Environmental Impact Assessment

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MLD: Greater Malé Waste-to-Energy Project – Waste to Energy Plant PART H

Prepared by Ministry of Environment of the Republic of Maldives for the Asian Development Bank.

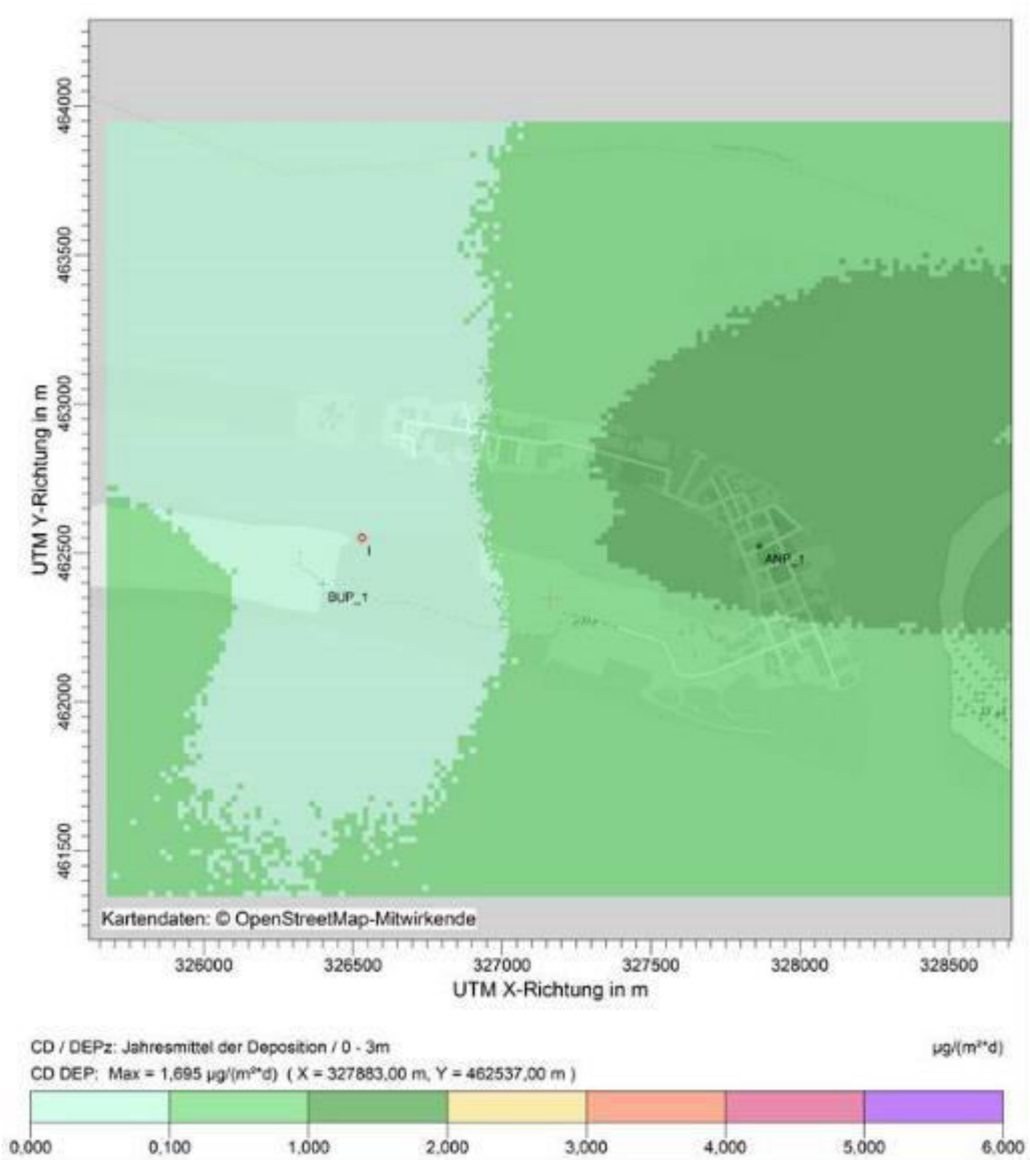


Figure 29: Cd-Deposit from the dispersion model.

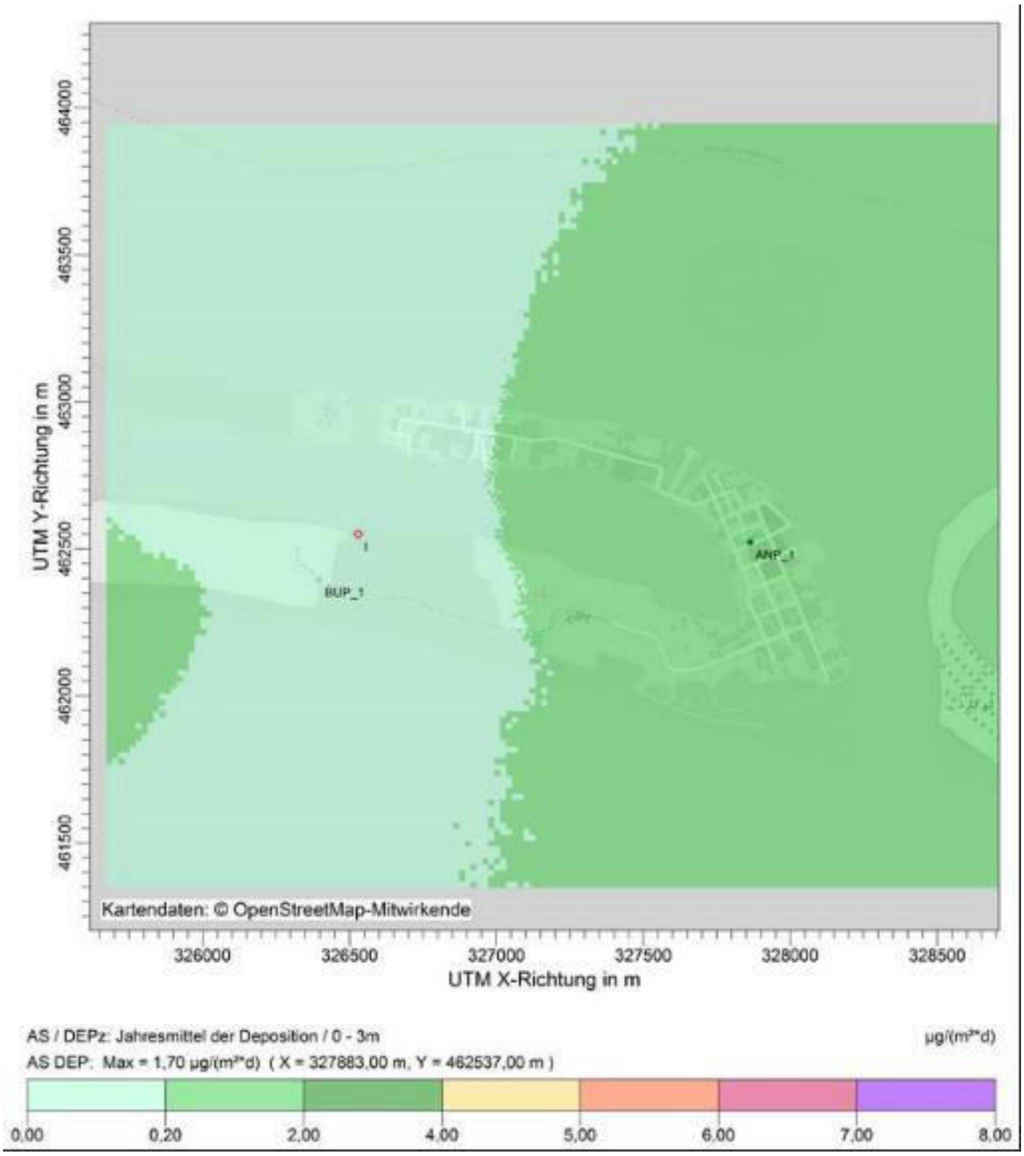


Figure 30: As-Deposit from the dispersion model.

The overall air quality of the project site is expected to increase with time. More significantly when the existing dumpsite is closed. Therefore, a long term, positive, and significant impact is expected with the operation of this project.

8.4 Interpretation of the results with respect to baseline conditions

Considering only the additional from process contribution it is clear that no harmful pollution is to be expected from the installation. Actually the baseline situation is mainly characterized by the dumpsite of Thilafushi which is set to be closed at the start of the operation of the new facility. Therefore the following results needs to be considered with care

Substance	Averaging time	AQ Standard/ Guideline (µg/m³)	Baseline (µg/m3)	Process contribution (µg/m3)	PC/ AQSG	Combined process + baseline (µg/m3)	Combined/ AQSG
Particulate matter (PM_{10})	24 hr average	50	**538,94**	0,100	0,20%	539,04	**1078,08%**
Particulate matter (PM10)	1 year	20		0,000	0,00%		
Particulate matter (PM2,5)	24 hr average	25	**387,57**	0,100	0,40%	387,67	**1550,68%**
Particulate matter (PM 2,5)	1 year	10		0,000	0,00%		
Sulfur dioxide SO2	24 hr average	20	**291,24**	0,200	1,00%		
Sulfur dioxide SO2	10 minutes	500	**970,00**	1,333	0,27%	971,33	**194,27%**
Nitrogen dioxide (NO2)	1 year	40		0,000	0,00%		
Nitrogen dioxide (NO2)	1 hr	200	72,80	0,017	0,01%	72,82	36,41%

9 Conclusions

The ambient air quality status of Maldives had been unknown due to the lack of air quality monitoring data. The air quality is generally considered good as the sea breezes flush the air masses over the small the islands. However rapid urbanization and economic growth in the recent years has shown noticeable changes in the air quality, particularly in the Male' region. Thilafushi Island is being used to dump huge volume of wastes from the neighbouring inhabited islands (Malé, Villingili and Hulhumalé) and nearby resort islands. Open burning of mixed wastes is being practiced at the island to reduce the volume of the waste. The smoke generated from burning increases the air pollutant load in the local air shed and also affects the air quality of the island.

The air quality at the Thilafushi Island is expected to be polluted i.e. the values for the pollutants such as $PM_{2.5}$, PM_{10}, SO_2 and NOx are expected to be higher in the region downwind of Thilafushi as the smoke plume generated from the open burning of waste frequently passes through this region. The numbers of stations and their locations for baseline air quality monitoring was selected to collect ambient air quality data that is representative of the baseline air quality of the Thilafushi Island and its surrounding areas.

Air quality monitoring for baseline was conducted at four locations. One station was selected in the downwind direction of the WtE stack emission plume while another station was placed at the cross wind direction of the plume. One station was selected in the cross wind direction of the smoke plume from the existing dump site at Thilafushi. Additional station was selected at Vilingili as a control site.

The ambient air quality results obtained from the monitoring at Villingili undertaken indicate that all parameters were within the WHO guidelines for ambient air quality at station AQ-4 (Villingili Island). The stations at AQ-1 AQ-2 and AQ-3 had all parameters that were beyond the WHO guidelines for ambient air quality. The monitoring results showed that the air quality of Thilfushi which are on downwind wind direction of the existing waste dump site is degradaded with the smoke from the dumpsite.

In order to estimate exposures to airborne pollutants from the incineration and emergency electricity generation, air pollutant dispersion modelling was carried out. Modelling was done for the pollutants: total dust including fine dust, fluoride and its compound specified as hydrogen fluoride, ammonia, sulphur (sulphur dioxide and sulphur trioxide), specified as sulphur dioxide, nitrogen oxide (nitrogen monoxide and nitrogen dioxide) specified as nitrogen dioxide and mercury and its compound specified as mercury from the waste to energy plant.

The dispersion modelling for the pollutants was carried out using the dispersion model AUSTAL2000. The computer program AUSTAL2000 is a reference implementation developed on behalf of the German Federal Environmental Agency. AUSTAL2000 is a steady-state dispersion model that is designed for long-term sources and continuous buoyant plumes. Given that poor meteorological data coverage near the proposed project site, the dispersion model AUSTAL2000 was preferred to a popular dispersion model AERMOD, which requires high quality meteorological data to run the AERMOD.

The proposed site for the establishment of the WtE was reclaimed in 2018. The entire Island and the project location are mainly on the main level over MSL and do not present any substantial elevation.

The stack emission dispersion modelling showed, except for mercury as well as heavy metals and their components (referred to thallium and arsenic/cadmium and lead/nickel), maximum mass concentrations was achieved by the flue gas cleaning and will be mass concentration of the emission from the stack. Hence emission characteristics was not required as the emissions of the air pollutants do not exceed the minor mass flows. For mercury as well as other heavy metals and their components the values were over the minor flows, therefore dispersion modelling was carred out for these substances.

Dispersion modelling showed that the level of lead, thallium, cadmium, arsenic, would be below the ambient air quality value and for mercury, level in the the ambient air quality would be reached but not exceeded. It is not expected that heavy metal group occur in the exhaust gas, so that the exceeding of the ambient air quality value for nickel is not expected. The desired mass concentrations by means of flue gas cleaning are below the limit values for ammonia and a negative impact on the environment is therefore not expected. Similar is with hydrogen chloride, total carbon, carbon monoxide, dioxins and furans as desired mass concentrations by means of flue gas cleaning would achieve below the emission value limits.

Based on the predicted concentrations and the post project concentrations of concerned pollutants, it can be inferred that the ambient air quality of the area is unlikely to be affected significantly due to proposed project. The overall air quality of the project site is expected to increase with time. More significantly when the existing dumpsite is closed. Therefore, a long term, positive, and significant impact is expected with the operation of this project.

References

German Engineer Association (2000) Guideline 3945 part 3 “Environmental meteorology/Atmospheric dispersion models –Particle model”

German Federal Environmental Agency (2000) AUSTAL2000

German Federal Environmental Agency (2002) First General Administrative Regulation Pertaining the Federal Immission Control Act (Technical Instructions on Air Quality Control – TA Luft)

MEE (2018). Feasibility Study for an Integrated Solid Waste Management System for Zone 3 (including Greater Malé) and Design of the Regional Waste Management Facility at Thilafushi, Ministry of Environment and Energy and Energy.

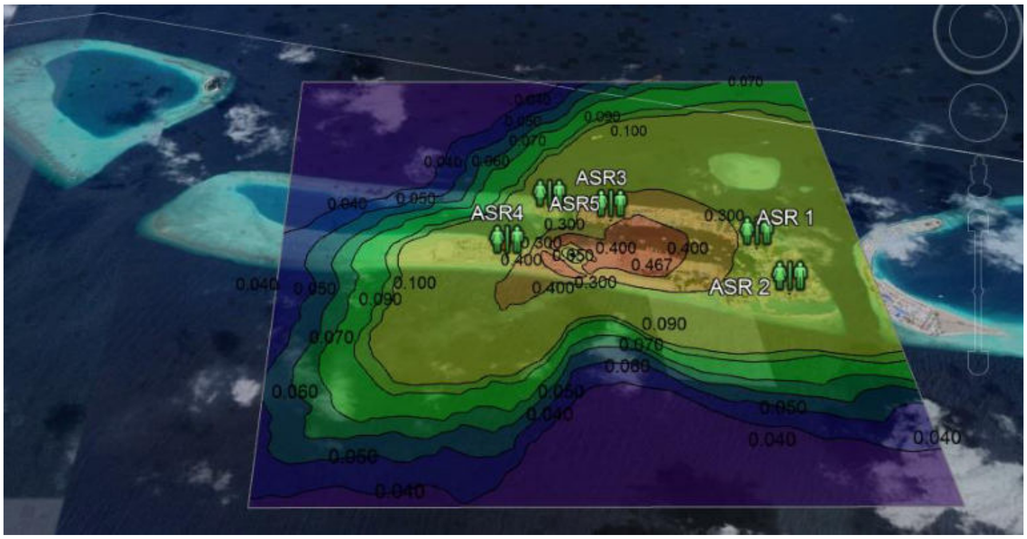
MEE (2017) EIA for the Proposed Reclamation of Thilafalhu for the establishment of the Regional Waste Management Facility for Zone 3, Kaafu Atoll, Ministry of Environment and Energy and Energy, Malé.

Ulbricht GmbH (2019) Revision and addition of the Stack height calculation and the determination of the emission of air pollutants for a waste incineration plant on Thilafushi / Maldives.

WHO (2005) Ambient Air Quality Guidelines

DISPERSION MODEL REPORT
AERMOD VALIDATION PROJECT

2 UNITS X 250 TON/DAY WTE GRATE TYPE INCINERATOR AND
0.8 MW DIESEL GENRATORSET ENGINE



Greater Male' Waste to Energy Project
Environmental Impact Assessment Waste to Energy

Draft as of 11 OCTOBER 2019

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EXECUTIVE SUMMARY

AERMOD validation modeling was conducted in comparison with the Austal2000 German Lagrangian model. In said report, it was highly acknowledged that AERMOD is a “Stronger model” compared to Austal2000 in complex and urban terrain. It was also noted that Austal2000 was used as an alternative only because of the complexity of the meteorological data requirement of AERMOD. For the AERMOD validation run, the meteorological (metdata) provides a strong advantage because it accounts land use data, surface and upper air and its influence mechanical and convective mixing among other Planetary Boundary Layer (PBL) Parameters included met data set.

AERMOD meteorological data utilize surface characteristics in the form of albedo, surface roughness and Bowen ratio, plus standard meteorological observations such as wind speed, wind direction, temperature, and cloud cover. Using the AERMOD metdata processor AERMET, it calculates the PBL parameters such as: friction velocity, Monin-Obukhov length, convective velocity scale, temperature scale, mixing height, and surface heat flux . These parameters are then passed to the Interface within AERMOD where similarity expressions in conjunction with measurements are used to calculate vertical profiles of wind speed, lateral and vertical turbulent fluctuations, potential temperature gradient, and potential temperature. The AERMOD processes the MM5 formatted data to generate *.SFC and *.PFL met data files. See snapshot of the generated *.SFC met data file and *PFL met data file. Figure below also shows the AERMOD treatment of boundaries parameters.

In the same way as the Austal2000 model, AERMOD validation run has considered the effects of building downwash. Waste to Energy (WTE) dimensions: Approx. Length x width x height [m]: 100 x 70 x 30. Surrounding building location have been considered according to land use plan, topographical survey and Google Earth maps. The height of the buildings has been considered to maximum 10m. This is another strong feature in AERMOD that the aerodynamic turbulence induced by nearby buildings cause a pollutant emitted from an elevated source to be mixed rapidly toward the ground (downwash), resulting in higher ground-level concentrations.

Terrain effects, such as elevations, were also incorporated which have impact on the air dispersion, deposition modeling results and potential risk to human health and the environment. Terrain elevation is the elevation relative to the facility base elevation. Complex Terrain are those elevations defined as anywhere within 50 km from the stack, are above the top of the stack being evaluated in the air modelling analysis. Terrain consideration was determined using SRTM3 terrain data processed by AERMAP terrain processor and has noted that highest elevations in the project area is at 7 meters only above sea level. Nevertheless, this AERMOD validated executed terrain situations using SRTM3 terrain data processed by AERMAP terrain processor where model considers terrain height exceeds stack base elevation, model receptors are also assumed on elevated terrain. Terrain elevations for receptors in the receptor Pathway are also considered.

Output of model run includes: one (1) hour, twenty-four (24) hour, and one (1) year averaging time plot files, isopleths diagrams, and table of worst-case scenarios. Meteorological data used is based on TIER 4 meteorological data, NCAR MM5 (5th-generation Mesoscale Model) prognostic meteorological model was the basis for meteorological background of the areas. Prognostic MM5 meteorological model are specified location and site domain. Once the MM5 preprocessing has been completed, the MM5 output file is converted into a format recognized by the **AERMET model** (meteorological preprocessor for the AERMOD model). The final output is generated by creating a pseudo met-station at the specified site location.

AREA SENSITIVE RECEPTORS (ASRs)

Area Sensitive Receptors (ASRs) include, but are not limited to residential areas, hospitals, schools, daycare facilities, elderly housing and convalescent facilities. These are areas where the occupants are more susceptible to the adverse effects of exposure to air pollutants. Extra monitoring and abatement efforts must be taken when dealing with contaminants and pollutants in close proximity to areas recognized as ASRs. For the WTE project and for the purpose of assessing potential impacts, Thillafushi islands' industrial areas are considered as ASRs as there are identified facilities with workers quarters. ASRs are located in the following area and details are provided in the main text of this report: (1.) ASR1-ENE; (2.) ASR2-SSE; (3.) ASR3-NNE; (4.) ASR4- SSW; (5) ASR5-NNW 474 to 1273 meters upwind and downwind directions from the center of the domain at UTM coordinates Easting 326540 and Northing 462472. This AERMOD Report includes results of the dispersion model showing the highest predicted ground level concentrations (GLC) in the ASRs.

The results and outputs of the models are compared with TA Luft Standards as specified in the Austal2000 Report and applicable United States Environmental Protection Agency (USEPA) standards and World Health Organization (WHO) Air Quality Guidelines.

TOTAL DUST (TD)

Predicted short term (1 hour) for controlled[1] total dust (TD) maximum ground level concentrations is 7.60 ug/m3 located 280 meters ENE from the center of the domain. The 24 hour controlled total dust (TD) maximum ground level concentrations is 3.188 ug/m3 located 608 meters ENE from the center of the domain. Simulated concentrations for maximum ground level concentration for 1 hour total dust (TD) are generally very low. There is no available the Ambient Air Quality Standards for total dust in the Austal2000 Report. For the total dust (TD) deposition, AERMOD results shows 0.00754 g/m2 for 1 hour, 0.038505 g/m2 for 24 hr, and 0.43394 g/m2 for 1 year deposition. Deposition simulations are all below the TALuft precipitation limit of 0.35 g/m2-d. There are no applicable USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at Universal Transverse Mercator (UTM) coordinates Easting 326540 and Northing 462472.

Summary Maximum Ground Level Concentration using AERMOD

Parameters	Ave.Time	Results	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
Total Dust	1 hour	7.60628	-	-	-	-	-
Total Dust	24 hour	3.18863	-	-	-	-	-
Total Dust	1 year	0.34134	-	0.35	-	-	-

PARTICULATE MATTER 10 (PM10)

Predicted short term (1 hour) for controlled particulate matter 10 (PM-10) maximum ground level concentrations is 0.102 ug/m3 located 100 meters E from the center of the domain. The 24-hour controlled PM-10 maximum ground level concentrations is 0.02844 ug/m3 located

[1] Controlled emission parameters refer to post-air pollution control devices. For the WtE, each stack will include baghouse and electostatic precipitators.

