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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* — Mercury

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 May 11, 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 Mercury Toxicity Section

The effects of mercury on natural resources are influenced by interactions with the surrounding matrix, the lifestage of the organism, and the form of mercury. In general, early developmental stages are the most sensitive, and organomercury compounds –especially methylmercury – are more toxic than inorganic forms. In addition, when mercury and selenium occur together, they appear to have an antagonistic relationship, reducing the observed toxicity (Bjerregaard et al. 2011). PCBs have also been shown to have antagonistic effects with mercury (Vettori, *et al.* 2006).

In general, mercury can adversely affect biochemical, reproductive, neurological, growth, and survival endpoints in a suite of organisms. The remainder of this section contains a brief, resource-specific review of the toxicological effects of mercury on plants, aquatic invertebrates, fish, amphibians and reptiles, birds, and mammals. Additional details are provided in the Attachments.

The effects of mercury on plants depend on a variety of factors such as species, seasonal growth changes, and the organ exposed (Thomas and Mantes 1978). For example, mercury effects in algae include, but are not limited to, bleaching of individual cells, cell size changes and destruction of whole cells (Thomas and Mantes 1978). The authors report growth-related inhibitory effects in *Anabaena* at a methylmercuric chloride concentration as low as 1 part per billion (ppb; Thomas and Mantes 1978). Stanley (1974) examined the effects of mercury contamination in the aquatic plant *Miriophyllum spicatum*. He showed that mercuric chloride water concentrations of 3.4 parts per million (ppm) resulted in 50 percent inhibition of root weight.

The effects of mercury on aquatic invertebrates vary widely across species, and depend on abiotic factors such as temperature, salinity and hardness. In general, organisms in the larval stage are the most sensitive, and levels of one to ten ppb can cause acute toxicity at this stage (Boening 2000). Potential effects include, but are not limited to, decreased growth and reproduction and increased mortality (Boening 2000). The World Health Organization reports a concentration lethal to 50 percent of test organisms ($LC_{50}$) for the freshwater invertebrate *Lamellidens maginalis* at water concentration of 5.9 ppm of inorganic mercury (Boening 2000).

Literature on mercury toxicity to fish is robust, and studies identify a suite of effects. For example, fish exposed to mercury experienced reduced growth, reduced spawning success, impaired gonadal development and reduced immune function, among other effects (Hammerschmidt *et al.* 2002,

Friedmann *et al*. 1996). Sandheinrich and Wiener (2011) demonstrate that fish species experience adverse effects at tissue concentrations well below 1.0 ppm wet weight (ww) whole body: changes in biochemical processes, damage to cells and tissues, and effects on reproduction occurred at mercury concentrations of approximately 0.3-0.7 ppm ww in whole body.

Limited information on mercury toxicity in amphibians and reptiles is available, but mercury has been associated with a variety of immunotoxic, endocrine, and reproductive disorders in some species (Grillitsch and Schiesari 2010). Highest tissue concentrations are consistently found in the livers and kidneys of reptile species (Grillitsch and Schiesari 2010). Reptiles such as garter snakes reported no signs of mercury toxicity at concentrations of 200 ppb (Wolfe *et al*. 1998). Amphibians are more sensitive; the World Health Organization reports $LC_{50}$ at the larval and embryo stages (the most sensitive stages) at water concentrations as low as 1.3 ppb of inorganic mercury (Boening 2000).

In birds, signs of mercury poisoning include decreased food intake, decreased growth, increased enzyme production, blood parameter changes, decreased immune response, affected kidney function and structure, and behavioral changes (Boening 2000). Impaired reproduction (eggs without shells, reduced hatchability, unfertilized eggs) has also been reported in laboratory studies (Shore et al. 2011). In aquatic systems, piscivorous birds tend to have higher mercury levels than non-fishing birds (Boening 2000). Burgess and Meyer (2008) looked at the effects of methylmercury exposure from fish consumption associated with reduced reproduction in common loons. They found that loon reproduction dropped by 50 percent when fish mercury levels where 0.21 ppm ww, and failed completely at fish mercury levels of 0.51 ppm ww.

Methylmercury affects the central nervous system in mammals, including sensory, visual, and auditory areas, with more severe effects leading to widespread brain damage (Eisler 1987). Concentrations reportedly associated with reproductive effects for mammals fall within the range associated with lethality (Shore et al. 2011). For mink, body burden concentrations of 5 ppm resulted in ataxia, loss of balance, anorexia, loss of weight and subsequently death (Aulerich *et al*. 1974). Wren *et al.* (1987) fed mink a diet containing 1 ppm of methylmercury for 3 months. This resulted in the death of approximately 50 percent of the population during that time period.

**Response:** The highlighted text has been added to Section 15.4 of the Toxicological Profiles Report, as suggested.

## SPECIFIC COMMENTS

### Proposed Ammendments To Appendix C: Fish

1. Remove all information on 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.

**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.

5. Add endpoints for the following references in the eco-toxicity and effects-based Appendices: Dillon et al. (2010), Drevnick et al. (2006), Sandheinrich and Miller (2006), Webb et al. (2006), Drevnick and Sandheinrich (2003), Webber and Haines (2003), Hammerschmidt et al. (2002), Fjeld et al. (1998), and Friedmann et al. (1996).

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

6. Revise endpoints reported for Beckvar et al. (2005) to reflect the original references for this study (i.e., Drevnick 2003, Friedman 1996).

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

## Proposed Ammendments To Appendix C: Birds

1. Add endpoints for the following references to the eco-toxicity and effects-based tissue concentration Appendices: Jackson *et al*. (2011), Frederick and Jayasena (2010), Hallinger *et al*. (2010), Wada *et al*. (2009), Burgess and Meyer (2008), and Evers *et al*. (2008).

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

2. 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.

3. Remove the fields “class” and “water type” from the effects-based tissue concentrations 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. Revise endpoints reported for Brasso and Cristol (2008) and Heinz (1979) to more accurately reflect the results of these studies.

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