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Dear Mr. Wilson:

SUBJECT: Approval of Emergency Planning Hazards Assessment (EPHA) for Effluent Treatment Project (ETP), S-EHA-H- 00010, R1, December 2011

REFERENCES: Letter, Floyd to Bartholomew, December 2011, Approval of Emergency Planning Hazards Assessment for ETP, S-EHA-H- 00010, R1, December 2011

The Department of Energy (DOE) Savannah River Operations Office (SR) has reviewed the subject document. Based on the evaluation completed by DOE-SR, the subject document is approved.

If you have any questions, please contact R. T. Bartholomew or Howard Burgess of my staff at (803)952-5538.

Sincerely,

T. R. Bartholomew

For David C. Moody
Manager

SPESD-12-049

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S-EHA-H-00010

Revision 1

Emergency Planning Hazards Assessment for the Effluent Treatment Project

November 2011

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LIST OF ACRONYMS

AEGL	Acute Exposure Guideline Limit		IX	Ion Exchange
AIHA	American Industrial Hygiene Association		MAR	Material at Risk
ASA	Auditable Safety Analysis		MTC	Mass Transfer Coefficient
CCS	Cold Chemical System		OR	Organic Removal
CFR	Code of Federal Regulations		NPDES	National Pollutant Discharge Elimination System
CIF	Consolidated Incineration Facility		NPH	Natural Phenomena Hazard
CTF	Central Training Facility		PAC	Protective Action Criteria
DMM	Dimethyl Mercury		PPA	Property Protection Area
DOE	Department of Energy		RD	Release Designation
DWPF	Defense Waste Processing Facility		RMA	Radioactive Material Area
EAL	Emergency Action Level		RO	Reverse Osmosis
EDO	Emergency Duty Officer		SAE	Site Area Emergency
EE	Ethyl Ether		SB	Site Boundary
EMG	Emergency Management Guide		SRS	Savannah River Site
EMPP	Emergency Management Program Procedures		SRSOC	SRS Operations Center
EPA	Environmental Protection Agency		ST	Source Term
EPHA	Emergency Planning Hazards Assessment		TED	Total Effective Dose
EPIP	Emergency Plan Implementing Procedure		TEEL	Temporary Emergency Exposure Limit
EPZ	Emergency Planning Zone		TEL	Threshold for Early Lethality
ERPG	Emergency Response Planning Guideline		USDA	United States Department of Agriculture
ETP	Effluent Treatment Project		WAC	Waste Acceptance Criteria
FB	Facility Boundary		WCT	Waste Concentation Tanks
GE	General Emergency		WCHT	Waste Concentrate Hold Tank
HEPA	High Efficiency Particulate Air		WMA	Wildlife Management Area
HHS	Health and Human Services		WWCT	Wastewater Collection Tanks

ABBREVIATIONS

C	Celsius
Ci	Curies
cm	centimeter
cP	centipoise
F	Fahrenheit
ft	feet
g	gram
gal	gallons
gmol	gram mole
gpm	gallons per minute
hr	hour
in	inch
K	Kelvin
kg	kilogram (10^3 g)
km	kilometer
lb	pound
L	liter
m	meter
M	Molar
mg	milligram (10^{-3} g)
min	minutes
ml	milliliter
pH	negative log of the hydrogen ion concentration
ppm	parts per million
psig	pounds per square inch - gauge
rem	roentgen equivalent man
s/sec	second
wt%	weight percent (concentration)
µg	microgram (10^{-6} g)

1.0 INTRODUCTION

1.1 Purpose

This report documents the Emergency Planning Hazards Assessment (EPHA) for the Effluent Treatment Project (ETP) located on the Department of Energy (DOE) Savannah River Site (SRS) (Appendix A, Figure 1). This EPHA was conducted in accordance with the Emergency Management Program Procedure (EMPP) 6Q-001 (Ref. 1). The purpose of this EPHA is to provide the technical basis for facility emergency planning efforts.

1.2 Scope

The scope of this EPHA includes the facilities associated with the ETP. These include the Cooling Water & Retention Basins located in F & H Tank Farms, the Lift Stations (2) located in F & H Tank Farms, and the Wastewater Treatment Plant located in the southeast corner of H-Area.

1.3 Background

This EPHA provides the technical basis for ETP emergency planning compliant with the requirements of DOE Order 151.1C (Ref. 2), EMPP 6Q-001 (Ref. 1), and guidance from DOE G 151.1-2 (Ref. 3).

The EPHA methodology specified in EMPP 6Q-001 (Ref. 1) differs from that used in other facility safety documentation (e.g., an Auditable Safety Analysis [ASA]). The EPHA uses barrier analysis as opposed to risk or probabilistic analysis. This method involves the compilation and screening of facility radiological, chemical, and biological inventories. For materials that exceed screening thresholds, hazard characterization and barrier identification are performed. Then, event scenarios ranging from minor to severe (e.g. beyond design basis) are postulated. Scenarios specify release mechanism, duration, and respirable source term. From these scenarios, consequence assessments are performed to determine downwind dose/concentration at defined receptor locations.

The EPHA is required to address malevolent acts within the accident analysis in accordance with EMPP 6Q-001 (Ref. 1) and guidance in the DOE Emergency Management Guide (EMG) (Ref. 3). In most cases, malevolent acts will produce releases similar to those that could be caused by other external initiators. For example, the catastrophic failure of a chemical storage tank might be postulated. However, if approximately the same level of damage and source term might also be caused by an act of sabotage, such as running a vehicle into the tank, the malevolent act would simply be considered another initiator for the failure of the storage tank.

Finally, the Emergency Action Levels (EALs) and the facility Emergency Planning Zone (EPZ) are determined from these results. Events capable of exceeding defined Protective Action Criteria (PAC) at the receptor locations are assigned an emergency classification. Based on the consequence assessment, it will be determined whether a facility Emergency Plan Implementing Procedure (EPIP) will be developed or revised for use by facility personnel to classify events in a timely manner.

1.4 Revision Summary

1.4.1 Revision 1

This revision constitutes a triennial review and addresses the following:

- Updated chemical hazards
- Updated accident and consequence analysis to address new chemical hazards
- Incorporated new Waste Concentrate Hold Tank.

1.4.2 Revision 0

The following items were addressed in this revision:

- Initial issue of the EPHA for the ETP Facility. The ETP Facility EPHA was part of the EPHA for the CIF, ETF and Saltstone Facility. CIF and Saltstone are no longer part of this EPHA. CIF is currently in indefinite Cold Standby with all process vessels and tanks capable of containing hazardous wastes de-inventoried and cleaned and hazardous chemical and radiological transfers to or from CIF are no longer performed. Saltstone is now contained in a separate EPHA (S-EHA-G-00005). Previous development of the ETP Facility EPHA can be obtained in S-EHA-G-00004.
- Updated radiological and chemical inventories.
- Updated to match with the revised EMPP 6Q-001, EMPP 6Q-002, and EMPP 6Q-011.
- Updated EPHA based on the current EPHA Style Guide.
- Addressed malevolent acts.
- Removed the Barrier Identification section.

2.0 SUMMARY

An EPHA was conducted for ETP in accordance with EMPP 6Q-001. Analysis included the following:

- Compilation, screening, and hazard characterization of chemical, radiological, and biological materials
- Accident scenario development for potential releases of identified hazardous materials
- Consequence assessment of the identified scenarios.

Hazardous materials present within ETP that require full consequence assessment are as follows:

- Chemical: Ammonia, Mercury, Dimethyl Mercury (DMM)
- Radiological: None
- Biological: None.

For the materials identified above, accident scenarios were identified that may exceed the specified PAC at the downwind receptor locations of interest. Results do not show the potential for classifiable operational emergencies. Therefore, an EPIP and determination of a facility EPZ is not required for ETP.

3.0 FACILITY DESCRIPTION

Located in H-Area adjacent to Road E, the ETP is designed to remove hazardous chemical and radioactive contaminants from 200-Area liquid effluent wastewater streams. Along with the ETP treatment plant, basins at both F- and H-Areas collect contaminated cooling water and stormwater. Treatment of waste liquids includes pH adjustment, sub-micron filtration, activated carbon adsorption, reverse osmosis purification, ion exchange, and evaporation. Two product streams exit the facility: treated water and waste concentrate. Treated water is released to Upper Three Runs Creek after sample analysis satisfies discharge requirements. Waste concentrate is transferred to H-Tank Farm for final processing at the Saltstone Facility.

The ETP process can be broken down into the following seven (7) distinct segments (Ref. 4):

- F-Area Cooling Water Basin and Adjacent Radioactive Material Area (RMA).
- F-Area Retention Basin and Adjacent RMA.
- H-Area Cooling Water Basin and Adjacent RMA.
- H-Area Retention Basin and Adjacent RMA.
- Lift Stations, Force Main, Wastewater Collection Tanks (WWCT), Organic Removal (OR) System (Mercury Removal and Activated Carbon Columns), and Cold Chemical System (CCS) Storage Tanks.
- Treatment Building, Control Building, Other Outside Tanks, Outfall at Upper Three Runs Creek, and High Efficiency Particulate Air (HEPA) units.
- Waste Storage Area east of the Treatment Building.

Major processing steps and associated equipment at ETP are described in the following sections (Ref. 4, 5).

3.1 Major Process Descriptions

3.1.1 Cold Chemical System

The CCS is used for wastewater pH adjustment, flocculant addition to the Filtration System, chemical cleaning of components in the Filtration, OR and Reverse Osmosis (RO) Systems, and regeneration of the cation exchange columns in the Ion Exchange System. The CCS includes the nitric acid/caustic truck unloading station, the aluminum nitrate and ferric nitrate truck unloading station, 10,000 gal nitric acid and caustic storage tanks, 10,000 gal aluminum nitrate and ferric nitrate storage tanks, 13,000 gal agitated nitric acid day tank, 3500 gal agitated caustic day tank, and a 4500 gal agitated sodium nitrate mix tank with cooler. Ferric nitrate is currently not used and the ferric nitrate system is out-of-service.

3.1.2 Wastewater Collection Tanks/Pretreatment System

The WWCT/Pretreatment System consists of two nominal 450,000 gal tanks and two wastewater transfer pumps contained within diked areas. When a sufficient volume of wastewater is available for processing (~ 300,000 gal), a chemical pretreatment (pH adjustment, flocculant addition) of the wastewater is performed in the WWCTs. The pH of the wastewater is adjusted to

a range of 1.5 - 2.5 to keep dissolved metals (sludge) from precipitating out of the solution. A flocculant, aluminum nitrate, is added to the wastewater to reduce fouling and optimize the efficiency of the filtration system filters. Flow from the WWCTs is routed through one of two basket strainers to remove any debris/large particles present in the wastewater.

3.1.3 Filtration

Prior to filtration, the influent wastewater is adjusted to a pH of 6-9 to precipitate solids using < 25 wt% nitric acid and 2-10 wt% caustic. The pH adjustment system consists of two agitated tanks in series (one 1500 gal, one 2500 gal) with gravity flow from each tank. The first tank does a coarse adjustment to a pH of 3-11 and the second tank adjusts the wastewater to the required range of 6-9.

Following the pH adjustment step, suspended solids are removed from the wastewater using sub-micron filtration to prevent fouling of the RO membranes. The filtration system consists of a 2500 gal filter feed tank, three parallel filter trains, a 250 gal filter concentrate tank, and a 300 gal filter cleaning tank. Each filter train has three stages with each stage consisting of a pump and four filter housings. The filters separate the feed stream into a concentrated stream of approximately 1 wt% suspended solids and a filtrate stream. The concentrate is directed to the filter concentrate tank and then to the evaporator feed tank. Filtrate is sent to the OR system.