100 meters E from the center of the domain. Simulated concentration for maximum ground level concentration for 24 hour PM10 is below the 35 ug/m3 TA Luft standards. There is no available Ambient Air Quality Standards for PM-10 in the Austal2000 report. For the PM-10 deposition, AERMOD results shows 0.00037 g/m2 for 1 hour, 0.0007g/m2 for 24 hour and 0.025 g/m2 for 1 year deposition. There is no TALuft limit for PM10 for 1-hour in the Austal2000 report. Results are below TA Luft and WHO Air Quality Guideline Values. There are no USEPA standards in ug/Nm3 unit, the values used are converted from parts per billion by volume (ppbv). The results show insignificant increase of 0.51% for 1-hour, 0.06% for 24-hour, and 0.01% for 1-year. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Summary Maximum Ground Level Concentration using AERMOD

Parameters	Ave.Time	Results	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
PM10	1 hour	0.10288	-	-	-	20	0.51
PM10	24 hour	0.02844	50	-	150	50	0.06
PM10	1 year	0.0025	40	-	50	20	0.01

SULFUR DIOXIDE (SO_2)

Predicted short term (1 hour) for controlled sulfur dioxide (SO_2) maximum ground level concentrations is 10.34 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled SO_2 maximum ground level concentrations is 2.85 ug/m3 located 100 meters E from the center of the domain. For 1-year averaging time, results of maximum concentration is 0.25302 ug/m3. Results for maximum ground level concentration for 1 hour, 24 hour and 1 year SO_2 are all below the TA Luft standards of 350 ug/m3 for 1 hour, 125 ug/m3 for 24 hr and 50 ug/m3 for 1 year respectively. There are no USEPA standards in ug/Nm3 unit, the values used are converted from parts per billion by volume (ppbv). The results show insignificant increase of 4.88% for 1-hour, 14.29% for 24-hour, and 0.32% for 1-year. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Summary Maximum Ground Level Concentration using AERMOD

Parameters	Ave.Time	Results	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
SO2	1 hour	10.33980	350	-	212	-	4.88
SO2	24 hour	2.85793	125	-	365	20	14.29
SO2	1 year	0.25302	50	-	79	-	0.32

NITROGEN OXIDES (NOX)

Predicted short term (1 hour) for controlled NO_2 maximum ground level concentrations is 48.91 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled NO_2 maximum ground level concentrations is 14.16 ug/m3 located 100 meters E from the center of the domain. For 1 year averaging time, results of maximum NO_2 concentration is 2.1 ug/m3. Simulated concentration for maximum NO_2 ground level concentration for 1 year is below the TA

Luft standards of 40 ug/m3. There are no USEPA standards in parts per billion by volume (ppbv) therefore cannot be converted to ug/Nm3 unit. The results show increase of 24.46% for 1-hour, and 5.25% for 1-year if compared to WHO Air Quality Guidelines. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Summary Maximum Ground Level Concentration using AERMOD

Parameters	**Ave. Time**	**Results**	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
NO2(Nox)	1 hour	48.91013	200	-	100 ppb	200	24.46
NO2(Nox)	24 hour	14.16085	-	-	-		-
NO2(Nox)	1 year	2.10000	40	-	53 ppb	40	5.25

MERCURY (HG)

Predicted short term (1 hour) for controlled mercury (Hg) maximum ground level concentrations is 0.00643 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled Hg maximum ground level concentrations is 0.00178 ug/m3 located 100 meters E from the center of the domain. For 1 year averaging time, results of maximum concentration is 0.0057 ug/m3. There are no TA Luft, USEPA standards and WHO Air Quality Guideline Values. The results show insignificant increase of 0.18% for 24-hour and 3.14% for 1-year using TA Luft standards. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Summary Maximum Ground Level Concentration using AERMOD

Parameters	**Ave. Time**	**Results**	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
Hg	1 hour	0.00643	-	-	-	-	
Hg	24 hour	0.00178	-	1	-	-	0.18
Hg	1 year	0.00157	-	0.05	-	-	3.14

AMMONIA (NH_3)

Predicted short term (1 hour) for controlled ammonia (NH_3) maximum ground level concentrations is 2.066 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled NH_3 maximum ground level concentrations is 0.57123 ug/m3 located 100 meters E from the center of the domain. There are no NH_3 TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Summary Maximum Ground Level Concentration using AERMOD

Parameters	**Ave. Time**	**Results**	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%

NH3	1 hour	2.06667	-	-	-	-	-
NH3	24 hour	0.57123	-	-	-	-	-
NH3	1 year	0.00147	-	-	-	-	-

HYDROGEN CHLORIDE (HCL)

Predicted short term (1 hour) for controlled hydrogen chloride (HCl) maximum ground level concentrations is 2.066 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled NH_3 maximum ground level concentrations is 0.57123 ug/m3 located 100 meters E from the center of the domain. There are no HCl TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Parameters	Ave. Time	Results	German Standard (TA Luft)		USEPA	WHO Air Quality Guidelines	% of the Applicable Standards
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
HCl	1 hour	2.06667	-	-	-	-	-
HCl	24 hour	0.57123	-	-	-	-	-
HCl	1 year	0.00147	-	-	-	-	-

HYDROGEN FLOURIDE (HF)

Predicted short term (1 hour) for controlled hydrogen fluoride (HFl) maximum ground level concentrations is 2.066 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled HFl maximum ground level concentrations is 0.57123 ug/m3 located 100 meters E from the center of the domain. There are no HFl TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Parameters	Ave. Time	Results	German Standard (TA Luft)		USEPA	WHO Air Quality Guidelines	% of the Applicable Standards
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
Hf	1 hour	0.20705	-	-	-	-	-
Hf	24 hour	0.05723	-	-	-	-	-
Hf	1 year	0.00015	-	-	-	-	-

DIOXINS AND FURANS (D/F)

Predicted short term (1 hour) for controlled Dioxins and Furans maximum ground level concentrations is 0.0258 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled Dioxins and Furans maximum ground level concentrations is 0.00569 ug/m3 located 100 meters E from the center of the domain. There are no Dioxins and Furans TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Parameters	**Ave.Time**	**Results**	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
D/F	1 hour	0.02058	-	-	-	-	-
D/F	24 hour	0.00569	-	-	-	-	-
D/F	1 year	0.00002	-	-	-	-	-

SUM OF HEAVY METALS AND THEIR COMPONENTS: ANTIMONY, CHROMIUM,COPPER, MANGANESE, VANADIUM, TIN, LEAD, COBALT, NICKEL (TA LUFT CLASS II AND III)

Predicted short term (1 hour) for the Sum of heavy metals and their components: antimony, chromium,copper, manganese, vanadium, tin, lead, cobalt, nickel (TA Luft class II and III) ground level concentrations is 1.3161 ug/m3 located 316 meters NorthNorthEast (NNE) from the center of the domain. The 24 hour controlled total sum of metals maximum ground level concentrations is 0.4954 ug/m3 located 141 meters NorthWest (NW) from the center of the domain. For 1 year averaging time, results of maximum concentration is 0.0982 ug/m3. Simulated concentrations for maximum ground level concentration for both 1, 24 hours & 1 Year averaging which are generally very low. Results are generally lower than US RSLs for combined 24 hr averaging for Cu, Vn,Cr and Mn of 0.152 ug/m3 and the 3 month NAAQS for Lead of 0.15 ug/m3. There is no available the Ambient Air Quality Standards for said metals in the Austal2000 Report. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Parameters	**Ave.Time**	**Results**	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
Sum of Metals (Sb)[1]	1 hour	1.31607	-	-	-	-	-
Sum of Metals (Sb)[1]	24 hour	0.49540	-	-	-	-	-
Sum of Metals (Sb)[1]	1 year	0.09818	-	-	-	-	-

[1]Sum of metals: Antimony, Chromium, Copper, Manganese, Vanadium, in, Lead, Cobalt, Nickel

ARSENIC / CADMIUM AND ITS COMPOUNDS (EXPRESSED AS As AND Cd), BENZO (A) PYRENE, WATER-SOLUBLE COBALT COMPOUNDS (EXPRESSED AS CO), CHROMIUM (VI) COMPOUNDS (EXPRESSED AS CR) (TA LUFT CLASS I)

Predicted short term (1 hour) for the Sum of heavy metals and their components: Arsenic / cadmium and its compounds (expressed as As and Cd), benzo (a) pyrene, water-soluble cobalt compounds (expressed as Co), chromium (VI) compounds (expressed as Cr) (TA Luft Class I) ground level concentrations is 0.13161 ug/m3 located 316 meters NorthNorthEast (NNE) from the center of the domain. The 24 hour controlled total sum of metals maximum ground level concentrations is 0.049 ug/m3 located 141 meters NorthWest (NW) from the center of the domain. For 1 year averaging time, results of maximum concentration is 0.00982 ug/m3. Simulated concentrations for maximum ground level concentration for both 1, 24 hours & 1 Year averaging which are generally very low. Results are generally lower than the available ESL for Arsenic of 3 ug/m3 and 0.067 ug/m3 for 1 year. There is no available the Ambient Air Quality Standards for said metals in the Austal2000 Report. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Parameters	**Ave.Time**	**Results**	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
Sum of Metals (As)[1]	1 hour	0.13161	-	-	-	-	-
Sum of Metals (As)[1]	24 hour	0.04954	-	-	-	-	-
Sum of Metals (As)[1]	1 year	0.00982	-	-	-	-	-

[1]Sum of metals: Arsenic / cadmium and its compounds (expressed as As and Cd), benzo (a) pyrene, water-soluble cobalt compounds (expressed as Co), chromium (VI) compounds (expressed as Cr)

THALLIUM AND ITS COMPOUNDS (TA LUFT CLASS I) CADMIUM

Predicted short term (1 hour) for the Sum of heavy metals and their components: Thallium and its compounds (TA Luft class I) cadmium ground level concentrations is 0.13161 ug/m3 located 316 meters NorthNorthEast (NNE) from the center of the domain. The 24 hour controlled total sum of metals maximum ground level concentrations is 0.049 ug/m3 located 141 meters NorthWest (NW) from the center of the domain. For 1 year averaging time, results of maximum concentration is 0.00982 ug/m3. Simulated concentrations for maximum ground level concentration for both 1, 24 hours & 1 Year averaging which are generally very low. There is no available the Ambient Air Quality Standards for said metals in the Austal2000 Report and in the USEPA NAAAQS, ESLs and RSLs. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

Parameters	**Ave.Time**	**Results**	**German Standard (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
		Conc (ug/Nm3)	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
Sum of Metals (Tl)[1]	1 hour	0.13161	-	-	-		
Sum of Metals (Tl)[1]	24 hour	0.04954	-	-	-		
Sum of Metals (Tl)[1]	1 year	0.00982	-	-	-		

[1]Sum of metals: Thallium and its compounds and cadmium

For all the above parameters, controlled emissions have been validated to be in compliance with the TA Luft Standards as provided in the Austal2000 Report and with the USEPA standards and the WHO Air Quality Guidelines.

RESULTS

AERMOD validation of the Austal2000 model results shows slightly higher results than the Austal2000 report but still within TA Luft Standards and USEPA Standards. For the deposition results, Total Dust, SO2, NO2 and Hg are confirmed to be way below the 1 year TA Luft precipitation standards. Toxic heavy metal parameters such Ni, Ti, As,Cd, and Pb was excluded in the validation model due to absence of design emission data.

Based on the design emission of the proposed WTE plant, proposed stack height of 50 meters in the Austal2000 report was found to be favorable considering all predicted ground level concentrations in the AERMOD validation model are below the TA Luft and USEPA standards.

RECOMMENDATIONS

It recommended to (i) retain the four (4) ambient monitoring stations used in conducting ambient air quality in Thillafushi island for the EIA study; and (ii) put up additional ambient monitoring stations in ASR 2, ASR 3 and ASR 5 areas due to industrial facilities with workers quarters.

Background ambient air quality was not accounted in the modeling run. However given there are no potential significant sources of air pollution (such as mobile, area, line sources, community and other air-pollutant emitting industries) near the WTE plant, the results of both the Austal2000 and AERMOD models are generally acceptable and can be seen as below TA Luft and USEPA Standards. However, it is highly recommended to conduct a validation run after 1 to 3 months during operations stage using actual CEMS, stack testing, and ambient air monitoring results.

1. BACKGROUND INFORMATION

Atmospheric dispersion modeling is the mathematical simulation of how air pollutants disperse in the ambient atmosphere. The dispersion models are used to estimate the downwind ambient concentration of air pollutants emitted from sources. They can also be used to predict future concentrations under specific scenarios (i.e. changes in emission sources) and are most useful for pollutants that are dispersed over large distances and that may react in the atmosphere. advanced dispersion modeling programs include a pre-processor module for the input of meteorological and other data, and many also include a post-processor module for graphing the output data and/or plotting the area impacted by the air pollutants on maps. The plots of areas impacted may also include isopleths showing areas of minimal to high concentrations that define areas of the highest health risk. The isopleths plots are useful in determining protective actions for the public and responders.

Objectives of This Study[2]

The objectives of this validation studies are: (i) evaluation of Austal2000 model conducted as part of the EIA study; (ii) compare results with relevant TA Luft and USEPA standards and guidelines; and (iii) identify and forecast levels of relevant pollutants at different area sensitive receptors (ASRs) in Thillafushi to assess effects of air quality with regards to human health, risks and environment.

Component of the WTE Plant[3]

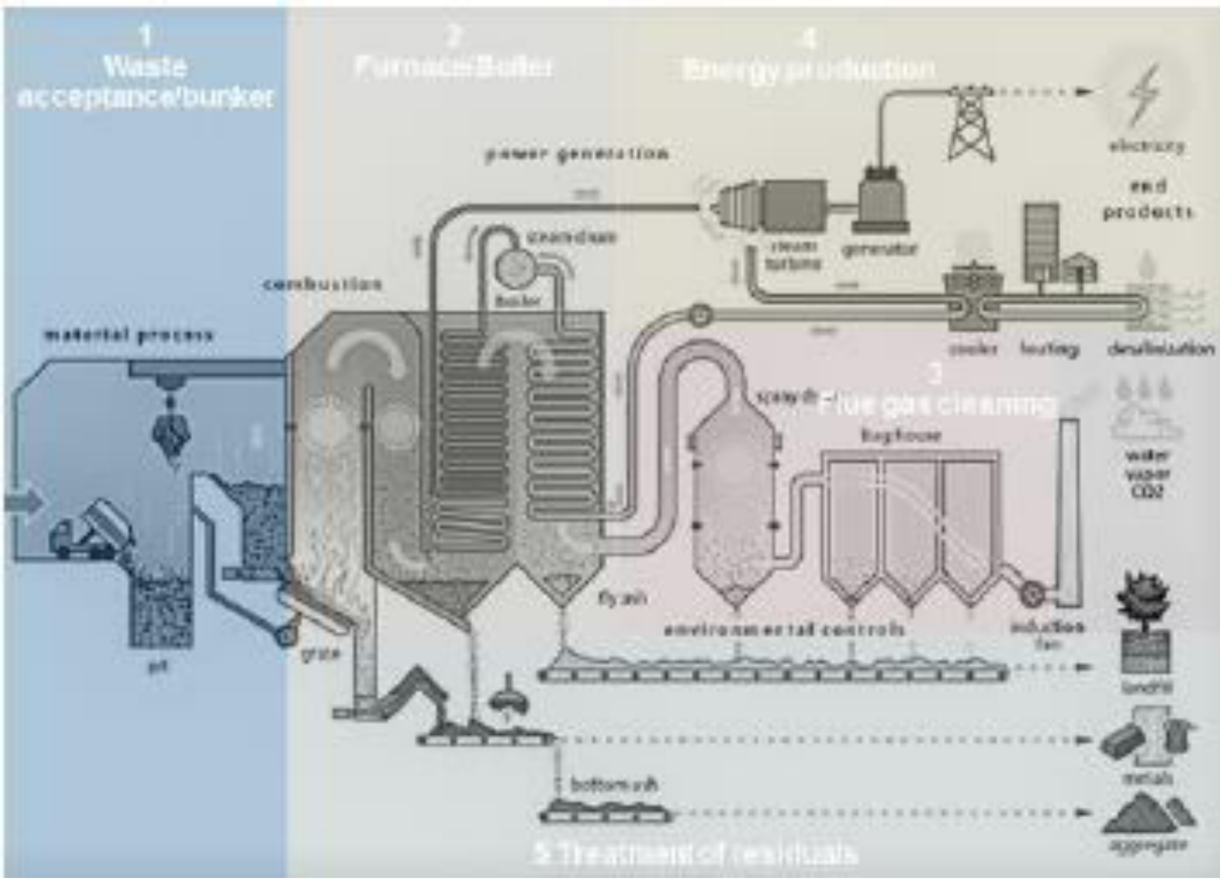
The WTE plant shall be designed and built as a conventional state-of-the-art grate type incinerator of two lines of 250 Mg/d each (total of 500 Mg/d), that shall consist of the following main set of process units and plant components:

a) Waste reception, storage and feeding consisting of a weigh bridge incl. guard house, tipping hall and waste bunker, a shredder and waste cranes;
b) Thermal treatment consisting of combustion system; boiler and heat recovery system and boiler feed water and make-up water system;
c) Air pollution control (APC) system and ID fan and stack and continuous emission monitoring system (CEMS);
d) Turbine with generator and condenser, cooling water pre-treatment system and cooling water pumps;
e) Other balance of plant components incl. fuel and chemicals supply and storage; fire-fighting water supply system; wastewater treatment plant for sewerage, water supply system;
f) Bottom ash treatment plant incl. bottom ash bunker and conveying system;
g) Residue sanitary landfill and leachate collection, management and treatment system;
h) Electric system incl. connection to public network

All process units and the balance of plant components are to be equipped with necessary electrical and control components, with valves, fittings, piping, utility mains etc. and shall be combined to a fully functional system that is fit for purpose and that is operated and controlled by a DCS which shall facilitate monitoring and recording of operational data.

[2] Greater Male' Waste to Energy Project Environmental (EIA) Waste to Energy Facility in Thilafushi
[3] Greater Male' Waste to Energy Project Environmental (EIA) Waste to Energy Facility in Thilafushi

Figure 1: Schematic Diagram of the WTE Plant Boiler (per line)



2. The Study Area

The WTE plant will be located on a 27 hectares government-owned land, of which 15 hectares have been reclaimed from shallow lagoon in Thilafushi island. It is on the southern rim of North Malé atoll, and on the eastern line of atolls within the archipelago. Thilafushi is located 9.5 km from Malé. In terms of geographic coordinates, it is located at 04° 11' 00" N and 73° 26' 44" E. The nearest inhabited island is Villingili, approximately 7.1 km east of Thilafushi.

3. Air Pollutants of Concern

Particulate Matter Emissions (PM)

Particulate matter (PM) can vary greatly in size with diameters ranging from less than 1 micrometer to hundreds of micrometers (µm). Fine particulates, having diameters less than 10µm (known as PM-10), are of increased concern because a greater potential for inhalation and passage into the pulmonary region exists. Further, acid gases, metals, and toxic organics may preferentially adsorb onto particulates in this size range. Particulate emissions may be categorized as either filterable or condensable. Filterable emissions are generally considered to be the particles that are trapped by the glass fiber filter in the front half of USEPA Reference Method 5 or Method 17. Vapors and particles less than 0.3 microns pass through the filter. Condensable particulate matter is material that is emitted in the vapor state which later condenses to form homogeneous and/or heterogeneous aerosol particles. The condensable particulate emitted from boilers is primarily inorganic in nature.

The level of PM at the inlet of the APC SYSTEM will vary according the combustor design, air distribution, waste characteristics, and the combustor's operation. Under normal combustion conditions, solid fly ash particulates formed from inorganic, noncombustible constituents in MSW are released into the flue gas. Most of this particulate is captured by the facility's APC system and are not emitted to the atmosphere.

Carbon Monoxide Emissions (CO)

The presence of carbon monoxide (CO) in the exhaust gases of combustion systems results principally from incomplete fuel combustion. High levels of CO indicate that the combustion gases were not held at a sufficiently temperature in the presence of oxygen (O2) for a long enough time to convert CO to carbon dioxide (CO_2). Several conditions can lead to incomplete combustion, including insufficient oxygen (O_2) availability; poor fuel/air mixing; cold-wall flame quenching; reduced combustion temperature; decreased combustion gas residence time; and load reduction (i.e., reduced combustion intensity).

By controlling the combustion process carefully, CO emissions can be minimized. Thus, if a unit is operated improperly or not well maintained, the resulting concentrations of CO (as well as organic compounds) may increase by several orders of magnitude. Smaller boilers, heaters, and furnaces tend to emit more of these pollutants than larger combustors. This is because smaller units usually have a higher ratio of heat transfer surface area to flame volume than larger combustors have; this leads to reduced flame temperature and combustion intensity and, therefore, lower combustion efficiency.

Since various combustion modifications for NOx reduction can produce one or more of the mentioned conditions, the possibility of increased CO emissions is a concern for environmental, energy efficiency, and operational reasons.

Nitrogen Oxides Emissions (NOX)

Oxides of nitrogen (NOx) formed in combustion processes are due either to thermal fixation of atmospheric nitrogen in the combustion air ("thermal NOx"), or to the conversion of chemically-bound nitrogen in the fuel ("fuel NOx"). The term NOx refers to the composite of nitric oxide (NO) and nitrogen dioxide (NO_2). Test data have shown that for most external fossil fuel combustion systems, over 95 percent of the emitted NOx is in the form of nitric oxide (NO). Nitrous oxide (N_2O) is not included in NOx but has recently received increased interest because of atmospheric effects. The formation of thermal NOx is affected by four factors: (1) peak temperature, (2) fuel nitrogen concentration, (3) oxygen concentration, and (4) time of exposure at peak temperature. The emission trends due to changes in these factors are generally consistent for all types of boilers: an increase in flame temperature, oxygen availability, and/or residence time at high temperatures leads to an increase in NOx production.

Conversion of nitrogen in the waste occurs at relatively low temperatures (less than 109 ^{0}C), while fixation of atmospheric nitrogen occurs at higher temperatures. Because of the relatively low temperatures at which WTE plants operate, 70 to 80% of NO formed is associated with nitrogen in the waste.[4]

[4] USEPA AP 42- Chapter 2.1 Refuse Combustion

Sulfur Oxides Emissions (SOX)

Sulfur oxides (SOx) emissions are generated during combustion from the oxidation of sulfur contained in the fuel. The emissions of SOx are predominantly in the form of SO_2. Uncontrolled SOx emissions are almost entirely dependent on the sulfur content of the fuel and are not affected by boiler size, burner design, or grade of fuel being fired. On average, more than 95% of the sulfur content in the municipal solid waste is converted to SO_2, about 1% to 5% is further oxidized to sulfur trioxide (SO_3), and 1% to 3% is emitted as sulfate particulate. SO_3 readily reacts with water vapor (both in the atmosphere and in flue gases) to form a sulfuric acid mist.

Metals Emissions and Acid Gases

Metals are present in a variety of municipal solid waste streams are emitted from WTE plant in association with PM (e.g., arsenic [As], Cd, chromium [Cr], and Pb) and as vapors, such as Hg. Due to the variability in municipal solid waste composition, metal concentrations are highly variable and are essentially independent of combustor type. If the vapor pressure of a metal is such that condensation onto particulates in the flue gas is possible, the metal can be effectively removed by the PM control device. Except for mercury (Hg), most metals have sufficiently low vapor pressures which result in almost all of the metals being condensed. Therefore, removal in the PM control device for these metals is generally greater than 98%. Hg, on the other hand, has a high vapor pressure, but the level of carbon in the fly ash appears to affect the level of Hg control. A high level of carbon in the fly ash can enhance Hg adsorption onto particles. Hg can be removed in a typical APC system controlling the operating temperature and by the PM control device.[5]

The chief acid gases of concern from WTE plants are hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) from SO_2. Hydrogen fluoride (HF), hydrogen bromide (HBr), and sulfur trioxide (SO_3) are also generally present, but at much lower concentrations. Concentrations of HCl and H_2SO_4 in flue gases directly relate to the chlorine and sulfur content in the municipal solid waste the availability of alkali materials in combustion-generated fly ash that act as sorbents, and the type of APC system used. Acid gas concentrations are considered to be independent of combustion conditions.

Greenhouse Gases

WTE plants involve generation of climate-relevant emissions such as CO_2 (carbon dioxide) as well as N2O (nitrous oxide), N_2O, ammonia (NH_3) and organic carbon, measured as total carbon. Methane (CH_4) is not generated in a WTE plant during normal operation. It only arises, in exceptional cases and to a small extent (from waste remaining in the waste bunker), therefore that in quantitative terms CH_4 is not to be regarded as climate relevant.

CO_2 constitutes the chief climate-relevant emission of WTE plant. A WTE plant of 1 Mg of municipal solid waste is associated with the production/release of about 0.7 to 1.2 Mg of CO_2 output. The proportion of carbon of biogenic origin is usually in the range of 33% to 50%. The climate-relevant CO_2 emissions from WTE plants are determined by the proportion of waste whose carbon compounds are assumed to be of fossil origin. The allocation to fossil or biogenic carbon has a crucial influence on the calculated amounts of climate-relevant CO_2 emissions. An energy transformation efficiency equal to or greater than about 25% results in an allowable

[5] USEPA AP 42- Chapter 2.1 Refuse Combustion

average substituted net energy potential that renders the emission of WTE plants (calculated as CO_2 equivalents) climate-neutral due to the emission credits from the power plant mix.[6]

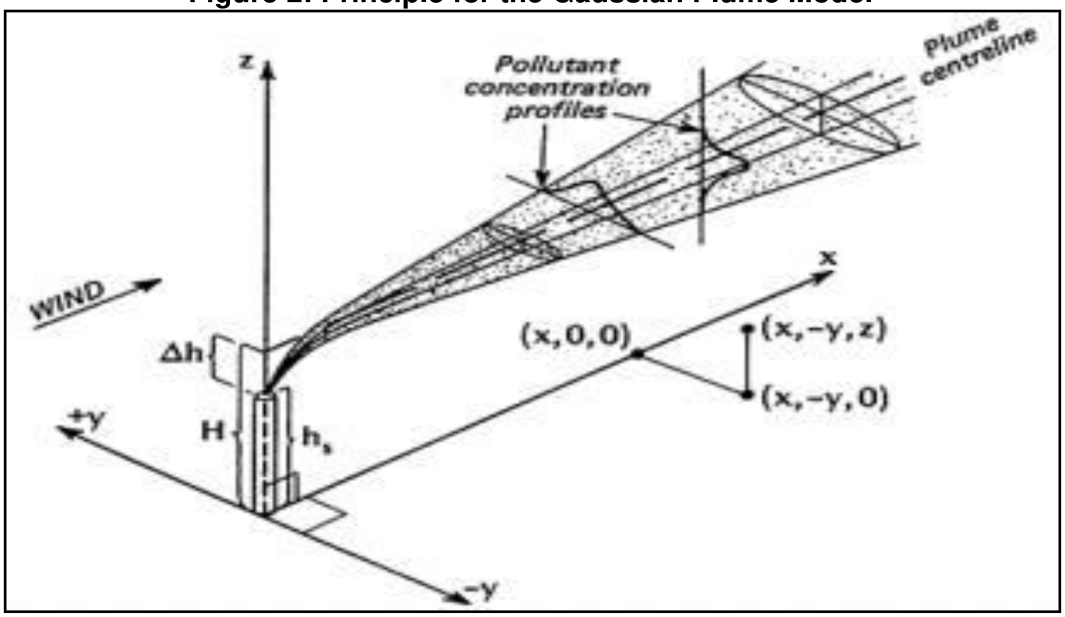
The Air Dispersion Model

Gaussian plume model

Gaussian plume model uses a realistic description of dispersion, where it represents an analytical solution to the diffusion equation for idealized circumstances. The model assumes that the atmospheric turbulence is both stationary and homogeneous. The model is the method of choice for many, especially for the prediction of yearly averaged concentration. It is the most widely used plume model and is the basis for most of the computer models distributed by the USEPA.

