses ranging from 2.5-33 ppm bw.

Response: The highlighted text has been added to Section 4.4 of the Toxicological Profiles Report, as suggested.

SPECIFIC COMMENTS

Proposed Ammendments To Appendix C: Fish

1. Remove all references regarding fish that are not relevant to the assessment area from the eco-toxicity and effects-based tissue concentration tables.

Response: While some fish species not specifically found in the assessment area were included in the database of eco-toxicity and effects-based tissue concentration tables, these data were not removed as they provide additional comparisons for sizes and feeding guilds.

2. Remove all references that had “NR” (not reported) as endpoints from the eco-toxicity and effects-based tissue concentration tables.

Response: While the proposed change might improve the overall readability of the tables, it is unnecessary and impractical to make this revision given the required submission date of the BERA.

3. Remove the fields “response site description,” “class,” “con 2,” and “con 2 type” from the eco-toxicity table.

Response: While the proposed changes might improve the overall readability of the tables, it is unnecessary and impractical to make these revisions given the required submission date of the BERA.

4. Remove the field “class” from the effects-based tissue concentration table. Add endpoints for the following references in the eco-toxicity Appendix: USEPA (1985, as cited in Eisler 2004), Lima et al. (1984, as cited in Eisler 2004), Spotila and Paladino (1979, as cited in Irwin 1997), NRCC (1978, as cited in Eisler 2004), Gilderus (1966, as cited in Irwin 1997).

Response: While the proposed change of removing the field “class” might improve the overall readability of the tables, it is unnecessary and impractical to make this revision given the required submission date of the BERA. The suggested revisions of endpoints are currently under review.

5. Revise endpoints reported for Sorensen (1976) to reflect the original references for this study in both the eco-toxicity and in the effects-based tissue concentration tables.

Response: The suggested revisions of endpoints are currently under review.

Proposed Ammendments To Appendix C: Birds

1. Simplify the eco-toxicity table so that is easier to understand. Remove the fields “Wet Weight Reported,” “Percent Moisture,” “Route of Exposure,” “Exposure Duration,” “Duration Units,” “Age,” “Age Units,” “Sex,” “Response Site,” “Study NOAEL,” “Study LOAEL,” “Body Weight Reported?,” “Body Weight in kg,” “Ingestion Rate Reported?,” “Ingestion Rate in kg/day or L/day,” “NOAEL Dose (mg/kg/day),” and “LOAEL Dose (mg/kg/day).” Add the fields Effect, Endpoint, Concentration, Units and Test Type.

Response: While the proposed changes might improve the overall readability of the tables, it is unnecessary and impractical to make these revisions given the required submission date of the BERA.

2. Add endpoints from the following references to the eco-toxicity appendix: Camardese et al. (1990), Moore et al. (1990, as cited in Irwin 1997), Hood (1985, as cited in Eisler 2004), USEPA (1985, as cited in Eisler 2004), NRCC (1978, as cited in Eisler 2004).

Response: The suggested references and corresponding effects-based tissue concentrations are currently under review.

3. Revise endpoints reported for Holcman and Stibilj (1997) to reflect the original references for this study in the eco-toxicity table.

Response: The suggested revisions of endpoints are currently under review.