Filter trains are periodically cleaned using premixed solutions of caustic, hypochlorite (bleach), nitric acid, or oxalic acid. The cleaning solutions are sent to the evaporator feed tank.

3.1.4 Organic Removal System

The OR system removes heavy metals (primarily mercury) and organics from the wastewater to prevent fouling of the RO membranes. It consists of a 5400 gal feed tank, two feed pumps, three mercury removal columns, three activated carbon columns, two cartridge filters, a caustic cleaning tank for the mercury columns and cartridge filters, and a dewatering system. The system is located outside adjacent to the WWCTs within concrete diked areas. The three mercury removal columns operate simultaneously in parallel. The activated carbon columns operate two at a time in series with a third on standby. One 5 micron cartridge is on line at a time (with the other on standby) to remove carbon fines. OR effluent is directed to the RO system for further processing.

Periodic chemical cleaning of the OR System components may be performed to reduce differential pressure across the components. A dilute, approximately 15 wt%, caustic solution is circulated through the system to remove deposits, however this process does not remove the fixated species, i.e. mercury and other heavy metals or organics. Spent cleaning solution is transferred to the evaporator feed tank.

3.1.5 Reverse Osmosis System

The RO system removes dissolved solids (mainly sodium nitrate salts) and radionuclides from the wastewater. It includes the RO feed cooler and three evaporative fluid coolers, a 3000 gal agitated pH adjustment tank, a 5000 gal feed tank, three feed pumps, three 100 gpm RO trains, and a RO cleaning circulation tank. The RO feed cooler reduces feed temperature to prevent damage to the RO membrane. Feed is then pH adjusted to approximately 6.0 by use of <25 wt% nitric acid. RO feed pumps raise feed pressure to 500-800 psig as it enters RO trains. Each of the three trains has four staged modules containing multiple semi-permeable membranes that separate the wastewater into a concentrated dissolved solids stream and a permeate stream. Concentrate is directed to the evaporator feed tank while permeate flows to the Ion Exchange (IX) system.

3.1.6 Ion Exchange System

The IX System removes most of the cesium, strontium, and heavy metals that may still be present in the treated wastewater. It consists of a 3200 gal agitated pH adjustment tank, a 5400 gal feed tank with two transfer pumps, two mercury removal columns, three cation columns, and two cartridge filters. In addition, a 3573 gal spent resin tank is included for IX column resin change out and a sodium nitrate tank and pumps are included for cation exchange column regeneration.

IX influent is adjusted to a pH of 6-9 using 2-10 wt% caustic. The mercury columns operate in parallel and contain a specialized resin that removes residual mercury. The cation columns are operated with two in series and one is standby to remove residual cesium and strontium. The cartridge filters remove any resin fines from the ion exchange column effluent to the Treated Water System.

The cation exchange columns are periodically regenerated by circulating sodium nitrate solution through the columns to displace the accumulated cesium and strontium. Spent regenerate solution is transferred to the evaporator feed tank.

3.1.7 Evaporation System

Evaporation reduces the volume of waste concentrate by reclaiming water from concentrates of filtration, RO, spent IX regenerant, and miscellaneous cleaning solutions. The system includes two 24,000 gal agitated feed tanks, two sample pumps, two 50 gpm feed pumps, two 4500 gpm forced circulation evaporators, an air cooled condenser with two fans, a process condensate tank with two pumps, and two waste concentrate tanks with two transfer pumps. The feed tanks run alternately, i.e., one is feeding the evaporator while the other is receiving feed. The feed is adjusted to a pH of 5.0-7.0 by use of <25 wt% nitric acid before being fed to the evaporators. The feed is then heated to vaporize some of the liquid. The overheads pass through an entrainment separator to remove entrained liquid before reaching the condenser. Overhead condensate is collected in the condensate hold tank prior to being transferred to the OR feed tank, IX pH adjustment tank, or WWCT for further treatment. The evaporator bottoms, consisting of approximately 30 wt% concentrate, are transferred to the 1850 gal waste concentrate tanks. The waste concentrate tanks are adjusted with 50% caustic before being transferred to the Waste Concentrate Hold Tank (WCHT) or to H-Tank Farm before final processing at the Saltstone Facility.

3.1.8 Treated Water System

The Treated Water System is the final stage of the treatment process. This system consists of two samplers, three storage tanks, two transfer pumps, and one recycle pump. Effluent leaving the IX columns is sampled using a continuous, proportional type sampler and collected in one of the three 160,000 gal Treated Water Tanks. Once a batch of treated water is confirmed to meet selected National Pollutant Discharge Elimination System (NPDES) limits, it is discharged to Upper Three Runs Creek. If it does not meet NPDES limits, it is recycled to the WWCTs for retreatment through the entire process. An additional sampler is located near the outfall at Upper Three Runs Creek to draw a series of samples from the treated water as it is discharged to the creek.

3.2 Boundary Descriptions

3.2.1 Facility Boundary (FB)

The FB is determined in accordance with EMPP 6Q-001 and differentiates between an Alert and Site Area Emergency (SAE) for each facility (Ref. 1). The FB is the Property Protection Area (PPA) security fence. If the fence is closer than 100 m, the default distance is 100 m from the center of the facility (Ref. 1). A distance of 100 m for ETP (default) was chosen as the FB for all release scenarios. For the purposes of the ETP EPHA, the FB is assumed to be measured from the main process facility. Other processes or buildings (e.g., basins, lift stations) either had associated hazardous materials screened out or no plausible release scenarios were postulated.

3.2.2 Site Boundary (SB)

The SB is normally defined as the perimeter of DOE-owned and controlled land at SRS. From EMPP 6Q-001, the minimum distance to the nearest SB is 11.54 km for ETP.

3.2.3 Other Receptors of Interest

Other receptors of interest are given in Table 3.1 below for the minimum distance from ETP to the Central Training Facility (CTF) and the Crackerneck Wildlife Management Area (WMA) (Ref. 1). The Crackerneck WMA is located south of Jackson off Highway 125 and is bounded by Upper Three Runs Creek, the Savannah River and the SB. The CTF is located in H-Area north of H-Separations, between the Tritium Facility and the Defense Waste Processing Facility (DWPF).

Table 3.1 - CTF and Crackerneck WMA Distances

Facility	CTF Distance	Crackerneck WMA Distance
ETP	0.70 km	8.85 km

4.0 IDENTIFICATION, SCREENING, AND CHARACTERIZATION OF HAZARDS

The objective of this section is to identify hazards that are significant enough to warrant consideration in a facility's operational emergency hazardous material program (Ref. 6). Note that "hazard", as used in this section, refers to biological, chemical, and radioactive hazardous materials.

4.1 Hazardous Chemicals

4.1.1 Hazardous Chemical Screening

According to the Hazards Surveys for F- and H-Areas (Ref. 7, 8), all chemicals within ETP were screened out except ammonia, mercury, and dimethyl mercury. Mercury can be screened out at ambient temperatures, but should be considered in processes with elevated temperatures, e.g. evaporators.

4.2 Radioactive Materials

4.2.1 Radiological Screening

The ETP is a Radiological/Low Hazard Chemical Facility. Therefore, according to EMPP 6Q-011 (Ref. 6), treatment of radiological material in an EPHA is not required.

4.3 Hazardous Biological Agents and Toxins

Hazardous biological agents and toxins identified in DOE Order 151.1C (Ref. 2) require an EPHA and Hazardous Material Program. Specific hazardous biological agents and toxins must include federally regulated agents and toxins identified in lists published in Department of Health and Human Services (HHS) regulations [42CFR73] (Ref. 9) and United States Department of Agriculture (USDA) regulations [7CFR331 and 9CFR121] (Ref. 10, 11), and require an EPHA and a Hazardous Material Program. Toxins listed in 42CFR73 and 9CFR121 must exceed the minimum quantities specified to be federally regulated. Toxins and hazardous biological agents identified in these Codes of Federal Regulations (CFRs) are referred to collectively as select agents and toxins in DOE Order 151.1C (Ref. 2).

The ETP does not handle any of the select agents and toxins identified in the CFRs noted above as stated in Reference 12. Therefore, biological agents and toxins will not be considered further in this EPHA.

4.4 Hazardous Material Requiring Further Analysis

After applying the methodologies described above to the ETP chemical and radionuclide inventories, hazardous materials requiring further analysis are identified and summarized in Table 4.1.

Table 4.1 - Hazards Requiring Further Analysis

Chemicals	Radionuclides	Biological
ammonia, mercury, dimethyl mercury	None	None

4.5 Protective Action Criteria for Remaining Hazards

The chemical PAC used in emergency planning listed in order of preference, are: Acute Exposure Guideline Levels (AEGLs) promulgated by the Environmental Protection Agency (EPA) (Ref. 13); Emergency Response Planning Guidelines (ERPGs) published by the American Industrial Hygiene Association (AIHA) (Ref. 14); and Temporary Emergency Exposure Limits (TEELs) developed by DOE (Ref. 15). Two chemical PACs are used for Emergency Planning. The PAC-2 (AEGL-2, ERPG-2, or TEEL-2) represents no irreversible health effects and is used as the threshold at specific receptors for triggering an operational emergency (Ref. 1). The PAC-3 (AEGL-3, ERPG-3, or TEEL-3) is the Threshold for Early Lethality (TEL) and is an input into the facility EPZ determination (Ref. 1). The values used for the chemicals of concern in this EPHA are shown below.

Table 4.2 - PAC for Remaining Chemicals

Chemical	CAS Number	PAC-2	PAC-3 (TEL)
Ammonia	7664-41-7	111 mg/m^3	766 mg/m^3
Mercury	7439-97-6	1.7 mg/m^3	8.9 mg/m^3
Dimethyl Mercury	593-74-8	0.046 mg/m^3	2.3 mg/m^3

5.0 ACCIDENT ANALYSIS

Barriers that maintain control over hazardous materials that failed initial screening/hazard characterization have been analyzed and possible failure modes considered. Results of barrier analysis and resulting release designations (RDs) are described in this section. Section 6.0 contains a summary of the consequences from each release designation.

Within Section 5.0, potential events that would challenge a barrier are not normally described in detail as the list can become quite long. A list of potential accident initiators will be identified for each barrier failure but is not intended to be an exhaustive listing. Details of various accident initiators are described in the ETP ASA (Ref. 4).

The accident initiator is not an essential factor in the development of EALs, the end product of an EPHA. Many accident initiators will often produce the same barrier failure and consequence. How an accident originated may not be decisive in the recognition and categorization of an event. In those cases where the accident initiator has a direct bearing on the source term (ST) and the consequences, the initiator is identified and described. If events are identified where the only initiator to a release is a malevolent act, it is explicitly stated in the EPHA.

The method used to transform inventories of hazardous materials into STs is as follows:

- Determine barrier failure modes by identifying initiating events.
- For each failure mode, determine mechanisms for release.
- Based on release mechanisms, a quantitative estimate of the ST is developed, considering the nature of the material (physical state, vapor pressure, etc.), and the postulated mode of failure.

5.1 Release Designations

5.1.1 Chemical Releases

The accident analyses for chemical releases from the Wastewater Collection Tanks and Waste Concentrate Tanks are developed in Appendix B - Calculations 1 and 2, respectively, and are summarized in this section.

5.1.1.1 Wastewater Collection Tank (WWCT) Spill

Failure of the Primary Barrier – The primary barrier preventing the release of the wastewater and its associated contaminants is the tank wall of the WWCT.