In the Gaussian plume dispersion model the concentration of pollution downwind from a source is treated as spreading outward from the centerline of the plume following a normal statistical distribution. The plume spreads in both the horizontal and vertical directions (Figure 2).

Figure 2: Principle for the Gaussian Plume Model



In the model, determining the pollutant concentrations at ground-level beneath an elevated plume involves two main steps:

(i) first, the height to which the plume rises at a given downwind distance from the plume source is calculated. The calculated plume rise is added to the height of the plume's source point to obtain the so-called "effective stack height"

(ii) second, the ground-level pollutant concentration beneath the plume at the given downwind distance is predicted using the Gaussian dispersion equation.

The Gaussian dispersion equation can be written as Figure 3:

[6] Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, paper was written by Mr. Bernt Johnke (Germany) and reviewed by Robert Hoppaus (IPCC/OECD/IEA), Eugene Lee (US), Bill Irving (USEPA), T. Martinsen (IPCC/OECD/IEA), and K. Mareckova (IPCC/OECD/IEA).

Figure 3: Gaussian Dispersion Equation

$$C(x,y,z) = \frac{Q}{2\pi\pi_y\sigma_z u} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \times \left\{\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right\}$$

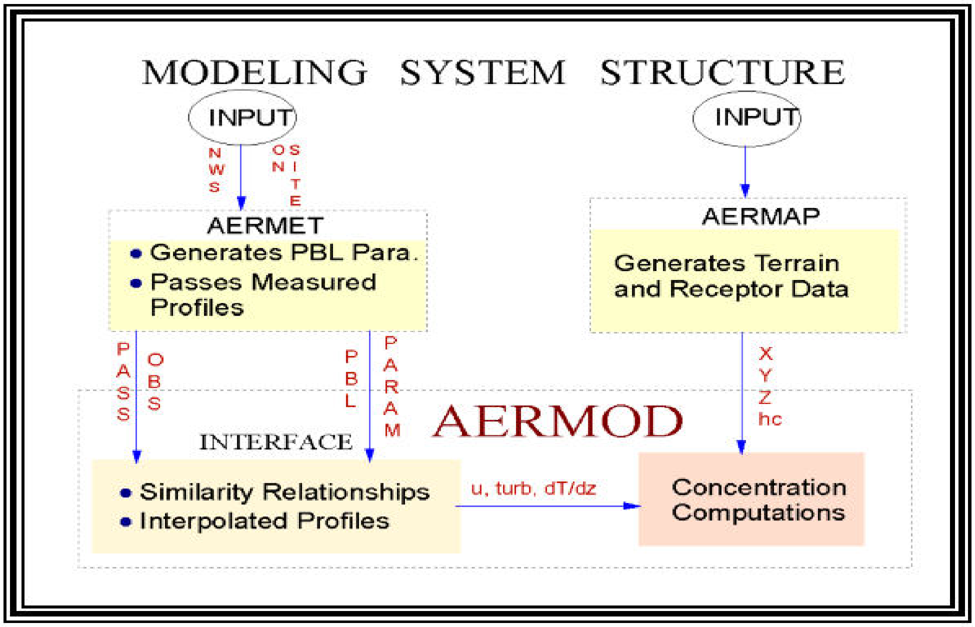
Where	C	=	concentration
	Q	=	emission rate of the pollutant from the source
	u	=	wind speed which defines the direction
	x, y	=	horizontal distance perpendicular to the wind direction
	z	=	vertical direction
	h_s	=	Height of the source
	H	=	effective height of the plume (considering the additional height Δh to which the hot gases rise above the physical height of the source, h_s); i.e., $H = h_s + \Delta h$
	σy, σz		parameters of the normal distributions in y and z directions, usually called the dispersion coefficients in y and z directions respectively

AERMOD Modeling System

The American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee (AERMIC) was formed to introduce state-of-the-art modeling concepts into the USEPA's air quality models. Through AERMIC, a modeling system, AERMOD, was introduced that incorporated air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

There are two input data processors that are regulatory components of the AERMOD modeling system: AERMET, a meteorological data pre-processor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, and AERMAP, a terrain data pre-processor that incorporates complex terrain using United States Geological Survey (USGS) Digital Elevation Data.

Figure 4: Data flow in AERMOD Modeling System



AERMOD is a steady-state plume model. In the stable boundary layer (SBL), it assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL), the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf). This behavior of the concentration distributions in the CBL was demonstrated by Willis and Deardorff (1981) and Briggs (1993). Additionally, in the CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL.

AERMOD also tracks any plume mass that penetrates the elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate. Using a relatively simple approach, AERMOD incorporates current concepts about flow and dispersion in complex terrain. Where appropriate the plume is modeled as either impacting and/or following the terrain. This approach has been designed to be physically realistic and simple to implement while avoiding the need to distinguish among simple, intermediate and complex terrain, as required by other regulatory models. As a result, AERMOD removes the need for defining complex terrain regimes. All terrain is handled in a consistent and continuous manner while considering the dividing streamline concept (Snyder et al. 1985) in stably stratified conditions.

Meteorology in the Study Area - Wind Rose

The prevailing wind over the Maldives represents typical Asian monsoonal characteristics. It follows the traditional definition of monsoon as seasonal reversal of wind direction by more than 120° between the months January and July. Looking at annual variations, westerly winds are predominant throughout the country, varying between west-southwest and west-northwest.[7]

[7] Consultancy Services for Feasibility Study for an Integrated Solid Waste Management System for Zone III and Prepare Engineering Design of the Regional Waste Management Facility at Thilafushi

The southwest monsoon, with winds predominantly between SW and NW, lasts from May to October. In May and June, winds are mainly from WSW to WNW, and in July to October, winds between W and NW predominate. The northeast monsoon, with winds predominantly from NE to E, lasts from December to February. During March and April, winds are variable. During November, winds are primarily from the west, becoming variable and can occasionally exceed 30 knots from the NE sector. However, yearly wind speed in the northeast and southwest monsoons are observed to be between 9-13 knots.

As part of the recent update to the USEPA Guideline on Air Quality Models (EPA,2017), the use of prognostic data is allowed for regulatory applications of AERMOD where it is cost-prohibitive or not feasible to collect site-specific data and there is no representative weather data or comparable station nearby. EPA developed the Mesoscale Model Interface Program, or MMIF for processing prognostic meteorological data for AERMOD (Environ, 2014).

For the study area, meteorological data was obtained from Lakes Environmental https://www.weblakes.com/services/met_data.html which employs the Weather Research and Forecasting (WRF) model[8] to compute accurate wind fields and provide modeled meteorological data. The data is obtained by running the Fifth-Generation Penn State/NCAR Mesoscale Model (MM5)[9] prognostic meteorological model for a specified location and site domain. Once the MM5 pre-processing has been completed, the MM5 output file is converted into a format recognized by the AERMET model. The final output is generated by creating a pseudo met-station at the specified site location.

Below is the frequency distribution and wind rose of Maldives for 2018 based on MM5 AERMET processed prognostic meteorological data.

[8] Weather Research and Forecasting (WRF) model is a numerical weather prediction (NWP) system designed to serve both atmospheric research and operational forecasting needs. NWP refers to the simulation and prediction of the atmosphere with a computer model, and WRF is a set of software for this. WRF features two dynamical (computational) cores (or solvers), a data assimilation system, and a software architecture allowing for parallel computation and system extensibility. The model serves a wide range of meteorological applications across scales ranging from meters to thousands of kilometres. WRF can produce simulations based on actual atmospheric conditions (i.e., from observations and analyses) or idealized conditions.

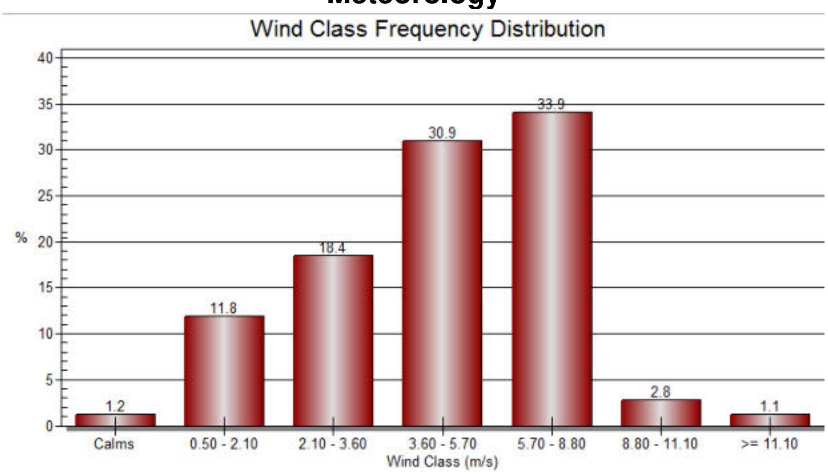
[9] It is a community model maintained by Penn State University and the National Center for Atmospheric Research. The MM5 is a limited-area, terrain-following sigma coordinate model that is used to replicate or forecast mesoscale and regional scale atmospheric circulation.

Table 1: Wind Direction Frequency Diagram for Maldives, 2018

	Directions / Wind Classes (m/s)	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
1	348.75 - 11.25	0.00502	0.00400	0.00731	0.00342	0.00000	0.00000	0.01975
2	11.25 - 33.75	0.00662	0.00628	0.01370	0.01199	0.00000	0.00000	0.03858
3	33.75 - 56.25	0.00765	0.01267	0.02500	0.01450	0.00137	0.00000	0.06119
4	56.25 - 78.75	0.00947	0.01267	0.02078	0.00970	0.00000	0.00000	0.05263
5	78.75 - 101.25	0.00811	0.01370	0.01290	0.00571	0.00000	0.00000	0.04041
6	101.25 - 123.75	0.00788	0.00993	0.00422	0.00285	0.00000	0.00011	0.02500
7	123.75 - 146.25	0.00639	0.00868	0.00685	0.00126	0.00000	0.00000	0.02317
8	146.25 - 168.75	0.00377	0.00742	0.01016	0.00354	0.00000	0.00000	0.02489
9	168.75 - 191.25	0.00491	0.00856	0.01587	0.00537	0.00000	0.00000	0.03470
10	191.25 - 213.75	0.00514	0.01438	0.02078	0.01769	0.00000	0.00000	0.05799
11	213.75 - 236.25	0.00913	0.01781	0.03185	0.05342	0.00148	0.00000	0.11370
12	236.25 - 258.75	0.00856	0.01747	0.04075	0.08950	0.01005	0.00616	0.17249
13	258.75 - 281.25	0.01005	0.01564	0.04669	0.06815	0.01107	0.00457	0.15616
14	281.25 - 303.75	0.00902	0.01450	0.02443	0.03779	0.00342	0.00034	0.08950
15	303.75 - 326.25	0.00970	0.01221	0.01975	0.00936	0.00011	0.00000	0.05114
16	326.25 - 348.75	0.00628	0.00788	0.00753	0.00502	0.00000	0.00000	0.02671
	Sub-Total	0.11769	0.18379	0.30856	0.33927	0.02751	0.01119	0.98801
	Calms							0.01199
	Missing/Incomplete							0.00000
	Total							1.00

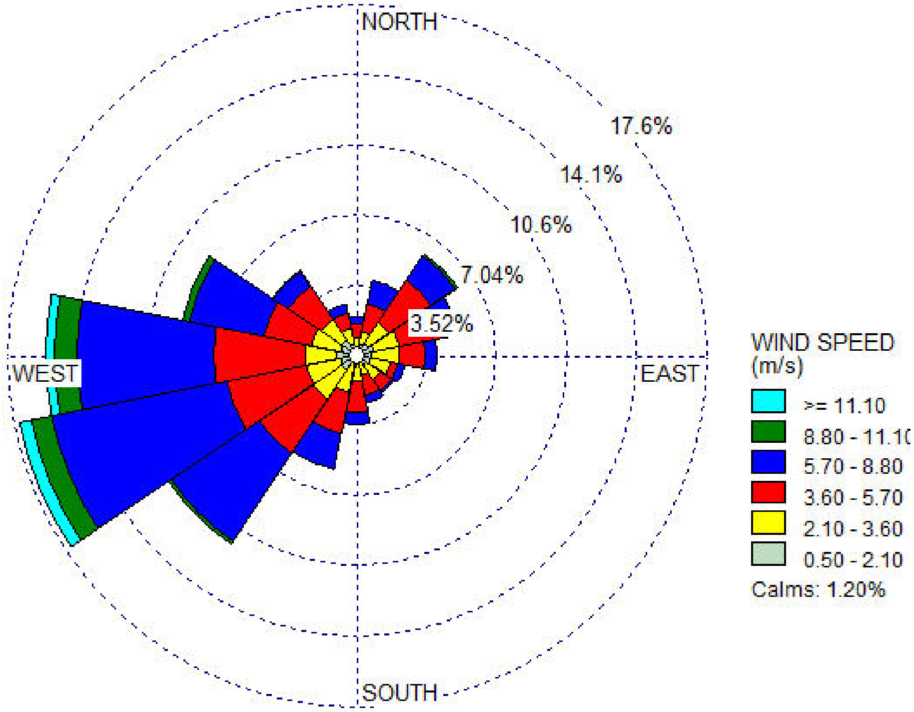
** Reference bearing CW 90^0*

Figure 5: MM5 Frequency Distribution of Wind Speed and Direction 2018 Maldives Meteorology



Windrose diagram generated using WRPlot view Version 5.8 software which utilizes SCRAM (.DAT) files. Wind direction was oriented in "Blowing from" configuration. Figure 6 presents the annual wind rose diagram at Maldives Synoptic Station.

Figure 6: MM5 Annual Wind Rose Wind Speed and Direction Windrose, 2018 Maldives

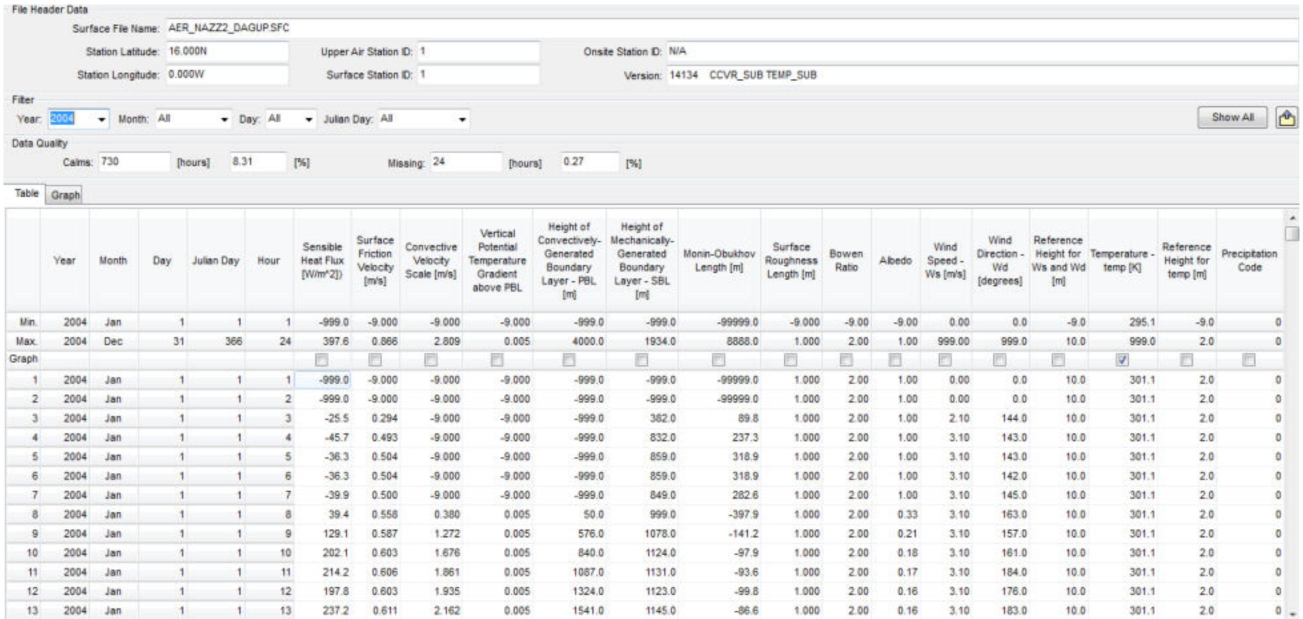


Meteorological data such as stability classes and wind speeds, mixing height, cloud cover among other are considered this model run. TIER 3 meteorological data was used.

AERMET meteorological processor (EPA, 2018a) was applied to prepare the meteorological data for the AERMOD model (EPA, 2018b). Values for three surface characteristics: surface roughness length {zo},[10] albedo {r},[11] and Bowen ratio {Bo}[12] were determined.

[10] The surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and is an important factor in determining the magnitude of mechanical turbulence and the stability of the boundary layer.
[11] The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption.
[12] The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux.

Figure 7: MM5 Surface Meteorology (SFC)



File Header Data

Surface File Name: AER_NAZZ2_DAGUP.SFC
Station Latitude: 16.000N | Upper Air Station ID: 1 | Onsite Station ID: N/A
Station Longitude: 0.000W | Surface Station ID: 1 | Version: 14134 CCVR_SUB TEMP_SUB

Filter
Year: 2004 | Month: All | Day: All | Julian Day: All | Show All

Data Quality
Calms: 730 [hours] 8.31 [%] | Missing: 24 [hours] 0.27 [%]

Table | Graph

	Year	Month	Day	Julian Day	Hour	Sensible Heat Flux [W/m^2])	Surface Friction Velocity [m/s]	Convective Velocity Scale [m/s]	Vertical Potential Temperature Gradient above PBL	Height of Convectively-Generated Boundary Layer - PBL [m]	Height of Mechanically-Generated Boundary Layer - SBL [m]	Monin-Obukhov Length [m]	Surface Roughness Length [m]	Bowen Ratio	Albedo	Wind Speed - Ws [m/s]	Wind Direction - Wd [degrees]	Reference Height for Ws and Wd [m]	Temperature - temp [K]	Reference Height for temp [m]	Precipitation Code
Min.	2004	Jan	1	1	1	-999.0	-9.000	-9.000	-9.000	-999.0	-999.0	-99999.0	-9.000	-9.00	-9.00	0.00	0.0	-9.0	295.1	-9.0	0
Max.	2004	Dec	31	366	24	397.6	0.866	2.809	0.005	4000.0	1934.0	8888.0	1.000	2.00	1.00	999.00	999.0	10.0	999.0	2.0	0
Graph																					
1	2004	Jan	1	1	1	-999.0	-9.000	-9.000	-9.000	-999.0	-999.0	-99999.0	1.000	2.00	1.00	0.00	0.0	10.0	301.1	2.0	0
2	2004	Jan	1	1	2	-999.0	-9.000	-9.000	-9.000	-999.0	-999.0	-99999.0	1.000	2.00	1.00	0.00	0.0	10.0	301.1	2.0	0
3	2004	Jan	1	1	3	-25.5	0.294	-9.000	-9.000	-999.0	382.0	89.8	1.000	2.00	1.00	2.10	144.0	10.0	301.1	2.0	0
4	2004	Jan	1	1	4	-45.7	0.493	-9.000	-9.000	-999.0	832.0	237.3	1.000	2.00	1.00	3.10	143.0	10.0	301.1	2.0	0
5	2004	Jan	1	1	5	-36.3	0.504	-9.000	-9.000	-999.0	859.0	318.9	1.000	2.00	1.00	3.10	143.0	10.0	301.1	2.0	0
6	2004	Jan	1	1	6	-36.3	0.504	-9.000	-9.000	-999.0	859.0	318.9	1.000	2.00	1.00	3.10	142.0	10.0	301.1	2.0	0
7	2004	Jan	1	1	7	-39.9	0.500	-9.000	-9.000	-999.0	849.0	282.6	1.000	2.00	1.00	3.10	145.0	10.0	301.1	2.0	0
8	2004	Jan	1	1	8	39.4	0.558	0.380	0.005	50.0	999.0	-397.9	1.000	2.00	0.33	3.10	163.0	10.0	301.1	2.0	0
9	2004	Jan	1	1	9	129.1	0.587	1.272	0.005	576.0	1078.0	-141.2	1.000	2.00	0.21	3.10	157.0	10.0	301.1	2.0	0
10	2004	Jan	1	1	10	202.1	0.603	1.676	0.005	840.0	1124.0	-97.9	1.000	2.00	0.18	3.10	161.0	10.0	301.1	2.0	0
11	2004	Jan	1	1	11	214.2	0.606	1.861	0.005	1087.0	1131.0	-93.6	1.000	2.00	0.17	3.10	184.0	10.0	301.1	2.0	0
12	2004	Jan	1	1	12	197.8	0.603	1.935	0.005	1324.0	1123.0	-99.8	1.000	2.00	0.16	3.10	176.0	10.0	301.1	2.0	0
13	2004	Jan	1	1	13	237.2	0.611	2.162	0.005	1541.0	1145.0	-86.6	1.000	2.00	0.16	3.10	183.0	10.0	301.1	2.0	0

Figure 8: MM5 Surface Meteorological Data MM5

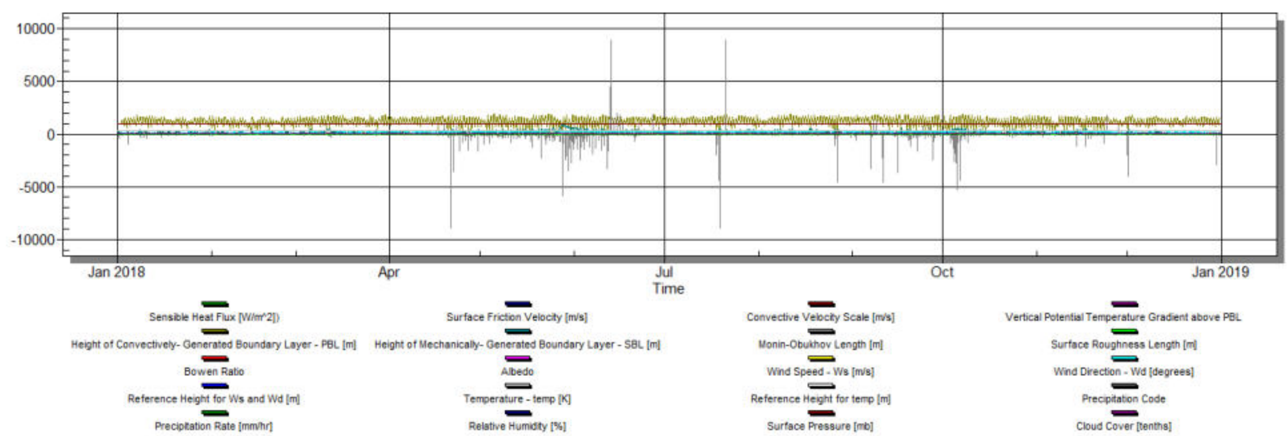


Figure 9: MM5 Profile Meteorology (PFL)

