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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* — Chromium

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 July 18, 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 Chromium Toxicity Section

The effects of chromium on natural resources are influenced by a number of factors including, but not limited to, species and/or species group, organism life stage and the valence state of chromium. For example, sensitivity to chromium varies widely, even among closely related biota (Eisler 1986). In addition, hexavalent chromium (Cr^{+6}) has been shown to be more toxic than trivalent chromium (Cr^{+3}). Hexavalent chromium damages cells via its role as a strong oxidizing agent, whereas Cr^{+3} affects various enzyme processes and reacts with organic molecules (Moore *et a*l. 1990, as cited in Irwin 1997). More detailed information on the toxicity of chromium to plants, invertebrates, fish, amphibians and reptiles, birds, and mammals are summarized below.

Chromium toxicity to plants is affected by many variables, such as soil pH, cation exchange capacity, organic content, and clay content, among other factors (Will and Suter 1994, as cited in Irwin 1997). The greatest toxicity risk is associated with acidic, sandy soils with low organic content. Studies report a wide array of effects of Cr^{+6} exposure to plants including, but not limited to, photosynthesis disruption, germination disruption, reduced growth, reduced yield, decreased mineral nutrition and metabolic alterations (Shanker, *et al*. 2005). A study by Kabata-Pendias and Pendias (1992, as cited in Irwin 1997), considered levels of chromium higher than 100 parts per million (ppm) dw (dry weight) as phytotoxic to terrestrial plants. Aquatic plants are among the most sensitive groups of organisms that have been tested (Eisler 2000). A study by Mangi *et al*. (1978, as cited in Driver 1994) showed that common duckweed is the most sensitive aquatic plant, exhibiting reduced growth at Cr^{+6} concentrations of 0.01 mg/l. In addition, the authors identified a lethal concentration to 50 percent of organisms (macrophytes) (LC_{50}) between 3 and 28 mg/l of Cr^{+6}.

In invertebrates, toxicity of chromium is affected by temperature and salinity. For example, high temperature and low salinity result in the greatest possible toxicity (McLusky and Bryant, 1985, as cited in Irwin 1997). Hexavalent chromium exposure has been associated with reduced survival and fecundity (USEPA 1980, as cited in Eisler 2000). Specifically, for *Dapnia magna* at Cr^{+6} concentrations of 0.01 mg/l and Cr^{+3} concentrations of 0.044 mg/l, one EPA study (1980, as cited in Driver 1994) showed reduced fecundity after 32 days of exposure. For rotifers, the effects concentration to 50 percent of organisms (EC_{50}) for Cr^{+6} was 3.1 mg/l after 4 days of exposure (Buikema *et al*. 1974, as cited in Irwin 1997). Finally, Murti *et al*. (1983, as cited in Irwin 1997), determined the EC_{50} for freshwater prawn to be at a Cr^{+6} concentration of 1.84 mg/l after 4 days of exposure.

Chromium toxicity in fish is dependent on the species type, fish size and water pH; larger fish and higher pH result in a higher LC_{50} (Irwin 1997). Broderius and Smith (1979, as cited in Irwin 1997) determined the LC_{50} for juvenile fathead minnows to be at a Cr^{+6} concentration of 4.36 mg/L after 30 days of exposure. In addition, Pickering and Henderson (1966, as cited in Driver 1994), identified an LC_{50} for fathead minnow to be 17.6 mg/l after four days of exposure.

There is little information on the effects of chromium on reptiles and amphibians. Only one study was identified: Bosisio *et al*. (2009) reported that Cr^{+6} is toxic to embryos of Africa clawed frogs *(Xenopus laevis).*[1] This study found an LC_{50} at concentrations of Cr^{+6} of 46 mg/l, and significant growth retardation at Cr^{+6} concentrations of 1.3 mg/l.

Few studies are available on the effects of chromium exposure on birds. Adult black ducks exposed to diets containing 10 to 50 ppm Cr^{+3} for five months had no effects on survival and reproduction (Heinz and Haseltine, 1981, as cited in Eisler 1986). However, a study by Steven *et al*. (1976, as cited in Driver 1994), showed 100 ppm of dietary Cr^{+6} to be a lethal exposure for black ducks after three months of exposure. The same concentration had no effects on chickens, suggesting that they are more resistant to the adverse effects of chromium.

In mammalian species, chromium is considered one of the least toxic trace elements, as stomach pH converts Cr^{+6} to Cr^{+3} (Moore *et al*. 1990, as cited in Irwin 1997). Mammals can tolerate between one to two hundred times the normal body load without exhibiting negative effects (Moore *et al*. 1990, as cited in Irwin 1997). Dietary exposure of mice to 20 ppm of chromium oxide for three generations did not cause adverse effects on the animals (Mertz 1975, as cited in Driver 1994). According to Steven (1976, as cited in Eisler 2000) the toxic threshold for rats occurs at 1000 ppm of dietary Cr^{+6}. The minimum injected fatal dose of Cr^{+6} for most experimental mammalian animals (rabbits, mice, cats and dogs) ranges from 1 to 5 ppm body weight (bw). Lower injected doses of Cr^{+6} of 0.2 to 0.5 ppm bw produced decreased growth and kidney damage (Steven 1976, as cited in Eisler 2000).

Response: The highlighted text has been added to Section 9.4 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.

[1] This amphibian species is not local to the assessment area. However, very little information on chromium toxicity on reptiles and amphibians is available and therefore we include it for reference purposes.

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 Appendix: Lushchak *et al.* (2009), Abassi and Soni (1984 as cited in Irwin, 1997), Riva *et al.* (1981, as cited in Eisler 1986), Pickering (1980, as cited in Driver 1994), USEPA (1980, as cited in Driver 1994), Broderius and Smith (1979, as cited in Irwin 1997), Sauter *et al.* (1976, as cited in Driver 1994), Pickering and Henderson (1966, as cited in Driver 1994), Surber (1965, as cited in Driver 1994), Trama and Benoit (1960, as cited in Driver, C.J. 1994), and Fromm and Shiffman (1958, as cited in Driver 1994).

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

6. Revise endpoints reported for Roling *et al.* (2006).

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 for the following references to the eco-toxicity appendix: Heinz and Haseltine (1981, as cited in Driver 1994), Steven *et al*. (1976, as cited in Driver 1994), and Ridgeway and Karnofsky (1952, as cited in Driver 1994).

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