Effects of Other Barriers/Mitigative Features – Secondary barriers include the dike around the WWCT. Other mitigative engineered features include overflow piping to the off-service WWCT, vacuum relief valves, high level alarms, sump and sump pump with associated piping to transfer sump contents back to a WWCT, sump and dike level alarms. Administrative mitigative features include conduct of operations such as operator monitoring of all transfers.
Range of Possible Releases – The WWCT fails spilling its contents to the diked area. Breach of the vessel or associate piping will result in a release via evaporation.

Release Designation 1-RD-1

Material	Quantity (gal)	Surface Area (m^2)
WWCT Wastewater	4.50E+05	485

5.1.1.2 Wastewater Transfer Spill

Failure of the Primary Barrier – The primary barrier preventing the release of the wastewater and its associated contaminants is the piping system.

Effects of Other Barriers/Mitigative Features – Secondary barriers include the dike around the WWCT. Other mitigative engineered features include underground piping from the Lift Stations to the WWCTs. Administrative mitigative features include conduct of operations such as operator monitoring of all transfers.

Range of Possible Releases – The piping system fails during a transfer of wastewater from the Lift Stations to the WWCTs or from the WWCTs to the Treatment Building. Breach of the piping will result in an unconfined spill and release via evaporation from the pool.

Release Designation 1-RD-2

Material	Quantity (gal)	Surface Area (m^2)
Wastewater	2950	1117

5.1.1.3 Waste Concentrate Tank (WCT) Spill

Failure of the Primary Barrier – The primary barrier preventing the release of the waste concentrate is the WCT wall and associated piping.

Effects of Other Barriers/Mitigative Features – Other mitigative engineered features include vacuum relief valves, overflow piping to the evaporator sump, sloped flooring to process trench and sumps, tank high level alarms, sump and sump pump with associated piping to transfer sump contents back to an Evaporator Feed Tank, sump level alarms. Administrative mitigative features include conduct of operations such as operator monitoring of all transfers.

Range of Possible Releases – The WCT fails spilling its contents to the process floor. Breach of the vessel or associate piping will result in a release via evaporation.

Release Designation 1-RD-3

Material	Quantity (gal)	Surface Area (m^2)
Waste Concentrate	1747	N/A

5.1.1.4 Waste Concentrate Hold Tank (WCHT) Spill

Failure of the Primary Barrier – The primary barrier preventing the release of the waste concentrate is the WCHT wall and associated piping.

Effects of Other Barriers/Mitigative Features – Other mitigative engineered features include diked containment, overflow piping to the sump, sloped flooring to sump, tank high level alarms, automatic sump pump activation with conductivity probes, sump and sump pump with associated piping to transfer sump contents back to the WCHT or an Evaporator Feed Tank. Administrative mitigative features include conduct of operations such as operator monitoring of all transfers.

Range of Possible Releases – The WCHT fails spilling its contents to the dike. Breach of the vessel or associate piping will result in a release via evaporation.

Release Designation 1-RD-4

Material	Quantity (gal)	Surface Area (m^2)
Waste Concentrate	30,000	64

5.1.2 Radiological Releases

None identified.

5.1.3 Hazardous Materials in ETP Requiring No Further Analysis

The scenarios analyzed involve the largest volume of pretreated wastewater (WWCT), the highest concentration wastewater (WCT/WCHT) at the highest process temperature, and the maximum anticipated transfer spills. These analyzed scenarios are considered to reasonably bound other potential scenarios involving smaller wastewater volumes, lower concentrations, or lower temperatures.

Mercury is not analyzed in the WWCT Spill (1-RD-1) or wastewater transfer spill (1-RD-2) because mercury screens at ambient temperature on low volatility. Dimethyl mercury is not analyzed in the waste concentrate spills (1-RD-3, 1-RD-4) because the majority is processed through the OR System where the DMM is removed and the remainder is removed in the evaporator overheads, which is reprocessed through the OR System. No additional material is stored in ETP that would require further consideration in this EPHA.

5.2 Malevolent Acts

Malevolent act scenarios will result in releases and consequences similar to those caused by the analyzed event initiators. Therefore no explicit analysis of malevolent acts is required since the postulated events did not result in any emergency action levels.

5.3 Accident Summary

Table 5.1 summarizes the accidents presented within this section based on release designation.

Table 5.1 - Accident Summary

RD	Accident Scenario	Spill Quantity
1-RD-1	WWCT Spill	450,000 gal
1-RD-2	Wastewater Transfer Spill	2,950 gal
1-RD-3	WCT Spill	1,747 gal
1-RD-4	WCHT Spill	30,000 gal

6.0 CONSEQUENCE ASSESSMENT

This section presents the results of the analysis used to transform the accident scenarios identified in Section 5.0 into projected ground-level concentrations at previously identified receptor locations. The consequence analyses for chemical releases from the Wastewater Collection Tanks and Waste Concentrate Tanks are developed in Appendix B - Calculations 1 and 2, respectively, and are summarized in this section.

6.1 Description of Methodology

6.1.1 Chemical Dispersion Modeling

The chemical contaminants in the ETP wastewater are present in relatively dilute concentrations for which the normal evaporative release source term and dispersion modeling techniques such as the ALOHA dispersion program are not valid. Therefore, alternative source term and dispersion modeling hand calculations are performed in Appendix B to estimate the downwind chemical concentrations at the receptor locations of interest. The Hotspot computer code is used in the WCT/WCHT Spill Calculations to determine the dispersion factor for a release (Ref. 16). The details of the analysis methodology for each scenario are described in Appendix B.

6.1.2 Dispersion Modeling Parameters

The following parameters are used in the calculations in Appendix B:

WWCT/Wastewater Transfer Spills (1-RD-1/1-RD-2)

- Gaussian dispersion model with Briggs urban dispersion coefficients
- For the outside evaporative pool release, a virtual upwind source for which the crosswind dispersion coefficient is equal to half the equivalent radius of the pool is assumed. The vertical dispersion coefficient is assumed to be zero at the center of the pool. The crosswind dispersion coefficient is corrected for plume meander from the reference averaging time in accordance with the method suggested by Gifford. (See Appendix B for discussion and references)
- An averaging time of 15 minutes (Ref. 3)

WCT/WCHT Spills (1-RD-3/1-RD-4)

- Surface area source geometry of 3m x 3m
- Urban terrain dispersion coefficients
- Ground level release
- Inversion layer height – 300m
- Wind height measurement – 2m
- Deposition velocity of 0 cm/sec

- Sampling time of 15 minutes
- Receptor height of 0m
- Source material of 1 Ci Pu-239 is used to convert the Time Integrated Air Concentration to a non-source specific dispersion factor, i.e. to convert from Ci-sec/m^3 to sec/m^3.

6.1.3 Receptor Locations of Interest

Consequences are determined at the receptor locations of interest as specified in EMPP 6Q-001 (Ref. 1):

- 30 m from the release point or edge of spill
- FB distance of 100 m
- CTF distance at 0.70 km
- Crackerneck WMA at 8.85 km
- SB distance of 11.54 km
- Maximum distance to PAC and TEL.

6.1.4 Meteorology

The stability classes and corresponding wind speeds used for the appropriate release heights and meteorological conditions (95% adverse or 50% average) are scenario dependent and selected in accordance with the guidance documents (Ref. 1, 17). Meteorological input parameters are listed in Table 6.1.

Table 6.1 - Meteorological Input Parameters

Release Height (m)	Meteorological Conditions	Stability Class	Wind Speed (m/s)	Temperature °C	Inversion Layer * (m)	Cloud Cover	Humidity %
≤10	Average	C	2.5	25	500	80%	50
≤10	Adverse	E	1.7	29	300	10%	50
>10	Average	C	2.5	25	500	80%	50
>10	Adverse	A E	1.7 1.7	29 29	None 300	10% 10%	50

(*Ref. 18)

6.2 Event Classification Determination

Consequence Assessment results are evaluated against the following criteria to determine the appropriate emergency class for the event scenario (Ref. 1):

1. 30 m from the release (or edge of spill): Dose/concentration at this receptor location provides the demarcation between an accident that would require emergency response organization involvement (e.g., Alert) and one that would not.

2. Distance from the release to the nearest FB. The FB is the demarcation between the facility and its immediate vicinity and the remainder of the site. Dose/concentration at this receptor location provides the demarcation between an Alert and an SAE. The FB is considered to be at 100 m.

3. Distance from the release to the closest SB. Dose/concentration at this receptor location is the demarcation for a General Emergency (GE) declaration. The SB is considered to be at 11.54 km.

4. Operational Emergency – An event or condition that poses a significant hazard to safety, health, and/or the environment and requires time-urgent response from outside the facility. An Operational Emergency involving the release of significant quantities of hazardous materials may require further classification as an Alert, SAE, or GE. The Emergency Duty Officer (EDO) in the SRS Operations Center (SRSOC) is the Site categorization and reporting authority for Operational Emergencies that do not require further classification.

5. Courtesy Notification Event – An event or condition that does not fall within the Operational Emergency categorization and classification system but has the potential for significant public or media interest.

In each of the zones, the releases are evaluated to determine if the PAC has been exceeded. The last zone where the PAC has been exceeded determines event classification. For classifiable Operational Emergencies, the PAC is a personnel radiation exposure level of 1 rem TED or toxic chemical concentration equal to AEGL-2 or equivalent value.

6.3 Consequence Assessment Results

Table 6.2 contains consequence assessment results for releases described in Section 5.0 under 95% adverse meteorological conditions. The dispersion conditions are considered in computing the consequence versus distance data for each source term determined. The meteorological conditions correspond to the 95% worst-case wind speed and stability class. The consequence calculations are located in Appendix B – Calculations 1 and 2.

Table 6.2 - Adverse Consequence Assessment Results - Chemical

RD	Chemical	Conc. @ 30 m* ($\mu g/m^3$)	PAC-2 ($\mu g/m^3$)	Probable Event Class
1-RD-1	Ammonia	281	111,000	None
1-RD-1	Dimethyl Mercury	28.9	46	None
1-RD-2	Ammonia	408	111,000	None
1-RD-2	Dimethyl Mercury	43.8	46	None
1-RD-3	Ammonia	< 111,000	111,000	None
1-RD-3	Mercury	< 1,700	1,700	None
1-RD-4	Ammonia	< 111,000	111,000	None
1-RD-4	Mercury	< 1,700	1,700	None

Note: * - 30m from edge of spill for 1-RD-1.

7.0 EMERGENCY CLASSES AND EMERGENCY ACTION LEVELS

Since the consequence assessment did not identify any classifiable Operational Emergencies (i.e., PAC are not expected to be exceeded at identified receptor locations), EALs are not required for ETP.

7.1 Radioactive Releases

General Emergency (GE)	**None identified**
Site Area Emergency (SAE)	**None identified**
ALERT	**None identified**

7.2 Chemical Releases

General Emergency (GE)	**None identified**
Site Area Emergency (SAE)	**None identified**
ALERT	**None identified**

7.3 Other

General Emergency (GE)	**None identified**
Site Area Emergency (SAE)	**None identified**
ALERT	**None identified**

8.0 EMERGENCY PLANNING ZONE DETERMINATION

Since no EALs are postulated, an EPZ is not required for ETP.

9.0 REFERENCES

1 *Standards for Development and Maintenance of an Emergency Planning Hazards Assessment*, Manual 6Q, EMPP 6Q-001, Rev. 10, Savannah River Site, Aiken, SC, November 2010.

2 *Comprehensive Emergency Management System*, DOE Order 151.1C, U.S. Department of Energy, Washington, DC, November 2005.