Filter
Year: All Month: All Day: All

Table Graph

	Year	Month	Day	Hour	Measurement Height [m]	1, if this is the last (highest) level for this hour, or 0 otherwise	Direction the wind is blowing from for the current level [degrees]	Wind Speed for the current level [m/s]	Temperature at the current level [C]	Standard deviation of the wind direction fluctuations [degrees]	Standard deviation of the vertical wind speed fluctuations [m/s]
Min.	2004	Jan	1	1	10.0	1	0.0	0.00	22.0	99.0	99.00
Max.	2004	Dec	31	24	10.0	1	999.0	999.00	99.9	99.0	99.00
Graph					☐	☐	☐	☐	☑	☐	☐
1	2004	Jan	1	1	10.0	1	0.0	0.00	28.0	99.0	99.00
2	2004	Jan	1	2	10.0	1	0.0	0.00	28.0	99.0	99.00
3	2004	Jan	1	3	10.0	1	144.0	2.10	28.0	99.0	99.00
4	2004	Jan	1	4	10.0	1	143.0	3.10	28.0	99.0	99.00
5	2004	Jan	1	5	10.0	1	143.0	3.10	28.0	99.0	99.00
6	2004	Jan	1	6	10.0	1	142.0	3.10	28.0	99.0	99.00
7	2004	Jan	1	7	10.0	1	145.0	3.10	28.0	99.0	99.00
8	2004	Jan	1	8	10.0	1	163.0	3.10	28.0	99.0	99.00
9	2004	Jan	1	9	10.0	1	157.0	3.10	28.0	99.0	99.00
10	2004	Jan	1	10	10.0	1	161.0	3.10	28.0	99.0	99.00
11	2004	Jan	1	11	10.0	1	184.0	3.10	28.0	99.0	99.00
12	2004	Jan	1	12	10.0	1	176.0	3.10	28.0	99.0	99.00
13	2004	Jan	1	13	10.0	1	183.0	3.10	28.0	99.0	99.00
14	2004	Jan	1	14	10.0	1	179.0	3.10	28.0	99.0	99.00
15	2004	Jan	1	15	10.0	1	322.0	3.10	28.0	99.0	99.00
16	2004	Jan	1	16	10.0	1	324.0	3.10	28.0	99.0	99.00
17	2004	Jan	1	17	10.0	1	321.0	3.10	28.0	99.0	99.00
18	2004	Jan	1	18	10.0	1	357.0	3.10	28.0	99.0	99.00
19	2004	Jan	1	19	10.0	1	4.0	3.10	28.0	99.0	99.00

Figure 10: MM5 Profile Meteorological Data (PFL)

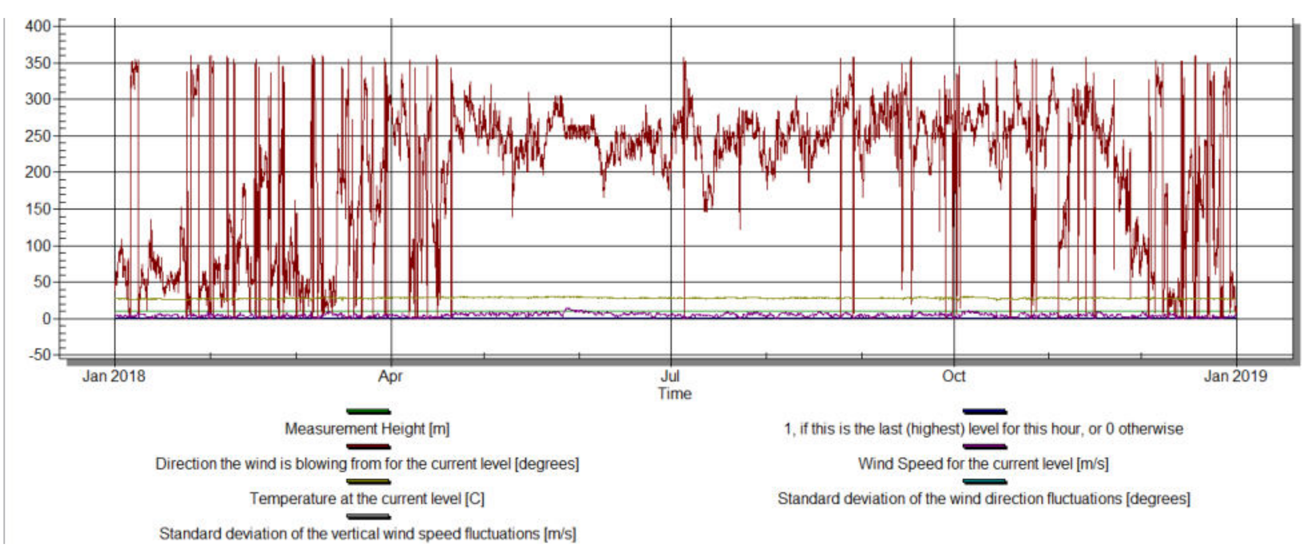
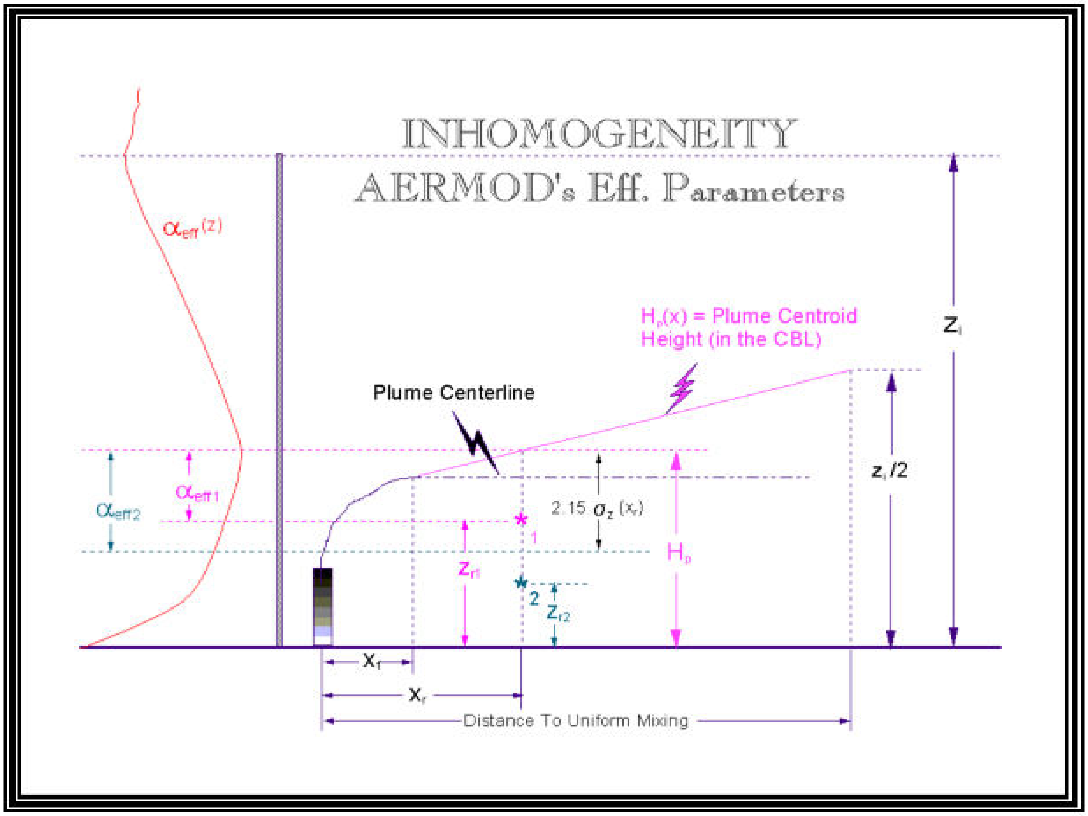


Figure 11: AERMOD Treatment of Boundary Parameters



Model Receptor Grid (Model Domain) and Grid Coordinates

The extent of the grid was chosen to include any regions of sensitive or important receptors such as residential areas and should also be sufficiently large to capture peak downwind pollutant predictions. For sources emitting pollutants close to ground level, the maximum ground-level concentration will be close to the source. However, for stack sources, the maximum ground-level concentration can be some distance away, and the model may have to be run more than once with increasing grid ranges to make sure the peak is captured.

The WTE plan stack 1 (designated as origin) is assigned with coordinates 0,0 m and all site measurements can relate to this benchmark. All facility buildings and sources could then be related spatially to this origin.

Model domain covers 4,000 meters by 4,000 meters with 100 meter grid spacing. This is to cover area sensitive receptors (ASRs) near the WTE plant site and in Thilafushi. Center of the model domain is based on the location of the WTE plant's of 250 TPD boilers (2 units) and 0.8 mW diesel generator set. Figures 12 to 14 show the model domain.

Figure 12: Domain of AERMOD Dispersion Modeling

Figure 13: 4 km X 4 km Model Domain (100 x 100 meters grid)

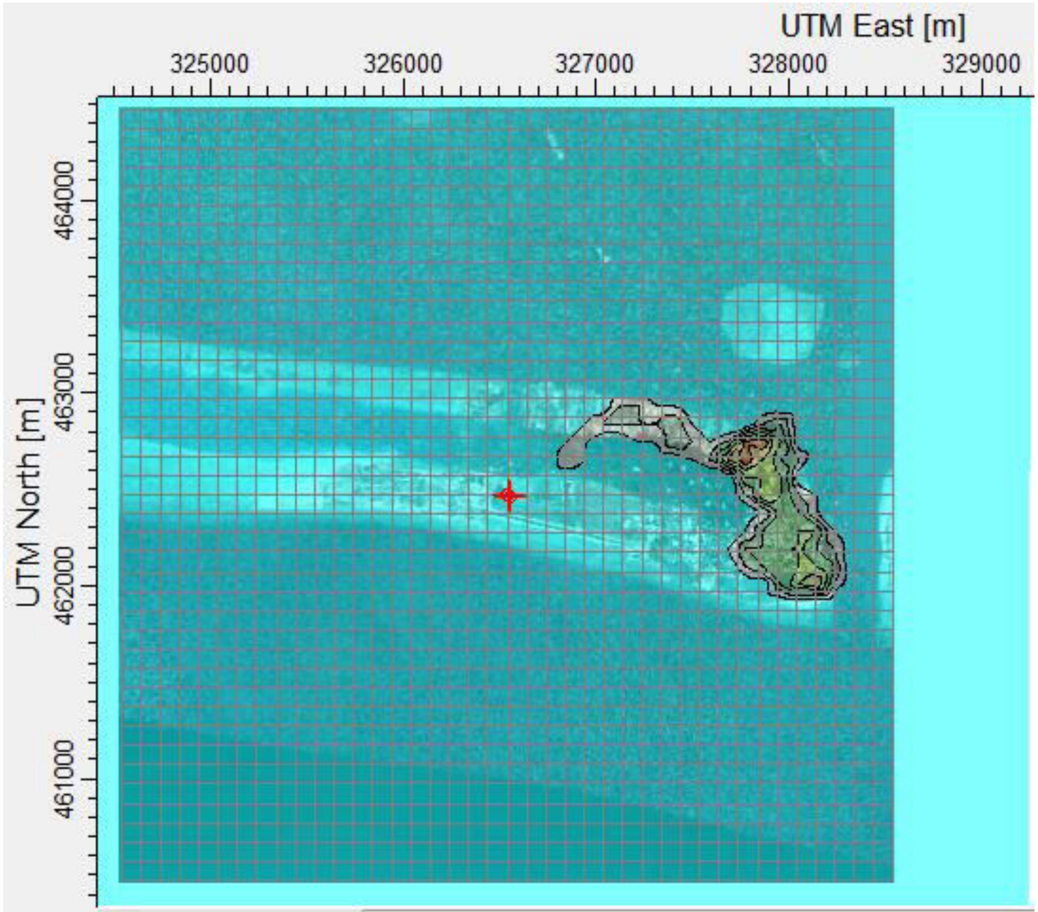
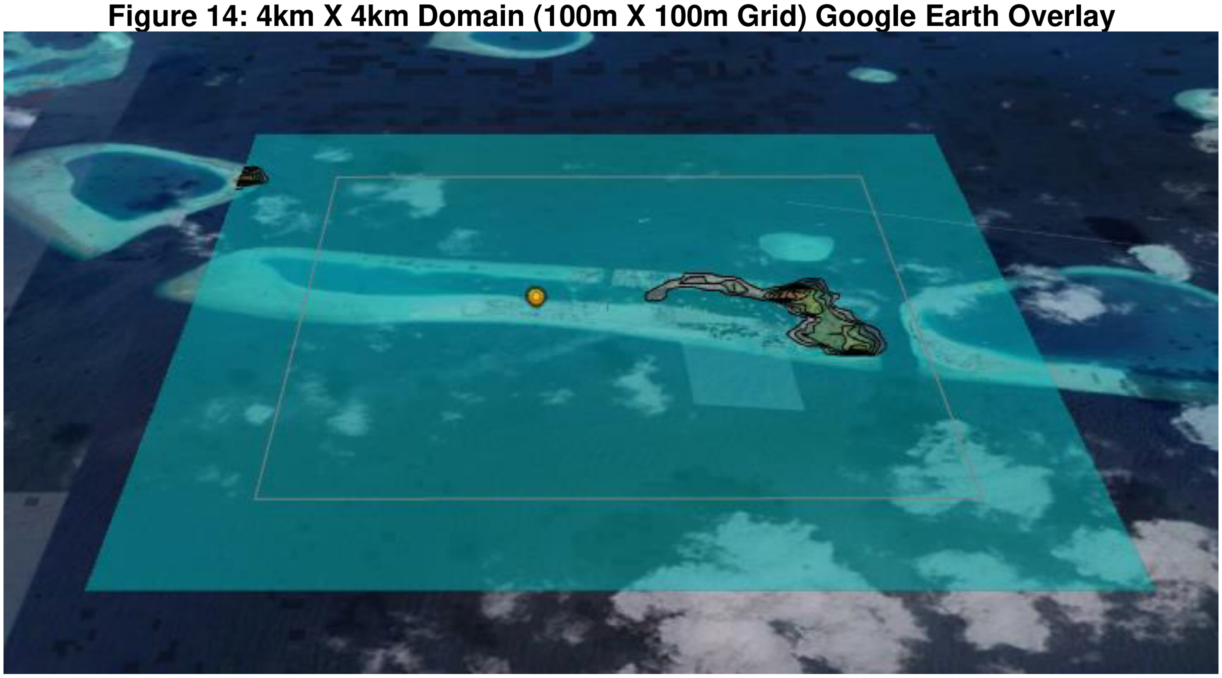


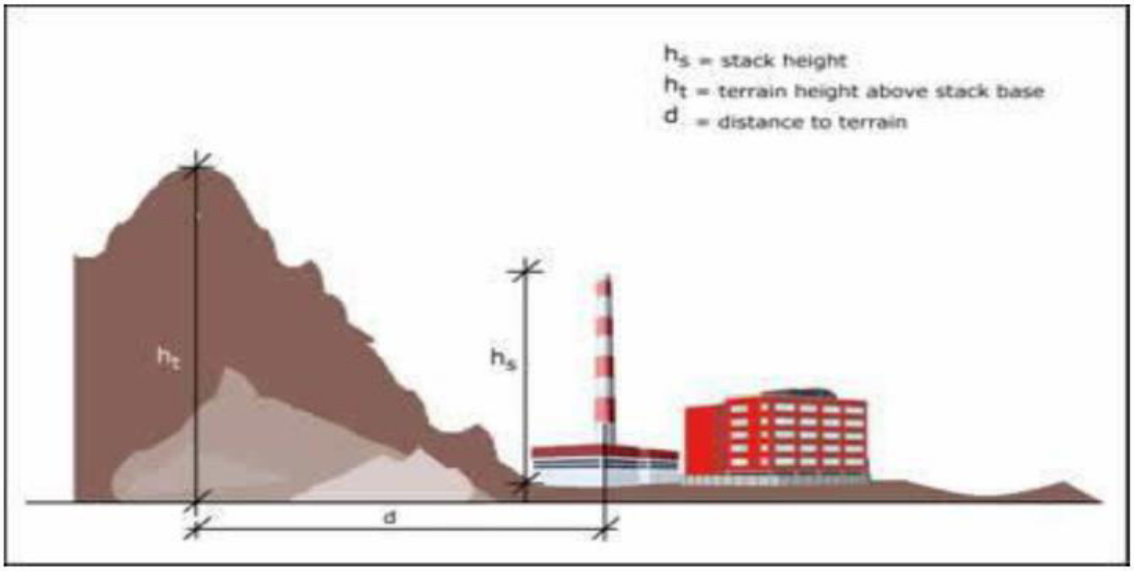
Figure 14: 4km X 4km Domain (100m X 100m Grid) Google Earth Overlay



Terrain Effects

Terrain elevations have a large impact on the air dispersion and deposition modelling results. Terrain elevation is the elevation relative to the facility base elevation (Figure XXX).

Figure 15: Terrain effects in AERMOD SYSTEM



The AERMOD model utilized elected terrain using Shuttle Radar Topography Mission (SRTM3) terrain data processed by AEMAP terrain processor. This option assumes terrain height exceeds stack base elevation; model receptors are also assumed on elevated terrain. Terrain elevations for receptors in the receptor pathway are also considered. Elevated terrain is selected, and receptor heights are not specified, then it is assumed to have a value of 0.0 meters. Figures 16 to 17 provides the SRMT terrain elevation used in the modelling. Complex terrain illustrated in figures are those elevations defined as anywhere within 50 km from the stack, are above the top of the stack being evaluated in the air modelling analysis.

Surface characteristics at the measurement site influence boundary layer parameter estimates. These influences are quantified through the albedo, Bowen ratio, and surface roughness length. The surface roughness length is the height at which the mean horizontal wind speed approaches zero and is related to the surface roughness characteristics of the terrain. It is not equal to the physical dimensions of the obstacles to the wind flow but is generally proportional to them. The surface roughness length dialog provides empirically determined surface roughness length values (from Sheih et al., 1979) for various land use types for each season. In order to better quantify these characteristics, frequency that these characteristics change (annual, seasonal, or monthly) and the number of different sectors have been specified in the modelling.

Figure 16: SRMT Terrain Elevation

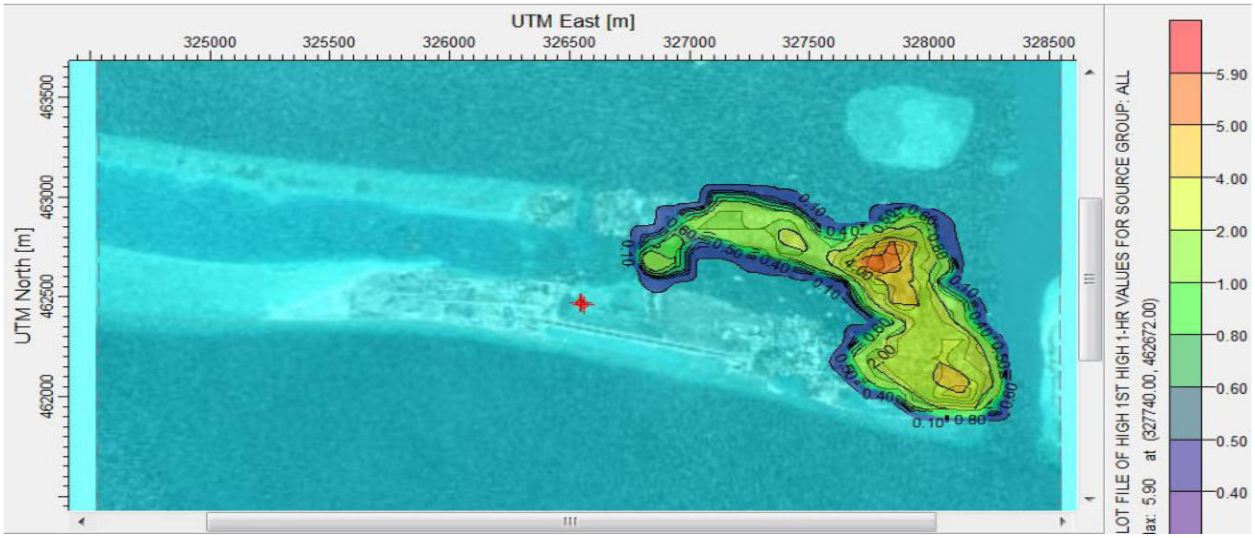


Figure 17: SRMT Terrain Elevation Google Earth Overlay

Area Sensitive Receptors (ASRs)

Area Sensitive Receptors (ASRs) include, but are not limited to residential areas, hospitals, schools, daycare facilities, elderly housing and convalescent facilities. These are areas where the occupants are more susceptible to the adverse effects of exposure to air pollutants. Extra monitoring and abatement efforts must be taken when dealing with contaminants and pollutants in close proximity to areas recognized as ASRs.

For the WTE plant and for the purpose of assessing potential impacts, Thillafushi islands' industrial areas are considered as ASRs as there are identified facilities with workers quarters. ASRs are located in the following area and details are provided in the figure and table below: (1.) ASR1-ENE; (2.) ASR2-SSE; (3.) ASR3-NNE; (4.) ASR4- SSW; (5) ASR5-NNW 474 to 1273 meters upwind and downwind directions from the center of the domain at Universal Transverse

Mercator (UTM) coordinates Easting 326540 and Northing 462472. This AERMOD Report includes results of the dispersion model showing the highest predicted ground level concentrations (GLC) in the ASRs.

Figure 18: Location of the ASRs and SRMT Terrain

Table 2: UTM Coordinates of Location of Area Sensitive Receptors (ASRs)

	Long	Lat
ASR1	327811.66	462535.58
ASR2	327938.27	462105.3
ASR3	326838.73	462821.63
ASR4	326087.04	462454.99
ASR5	326415.56	462929

Building Downwash

Building downwash occurs when the aerodynamic turbulence induced by nearby buildings cause a pollutant emitted from an elevated source to be mixed rapidly toward the ground (downwash), resulting in higher ground-level concentrations. Influence of buildings have been also considered in the model. The following building dimension and location (stack and Diesel genset) have been considered for the WTE plant. WTE dimensions: Approx. Length x width x height [m]: 100 x 70 x 30 Surrounded buildings location have been considered according land use plan, topographical survey and google earth maps. The height of the buildings have been considered to maximum 10 m[13].

[13] Environmental and Social Impact Assessment (ESIA) Waste to Energy Facility Thilafushi

Figure 19: Building Coordinates

Coordinates	North West: 4°10'58.73"N, 73°26'11.51"E
	North East: 4°10'58.87"N, 73°26'22.20"E
	South West: 4°10'50.71"N, 73°26'9.74"E
	South East: 4°10'48.09"N, 73°26'20.87"E

Tier Corners

#	X Coord [m]	Y Coord [m]
1	326463.89	462526.01
2	326793.57	462529.66
3	326751.00	462198.00
4	326408.81	462279.78

If stacks for new or existing major sources are found to be less than the height defined by EPA's refined formula for determining GEP height, then air quality impacts associated with cavity or wake effects due to the nearby building structures should be determined. (EPA 1986)

Figure 20: Building Perimeter of WTE Plant

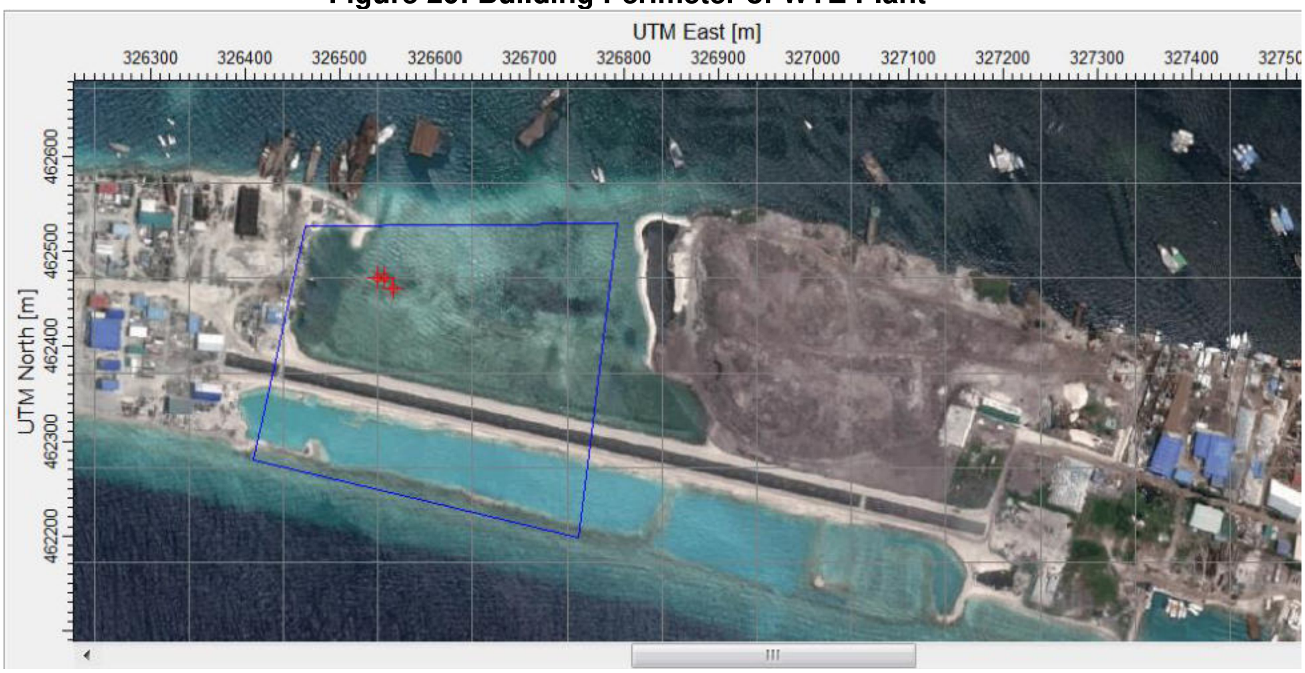


Figure 21: Building Area of WTE Plant

GEP STACK HEIGHT = H + 1.5L

In EPA's refined formula for determining GEP stack height, consider Building Downwash for point sources that are within the GEP 5L Area of Influence of a building. For point sources within the GEP 5L Area of Influence, Building Downwash information (direction-specific building heights and widths) should be included in your ISC3 modeling project. Using AERMOD View, you can easily calculate these direction-specific building heights and widths.For regulatory applications, a building is considered sufficiently close to a stack to cause wake effects when the distance between the stack and the nearest part of the building is less than or equal to five (5) times the lesser of the building height or the projected width of the building.

