EVALUATION OF HUMAN HEALTH RISK FROM POTENTIAL EXPOSURES TO FLY ASH AT THE TVA KINGSTON FLY ASH RECOVERY PROJECT

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ABSTRACT

The release of fly ash at the Tennessee Valley Authority (TVA) Kingston Fossil Plant (KIF) on December 22, 2008 discharged approximately 5.4 million cubic yards of coal ash slurry into the adjacent terrestrial and aquatic systems. The initial response focused on public protection and stabilization of the released ash, but rapidly evolved to include comprehensive monitoring of ambient media and ecological receptors.

KIF is located on the Emory River near the confluence of the Clinch and Tennessee Rivers. This portion of the Tennessee River Valley is bounded by ridges and impounded by Watts Bar Dam. The reach of Watts Bar Reservoir at KIF transitions from the upstream riverine reaches of the Emory River and the Clinch River to the more lacustrine conditions found in the impounded portions of the Emory River and the Clinch River to the more lacustrine conditions found in the impounded portions of the Clinch River and Emory River backwaters of Watts Bar Reservoir. This multi-use reservoir supports a diversity of aquatic and terrestrial wildlife. The size and complexity of the potentially affected ecosystems necessitates a comprehensive environmental sampling and monitoring program, which TVA has implemented in cooperation with numerous federal, state, and academic organizations.

The objective of the human health risk assessment for the TVA Kingston Fly Ash Recovery Project was to develop quantitative and qualitative estimates of potential cancer risks and noncancer hazards for human receptors potentially exposed to the ash. These estimates were developed to support remediation decision making. Risks to both current (or near-term) and potential future receptors were evaluated. Potential receptors were distinguished as on-site and off-site. Onsite receptors are those who reside, work, or play on the ash, whereas, off-site receptors are those whose activities occur in areas where ash is not present. The risk analysis was based on analytical data collected from ash in the failed dredge cell and surrounding land, surface water from the Swan Pond Embayment, and shallow and bedrock groundwater beneath the dredge cell. Metals including arsenic and selenium are the primary constituents of potential concern for human exposures to fly ash.

Dredge Cell Features. Image taken August 2009

DATA EVALUATION

Identification of site-related constituents and the data that are of acceptable quality for use in the quantitative risk assessment.

Consists of:

1. Review of analytical data adequacy
2. Identification of site related constituents
3. Determination of exposure point concentrations
4. Identification of constituents of potential concern (COPCs)

SUMMARY OF COPCs

ASH		GROUNDWATER	SURFACE WATER	
Metals	**Radionuclides**	**Metals**	**Metals**	**Other**
Aluminum	Actinium-228	Aluminum	**Aluminum, total**	Alkalinity
Antimony	Bismuth-214	Antimony	**Antimony, total**	Hardness (as CaCO3)
Arsenic	Lead-212	**Arsenic**	**Arsenic, total**	Total Dissolved Solids
Barium	Lead-214	**Barium**	**Barium, total**	Total Suspended Solids
Beryllium	**Potassium-40**	Beryllium	Beryllium, total	pH
Boron	**Radium-226**	**Boron, total**	**Boron, total**	
Cadmium	**Radium-228**	Cadmium	Cadmium, total	
Calcium	Thallium-208	Calcium	Calcium, total	
Chromium	**Thorium-228**	Chromium	**Chromium, total**	
Cobalt	Thorium-230	Cobalt	Cobalt, total	
Copper	**Thorium-232**	Copper	Copper, total	
Iron	Thorium-234	**Iron**	**Iron, total**	
Lead	**Uranium-234**	Lead	**Lead, total**	
Magnesium	**Uranium-235**	Magnesium	Magnesium, total	
Manganese	**Uranium-238**	**Manganese**	**Manganese, total**	
Mercury		Mercury	Mercury, total	
Molybdenum		Molybdenum	**Molybdenum, total**	
Nickel		Nickel	Nickel, total	
Potassium		Potassium	Potassium, total	
Selenium		Selenium	**Selenium, total**	
Silver		Silver	Silver, total	
Sodium		Sodium	Sodium, total	
Thallium		**Strontium**	Thallium, total	
Vanadium		Thallium	**Vanadium, total**	
Zinc		Vanadium	Zinc, total	
		Zinc		

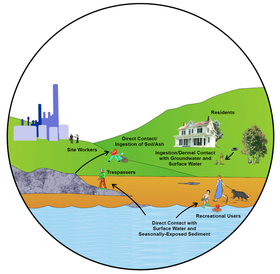
Note: Analytes in bold were retained as constituents of potential concern (COPCs).