3 *Technical Planning Basis* - Emergency Management Guide, DOE G 151.1-2, U. S. Department of Energy, Washington, D.C., July 2007.

4 *Auditable Safety Analysis for the Effluent Treatment Facility (U)*, WSRC-TR-98-00379, Rev. 14, Savannah River Site, Aiken, SC, July 2011.

5 Gleaton, W.L., et al, *Periodic Process Hazards Review Report, F/H-Area Effluent Treatment Facility (U)*, WSRC-PH-92-014, *PHR-200-H-439*, Rev. 1, Savannah River Site, Aiken, SC, July, 2001.

6 *Development and Maintenance of a Hazards Survey*, Manual 6Q, EMPP 6Q-011, Rev. 2, Savannah River Site, Aiken, SC, January 2011.

7 *Hazards Survey for F-Area*, S-EHS-F-00001, Rev. 1, as amended by S-DCF-F-00094, Rev. 0, Savannah River Site, Aiken, SC, November 2011.

8 *Hazards Survey for H-Area*, S-EHS-H-00001, Rev. 0, as amended by S-DCF-H-00200, Rev. 0, Savannah River Site, Aiken, SC, November 2011.

9 *Select Agents And Toxins, Title 42 Code of Federal Regulations, Part 73, Public Health Service*, Department of Health and Human Services**,** Washington, DC, October 1, 2006.

10 *Possession, Use, and Transfer Of Select Agents and Toxins*, Title 7 Code of Federal Regulations, Part 331, U.S. Department of Agriculture, Washington, DC, January 1, 2006.

11 *Possession, Use, and Transfer Of Select Agents and Toxins*, Title 9 Code of Federal Regulations, Part 121, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Washington, DC, January 1, 2006.

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13 Acute Exposure Guideline Levels (AEGLs), US Environmental Protection Agency, Office of Pollution Prevention and Toxics, http://www.epa.gov/oppt/aegl/, Washington, DC.

14 American Industrial Hygiene Association (AIHA), *The AIHA 2008 Emergency Response Planning Guidelines and Workplace Environmental Exposure Level Guides Handbook*, AIHA Press, Fairfax, VA, 2008.

15 *Protective Action Criteria (PAC) with AEGLs, ERPGs, & TEELs: Rev. 26 for Chemicals of Concern*, U.S. Department of Energy, http://orise.orau.gov/emi/scapa/teels.htm, Washington, DC, September 2010.

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17 Hunter, C.H. to J.W. Lightner, Inter-Office Memorandum, *Revised Onsite Meteorological Data for Emergency Planning Hazards Assessments*, SRT-ETS-931167, Westinghouse Savannah River Company, Aiken, SC, November 30, 1993.

18 Holzworth, G. C., *Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution throughout the Contiguous United States*, U. S. Environmental Protection Agency, Division of Meteorology, Research Triangle Park, North Carolina, January 1972.

Appendix A
Figure

Figure 1 - Location of ETP in Relation to Site Boundaries

Appendix B

Calculations

Calculation 1 WWCT Spill Accident & Consequence Analysis ..... 1 thru 15
Calculation 2 WCT/WCHT Spill Accident & Consequence Analysis ..... 1 thru 13

INTRODUCTION

This is a completely new calculation for Revision 1; therefore, no revision bars are included.

This calculation develops ground level, downwind centerline concentrations for a large spill from the Wastewater Collection Tanks (WWCT) into the diked area. The contaminant chemical concentrations are calculated at 30 m from the edge of the spill. Transfer spills are also addressed. Releases are considered under adverse meteorological conditions as directed by procedure EMPP 6Q-001 (Ref. 1).

ACCIDENT SCENARIO

Two accident scenarios involving wastewater spills are considered: 1) An accident (mechanical failure, overflow, operator error, Natural Phenomena Hazard (NPH) event, etc.) results in a large spill of wastewater into the diked area. 2) A mechanical failure during a transfer results in a 2950 gallon unconfined spill. Volatile chemical contaminants contained in the wastewater are released into the atmosphere.

ASSUMPTIONS

- The WWCT spill volume is assumed to be 450,000 gallons. The volume of each WWCT is approximately 450,000 gallons, but operational practice is to begin processing once a combined level of 264,000 gallons has been accumulated in order to provide a reserve volume of space in the collection tanks in case of a shutdown in the treatment process. (Ref. 2). The release is dependent on the total volume of the spill only to the extent that the total surface area of the dike is covered, which would only require approximately 1300 gallons. However, smaller spills may limit the amount of contaminant available for release.
- Accidents are modeled as a ground level releases.
- Meteorological conditions used are from References 1 and 3.

Adverse meteorological conditions

Stability Class	E
Wind speed	1.7 m/s
Temperature	29°C
Ground Roughness	urban

- The maximum concentration of dimethyl mercury (DMM) in the WWCT at the Effluent Treatment Plant (ETP) is 3 mg/L. This is considered a conservative bounding value for wastewater in the WWCT. It is representative of typical 3H Evaporator Overheads liquid, which is considered the highest potential source of dimethyl mercury in the Tank Farm. The only liquid sample from H-Lift Station was 96.7 µg/L and the only liquid sample from F-Lift Station was non-detectable (<0.002 µg/L). The only liquid sample from the WWCT was 12.1 µg/L (Ref. 4).
- The maximum concentration of ammonia in the WWCT at the ETP is 20 mg/L and is based on the ETP Waste Acceptance Criteria (WAC) (Ref. 5).
- The wastewater in the WWCT is sufficiently dilute that the density is ≈ 1 kg/L.

- Transfer spills are assumed to be limited to ten minute durations by Conduct of Operations protocol. Therefore, with the anticipated maximum flowrate associated with wastewater (295 gpm) (Ref. 2), the associated transfer spill volume is 2950 gallons.
- Pool depth for unconfined transfer spills is assumed to be 1 cm.

METHODOLOGY

Dimethyl Mercury

The evaporative release from a spill of wastewater containing very dilute contaminants is estimated using a two-resistance mass transfer model (Ref. 6). The overall mass transfer coefficient is given by:

$$1/K_L = 1/k_w + RT/Hk_a$$

where: K_L – overall mass transfer coefficient (MTC)
k_w – water phase MTC
R – gas constant
T – temperature
H – Henry's constant
k_a – air phase MTC.

For substances like mercury and dimethyl mercury with relatively large Henry's law constants, the rate of evaporation is controlled by the liquid phase coefficient (Ref. 6).

Therefore: $K_L \approx k_w$

The mass flux across the phase boundary can then be given in terms of the bulk liquid concentration and the partial pressure of contaminant in the atmosphere (Ref. 6).

$$N = K_L (C_L - p/H)$$

where: N – mass flux
C_L – bulk liquid phase concentration
p – partial pressure
H – Henry's constant

The background atmospheric level of DMM is conservatively assumed to be negligible.

Therefore: $N \approx K_L C_L$

The water phase MTC is calculated using an experimentally determined correlation by Lunney, Springer, and Thibodeaux (Ref. 7).

$$k_w = 2.788E\text{-}06 (D_{wi}/D_{we})^{2/3}$$

where: k_w – liquid phase mass transfer coefficient, m/s
D_{wi} – contaminant diffusivity in water, m^2/s
D_{we} – diffusivity of ethyl ether (EE) in water, 0.85E-09 m^2/s @ 25°C

The equation is valid for "shallow" systems with a fetch to depth ratio (similar to diameter of pool to depth ratio) of greater than 14 and for wind speeds from 0 to 5 m/s determined at 10m altitude.

The diffusivity of dimethyl mercury in water is estimated using the correlation of Wilke and Chang which is valid for dilute solutions of non-electrolytes (Ref. 8).

$$D_{wi} = [7.4E\text{-}08\ (\varphi\ M_w)^{0.5}\ T]/[\mu v_i^{0.6}]$$

where: D_{wi} – contaminant diffusivity in water, cm^2/s
φ – association factor for solvent = 2.6 for water
M_w – molecular weight of solvent = 18.02 for water
T – temperature, K
μ – solution viscosity, centipoises
v_i – solute molar volume at the normal boiling point, $cm^3/gmol$

The molar volume of dimethyl mercury is estimated using the method of Schroeder (Ref. 9).

$$v_i = \Sigma\ n_i v_{bi} + \Sigma\ n_i^{extra}\ v_{bi}^{extra}$$

where: v_i – solute molar volume at the normal boiling point, $cm^3/gmol$,
n_i – number of atoms of volume v_{bi}
v_{bi} – atomic volume, $cm^3/gmol$
$n_i^{extra}\ v_{bi}^{extra}$ – volumes associated with bonding, not applicable for DMM

Since all of the bonds in dimethyl mercury are single bonds, the above equation is simplified.

$$v_i = \Sigma\ n_i v_{bi}$$

<u>Ammonia</u>

The evaporative release from a spill of wastewater containing ammonia is estimated using the Kawamura-Mackay model (Ref. 10,11). The source term is given by:

$$ST = A\ k\ (M_a\ p_a/RT)$$

where: ST – source term
A – surface area
k – mass transfer coefficient
M_a – molecular weight of ammonia
p_a – partial pressure of ammonia
R – gas constant
T – temperature.

The mass transfer coefficient is calculated using a correlation by Mackay and Matsugu (Ref. 10,11).

$$k = 0.0048\ U^{7/9}\ Z^{-1/9}\ Sc^{-2/3}$$

where: k – mass transfer coefficient, m/s
U – wind speed at a height of 10 m, m/s
Z – pool diameter in the wind direction, m
Sc – laminar Schmidt number, dimensionless

The laminar Schmidt number is calculated by (Ref. 11):

$$Sc = \nu/D_a$$

where: Sc – laminar Schmidt number, dimensionless
ν – kinematic viscosity of the air, cm^2/s
D_a – diffusivity of ammonia in air, cm^2/s.

The molecular diffusivity of ammonia is approximated by (Ref. 11):

$$D_a = D_w(M_w/M_a)^{1/2}$$

where: D_a – diffusivity of ammonia in air, m^2/s
D_w – diffusivity of water in air, m^2/s
M_w – molecular weight of water
M_a – molecular weight of ammonia.

The partial pressure is determined from the Henry's Law constant for ammonia in pure water, which is described by the following equation (Ref. 12). For the dilute concentrations in the WWCT, this provides a close approximation, i.e. the activity coefficient ≈ 1.0.

$$\ln (H_a) = -8.09694 + 3917.50/T - 0.00314\ T$$

where: H_a – Henry's constant for ammonia in pure water, mols/kg-water-atm
T – temperature, K

$$p_a = C_a / H_a$$

where: p_a – partial pressure of ammonia, atm
C_a – liquid concentration of ammonia, molal units, mols/kg-water
H_a – Henry's constant for ammonia in pure water, mols/kg-water-atm

CALCULATIONS

Source Term – Dimethyl Mercury

The following calculations are performed to determine the evaporative mass flux from a spill of dimethyl mercury contaminated wastewater.