DISTANCE FROM STACK-BLDG <= 5L

For building downwash analyses with direction-specific building dimensions, wake effects are assumed to occur if the stack is within a rectangle composed of two lines perpendicular to the wind direction, one at 5L downwind of the building and the other at 2L upwind of the building and by two lines parallel to the wind direction, each at 0.5L away from each side of the building, as shown below. L is the lesser of the height and projected width of the building for the particular direction sector. This rectangular area has been termed a **Structure Influence Zone (SIZ)**.

Figure 22: AERMOD Source Influence Zones of buildings to plume dispersion

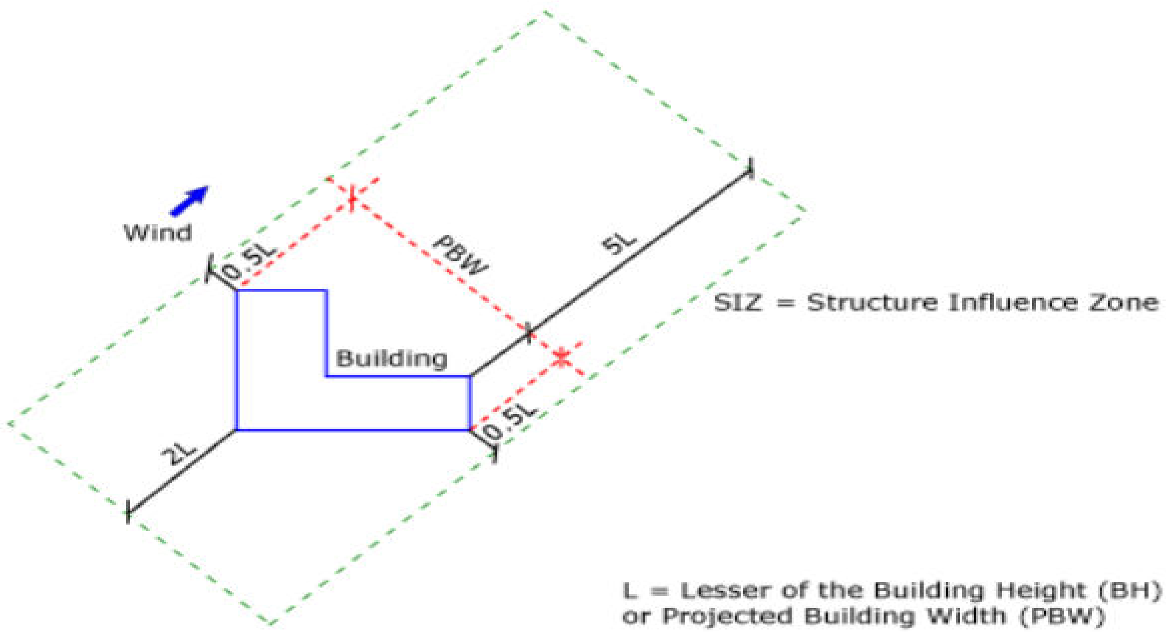


Figure 23: Building Source Influence Zones of buildings to plume dispersion

Stack Name	Stack Height	Stack-Building Base Elevation Differences	GEP** EQN1	Preliminary* GEP Stack Height Value

S1	50.00	0.00	0.00	75.00	75.00
S2	50.00	0.00	0.00	75.00	75.00
GSSTACK	10.20	0.00	0.00	75.00	75.00

Results are based on Determinants 1 & 2 on pages 1 & 2 of the GEP Technical Support Document. Determinant 3 may be investigated for dditional stack height credit. Final values result after Determinant 3 has been taken into consideration. ** Results were derived from Equation 1 on page 6 of GEP Technical Support Document. Values have been adjusted for any stack-building base elevation differences. Note: Criteria for determining stack heights for modeling emission limitations for a source can be found in Table 3.1 of the GEP Technical Support Document.

Table 3: AERMOD BPIP

Building Downwash Information

BPIP output is in meters

SO BUILDHGT S1	30	30	30	30	30	30
SO BUILDHGT S1	30	30	30	30	30	30
SO BUILDHGT S1	30	30	30	30	30	30
SO BUILDHGT S1	30	30	30	30	30	30
SO BUILDHGT S1	30	30	30	30	30	30
SO BUILDHGT S1	30	30	30	30	30	30
SO BUILDWID S1	351.19	381.98	412.65	430.78	435.82	427.53
SO BUILDWID S1	406.15	372.43	331.04	333.25	366.41	408.78
SO BUILDWID S1	438.74	455.36	458.15	447.02	422.31	384.76
SO BUILDWID S1	351.19	381.98	412.65	430.78	435.82	427.53
SO BUILDWID S1	406.15	372.43	331.04	333.25	366.41	408.78
SO BUILDWID S1	438.74	455.36	458.15	447.02	422.31	384.76
SO BUILDLEN S1	334.01	366.41	408.78	438.74	455.36	458.15
SO BUILDLEN S1	447.02	422.31	384.76	351.97	381.98	412.65
SO BUILDLEN S1	430.78	435.82	427.62	406.43	372.88	331.66
SO BUILDLEN S1	334.01	366.41	408.78	438.74	455.36	458.15
SO BUILDLEN S1	447.02	422.31	384.76	351.97	381.98	412.65
SO BUILDLEN S1	430.78	435.82	427.62	406.43	372.88	331.66
SO XBADJ S1	-233.2	-225.5	-232.06	-231.58	-224.05	-209.72
SO XBADJ S1	-189.02	-162.58	-131.19	-95.82	-89.99	-92.92
SO XBADJ S1	-93.02	-90.3	-84.83	-76.78	-66.41	-57.66
SO XBADJ S1	-100.82	-140.91	-176.72	-207.16	-231.31	-248.43
SO XBADJ S1	-258	-259.73	-253.57	-256.15	-291.99	-319.73
SO XBADJ S1	-337.76	-345.52	-342.79	-329.64	-306.48	-274
SO YBADJ S1	-79.78	-101	-113.41	-122.37	-127.61	-128.94
SO YBADJ S1	-126.29	-119.81	-107.86	-65.81	-42.29	-27.67
SO YBADJ S1	-12.21	3.63	19.35	34.49	48.58	61.19

SO YBADJ S1	79.78	101	113.41	122.37	127.61	128.94
SO YBADJ S1	126.29	119.81	107.86	65.81	42.29	27.67
SO YBADJ S1	12.21	-3.63	-19.35	-34.49	-48.58	-61.19
SO BUILDHGT S2	30	30	30	30	30	30
SO BUILDHGT S2	30	30	30	30	30	30
SO BUILDHGT S2	30	30	30	30	30	30
SO BUILDHGT S2	30	30	30	30	30	30
SO BUILDHGT S2	30	30	30	30	30	30
SO BUILDHGT S2	30	30	30	30	30	30
SO BUILDWID S2	351.19	381.98	412.65	430.78	435.82	427.53
SO BUILDWID S2	406.15	372.43	331.04	333.25	366.41	408.78
SO BUILDWID S2	438.74	455.36	458.15	447.02	422.31	384.76
SO BUILDWID S2	351.19	381.98	412.65	430.78	435.82	427.53
SO BUILDWID S2	406.15	372.43	331.04	333.25	366.41	408.78
SO BUILDWID S2	438.74	455.36	458.15	447.02	422.31	384.76
SO BUILDLEN S2	334.01	366.41	408.78	438.74	455.36	458.15
SO BUILDLEN S2	447.02	422.31	384.76	351.97	381.98	412.65
SO BUILDLEN S2	430.78	435.82	427.62	406.43	372.88	331.66
SO BUILDLEN S2	334.01	366.41	408.78	438.74	455.36	458.15
SO BUILDLEN S2	447.02	422.31	384.76	351.97	381.98	412.65
SO BUILDLEN S2	430.78	435.82	427.62	406.43	372.88	331.66
SO XBADJ S2	-234.41	-227.89	-235.56	-236.08	-229.42	-215.79
SO XBADJ S2	-195.6	-169.47	-138.19	-102.71	-96.57	-98.98
SO XBADJ S2	-98.38	-94.8	-88.33	-79.18	-67.62	-57.66
SO XBADJ S2	-99.6	-138.51	-173.22	-202.66	-225.95	-242.37
SO XBADJ S2	-251.42	-252.84	-246.57	-249.26	-285.41	-313.67
SO XBADJ S2	-332.4	-341.02	-339.29	-327.25	-305.26	-274
SO YBADJ S2	-72.88	-94.42	-107.34	-117.01	-123.11	-125.44
SO YBADJ S2	-123.9	-118.59	-107.86	-67.02	-44.69	-31.17
SO YBADJ S2	-16.71	-1.73	13.29	27.91	41.68	54.19
SO YBADJ S2	72.88	94.42	107.34	117.01	123.11	125.44
SO YBADJ S2	123.9	118.59	107.86	67.02	44.69	31.17
SO YBADJ S2	16.71	1.73	-13.29	-27.91	-41.68	-54.19
SO BUILDHGT GSSTACK	30	30	30	30	30	30
SO BUILDHGT GSSTACK	30	30	30	30	30	30
SO BUILDHGT GSSTACK	30	30	30	30	30	30
SO BUILDHGT GSSTACK	30	30	30	30	30	30
SO BUILDHGT GSSTACK	30	30	30	30	30	30
SO BUILDHGT GSSTACK	30	30	30	30	30	30
SO BUILDWID GSSTACK	351.19	381.98	412.65	430.78	435.82	427.53
SO BUILDWID GSSTACK	406.15	372.43	331.04	333.25	366.41	408.78
SO BUILDWID GSSTACK	438.74	455.36	458.15	447.02	422.31	384.76
SO BUILDWID GSSTACK	351.19	381.98	412.65	430.78	435.82	427.53
SO BUILDWID GSSTACK	406.15	372.43	331.04	333.25	366.41	408.78
SO BUILDWID GSSTACK	438.74	455.36	458.15	447.02	422.31	384.76
SO BUILDLEN GSSTACK	334.01	366.41	408.78	438.74	455.36	458.15
SO BUILDLEN GSSTACK	447.02	422.31	384.76	351.97	381.98	412.65
SO BUILDLEN GSSTACK	430.78	435.82	427.62	406.43	372.88	331.66

SO BUILDLEN GSSTACK	334.01	366.41	408.78	438.74	455.36	458.15
SO BUILDLEN GSSTACK	447.02	422.31	384.76	351.97	381.98	412.65
SO BUILDLEN GSSTACK	430.78	435.82	427.62	406.43	372.88	331.66
SO XBADJ GSSTACK	-225.28	-220.93	-230.99	-234.03	-229.96	-218.9
SO XBADJ GSSTACK	-201.19	-177.36	-148.15	-114.44	-109.7	-113.12
SO XBADJ GSSTACK	-113.1	-109.65	-102.86	-92.95	-80.21	-68.69
SO XBADJ GSSTACK	-108.73	-145.47	-177.79	-204.71	-225.41	-239.26
SO XBADJ GSSTACK	-245.83	-244.94	-236.61	-237.54	-272.28	-299.53
SO XBADJ GSSTACK	-317.68	-326.17	-324.76	-313.48	-292.67	-262.97
SO YBADJ GSSTACK	-61.16	-81.29	-93.2	-102.29	-108.26	-110.91
SO YBADJ GSSTACK	-110.13	-106	-96.83	-57.89	-37.73	-26.6
SO YBADJ GSSTACK	-14.66	-2.27	10.18	22.32	33.79	44.23
SO YBADJ GSSTACK	61.16	81.29	93.2	102.29	108.26	110.91
SO YBADJ GSSTACK	110.13	106	96.83	57.89	37.73	26.6
SO YBADJ GSSTACK	14.66	2.27	-10.18	-22.32	-33.79	

8.4 INPUT DATA IN THE DISPERSION MODEL (SOURCE PATHWAY)

The following parameters have been provided the ADM:

Table 4: Input Data for AERMOD Model Run 2 X 250 T/YR MW WTE Boiler and 0.8 MW Diesel Generator set

APSE	Capacity T/day	X Long	Y Lat	Stack Temp. ^{O}C	Stack Temp. (K)	VFR (Ncm/sec)	Stack Diam (m)	Stack Area (m^2)	Stack Ht. (m)
Boiler 1	250	4.183004N;	73.437155 E	144	417	16.07	1.5	1.76715	50.00
Boiler 2	250			144	417	16.07	1.5	1.76715	50.00
Genset 1	0.8 MW	4.182394	73.43737	400	673	3.4638889	0.5	0.13	10.2

UTM Coordinates (Boiler): 326540.00 N 462472.00 E
UTM Coordinates (Generatorset): 326556.96N 462460.97 E

Table 5: DESIGN EMISSION CONCENTRATION

TD /TD	PM10	CO	N0x	SOx	Hg	HCl	Hf	NH3	DF
mg/Nm3									
5.00	0.50	50.00	150.00	50.00	0.03	10.00	1.00	10.00	0.10
5.00	0.50	50.00	150.00	50.00	0.03	10.00	1.00	10.00	0.10
79.95	nd	300	319.968	nd	nd	nd	nd	nd	nd

Table 6: DESIGN EMISSION STRENGTH

TD /TD	PM10	CO	N0x	SOx	Hg	HCL	Hf	NH3	DF
g/sec									
0.0804	0.0080	0.8036	2.4107	0.8036	0.0005	0.1607	0.0161	0.1607	0.0016
0.0804	0.0080	0.8036	2.4107	0.8036	0.0005	0.1607	0.0161	0.1607	0.0016
0.2769	nd	1.0392	1.1083	nd	nd	nd	nd	nd	nd

9. RESULTS OF DISPERSION MODEL RUN

Dispersion model results are presented according to rankings of peak values of ground level concentrations. Below are summary of results for highest GLCs for the Partidulates, Metals and Gaseous Emissions. Results are presented within the 4 km by 4 km dimension graphical presentation Distance (X axis) and Concentration ug/Ncm (Y Axis). Maximum straight line domain is 4000 m (4 km). Raw data of model results are in output files following Nomenclatures : (x=distance from source, km), conc=ground-level centerline concentration, ug/m3), (sigmay=dispersion coefficient in Y direction, dimensionless) , (sigmaz=dispersion coefficient in Z direction, dimensionless), (xf=distance to final plume rise, km) , (h=plume height, m). See Table 7 Figures 24 to 48.

Table 7: Summary Maximum Ground Level Concentration - AERMOD

MAXIMUM GROUND LEVEL CONCENTRATION						**German Standards (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
Parameters	Ave.Time	Conc (ug/Nm3)	Deposition (g/m2)	X	Y	Conc (ug/Nm^3)	Deposition (g/m2)	Conc (ug/Nm^3)	Conc (ug/Nm^3)	%
Total Dust	1 hour	7.60628	0.00754	327040	462672	-	-	-	-	-
Total Dust	24 hour	3.18863	0.03805	327140	462572	-	-	-	-	-
Total Dust	1 year	0.34134	0.43994	326840	462572	-	0.35	-	-	
PM10	1 hour	0.10288	0.00037	326640	462472	-	-	-	20	0.51
PM10	24 hour	0.02844	0.00078	326640	462472	50	-	150	50	0.06
PM10	1 year	0.0025	0.02508	327240	462572	40	-	50	20	0.01
SO2	1 hour	10.3398	-	326640	462472	350	-	212	-	4.88
SO2	24 hour	2.85793	-	326640	462472	125	-	365	20	14.29
SO2	1 year	0.25302	-	327240	462572	50	-	79	-	0.32
NO2(NOx)	1 hour	48.91013	-	326640	462472	200	-	100 ppb	200	24.46
NO2(NOx)	24 hour	14.16085	-	326640	462472	-	-	-		-
NO2(NOx)	1 year	2.1	-	324540	460472	40	-	53 ppb	40	5.25
Hg	1 hour	0.00643	-	326640	462472	-	-	-	-	-
Hg	24 hour	0.00178	-	326640	462472	-	1	-	-	-
Hg	1 year	0.00157	-	327240	462572	-	0.05	-	-	-
NH3	1 hour	2.06667	-	326640	462472	-	-	-	-	-
NH3	24 hour	0.57123	-	326640	462472	-	-	-	-	-
NH3	1 year	0.00147	-	326340	461872	-	-	-	-	-
HCl	1 hour	2.06667	-	326540	462472	-	-	-	-	-
HCl	24 hour	0.57123	-	326540	462472	-	-	-	-	-
HCl	1 year	0.00147	-	324540	460472	-	-	-	-	-
Hf	1 hour	0.20705	-	326640	462472	-	-	-	-	-
Hf	24 hour	0.05723	-	326640	462472	-	-	-	-	-

MAXIMUM GROUND LEVEL CONCENTRATION						**German Standards (TA Luft)**		**USEPA**	**WHO Air Quality Guidelines**	**% of the Applicable Standards**
Hf	1 year	0.00015	-	324540	460472	-	-	-	-	-
D/F	1 hour	0.02058	-	326640	462472	-	-	-	-	-
D/F	24 hour	0.00569	-	326640	462472	-	-	-	-	-
D/F	1 year	0.00002	-	324540	460472	-	-	-	-	-
Sum of Metals (Sb)[1]	1 hour	1.31607	-	326440	462172	-	-	-	-	-
Sum of Metals (Sb)[1]	24 hour	0.49540	-	326440	462572	-	-	-	-	-
Sum of Metals (Sb)[1]	1 year	0.09818	-	326440	462472	-	-	-	-	-
Sum of Metals (As)[2]	1 hour	0.13161	-	326440	462172	-	-	-	-	-
Sum of Metals (As)[2]	24 hour	0.04954	-	326440	462572	-	-	-	-	-
Sum of Metals (As)[2]	1 year	0.00982	-	326440	462472	-	-	-	-	-
Sum of Metals (Tl)[3]	1 hour	0.13161	-	326440	462172	-	-	-	-	-
Sum of Metals (Tl)[3]	24 hour	0.04954	-	326440	462572	-	-	-	-	-
Sum of Metals (Tl)[3]	1 year	0.00982	-	326440	462472	-	-	-	-	-

[1]Sum of metals: Antimony, Chromium, Copper, Manganese, Vanadium, in, Lead, Cobalt, Nickel
[2]Sum of metals: Arsenic / cadmium and its compounds (expressed as As and Cd), benzo (a) pyrene, water-soluble cobalt compounds (expressed as Co), chromium (VI) compounds (expressed as Cr)
[3]Sum of metals: Thallium and its compounds and cadmium

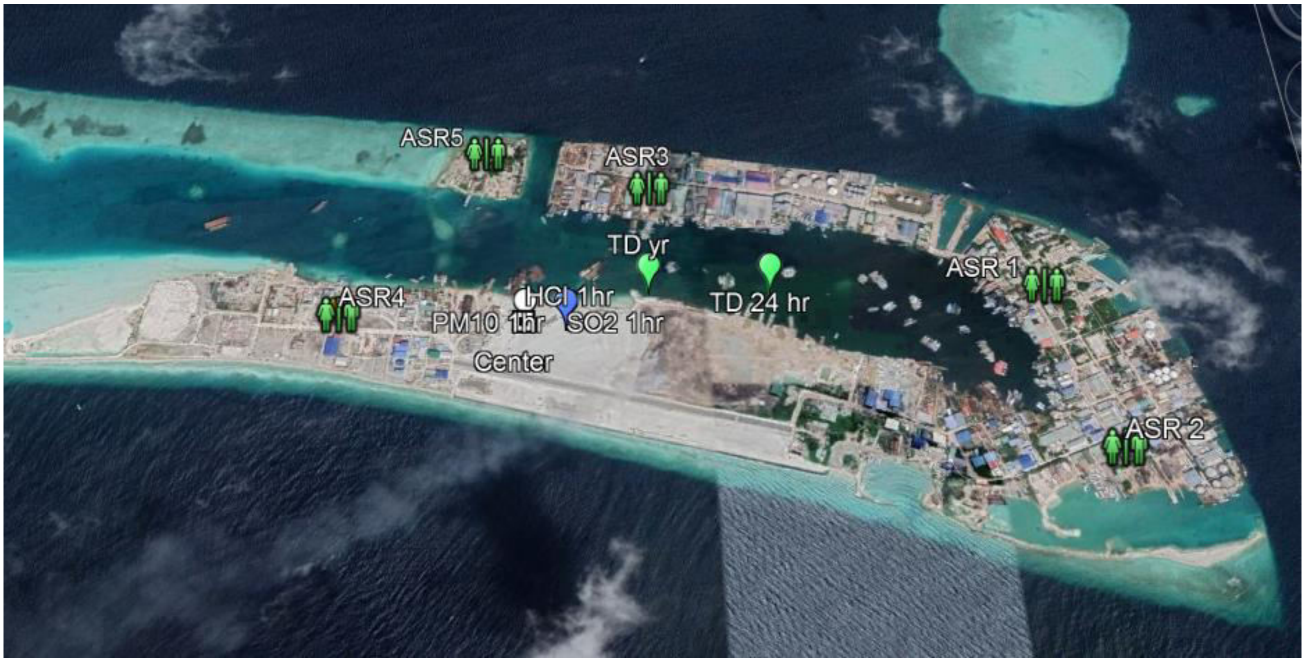


Figure 24: Location of Maximum Predicted Ground Level Concentration

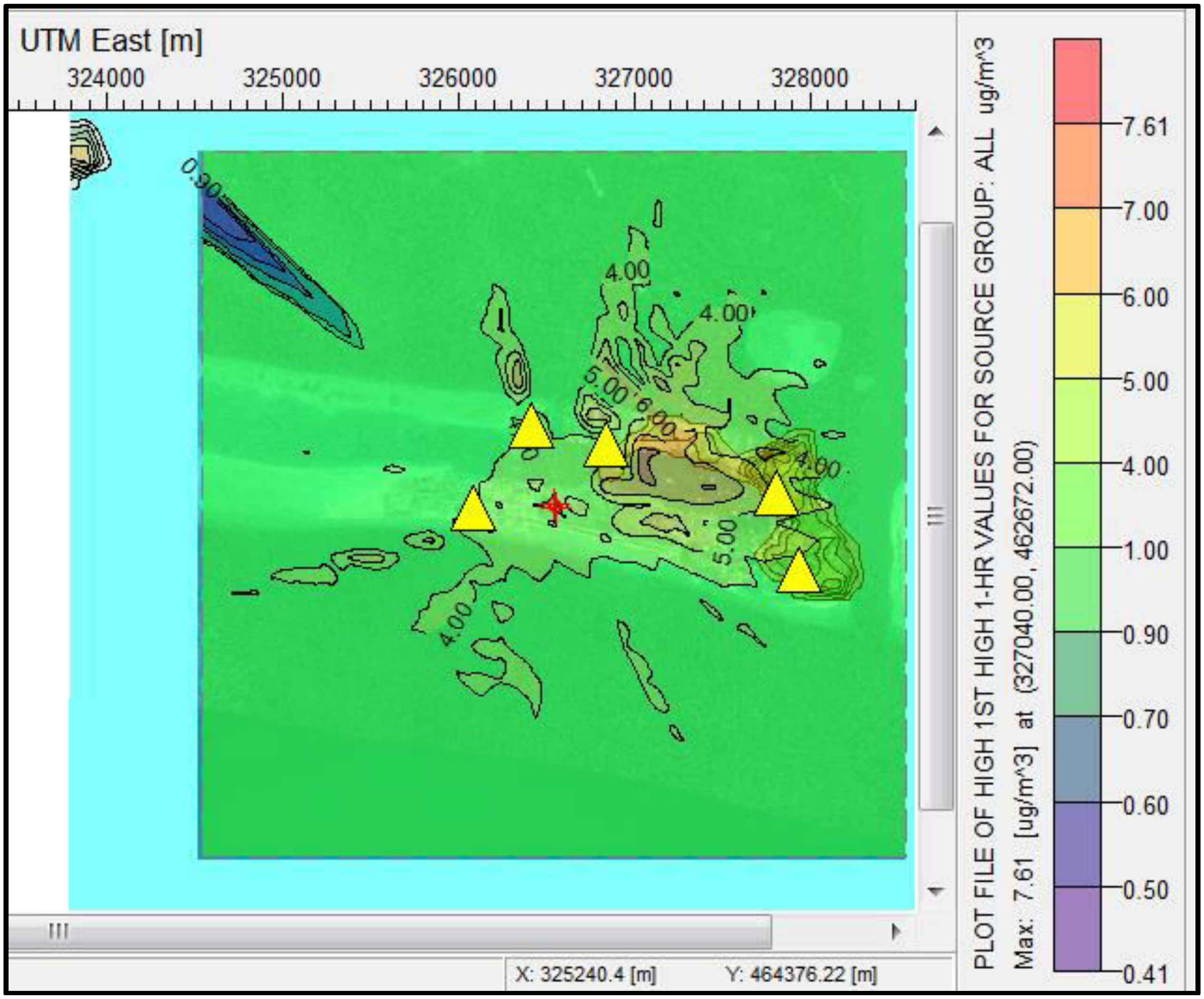


Figure 25: Total Dust (TD) (1 HR) (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