EXPOSURE ASSESSMENT

Exposure pathway analysis links the sources, locations, and types of environmental releases with population locations and activity patterns to determine the potential human exposure pathways.

An exposure pathway generally consists of five elements:

1. Source and mechanism of constituent release
2. Transport medium (or media in cases involving media transfer of constituents)
3. Point of potential human contact with the contaminated media
4. Exposure route at the point of contact
5. Receptor – Potential receptors are distinguished as on-site and off-site
   - On-site receptors are those who reside, work, or play on the ash
   - Off-site receptors are those whose activities occur in areas where ash is not present



EXPOSURE SCENARIOS

SOIL/ASH

Adult and Child Resident:
- Currently no residential properties onsite
- Current offsite residential receptors only potentially exposed to ash through inhalation of fugitive dust dispersed in the air away from the ash flow area
- Future residential receptors living onsite potentially exposed to ash

Indoor Worker (office or light industrial worker):
- Current offsite indoor workers potentially exposed to ash deposited by wind or tracked by human or vehicle traffic away from the ash flow area
- Future onsite indoor workers potentially exposed to ash from material tracked indoors from the ash flow area

Outdoor Worker:
- Current offsite worker involved in routine outdoor work not associated with removal or management of ash potentially exposed to ash deposited by wind or tracked by human or vehicle traffic off the ash flow area
- Future onsite worker involved in routine outdoor work potentially exposed to ash

Groundskeeper:
- Future onsite groundskeeper personnel employed to plant and maintain landscape material potentially exposed to ash

Onsite Trespasser:
- Current adolescent trespasser potentially exposed to ash in the sloughs and embayment areas adjacent to current or former residential properties

Recreator (adult hiker/spectator, child participant in sports or play):
- Future onsite child recreator potentially exposed to ash
- Future onsite adult recreator potentially exposed to ash

SURFACE WATER

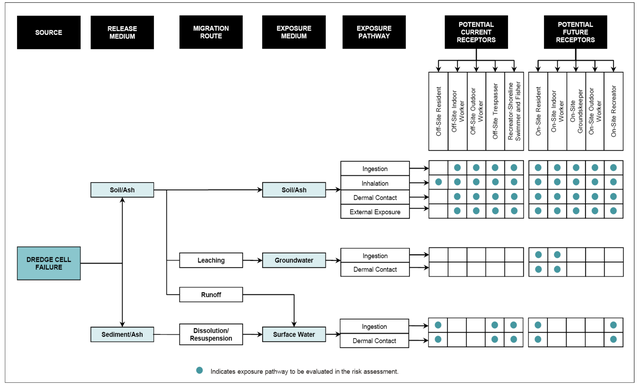
Recreator (adolescent wader):
- Current or future adolescent trespassers potentially exposed to surface water while wading in the Swan Pond Embayment

GROUNDWATER

Adult and Child Resident:
- Future onsite residential receptors potentially exposed to groundwater used for household water supply

Indoor Worker (office or light industrial worker):
- Future onsite indoor workers potentially exposed to groundwater used as a potable water supply

CONCEPTUAL SITE MODEL



TOXICITY ASSESSMENT

The HHRA used EPA-derived toxicity values, consisting of reference doses (RfDs) for evaluating noncarcinogenic effects and cancer slope factors for evaluating carcinogenic effects. Slope factors and RfDs used in the risk assessment were obtained from the latest version of the regional screening levels tables that follows EPA's three-tiered hierarchy:

Tier 1 - EPA's IRIS;

Tier 2 - EPA's Provisional Peer Reviewed Toxicity Values – The Office of Research and Development/National Center for Environmental Assessment/STSC develops PPRTVs on a constituent specific basis when requested by EPA's Superfund program;

Tier 3 - Includes additional EPA and non-EPA sources of toxicity information. Priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed.