Atomic Volume - Mercury

Inputs

Input	Value	Reference
Normal Boiling Point, NBP	356.58 °C	13, p. D-190
Density at NBP	12.755 g/cm^3	13, p. F-7
Atomic Weight - Hg	200.59	13, inside cover

Atomic Volume = Atomic Weight/Density
= 200.59 g/gmol / 12.755 g/cm^3
= 15.726 cm^3/gmol

Molar Volume

Inputs

Input	Value	Reference
Molecular Formula	C_2H_6Hg	
Atomic Vol – C, H	7 cm^3/gmol	9, p. 46
Atomic Vol - Hg	15.726 cm^3/gmol	Calculated

$v_i = \Sigma\, n_i v_{bi}$
= (2 carbons x 7) + (6 hydrogens x 7) + (1 mercury x 15.7)
= 71.7 cm^3/gmol

Diffusivity in Water - Dimethyl Mercury

Inputs

Input	Value	Reference
Association Factor, φ	2.6	8, p. 30
Molecular Weight Solvent, M_w	18.02	8, p. 31
Temperature, T	29°C/302 K	Assumption
Solution Viscosity, μ	0.821 cP	14, App 14
Solute Molar Volume, v_i	71.7 cm^3/gmol	Calculated

$D_{wi} = [7.4E\text{-}08\ (\varphi\ M_w)^{0.5}\ T]/[\mu v_i^{0.6}]$
$= [7.4E\text{-}08\ (2.6 \times 18.02)^{0.5}\ (302\ K)]/[0.821 \times (71.7)^{0.6}]$
= 1.435E-05 cm^2/s
= (1.435E-05 cm^2/s) x (1 m/100 cm)^2
= 1.435E-09 m^2/s

Water Phase Mass Transfer Coefficient - Dimethyl Mercury in Water

Inputs

Input	Value	Reference
Diffusivity in Water - DMM	1.435E-09 m^2/s	Calculated
Diffusivity in Water - EE	0.85E-09 m^2/s	7, p. 209

$k_w = 2.788E\text{-}06\ (D_{wi}/D_{we})^{2/3}$
$= 2.788E\text{-}06\ (1.435E\text{-}09/0.85E\text{-}09)^{2/3}$
$= 3.96E\text{-}06$ m/s

Evaporative Mass Flux - Dimethyl Mercury in Water

Inputs

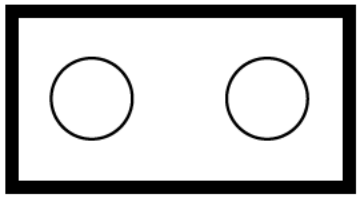
Input	Value	Reference
Mass Transfer Coefficient	3.96E-06 m/s	Calculated
Liquid Concentration - DMM	3 mg/L	Assumption

$N = K_L\ C_L$
$= 3.96E\text{-}06$ m/s x 3 mg/L x (1000 L/1 m^3)
$= 1.19E\text{-}02$ mg/m^2-s

Pool Surface Area – WWCT Spill (1-RD-1)

Inputs

Input	Value	Reference
Wastewater Collection Tank (WWCT) Dike Inside Width	75 ft	15
WWCT Dike Inside Length	145 ft	15
WWCT Radius (typ)	30 ft	16



Wastewater Collection Tanks Dike

Pool Surface Area = Dike Area – Tank Area
$= [75\ ft \times 145\ ft] - [2\pi(30\ ft)^2]$
$= 5220\ ft^2 \times (1m/3.28ft)^2$
$= 485\ m^2$

WWCT Spill (1-RD-1) Source Term – Dimethyl Mercury

ST = N x A
$= 1.19E\text{-}02$ mg/m^2-s x 485 m^2
$= 5.77$ mg/s

Pool Surface Area – Transfer Spill (1-RD-2)

Inputs

Input	Value	Reference
Spill Volume	2950 gals	Assumption
Unconfined Pool Depth	1 cm	Assumption

Pool Surface Area = Volume/Depth
= (2950 gals)(1 m^3/264.17 gals)/(0.01 m)
= 1117 m^2

Transfer Spill (1-RD-2) Source Term – Dimethyl Mercury

ST = N x A
= 1.19E-02 mg/m^2-s x 1117 m^2
= 13.3 mg/s

Source Term – Ammonia

The following calculations are performed to determine the evaporative release from a spill of ammonia contaminated wastewater.

Diffusivity in Air - Ammonia

Inputs

Input	Value	Reference
Diffusivity of Water in Air, 29°C	0.2714 cm^2/s	17, p. 194, Table 2
Molecular Weight Water, M_w	18.02	Periodic Table
Molecular Weight Ammonia, M_a	17.03	Periodic Table

$D_a = D_w(M_w/M_a)^{1/2}$
= 0.2714 cm^2/s $(18.02/17.03)^{1/2}$
= 0.2792 cm^2/s

Schmidt Number – Ammonia in Air

Inputs

Input	Value	Reference
Kinematic Viscosity of Air, 29°C	0.1614 cm^2/s	17, p. 194, Table 2
Diffusivity of Ammonia in Air, 29°C	0.2792 cm^2/s	Calculated

$Sc = \nu/D_a$
= 0.1614 cm^2/s / 0.2792 cm^2/s
= 0.5781

WWCT Spill (1-RD-1) Mass Transfer Coefficient – Ammonia in Air

Inputs

Input	Value	Reference
Wind Speed	1.7 m/s	Assumption
Diameter of Pool	24.84 m	Calculated (below)
Schmidt Number – Ammonia/Air	0.5781	Calculated

$$\text{Equivalent Radius} = (\text{Pool Surface Area}/\pi)^{1/2}$$
$$= (485\ m^2/\pi)^{1/2}$$
$$= 12.42\ m$$

$$k = 0.0048\ U^{7/9}\ Z^{-1/9}\ Sc^{-2/3}$$
$$= 0.0048\ (1.7\ m/s)^{7/9}\ (24.84\ m)^{-1/9}\ (0.5781)^{-2/3}$$
$$= 0.0073\ m/s$$

Transfer Spill (1-RD-2) Mass Transfer Coefficient – Ammonia in Air

Inputs

Input	Value	Reference
Wind Speed	1.7 m/s	Assumption
Diameter of Pool	37.7 m	Calculated (below)
Schmidt Number – Ammonia/Air	0.5781	Calculated

$$\text{Equivalent Radius} = (\text{Pool Surface Area}/\pi)^{1/2}$$
$$= (1117\ m^2/\pi)^{1/2}$$
$$= 18.86\ m$$

$$k = 0.0048\ U^{7/9}\ Z^{-1/9}\ Sc^{-2/3}$$
$$= 0.0048\ (1.7\ m/s)^{7/9}\ (37.7\ m)^{-1/9}\ (0.5781)^{-2/3}$$
$$= 0.0070\ m/s$$

Partial Pressure – Ammonia

Inputs

Input	Value	Reference
Temperature	29°C (302 K)	Assumption
Ammonia Concentration	20 mg/L	Assumption
Density of Wastewater - WWCT	1 kg/L	Assumption

$$\ln(H_a) = -8.09694 + 3917.50/T - 0.00314\ T$$
$$= -8.09694 + 3917.50/(302) - 0.00314\ (302)$$
$$= 3.927$$
$$H_a = e^{3.927}$$
$$= 50.74\ \text{mols/(kg-water-atm)}$$

$$p_a = C_a/H_a$$
$$= \frac{(20\ mg/L)(1L/kg\text{-}water)}{(50.74\ mols/kg\text{-}water\text{-}atm)(17.03\ g/mol)(1000\ mg/g)}$$
$$= 2.3E\text{-}05\ atm$$

WWCT Spill (1-RD-1) Source Term - Ammonia

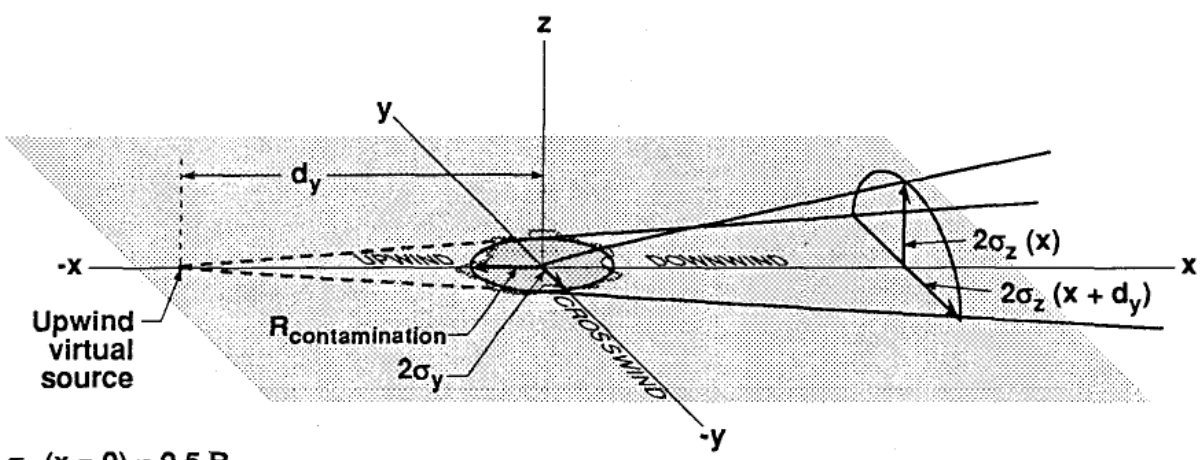
ST = A k (M_a p_a/RT)
= (485m^2)(0.0073m/s)(17.03g/mol)(2.3E-05atm)(1000 L/m^3)
(0.08206 L-atm/mol-K)(302K)
= (5.60E-02 g/s)(1000 mg/g)
= 56.0 mg/s

Transfer Spill (1-RD-2) Source Term - Ammonia

ST = A k (M_a p_a/RT)
= (1117m^2)(0.0070m/s)(17.03g/mol)(2.3E-05atm)(1000 L/m^3)
(0.08206 L-atm/mol-K)(302K)
= (1.24E-01 g/s)(1000 mg/g)
= 124 mg/s

Consequence Analysis

The downwind consequences are determined using the Gaussian plume equation with Briggs urban dispersion coefficients. An equivalent pool diameter and upwind virtual point source term model similar to the method used for resuspension source terms in Hotspot is used (Ref. 18).



σ_y (x = 0) = 0.5 $R_{contamination}$

σ_z (x = 0) = 0

Virtual Source Location

The upwind distance to the virtual source is the distance which gives a crosswind dispersion coefficient equal to half the radius of the pool. The Briggs urban dispersion coefficient for E-stability class is given by (Ref. 19):

$$\sigma_y = 0.11(x)(1 + 0.0004x)^{-1/2}$$

where: σ_y – crosswind dispersion coefficient, m
x – downwind distance, m

Adjusting the dispersion coefficient for averaging time in accordance with the relation suggested by Gifford (Ref. 19):

$$\sigma_y^* = \sigma_y (t/10)^{0.2}$$

where: σ_y^* – averaging time corrected crosswind dispersion coefficient, m
t – averaging time, min

For chemical consequence analysis, an averaging time of 15 minutes is used (Ref. 20).

$$\begin{aligned}\sigma_y^* &= \sigma_y (t/10)^{0.2} \\ &= \sigma_y (15/10)^{0.2} \\ &= 1.084\sigma_y \\ &= (1.084)(0.11)(x)(1 + 0.0004x)^{-1/2} \\ &= (0.12)(x)(1 + 0.0004x)^{-1/2}\end{aligned}$$

Downwind Dispersion Coefficients

The downwind Briggs dispersion coefficients are calculated at a distance 30 meters from the leading edge of the pool using the Briggs urban coefficient correlations for E-stability class adjusted for averaging time (Ref. 18,19).