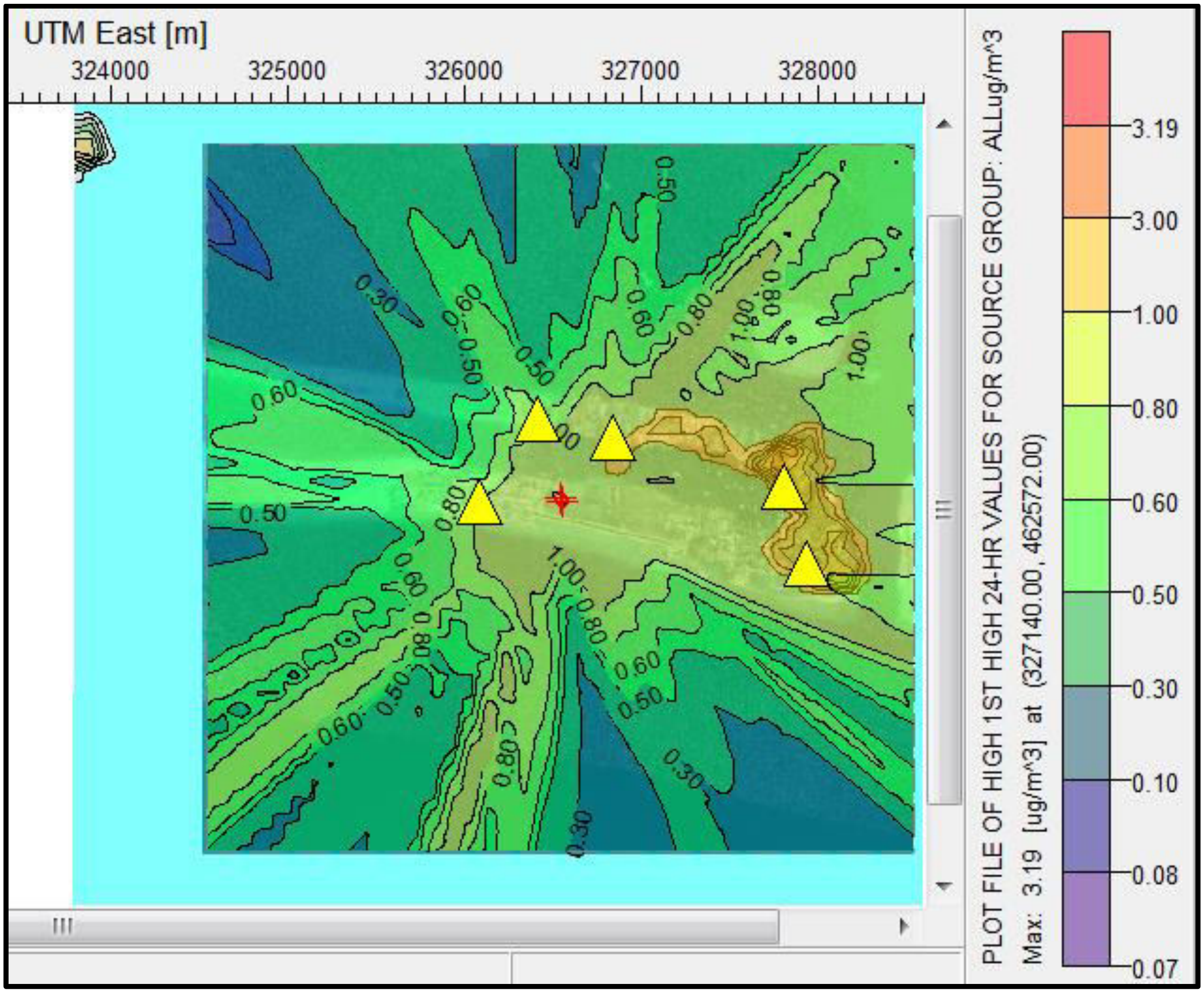


Figure 26: TD (24 HR) (1-HR RUN) (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

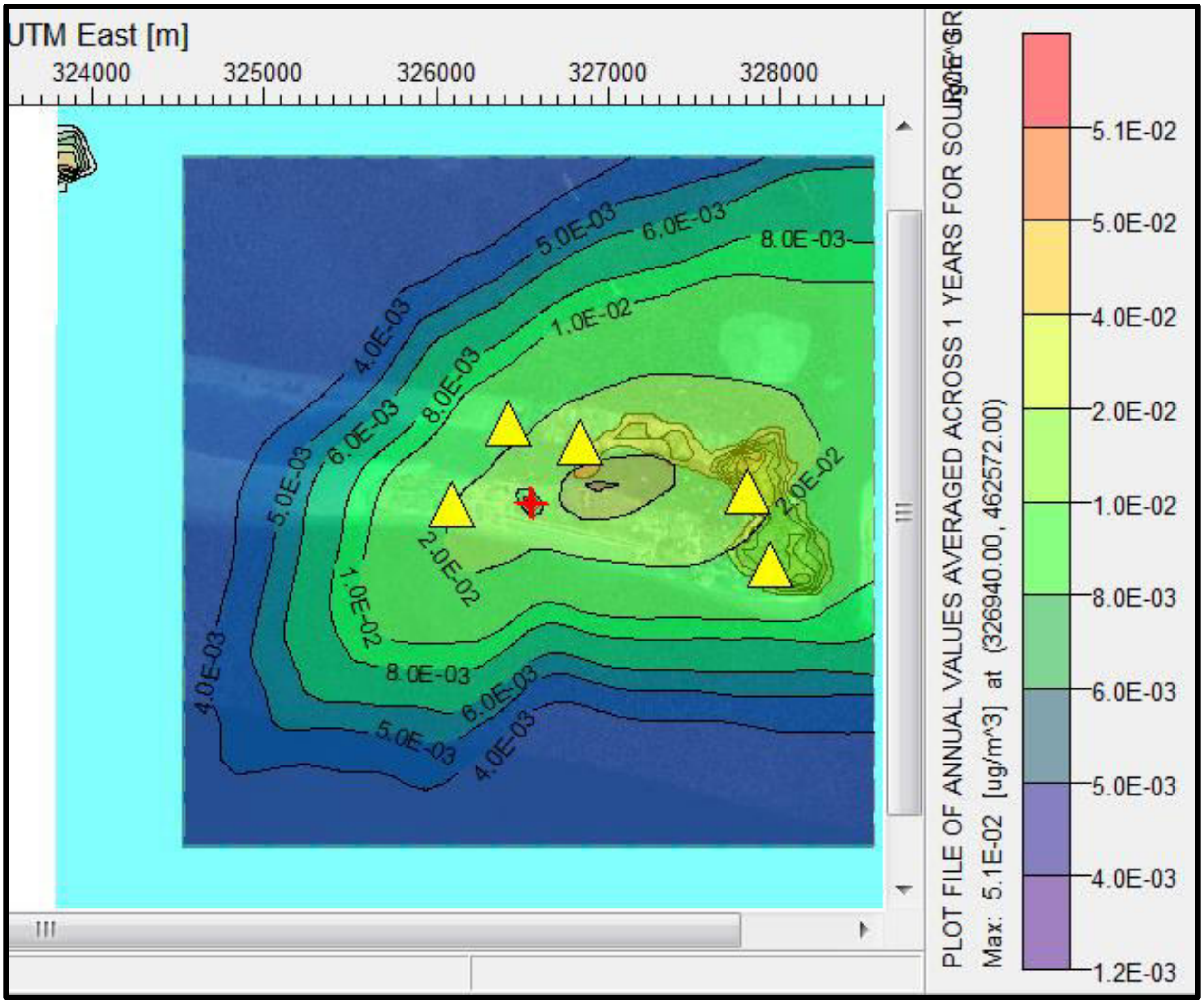


Figure 27: Total Dust 1YR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

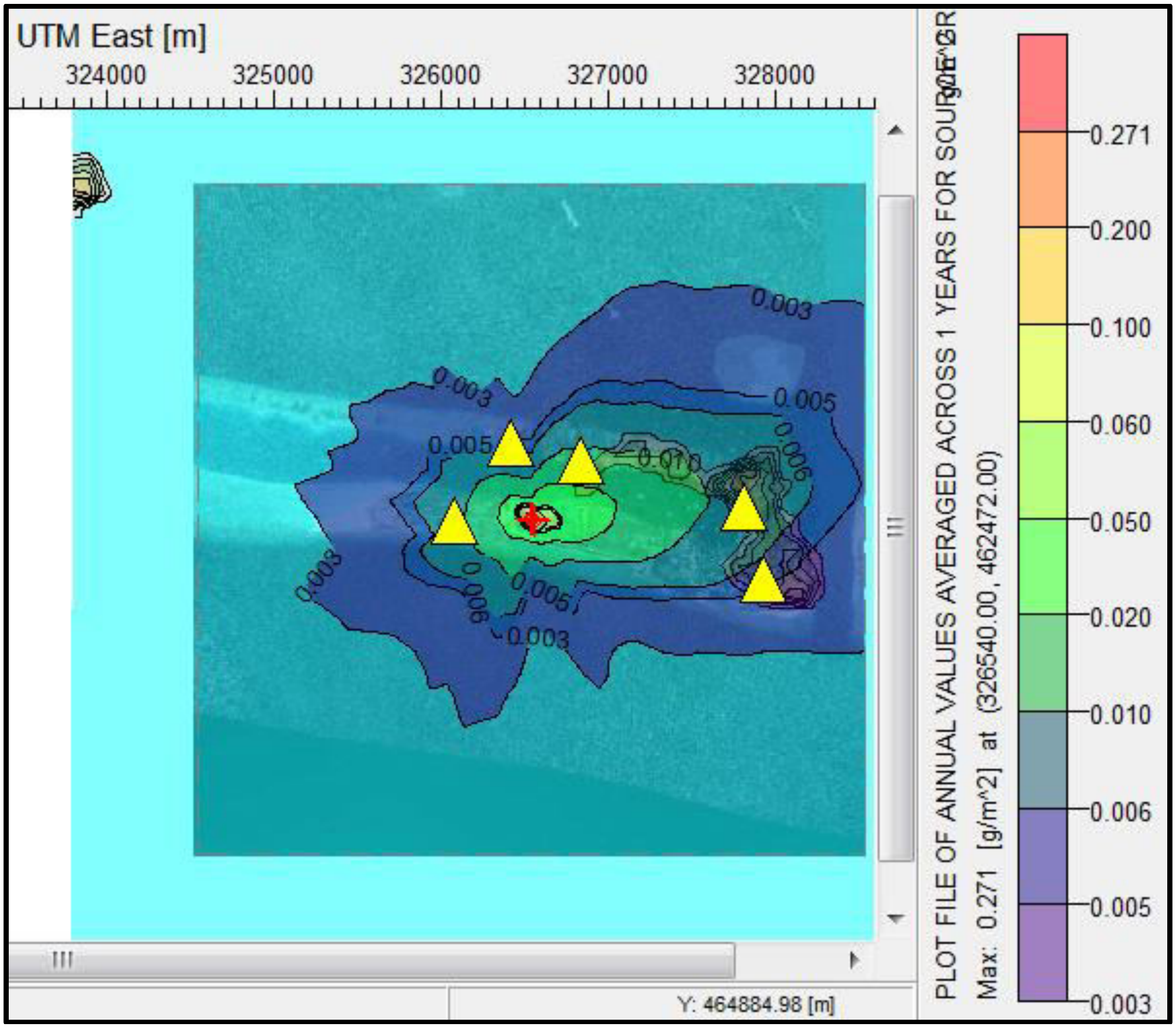


Figure 28: Total Dust 1YR Deposition (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

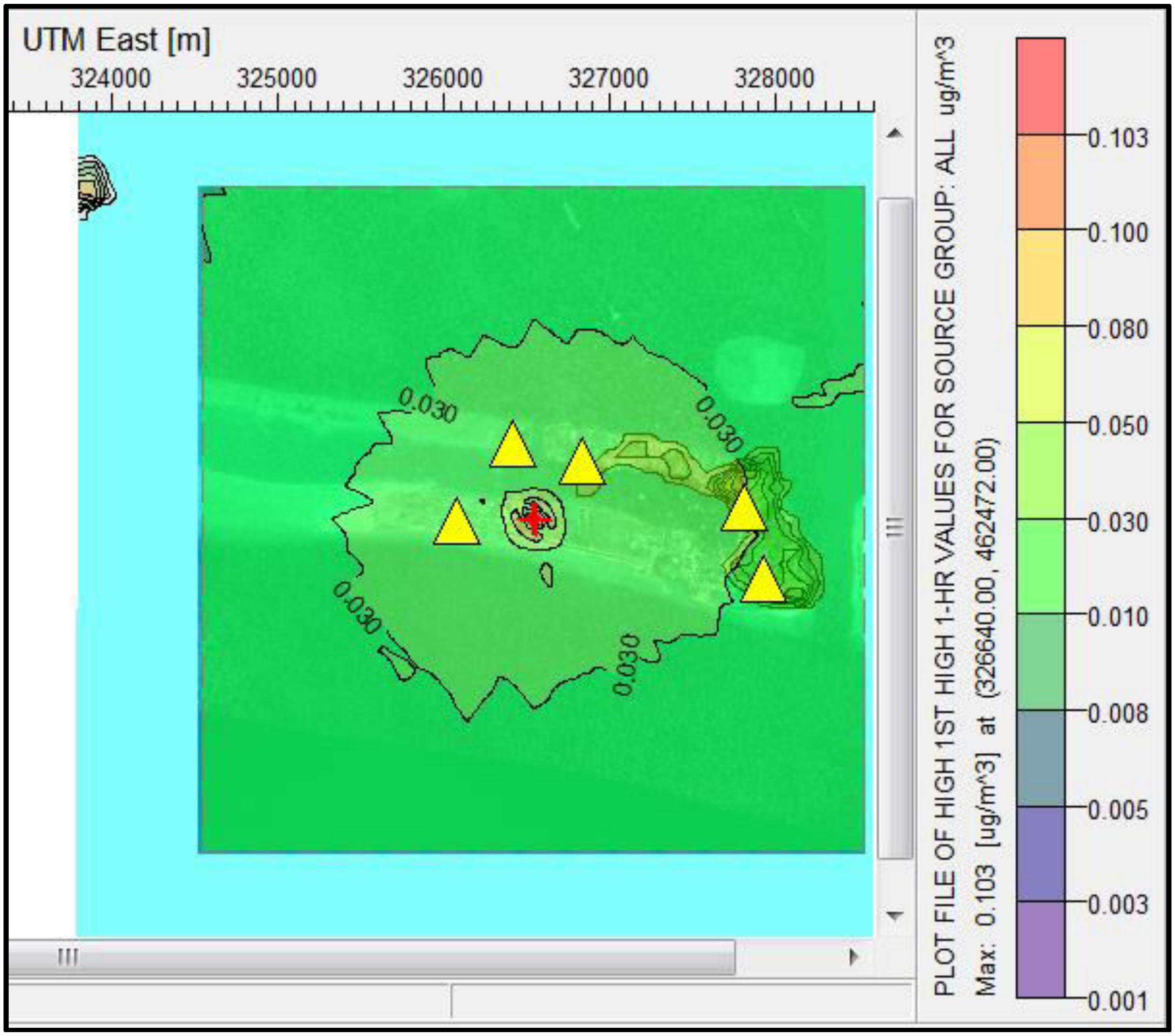


Figure 29: PM10 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

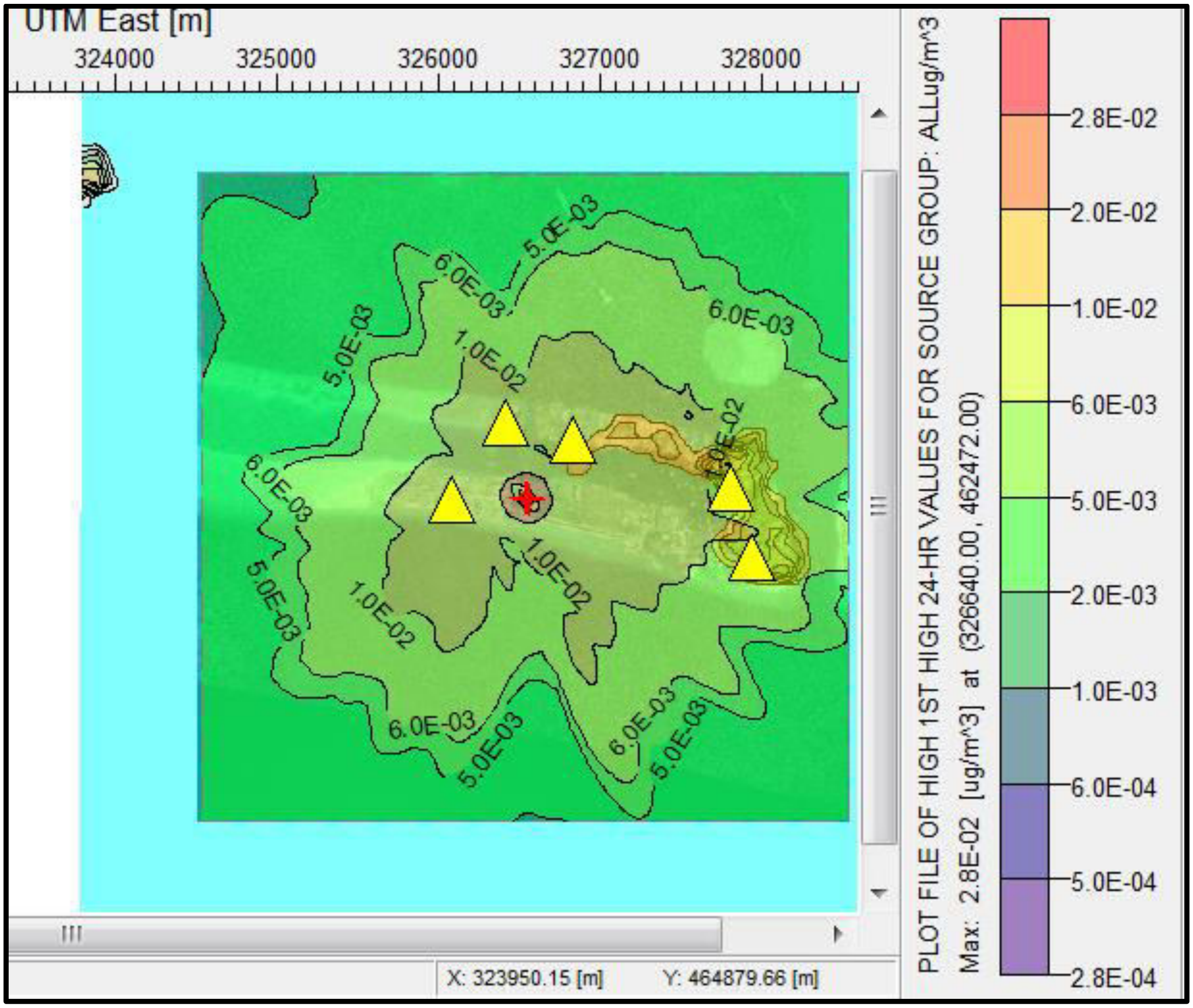


Figure 30: PM10 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs

Area Sensitrive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

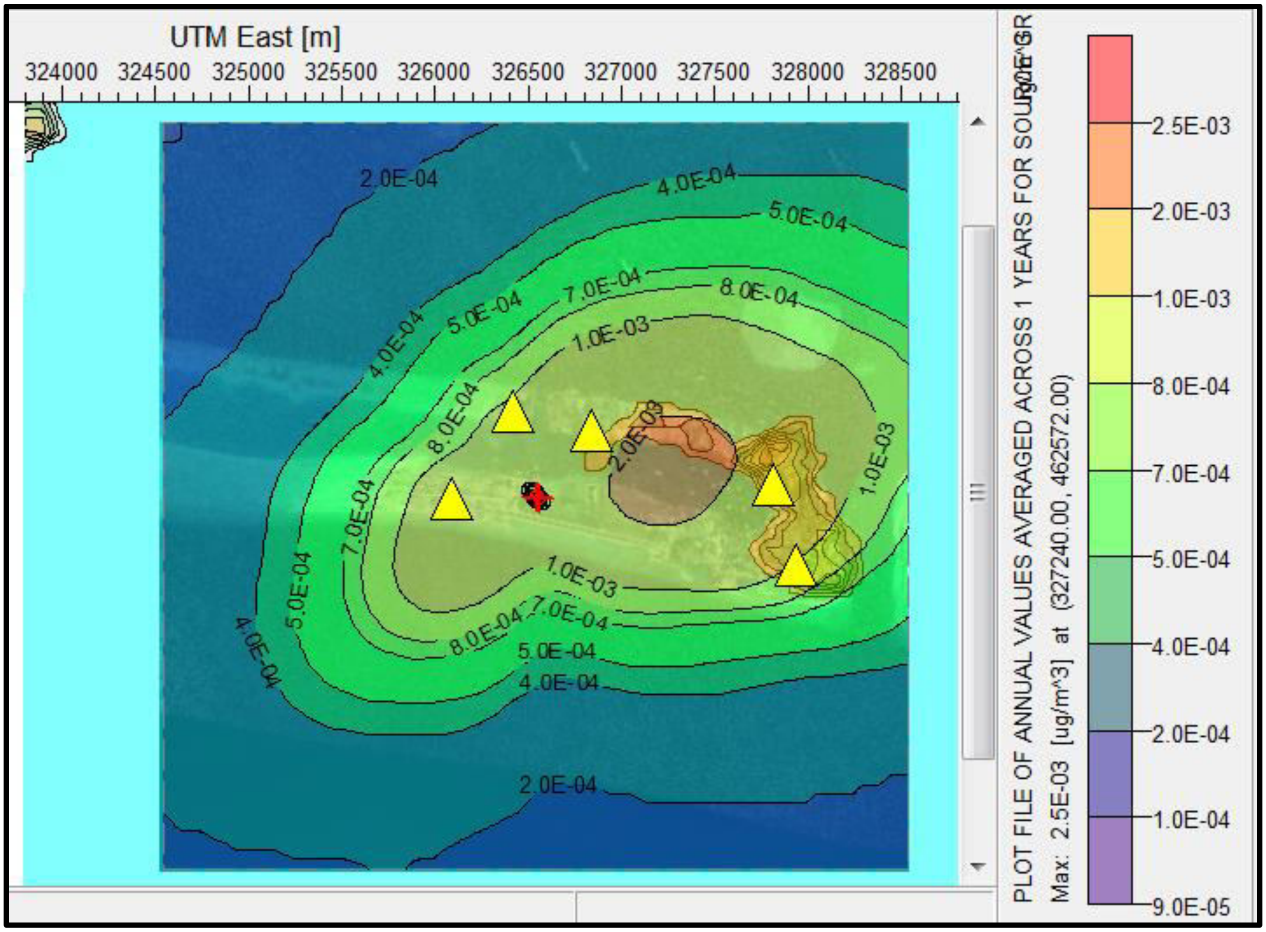


Figure 31: PM10 1 YR DEPOSITION (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs

Area Sensitrive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

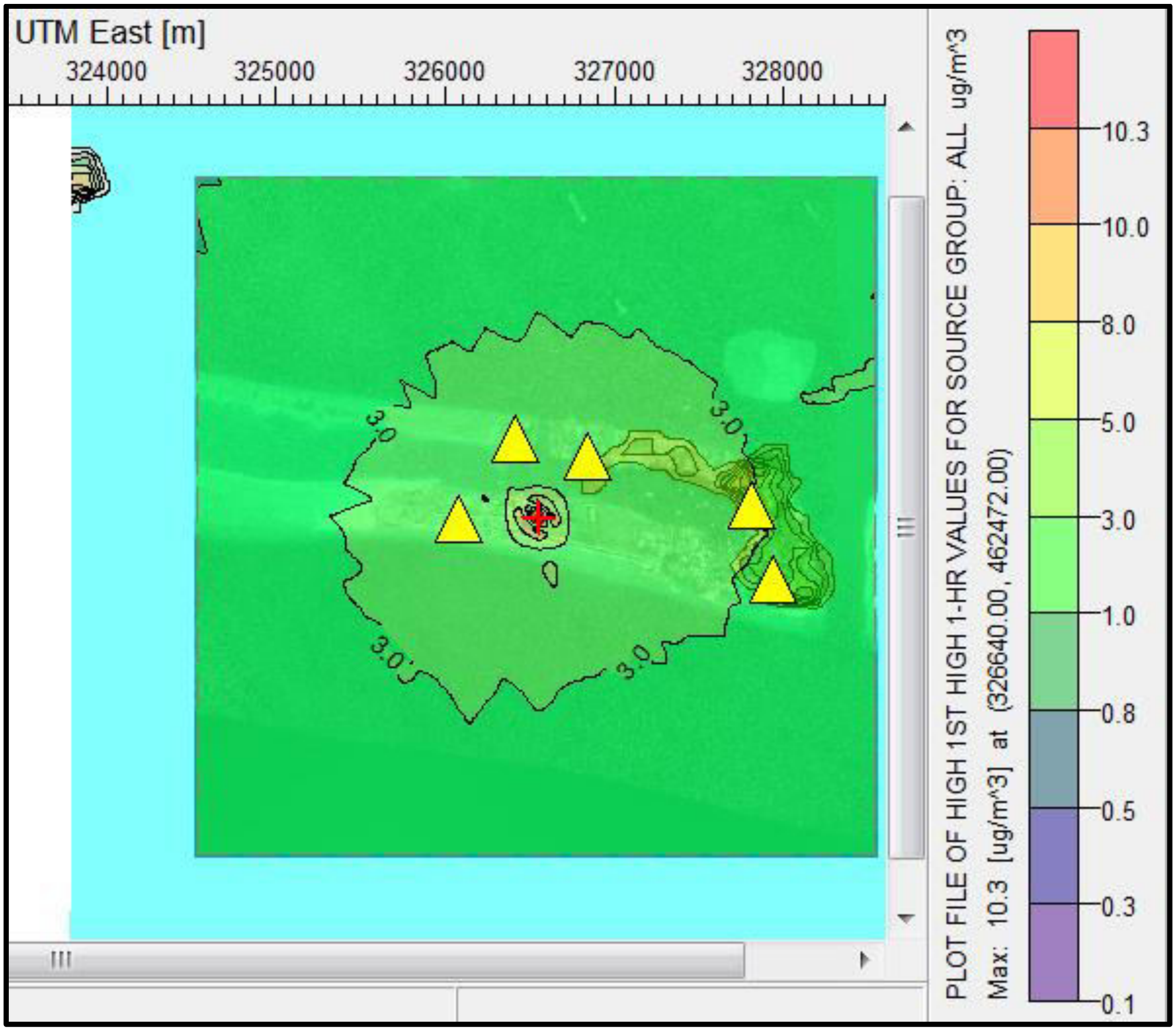


Figure 32: SO2 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

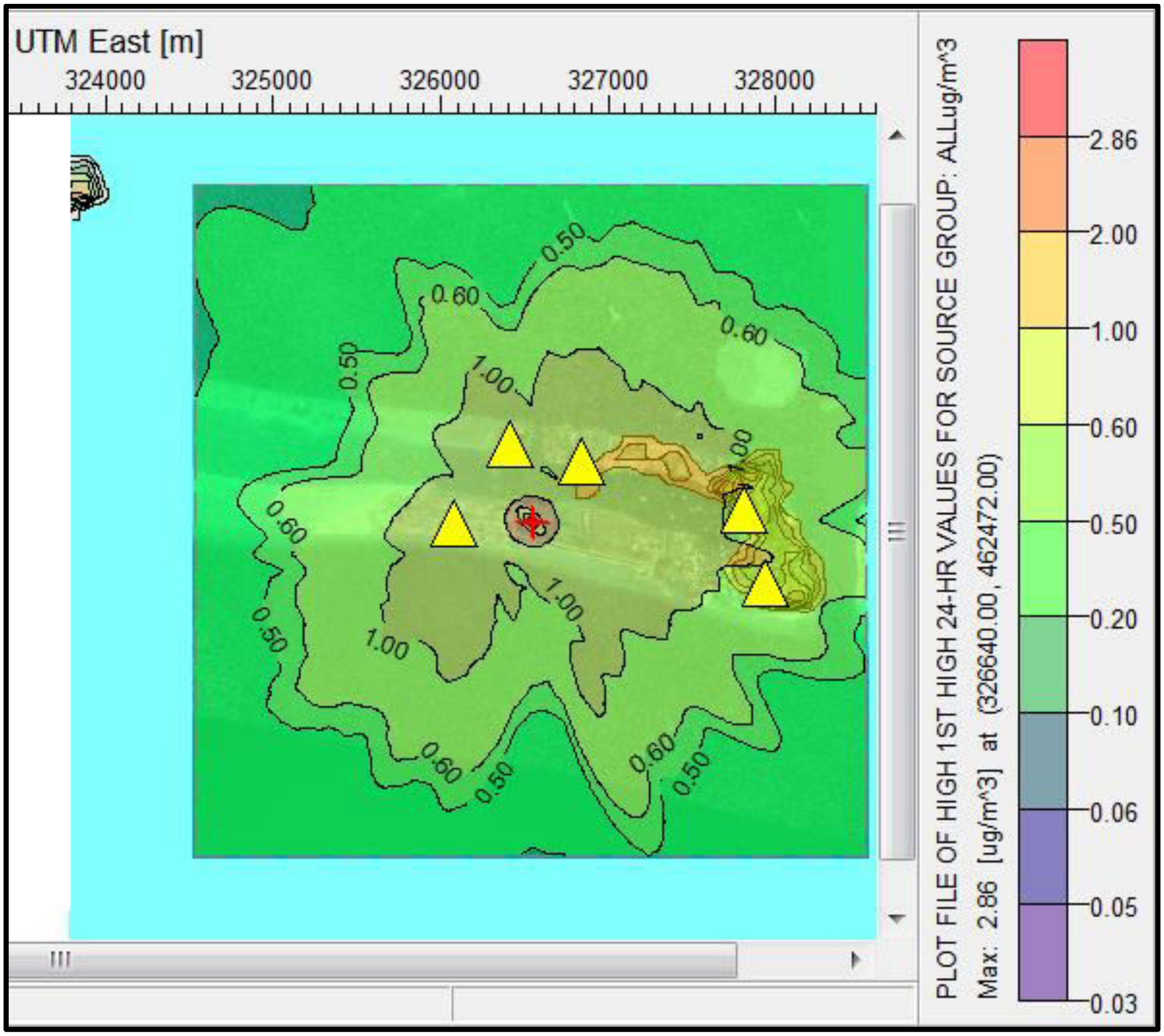


Figure 33: SO2 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

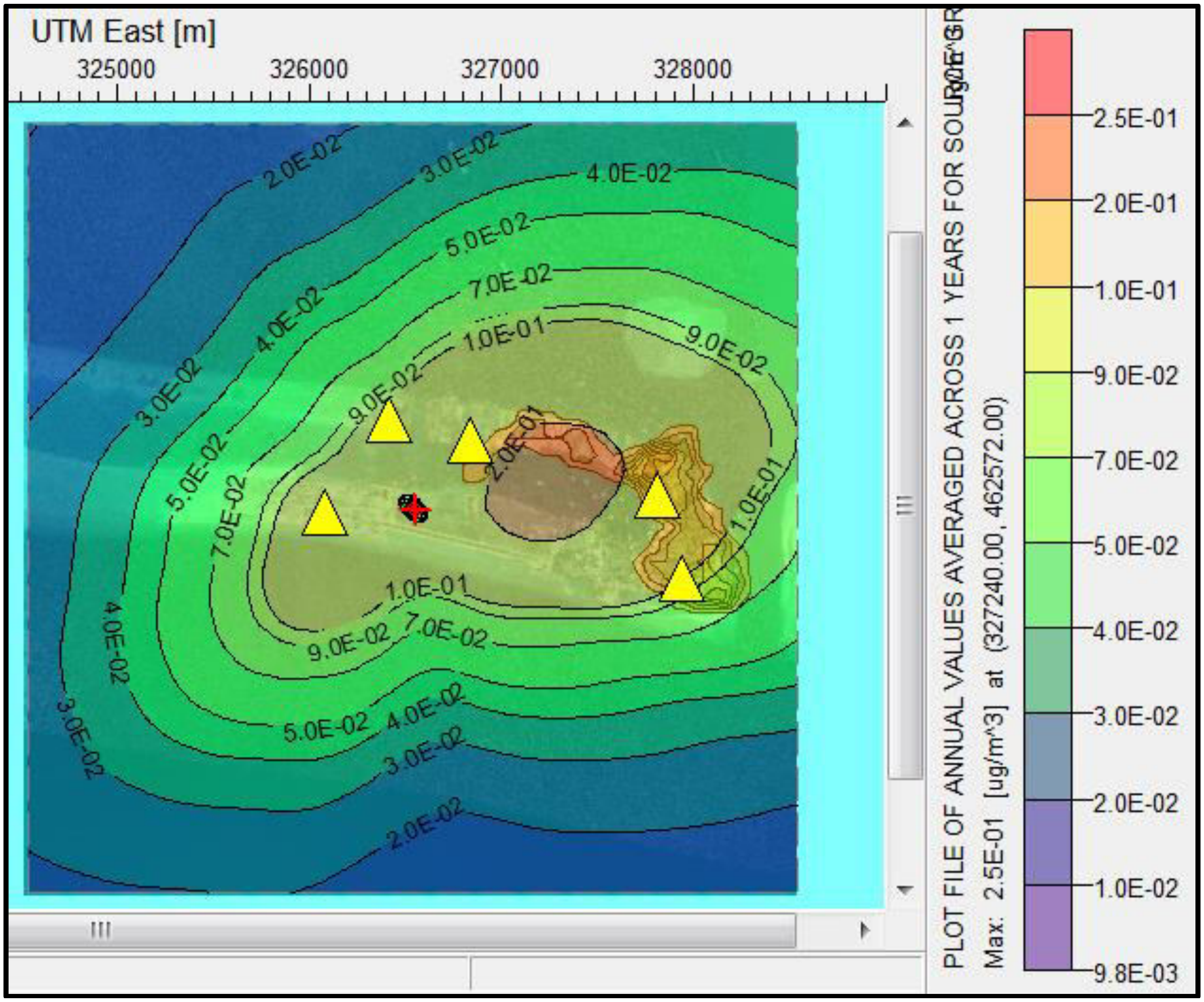


Figure 34: SO2 1 YR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

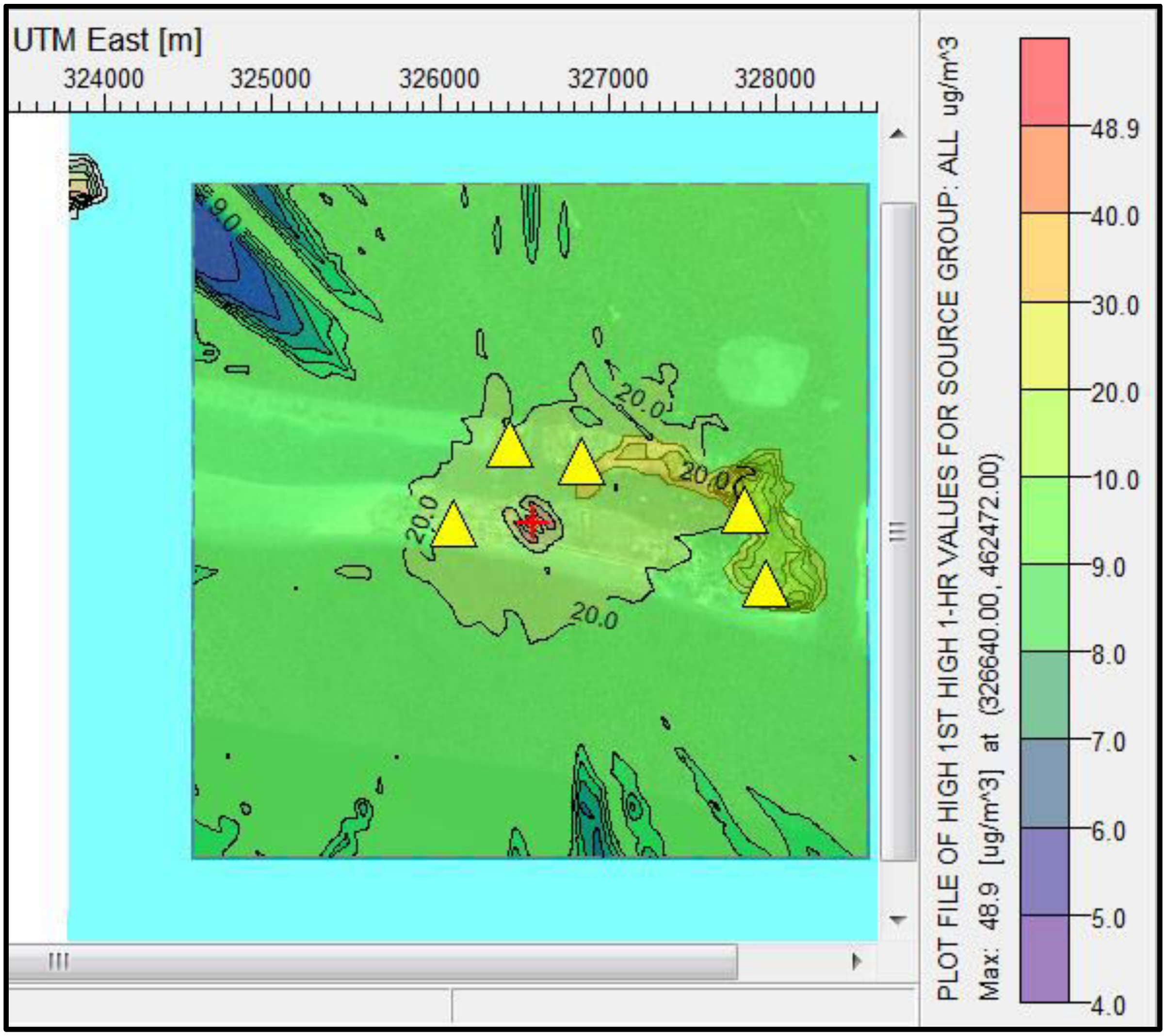


Figure 35: NO2 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

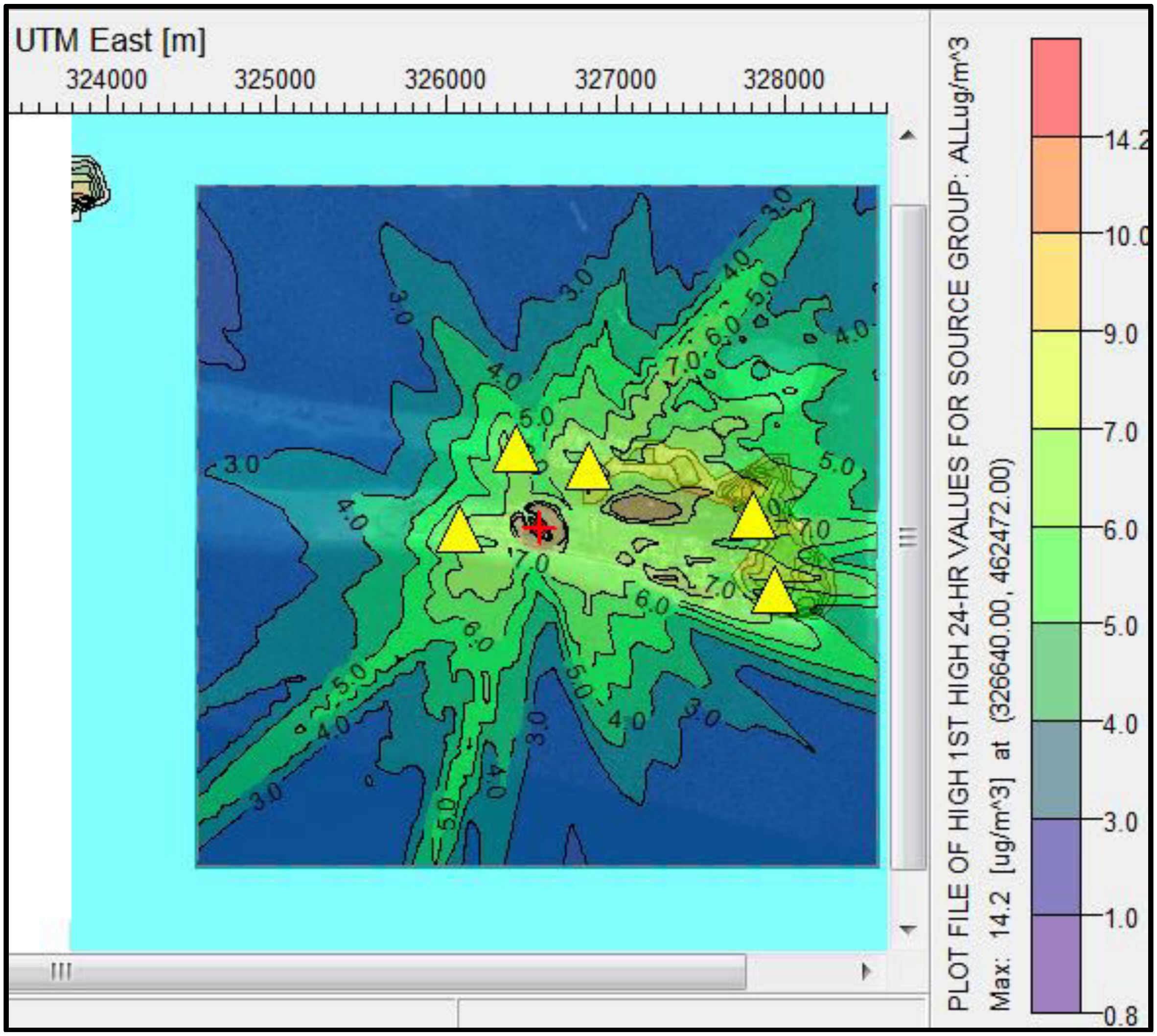


Figure 36: NO2 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs

Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

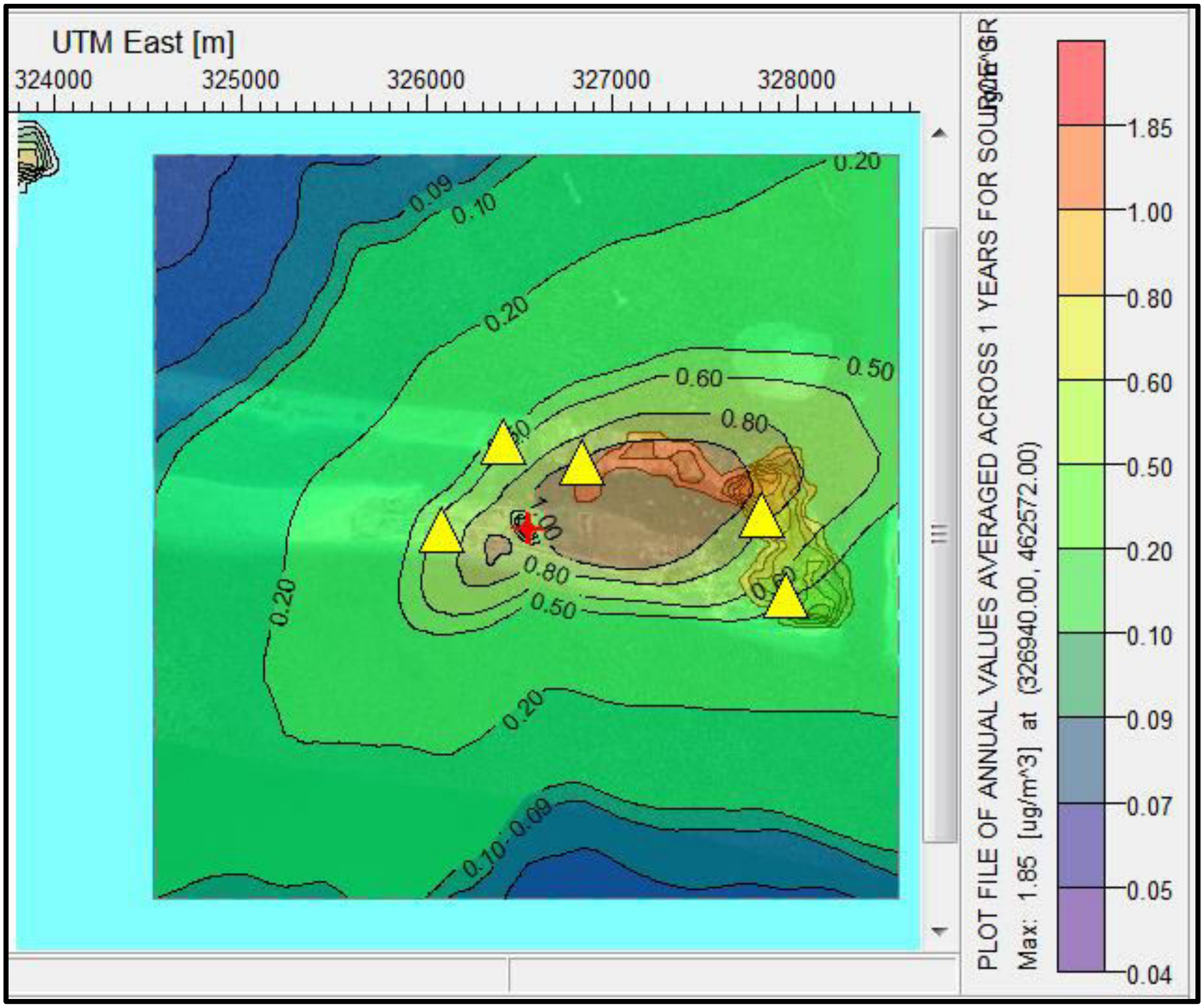


Figure 37: NO2 1 YR HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

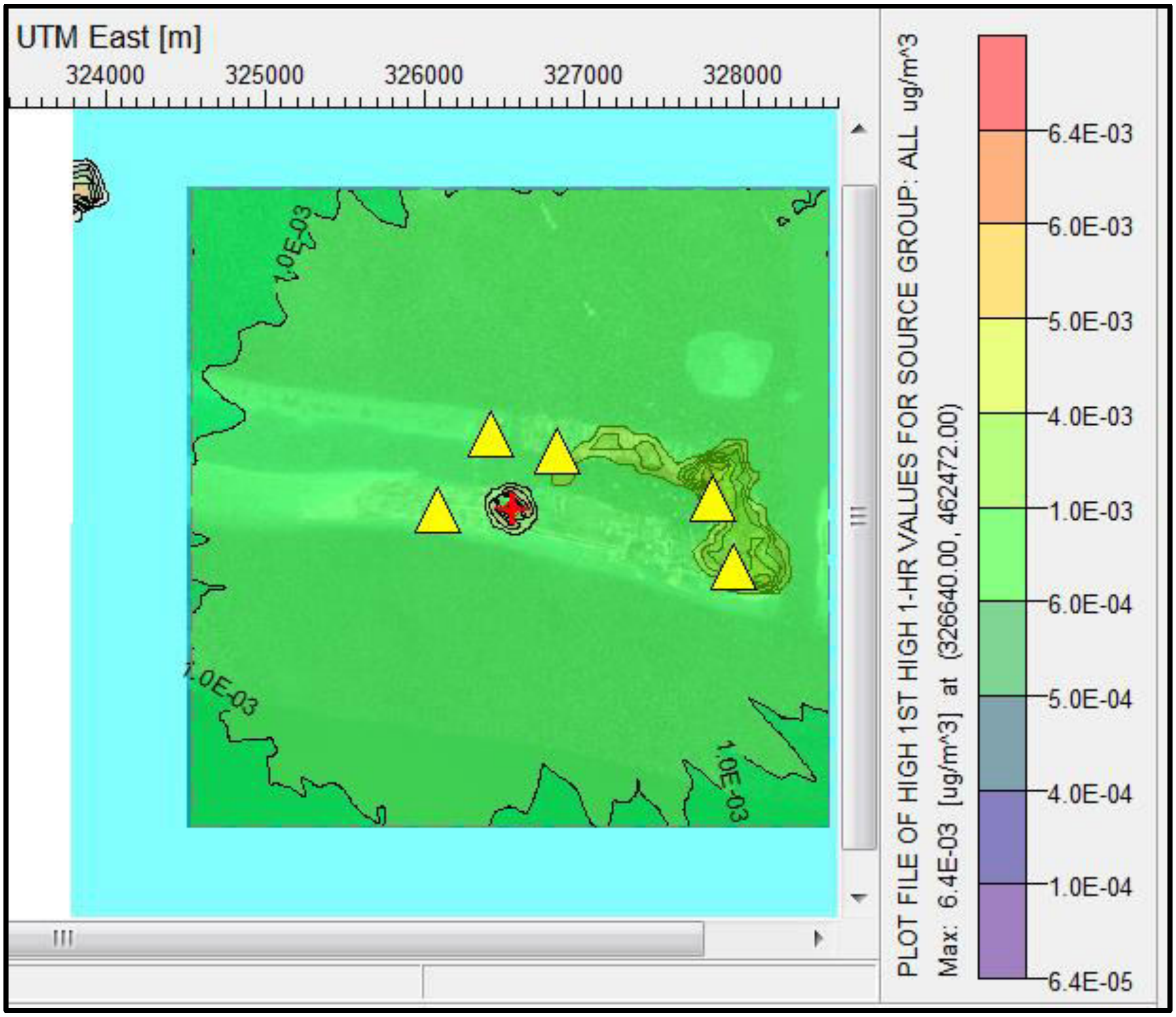