The Toxicity Assessment weighs available evidence regarding the potential for adverse effects and provides an estimate of the relationship between the extent of exposure and the increased likelihood and/or severity of adverse effects.

Toxicity Assessment consists of :

1. **Hazard identification –** Determines whether exposure to an agent can cause an increase in the incidence of a particular adverse health effect (e.g., cancer, birth defect) and whether the adverse health effect is likely to occur in humans.
2. **Dose-response assessment –** Quantitative evaluation of the toxicity information and characterizing the relationship between the dose of the contaminant administered or received and the incidence of adverse health effects in the exposed population.

RISK CHARACTERIZATION

Risk characterization integrates the results of the exposure and toxicity assessments to estimate potential cancer risks and noncancer hazards from constituents of concern (COCs) that exceed screening values.

Carcinogenic risk estimates are expressed in terms of the probability that an individual will contract cancer over a lifetime of exposure and are referred to as the incremental lifetime cancer risk (ILCR). The calculated cancer risk estimates are compared to the range specified in the National Oil and Hazardous Substances Pollution Contingency Plan of 10^{-6} to 10^{-4}

- ILCRs below 10^{-6} are considered acceptable
- ILCRs above 10^{-4} are considered unacceptable
- ILCRs between 10^{-6} and 10^{-4} are in EPA's risk management range

Noncarcinogenic hazards are expressed in terms of hazard quotients (HQs) and hazard indices (HIs). An HI greater than 1 has been defined as the level of concern for potential adverse noncarcinogenic health effects.

SUMMARY OF COCs

ASH		GROUNDWATER	SURFACE WATER
Metals	**Radionuclides**	**Metals**	**None**
Aluminum	Potassium-40	Arsenic	
Arsenic	Radium-226	Barium	
Chromium	Radium-228	Cobalt	
Cobalt	Thorium-228	Iron	
Iron	Thorium-232	Strontium	
Thallium	Uranium-234		
Vanadium	Uranium-238		

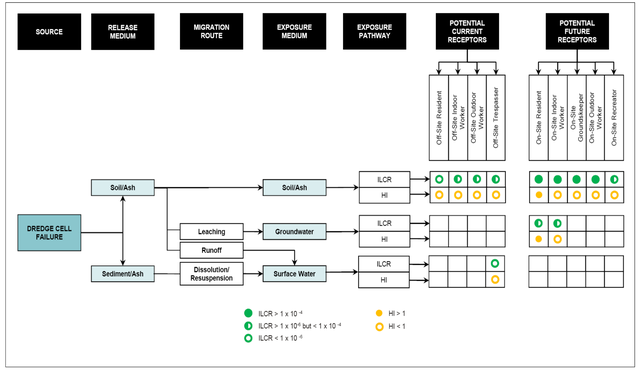
HUMAN HEALTH RISK RESULTS

CURRENT EXPOSURE SCENARIOS

Cancer Risk:
- ILCRs for current exposure scenarios did not exceed the target risk range for any receptor
- ILCRs for current exposure scenarios ranged from 3E-08 for the offsite resident (child and adult) to 5E-05 for the onsite adolescent trespasser
- ILCRs are driven by ingestion of arsenic and external exposure to gamma radiation from K-40, Ra-226, Ra-228, and Th-228

Noncancer Hazard:
- HIs for current exposure scenarios did not exceed the benchmark of 1.0 for any receptor
- HIs for current exposure scenarios ranged from 0.009 for the offsite adult and child resident to 0.2 for the offsite outdoor worker

FUTURE EXPOSURE SCENARIOS

Cancer Risk:
- ILCRs for future exposure scenarios exceeded the target risk range for some receptors
- ILCRs for future exposure scenarios ranged from 1E-06 for the adolescent recreator to 2E-03 for the onsite resident
- ILCRs are driven by ingestion of arsenic and external exposure to gamma radiation from K-40, Ra-226, Ra-228, and Th-228

Noncancer Hazard:
- HIs for future exposure scenarios exceeded the benchmark of 1.0 for some receptors
- HIs for future exposure scenarios ranged from 0.01 for the adult recreator to 8 for the onsite resident
- HIs are driven by ingestion of arsenic, cobalt, thallium, aluminum, iron, vanadium, and chromium in ash and ingestion of arsenic in groundwater