WWCT Spill (1-RD-1)

$$\sigma_y^* = (0.12)(x)(1 + 0.0004x)^{-1/2}$$

Solving for x when $\sigma_y^* = 0.5\ (12.42\ \text{m}) = 6.41\ \text{m} \Rightarrow x = 54\ \text{m}$ (d_y in the diagram).

$$\begin{aligned}x \text{ for } \sigma_y^* &= x + d_y + R \\ &= 30\text{m} + 54\text{m} + 12.4\text{m} \\ &= 96.4\ \text{m}\end{aligned}$$

$$\begin{aligned}\sigma_y^* &= (0.12)x(1 + 0.0004x)^{-1/2} \\ &= (0.12)(96.4\text{m})[1 + 0.0004(96.4\text{m})]^{-1/2} \\ &= 11.35\ \text{m}\end{aligned}$$

x for σ_z = x + R
= 30m + 12.4m
= 42.4 m

$\sigma_z = (0.08)(x)(1 + 0.0015x)^{-1/2}$
$= (0.08)(42.4m)[1 + 0.0015(42.4m)]^{-1/2}$
= 3.29 m

Transfer Spill (1-RD-2)

$\sigma_y^* = (0.12)(x)(1 + 0.0004x)^{-1/2}$

Solving for x when $\sigma_y^* = 0.5$ (18.86 m) = 9.43 m => x = 79.8 m (d_y in the diagram).

x for σ_y^* = x + d_y + R
= 30m + 79.8m + 18.9m
= 128.7 m

$\sigma_y^* = (0.12)x(1 + 0.0004x)^{-1/2}$
$= (0.12)(128.7m)[1 + 0.0004(128.7m)]^{-1/2}$
= 15.06 m

x for σ_z = x + R
= 30m + 18.9m
= 48.9 m

$\sigma_z = (0.08)(x)(1 + 0.0015x)^{-1/2}$
$= (0.08)(48.9m)[1 + 0.0015(48.9m)]^{-1/2}$
= 3.78 m

Downwind Concentration

Using the source terms determined above, the downwind centerline ground level concentration is calculated at a distance 30 meters from the leading edge of the pool using the Gaussian equation (Ref. 21).

$$C/Q\ (x,y,z) = 1/(2\pi\ \sigma_y^*\ \sigma_z\ u)\ \exp[-y^2/(2\ \sigma_y^{*\,2})] \times \{\exp[-(z-h)^2/(2\ \sigma_z^{\ 2}) + \exp[-(z+h)^2/(2\ \sigma_z^{\ 2})\}$$

where: C – downwind concentration at coordinates (x,0,0), mg/m^3
Q – source strength, mg/s
σ_y^* – averaging time corrected crosswind dispersion coefficient, m
σ_z –vertical dispersion coefficient, m
u – wind speed, m/s
y – crosswind distance from the plume axis, m
z – vertical height above ground, m
h – effective release height above ground, m

For ground level centerline concentrations in which y, z, and h are all equal to zero, the equation is simplified to the following:

$C(x,0,0) = Q/(\pi\ \sigma_y^*\ \sigma_z\ u)$

WWCT Spill (1-RD-1)

Downwind Concentration – Dimethyl Mercury

$C(\text{“30m”},0,0) = Q/(\pi\ \sigma_y^*\ \sigma_z\ u)$
$= (5.77\ \text{mg/s})/[\pi\ (11.35\text{m})(3.29\text{m})(1.7\text{m/s})]$
$= 0.0289\ \text{mg/m}^3\ (1000\ \mu\text{g/mg})$
$= 28.9\ \mu\text{g/m}^3$

Downwind Concentration – Ammonia

$C(\text{“30m”},0,0) = Q/(\pi\ \sigma_y^*\ \sigma_z\ u)$
$= (56.0\ \text{mg/s})/[\pi\ (11.35\text{m})(3.29\text{m})(1.7\text{m/s})]$
$= 0.2808\ \text{mg/m}^3\ (1000\ \mu\text{g/mg})$
$= 281\ \mu\text{g/m}^3$

Transfer Spill (1-RD-2)

Downwind Concentration – Dimethyl Mercury

$C(\text{“30m”},0,0) = Q/(\pi\ \sigma_y^*\ \sigma_z\ u)$
$= (13.3\ \text{mg/s})/[\pi\ (15.06\text{m})(3.78\text{m})(1.7\text{m/s})]$
$= 0.0438\ \text{mg/m}^3\ (1000\ \mu\text{g/mg})$
$= 43.8\ \mu\text{g/m}^3$

Downwind Concentration – Ammonia

$C(\text{“30m”},0,0) = Q/(\pi\ \sigma_y^*\ \sigma_z\ u)$
$= (124.0\ \text{mg/s})/[\pi\ (15.06\text{m})(3.78\text{m})(1.7\text{m/s})]$
$= 0.4079\ \text{mg/m}^3\ (1000\ \mu\text{g/mg})$
$= 408\ \mu\text{g/m}^3$

RESULTS AND CONCLUSION

The adverse meteorological 30 meter concentrations and PAC-2 concentrations (TEEL-2 DMM; AEGL-2 Ammonia) for the postulated spill scenarios are provided in Table 1 (Ref. 22). The results show that the concentrations are below the PAC-2 levels and, therefore, would not result in a classifiable operational emergency.

Table 1 Adverse Meteorological Results

RD	Chemical	Conc. @ 30 m* ($\mu g/m^3$)	PAC-2 ($\mu g/m^3$)	Probable Event Class
1-RD-1	Dimethyl Mercury	28.9	46	None
	Ammonia	281	111,000	None
1-RD-2	Dimethyl Mercury	43.8	46	None
	Ammonia	408	111,000	None

Note: * 30 m from the edge of the spill

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INTRODUCTION

This is a completely new calculation for Revision 1; therefore, no revision bars are included.

This calculation develops ground level, downwind centerline concentrations for a large spill from the Waste Concentrate Tanks (WCT) in the Treatment Building and for a large spill from the Waste Concentrate Hold Tank (WCHT) into the containment dike. The contaminant chemical concentrations are calculated at 30 m from the building. Transfer spills are also addressed. Releases are considered under adverse meteorological conditions as directed by procedure EMPP 6Q-001 (Ref. 1).

WCT/WCHT SPILL ACCIDENT SCENARIO

An accident (mechanical failure, overflow, operator error, Natural Phenomena Hazard (NPH) event, etc.) results in a large spill of waste concentrate into the building or dike. Volatile chemical contaminants contained in the waste concentrate evaporate into the building or dike and are released to the atmosphere.

ASSUMPTIONS

- Since the ventilation stack is not tall enough to allow credit for an elevated release or may not survive in certain NPH initiator scenarios, the accident is modeled as a ground level release (Ref. 2)
- Meteorological conditions used are taken from References 1 and 3.

Adverse meteorological conditions

Stability Class	E
Wind speed	1.7 m/s
Temperature	29°C
Ground Roughness	urban

- The maximum concentration of mercury in the WCT/WCHT at the Effluent Treatment Plant (ETP) is 325 mg/L. This is based on the Waste Acceptance Criteria (WAC) for Saltstone and is consistent with the current and proposed criteria (Ref. 4,5,6). However, this value is total mercury including both volatile and non-volatile species. This calculation assumes the maximum concentration of volatile mercury is determined by the solubility of elemental mercury at the maximum WCT temperature of 225 °F (107 °C) (Ref. 7, p. 637; Ref. 8, p. 56)
- The maximum spill volume for the WCT is 1747 gallons and is based on the tank overfill alarm and safety interlock level (Ref. 8, p. 60).
- The maximum spill volume for the WCHT is 30,000 gallons and is based on the tank overfill volume (Ref. 9).
- The maximum temperature of waste concentrate in the WCHT is 100 °C (Ref. 10).

- The maximum concentration of ammonia in the WCT/WCHT at the ETP is 1324 mg/L and is based on a flammability limit in the Auditable Safety Analysis (ASA) (Ref. 11, 12).
- The wind speed for the WCHT spill inside the diked area is assumed to be 1.0 m/s. This is less than the outdoor wind speed of 1.7 m/s, however, this diked area is inside a covered structure. Assuming a typical 3m x 3m release geometry, with the cross-section of the WCHT at approximately 22 ft high by 30 ft wide (6.7m x 9.1 m = 61 m^2) (Ref. 16), the speed reduction across the surface is ~ 9/61 = 0.15; therefore, the cross-flow wind speed would be ~ 0.25 m/s. Therefore, 1.0 m/s is conservative.
- Dimethyl mercury (DMM) release is assumed to be bounded by the Wastewater Collection Tank (WWCT) Spill Scenario (1-RD-1). This is based on the downstream treatment technology removing the majority (~ 95%) of the DMM and the much larger spill volume and surface area associated with the WWCT Spill Scenario.
- Transfer spills are assumed to be limited to ten minute durations by Conduct of Operations protocol. Therefore, with anticipated maximum flowrate associated with waste concentrate (100 gpm) (Ref. 8), the associated spill of 1000 gallons waste concentrate is bounded by the analyzed scenarios.

METHODOLOGY

The potential for release of hazardous components from the waste concentrate depends on the chemical composition and the volatility of the components. Accurate determination of this information would require detailed data on the multi-component chemical and phase equilibria of the waste concentrate solution in the evaporator and waste concentrate tanks. For the low contaminant concentrations in the waste concentrate, there may be insufficient inventory to result in a significant release. Therefore, it will be determined if complete releases of reasonably bounding concentrations of the volatile species result in airborne concentrations that exceed PAC-2 at the 30 meter receptor location. If not, no further analysis is required. If the inventory is sufficient to exceed the limiting source terms for a complete release, then an evaporative release estimate will be determined and compared to the limiting source term.

Utilizing a dispersion factor determined from Hotspot (Ref. 13), and setting the concentration equal to the PAC-2 values for the species concerned (ammonia and mercury), the following equation is used to determine the limiting case source terms.

$$ST = C / (X/Q)$$

where: ST = source term, mg/sec
C = concentration, mg/m^3
X/Q = dispersion factor, sec/m^3

The resulting STs are compared to the total potential amount released from the bounding concentrations in the spilled volume. A 15 minute time period is used commensurate with the standard averaging time for chemical releases (Ref. 14).

The modeling parameters used in Hotspot to determine the dispersion factor are as follows:

- adverse meteorological conditions
- surface area source geometry of 3m x 3m
- urban terrain dispersion coefficients
- ground level release
- inversion layer height – 300m
- wind height measurement – 2m
- deposition velocity of 0 cm/sec
- 15 minute sampling time
- receptor height of 0m
- source material of 1 Ci Pu-239 is used to convert the Time Integrated Air Concentration to a non-source specific dispersion factor, i.e. to convert from Ci-sec/m^3 to sec/m^3.

CALCULATIONS

Source Terms

The following calculations are performed to determine the limiting STs for a release of ammonia and mercury from a spill of waste concentrate from a WCT/WCHT.

Inputs

Input	Value	Reference
Dispersion Factor, X/Q	1.1E-02 sec/ m^3	Hotspot Output - below
Ammonia PAC-2	111 mg/m^3	15
Mercury Vapor PAC-2	1.7 mg/m^3	15

Hotspot Output

Hotspot Version 2.01 General Plume		Jun 06, 2011 03:09 PM	
Source Material : Pu-239 M 24065y		Stability Class (City) : E	
Source Term : 1.0000E+00 Ci		Respirable Dep. Vel. : 0.00E+00 cm/s	
Airborne Fraction : 1.000		Non-respirable Dep. Vel. : 0.00E+00 cm/s	
Respirable Fraction : 1.000		Receptor Height : 0.0 m	
Respirable Release Fraction: 1.000		Inversion Layer Height : 300 m	
Vertical Height : 3.00E+00 m		Sample Time : 15.000 min	
Horizontal Width : 3.00E+00 m		Breathing Rate : 3.33E-04 m3/sec	
Effective Release Height : 0.00 m		Maximum Dose Distance : 0.010 km	
Wind Speed (h=2 m) : 1.7 m/s		MAXIMUM CEDE : 2.54E+03 rem	
Distance Coordinates : All distances are on the Plume Centerline		FGR-13 Dose Conversion Data	
DISTANCE (km)	C E D E (rem)	TIME-INTEGRATED AIR CONCENTRATION (Ci-sec)/m^3	ARRIVAL TIME (hour min)
0.030	7.0E+02	1.1E-02	<00:01

ST (NH_3) = C / (X/Q)
= (111 mg/m^3)/(0.011 s/m^3)
= 1.01E+04 mg/s (15 min)(60 s/min)(1 g/1000 mg)
= 9.08E+03 g

ST (Hg) = C / (X/Q)
= (1.7 mg/m^3)/(0.011 s/m^3)
= 1.54E+02 mg/s (15 min)(60 s/min)(1 g/1000 mg)
= 1.39E+02 g

Limiting Source Terms

Chemical	ST (mg/s)	Total-15 min release (g)
Ammonia	1.01E+04	9.08E+03
Mercury	1.54E+02	1.39E+02

Material at Risk (MAR) – WCT Spill

Inputs

Input	Value	Reference
WCT Spill Volume	1747 gals	Assumption; 8, p. 60
WCT Ammonia Concentration, max	1325 mg/L	Assumption; 11, p. 29
WCT Mercury Concentration, max	3.88E-06 mol/kg	Assumption; 7, p. 637
Atomic Weight - Mercury	200.6	Periodic Table
Solution Density	1.2876 kg/L	12, p. 11
Solution Solvent Mass Fraction	0.733	12, p. 22

MAR (NH_3) = Spill Volume x Max Concentration
= (1747 gals)(3.785 L/gal)(1325 mg/L)(1 g/1000 mg)
= 8.76E+03 g

Since this value is below the limiting ST, no further analysis is required.

Max Conc Hg (mg/L) = Max Conc Hg (molality) x Atomic Weight Hg x Solution Density x Solvent Mass Fraction
= (3.88E-06 mol/kg)(200.6 g/mol)(1.2876 kg/L)(0.733 kg water/kg soln)
= 7.34E-04 g/L

MAR (Hg) = Spill Volume x Max Concentration
= (1747 gals)(3.785 L/gal)(7.34E-04 g/L)
= 4.86 g

Since this value is below the limiting ST, no further analysis is required.

Material at Risk (MAR) – WCHT Spill

Inputs

Input	Value	Reference
WCHT Spill Volume	30,000 gals	Assumption; 9, Sect. 2.2
WCHT Ammonia Concentration, max	1325 mg/L	Assumption; 11, p. 29
WCHT Mercury Concentration, max	3.88E-06 mol/kg	Assumption; 7, p. 637
Atomic Weight - Mercury	200.6	Periodic Table
Solution Density	1.2876 kg/L	12, p. 11
Solution Solvent Mass Fraction	0.733	12, p. 22

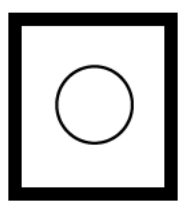
MAR (NH_3) = Spill Volume x Max Concentration
= (30,000 gals)(3.785 L/gal)(1325 mg/L)(1 g/1000 mg)
= 1.50E+05 g

Since this value exceeds the limiting ST, an evaporative release estimate is required. The evaporative source term is estimated using the Kawamura-Mackay model described in Calculation 1.

Pool Surface Area

Inputs

Input	Value	Reference
Waste Concentrate Hold Tank (WCHT) Dike Inside Width	30 ft	16
WCHT Dike Inside Length	31 ft	16
WCHT Diameter	17.5 ft	16



Waste Concentrate Hold Tank Dike

Pool Surface Area = Dike Area – Tank Area
= [30 ft x 31 ft] - [π(17.5 ft)^2/4]
= 689.5 ft^2 x (1m/3.28ft)^2
= 64 m^2

Equivalent Radius of the Pool

Equivalent Radius = (Pool Surface Area/π)$^{1/2}$
= (64 m^2/π)$^{1/2}$
= 4.5 m

Source Term – Ammonia

The following calculations are performed to determine the evaporative release from a spill of ammonia contaminated waste concentrate from a WCHT.

Diffusivity in Air - Ammonia

The diffusivity of ammonia in air is determined using the Wilke-Lee modification of the Hirschfelder-Bird-Spotz method (Ref. 17, p. 3-230).

$$D_a = [BT^{3/2}(1/M_{Air} + 1/M_a)^{1/2}]/Pr^2 I_d$$

where: D_a – diffusivity of ammonia in air, cm^2/s
B – calculated constant
T – absolute temperature, K
M_{Air} – molecular weight of air
M_a – molecular weight of ammonia
P – absolute pressure, atm
r – collision diameter, angstroms (A)
I_d – collision integral for diffusion, function of kT/ε from tables.

Inputs

Input	Value	Reference
Temperature	100°C	Assumption, 10
Molecular Weight Air, M_{Air}	28.982	18, p. 194, footnote
Molecular Weight Ammonia, M_a	17.03	Periodic Table
Collision Diameter, Air	3.617 A	17, Table 3-308, p. 3-234
Collision Diameter, Ammonia	2.624 A	17, Table 3-308, p. 3-234
$(\varepsilon/k)_{air}$	97.0	17, Table 3-308, p. 3-234
$(\varepsilon/k)_{ammonia}$	315	17, Table 3-308, p. 3-234
I_d (2.13)	0.5263	17, Table 3-309, p. 3-234

$$B = [10.85 - 2.50\,(1/M_{Air} + 1/M_a)^{1/2}] \times 10^{-4}$$
$$= [10.85 - 2.50\,(1/28.982 + 1/17.03)^{1/2}] \times 10^{-4}$$
$$= 10.1 \times 10^{-4}$$

$$r = (r_{air} + r_a)/2$$
$$= (3.617 + 2.624)/2$$
$$= 3.12$$

$$I_d = f\,(kT/\varepsilon)_{air\text{-}ammonia}$$

$$(\varepsilon/k)_{air\text{-}ammonia} = [(\varepsilon/k)_{air} \times (\varepsilon/k)_{ammonia}]^{1/2}$$
$$= [97.0 \times 315]^{1/2}$$
$$= 174.8$$

$$(kT/\varepsilon)_{air\text{-}ammonia} = 373/174.8$$
$$= 2.13$$

I_d = f (2.13) = 0.5263

$D_a = [BT^{3/2}(1/M_{Air} + 1/M_a)^{1/2}]/Pr^2 I_d$
$= [(10.1 \times 10^{-4})\ (373)^{3/2}(1/29.982 + 1/17.03)^{1/2}\ ]/[(1\ atm)(3.12)^2\ (0.5263)]$
$= 0.433\ cm^2/s$

Schmidt Number – Ammonia in Air

Inputs

Input	Value	Reference
Viscosity of Air, μ, 100°C	0.021 cP	19, App 9, p. 996
Diffusivity of Ammonia in Air, 100°C	0.433 cm^2/s	Calculated

kinematic viscosity, $\nu = \mu/\rho$

$\rho = PM_{air}/(RT)$
$= (1\ atm)(28.982\ g/gmol)/[(0.08206\ L\text{-}atm/gmol\text{-}K)(373K)]\ (1000\ L/m^3)$
$= 947\ g/\ m^3$
$\nu = \mu/\rho$
$= (0.021\ g/m\text{-}s)/(947\ g/\ m^3)$
$= 2.22 \times 10^{-5}\ m^2/s\ (100\ cm/m)^2$
$= 0.222\ cm^2/s$

$Sc = \nu/D_a$
$= 0.222\ cm^2/s\ /\ 0.433\ cm^2/s$
$= 0.513$

Mass Transfer Coefficient – Ammonia in Air

Inputs

Input	Value	Reference
Wind Speed	1.0 m/s	Assumption
Equivalent Diameter of Pool	9.0 m	Calculated
Schmidt Number – Ammonia/Air	0.513	Calculated

$k = 0.0048\ U^{7/9}\ Z^{-1/9}\ Sc^{-2/3}$
$= 0.0048\ (1.0\ m/s)^{7/9}\ (9.0\ m)^{-1/9}\ (0.513)^{-2/3}$
$= 0.0059\ m/s$

Partial Pressure – Ammonia

Inputs

Input	Value	Reference
Temperature	100°C (373 K)	Assumption, 10
Ammonia Concentration	1324 mg/L	Assumption, 10, 12
Density of Wastewater – WCT/WCHT	1.2876 kg/L	12, Sect. 9.0
Mass fraction of water in waste concentrate	0.733	12, Sect. 9.0

$\ln(H_a) = -7.357 + 3330.1/T - 0.002139\ T$
$= -7.357 + 3330.1/(373) - 0.002139\ (373)$
$= 0.773$
$H_a = e^{0.773}$
$= 2.17$ mols/(kg-water-atm)

$p_a = C_a / H_a$
$= \frac{(1324\ mg/L)(1L/1.2876\ kg\text{-}soln)(1\ kg\text{-}soln/0.733\ kg\text{-}water)}{(2.17\ mols/kg\text{-}water\text{-}atm)(17.03\ g/mol)(1000\ mg/g)}$
$= 0.038$ atm

Evaporative Source Term – Ammonia

$ST = A\ k\ (M_a\ p_a/RT)$
$= \frac{(64m^2)(0.0059m/s)(17.03g/mol)(0.038atm)(1000\ L/m^3)}{(0.08206\ L\text{-}atm/mol\text{-}K)(373K)}$
$= 7.94$ g/s

For a 15 minute release,

ST = (7.94 g/s)(15 min)(60 s/min)
= 7.15E+03 g

Since this value is below the limiting ST, no further analysis is required.

MAR – Mercury

Max Conc Hg (g/L) = Max Conc Hg (molality) x Atomic Weight Hg x Solution Density x Solvent Mass Fraction
= (3.88E-06 mol/kg-water)(200.6 g/mol)(1.2876 kg-soln/L) x (0.733 kg-water/kg soln)
= 7.34E-04 g/L

MAR (Hg) = Spill Volume x Max Concentration
= (30,000 gals)(3.785 L/gal)(7.34E-04 g/L)
= 83.3 g

Since this value is below the limiting ST, no further analysis is required.

RESULTS AND CONCLUSION

The available MAR for the volatile species of ammonia and mercury in the WCT are less than the limiting STs which would result in exceeding PAC-2 at the 30 m receptor location. These limiting STs were determined for adverse meteorological conditions and maximum concentrations of volatile species of ammonia and mercury in the WCT. Therefore, the WCT Spill Scenario would not result in a classifiable operational emergency and no EAL is required.

Table 1 MAR versus Limiting STs

RD	Chemical	Limiting ST (g)	MAR/ST (g)	Probable Event Class
1-RD-3	Ammonia	9.08E+03	8.76E+03	None
	Mercury	1.39E+02	4.86	None
1-RD-4	Ammonia	9.08E+03	7.15E+03	None
	Mercury	1.39E+02	8.33E+01	None

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Attachment 1

SAVANNAH RIVER REMEDIATION LLC

Savannah River Site, Aiken, SC 29808

April 11, 2011

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To: Shawn Graham, 766-H
CRS-SMS Project Lead

From: Robert J. Gray, 766-H 4/11/11
SDI Design Authority

ETP WCHT CLFL Calculation

Background

The Salt Disposition Integration (SDI) portfolio of projects will perform modifications in several existing Liquid Waste facilities to facilitate the operation of the new Salt Waste Processing Facility (SWPF). Among these modifications is the ETP Tk50 Return to Service project which will install a new Waste Concentrate Hold Tank (WCHT) to allow for quarterly transfers from ETP to either Tank 50H or directly to the Saltstone Production Facility (SPF). The ETP currently sends waste concentrate from the Waste Concentrate Tanks (WCT) to Tank 50H. The new transfer path for the waste concentrate will be from the Waste Concentrate Hold Tank (WCHT) to the Salt Solution Receipt Tanks (SSRT).

Evaluation

A CLFL calculation (S-CLC-H-01170) was performed for the WCHT. The overflow volume for the WCHT has changed since the original calculation was performed. The WCHT CLFL calculation (S-CLC-H-01170) shall be revised to change the maximum waste level from 40,000 gallons to 30,000 gallons. The name of the new tank shall be revised from Effluent Hold Tank (EHT) to Waste Concentrate Hold Tank (WCHT). A back calculation shall also be performed to determine the maximum ammonia concentration possible while remaining below 25% CLFL.

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Inputs

The following inputs shall be used for the calculation:

INPUT	VALUE	REFERENCE
Ammonia Concentration	1524 mg/L	G-TC-H-00048, Rev. 5
Hydrogen Generation Rate	1.52E-09 ft^3/hr/gal @ 100°C	X-CLC-H-00867, Rev. 0
Operating Temperature	10°C – 100°C	G-TC-H-00048, Rev. 5
Tank Overflow Volume	30,000 Gallons	G-TC-H-00048, Rev. 5
Tank Operating Volume	25,000 Gallons	G-TC-H-00048, Rev. 5
Agitator Power	10 Horse Power	WB01407A, Sheet 1

Cc: Charles Whitehurst
William Van Pelt
Robert Ervin
Robert Dittmar
Christopher Cope

Appendix C

Emergency Planning Hazards Assessment Definitions

EPHA Definitions

The Emergency Planning Hazards Assessment utilizes some terms that may have meanings different from other safety documentation. This appendix highlights important terms used.

Absorption Type - fast (F), moderate (M), and slow (S) broadly characterize the rate of absorption from the respiratory tract to body fluids of deposited radiological material.

Acute Exposure Guideline Level (AEGL) - Airborne concentration above which adverse health effects are predicted. One-hour AEGLs are the preferred PAC for chemical exposures, followed by ERPGs, then TEELs.

- **AEGL-1** - airborne concentration above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, effects are not disabling but transient and reversible upon cessation of exposure.
- **AEGL-2** - airborne concentration above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
- **AEGL-3** - airborne concentration above which it is predicted that the general population, including susceptible individuals, could experience life-threatening adverse health effects or death.

Aerodynamic Equivalent Diameter (AED) - Diameter of sphere of density 1 g/cm^3 that exhibits the same terminal velocity as particle in question.

Alert - An Alert represents events in progress or having occurred that involves an actual or potential substantial reduction in the level of facility safety and protection. At SRS, an Alert has occurred if unplanned events result in hazardous material being released to the environment in concentrations that may result in exposures greater than the protective action criteria (PAC) at or beyond 30 meters from the source but not at or beyond the facility boundary.

Auditable Safety Analysis (ASA) - The purpose of the ASA is to provide a systematic identification of hazards within the facility and to describe the measures taken to eliminate, control, or mitigate the identified hazards. ASAs are completed according to Procedure Manual 11Q.

Barriers - Facility design features that contain hazardous materials or separate them from people or the environment are physical barriers. Examples of these would include tanks, cylinders, containment cells, buildings, and piping systems.

Committed Effective Dose (CED) - The sum of the committed effective doses over a fifty-year period to various organs or tissues in the body, each multiplied by the appropriate weighting factor. CED is applicable to exposure from internally deposited radionuclides.

Consequence - The result or effect (especially projected doses or dose rates) of a release of radioactive and/or hazardous materials to the environment.

Effective Dose Equivalent (EDE) (H_E) - The summation of the products of the dose equivalent received by specified tissues of the body (H_T) and the appropriate weighting factor (W_T) - that is ($H_E = \Sigma W_T H_T$). It includes the dose from radiation sources internal and/or external to the body. The effective dose equivalent is expressed in units of rem.

Emergency Action Level (EAL) - Specific, predetermined, and observable criteria used to detect, recognize, and classify hazardous material emergencies. An EAL can be an instrument reading; an equipment status indicator; a measurable parameter, onsite or offsite; a discrete, observable event; results of analyses; or another observed phenomenon that indicates entry into a particular emergency class.

Emergency Classification - Classifies an Operational Emergency involving a hazardous material release by the degree of severity, depending on the actual or potential consequence of the emergency. Classification levels are Alert, Site Area Emergency (SAE), and General Emergency (GE).

Emergency Planning Zone (EPZ) - A geographic area surrounding a specific DOE facility for which special planning and preparedness efforts are carried out to ensure that prompt and effective protective actions can be taken to reduce or minimize the impact to onsite personnel, public health and safety, and the environment in the event of an Operational Emergency.

Emergency Response Planning Guideline (ERPG) - a hazardous chemical exposure level developed for the general public. There are three (3) exposure levels of ERPGs approved by a committee of the American Industrial Hygiene Association (AIHA). These levels are as follows:

- **ERPG-1** - The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.
- **ERPG-2**- The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
- **ERPG-3**- The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

Equivalent isotope - An analytic technique of summing the dose potential from all the radionuclides of interest in a source term into a single “equivalent” radionuclide in order to facilitate quick consequence assessment of that source term.

Facility Boundary - This boundary represents the receptor location that differentiates between an Alert and Site Area Emergency declaration.

General Emergency (GE) - A General Emergency represents events that are in progress or have occurred that involve actual or imminent catastrophic failure of facility safety systems with potential for loss of confinement integrity, catastrophic degradation of facility protection systems, or catastrophic failure in safety or protection systems threatening the integrity of a weapon or test device that could lead to substantial offsite impacts. Environmental releases of hazardous materials can reasonably be expected to exceed the appropriate protective action criteria at the site boundary.

Hazardous Material - Any solid, liquid, or gaseous material that is toxic, flammable, radioactive, corrosive, chemically reactive or unstable upon prolonged storage in quantities that could pose a threat to life, property or the environment.

Hazards Survey - Identifies hazards significant enough to include in an EPHA (see EMPP 6Q-011).

Material at Risk (MAR) - The amount of hazardous material that is available to be acted on by a given physical stress. In an accident analysis, the MAR is multiplied by the appropriate release fraction to determine the source term.

Maximum Inventory - For a process; the maximum quantity of a hazardous material that a process produces during the process cycle. For storage tanks the maximum inventory is equivalent to the capacity of the tank.

Offsite - Area outside the site boundary.

Onsite - Any area within the boundaries of SRS to which access is controlled.

Onsite transfer - Transport of material performed in accordance with Procedure Manual 19Q Transportation Safety Manual (TSM) that remains within controlled areas of the site. During Onsite Transfer, material typically exits one area and enters another. Onsite Transfer typically terminates when material is unloaded at its final destination.

Operational Emergency (OE) - Major unplanned or abnormal events or conditions that: involve or affect DOE/NNSA facilities and activities by causing or having the potential to cause serious health and safety or environmental impacts; require resources from outside the immediate/affected area or local event scene to supplement the initial response; and, require time-urgent notifications to initiate response activities at locations beyond the event scene. An Operational Emergency involving release of significant quantities of hazardous materials within the SRS Controlled Area may require further classification as an Alert, Site Area Emergency, or General Emergency.

In accordance with DOE O 151.1C, an event must be categorized as an Operational Emergency as promptly as possible, but no later than *15 min* after event recognition/identification/discovery.

Protective Action (PA) - Physical measures (remain indoors, shelter, evacuation, relocation) taken to reduce potential health hazards from the plume exposure pathway.

Protective Action Criterion (PAC) - A radiological dose or toxic material concentration level that acts as a trigger, for a receptor point of interest, to declare an operational emergency and issue or recommend protective actions to protect workers or the public. PAC are:

- For radiological dose, 1 rem Total Effective Dose Equivalent (TEDE) or 5 rem Committed Dose Equivalent (CDE) thyroid is used as the trigger for classification of operational emergencies and off-site protective action recommendations.
- For chemical concentration, the AEGL-2, ERPG-2, or, TEEL-2 (in order of preference) is the trigger for classification of operational emergencies and off-site protective action recommendations.

Receptor Location: A defined location or distance from a release source, where the actual or projected threshold dose received from the release of hazardous material, results in exposures ≥ PACs. For the purpose of emergency classification, the receptor locations are defined as 30 meters from the release, the facility boundary and the site boundary. These receptor location establish the zones for classification of an operational emergency.

Release - Airborne effluent to the environment, as this pathway typically represents the most time-urgent situation. Releases to aquatic and ground pathways, in most instances, do not have the time-urgency of airborne releases. The hazard assessment considers releases to an aquatic or ground pathway having a time-urgent affect on workers or the public (e.g., to a community water supply).

Release Fraction: The coefficient used to estimate the amount of a hazardous material (material at risk) suspended in air and made available for airborne transport under a specific set of induced physical stress. The release fraction is a combination of the fraction of the material released and the fraction of the material that is respirable.

Respirable Fraction - Fraction of airborne particles that can be transported through air and inhaled into the respiratory system; assumed to include particles 10-µm Aerodynamic Equivalent Diameter (AED) and less.

Safety Basis - The documented safety analysis and hazard controls that provide reasonable assurance that a DOE nuclear facility can be operated safely in a manner that adequately protects workers, the public, and the environment. Reference Procedure 11Q, 1.01 *Generation, Review and Approval of Safety Documents*.

Segment - Demarcation used in hazards assessment where the system, section, building, etc., is not affected by failure of other systems, sections, buildings, etc.

Site - Area over which DOE has access control authority. This includes any area that has been designated as a National Security Area.

Site Area Emergency (SAE) - An SAE represents events that are in progress or have occurred involving actual or likely major failure(s) of facility safety or safeguard systems needed for the protection of onsite personnel, the public health and safety, the environment, or national security. Environmental releases of hazardous materials are expected to exceed the appropriate PAC at or beyond the facility boundary but not beyond the site boundary.

Site Boundary - Perimeter of DOE-owned land at SRS. [From DOE G 151.1: The perimeter enclosing the area where DOE has the responsibility for implementing protective action is the site boundary. With regard to DOE land that lies outside the security fence, DOE assumes responsibility for implementing protective action on all of its property.]

Source Term - The amount of respirable material released to the environment. The source term takes into consideration the Material at Risk, the Damage Ratio (fraction), Airborne Release Fraction, Respirable Fraction, Leak Path Factor (fraction), Airborne Release Rate (fraction/hour), and in some cases the Release Duration (hours). There can be both a chemical and a radiological source term.

Temporary Emergency Exposure Limit (TEEL) - TEELs are an estimate of the concentration above which one could reasonably anticipate observing adverse effects, as described in definitions for TEEL-0, TEEL-1, TEEL-2, and TEEL-3, as a consequence of exposure to a specific substance. SCAPA recommends that for application of TEELs, concentration at the receptor be calculated as the peak 15-minute time-weighted average.

- **TEEL-0** - threshold concentration below which most people will experience no appreciable risk of health effects.
- **TEEL-1** - maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.
- **TEEL-2** - maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
- **TEEL-3** - maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

Total Effective Dose (TED) - The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). Deep dose equivalent to the whole body may be used as effective dose equivalent for external exposures. For accidents associated with most SRS facilities, the CED calculated by SRS dispersion models is equivalent to the TED.