Figure 38: Hg 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

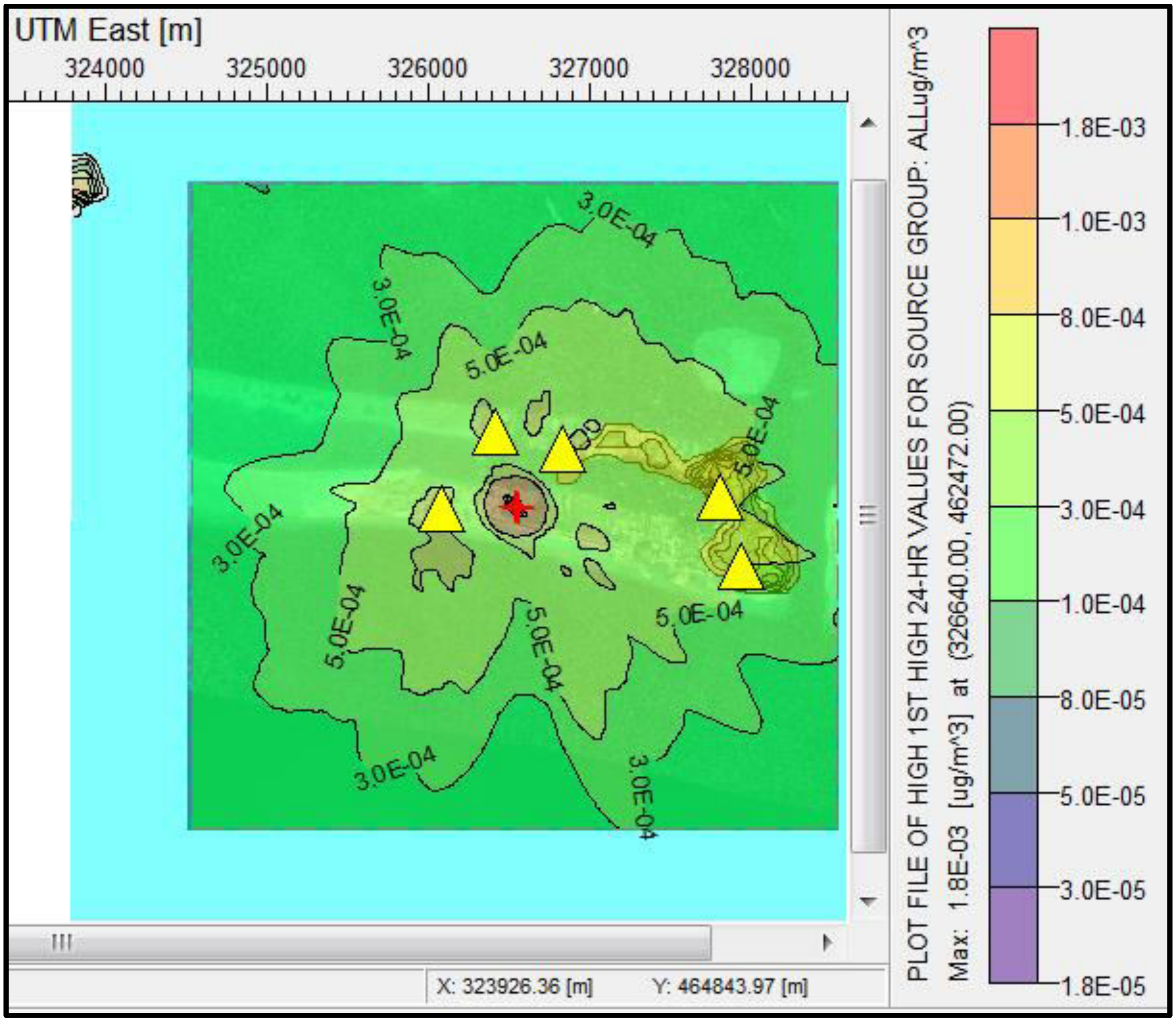


Figure 39: Hg 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

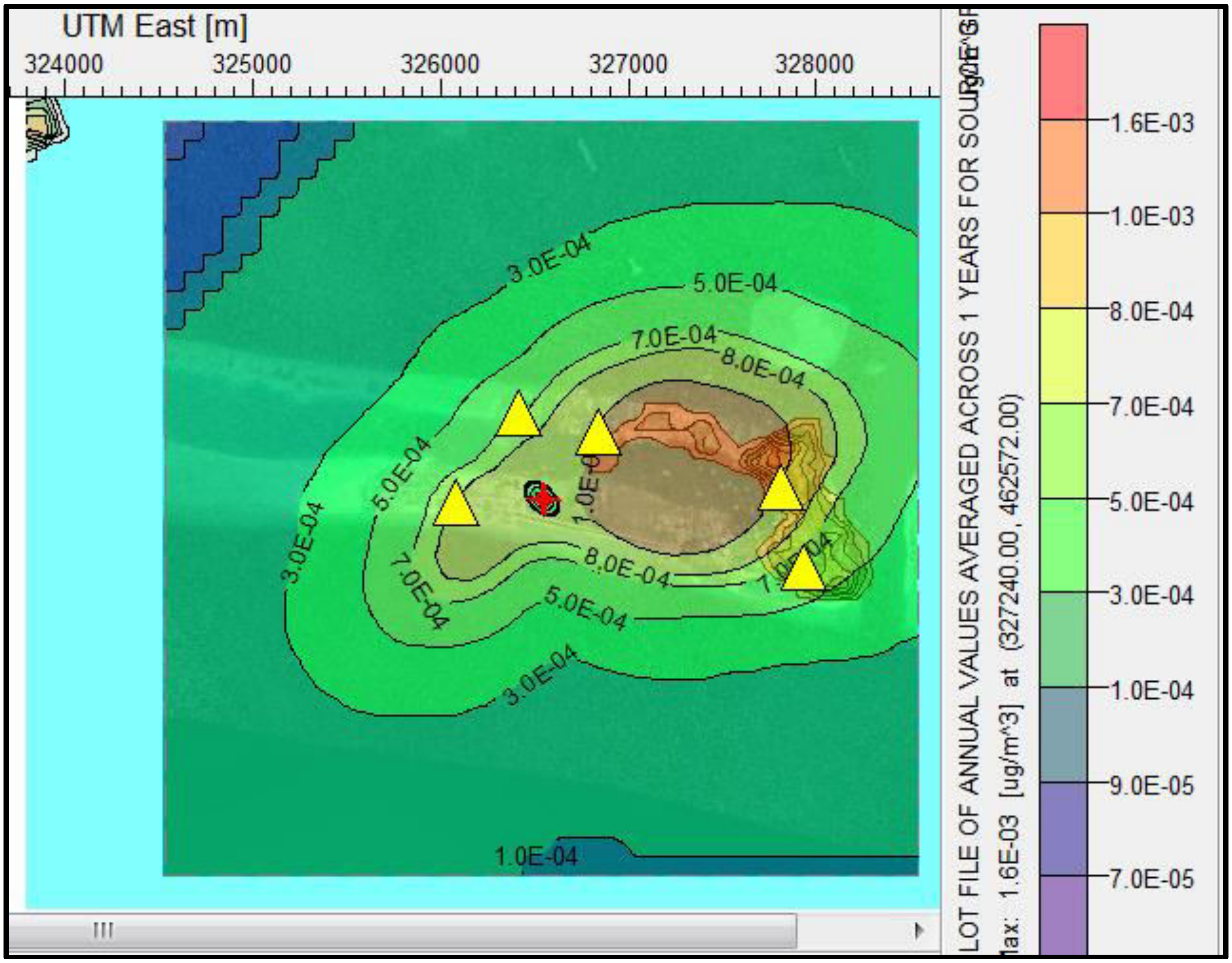


Figure 40: Hg 1 year (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

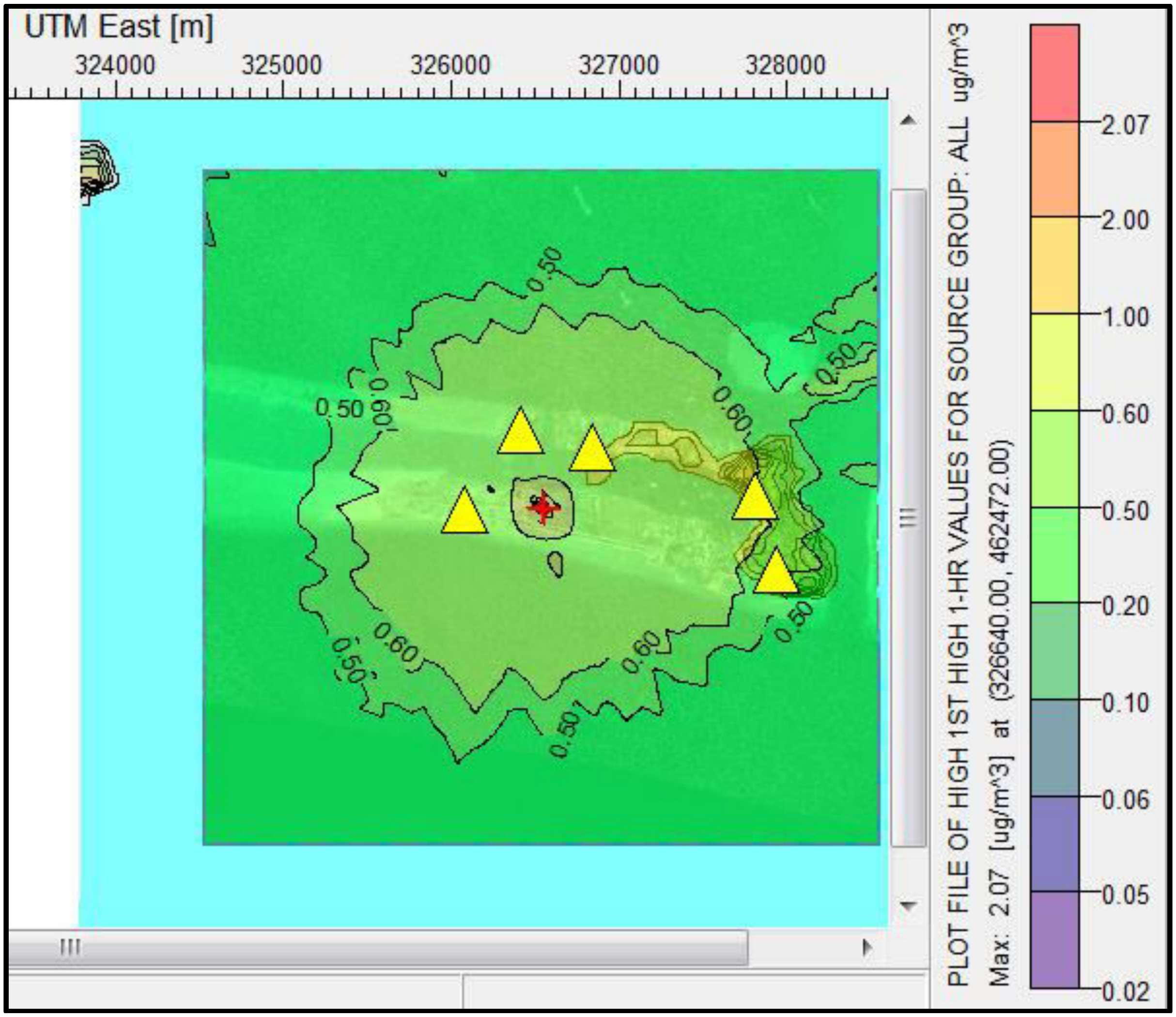


Figure 41: NH_3 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs

Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

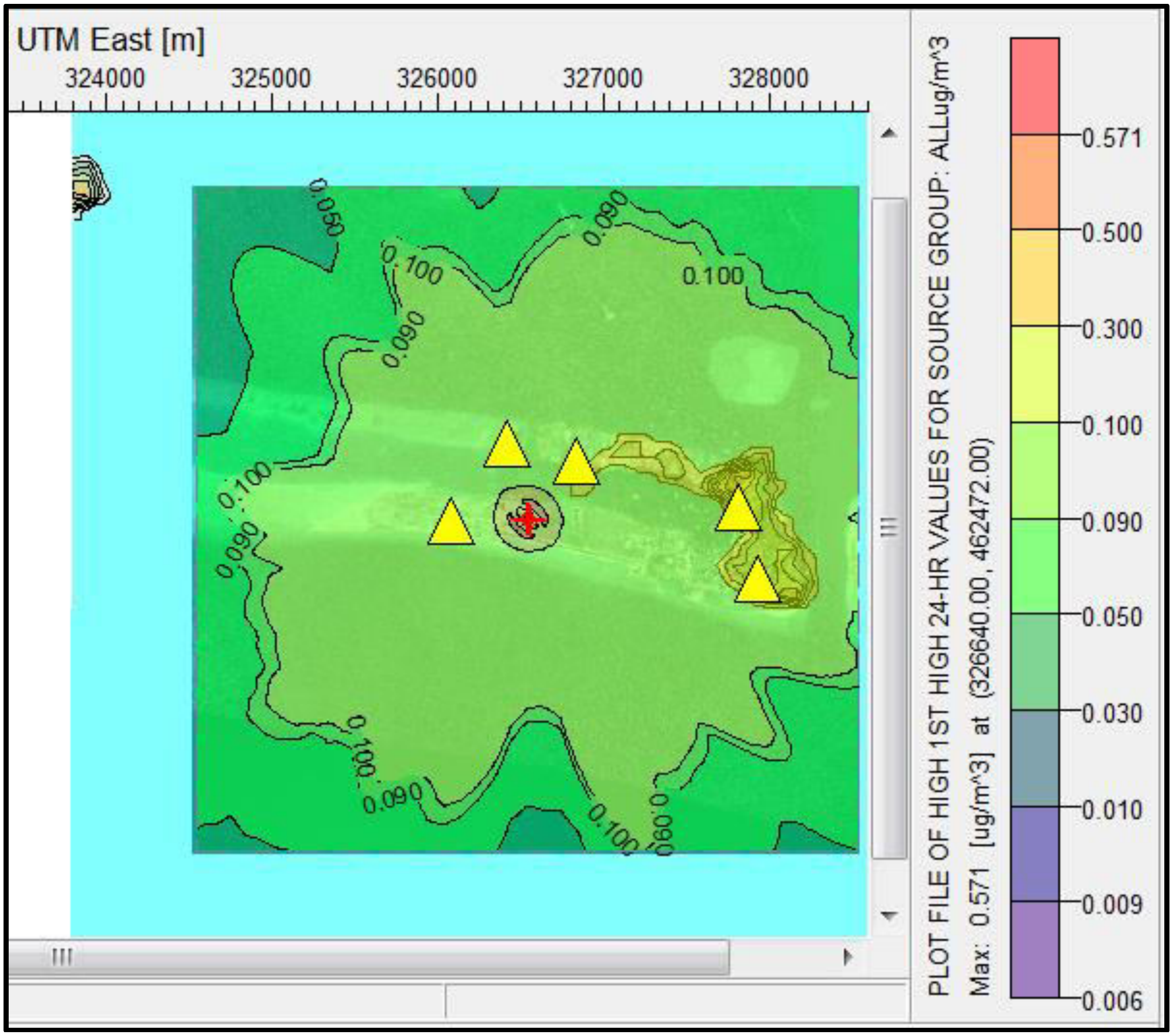


Figure 42: 5.19 NH_3 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

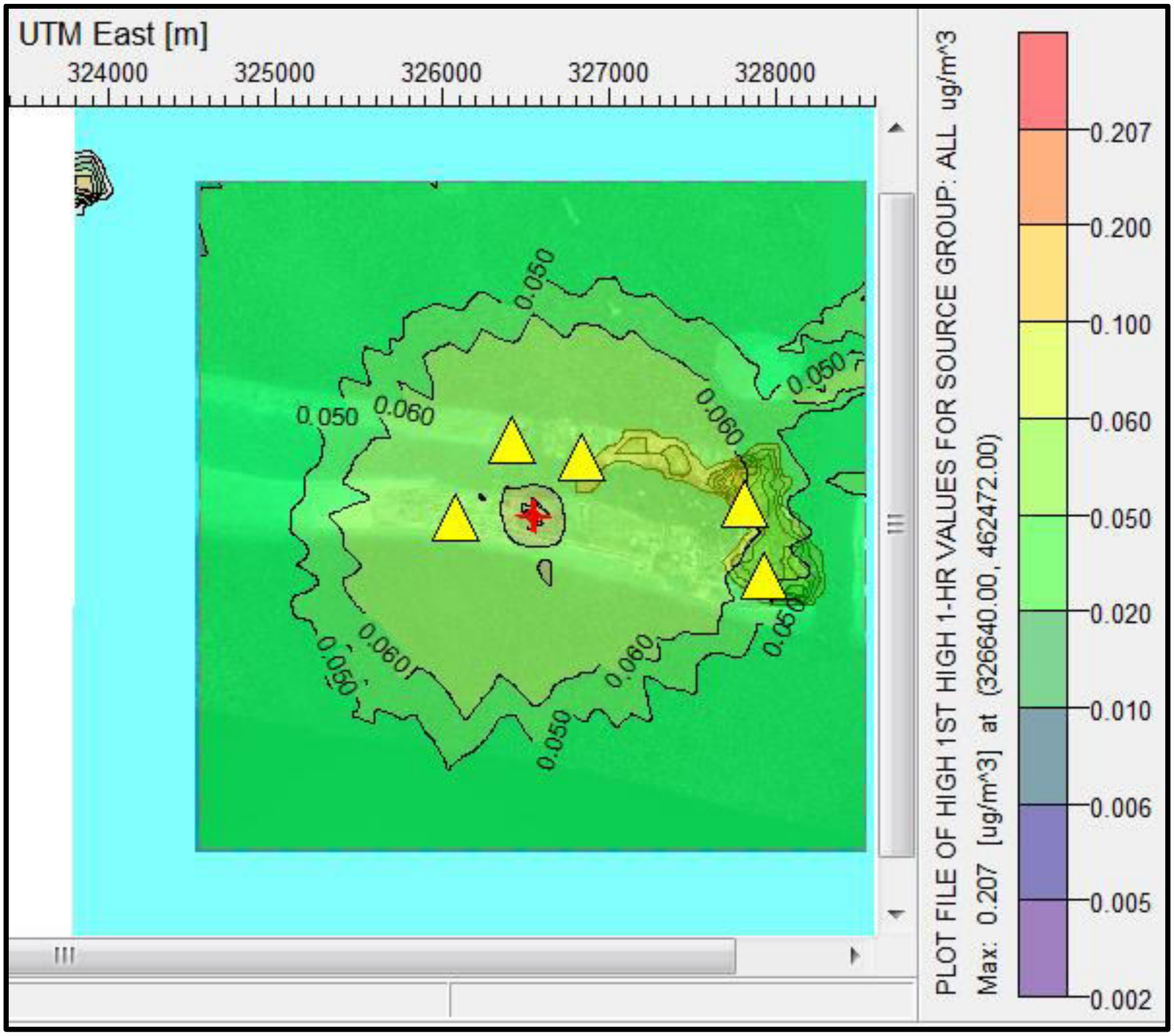


Figure 43: HF 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs

Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

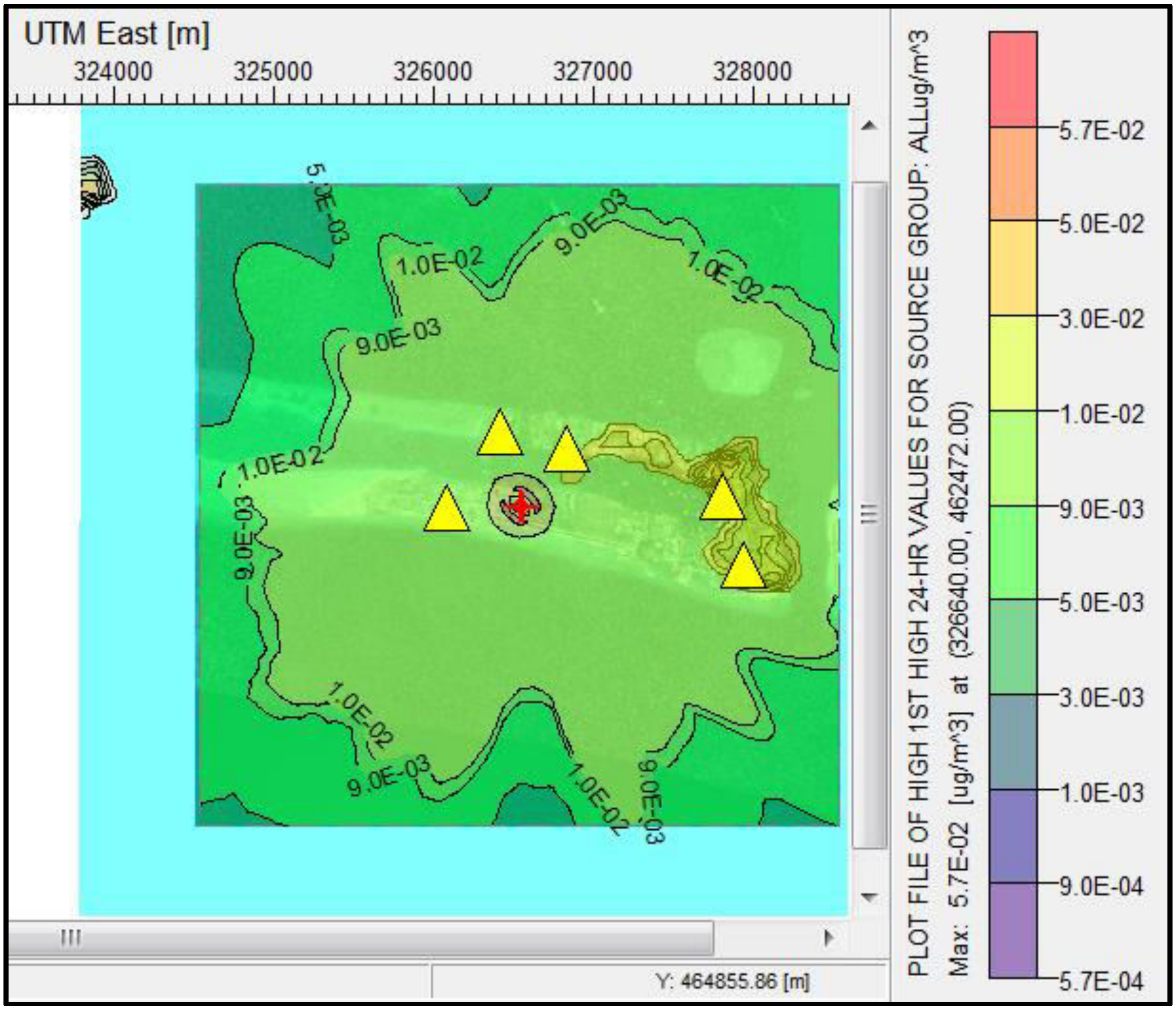


Figure 44: HF 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

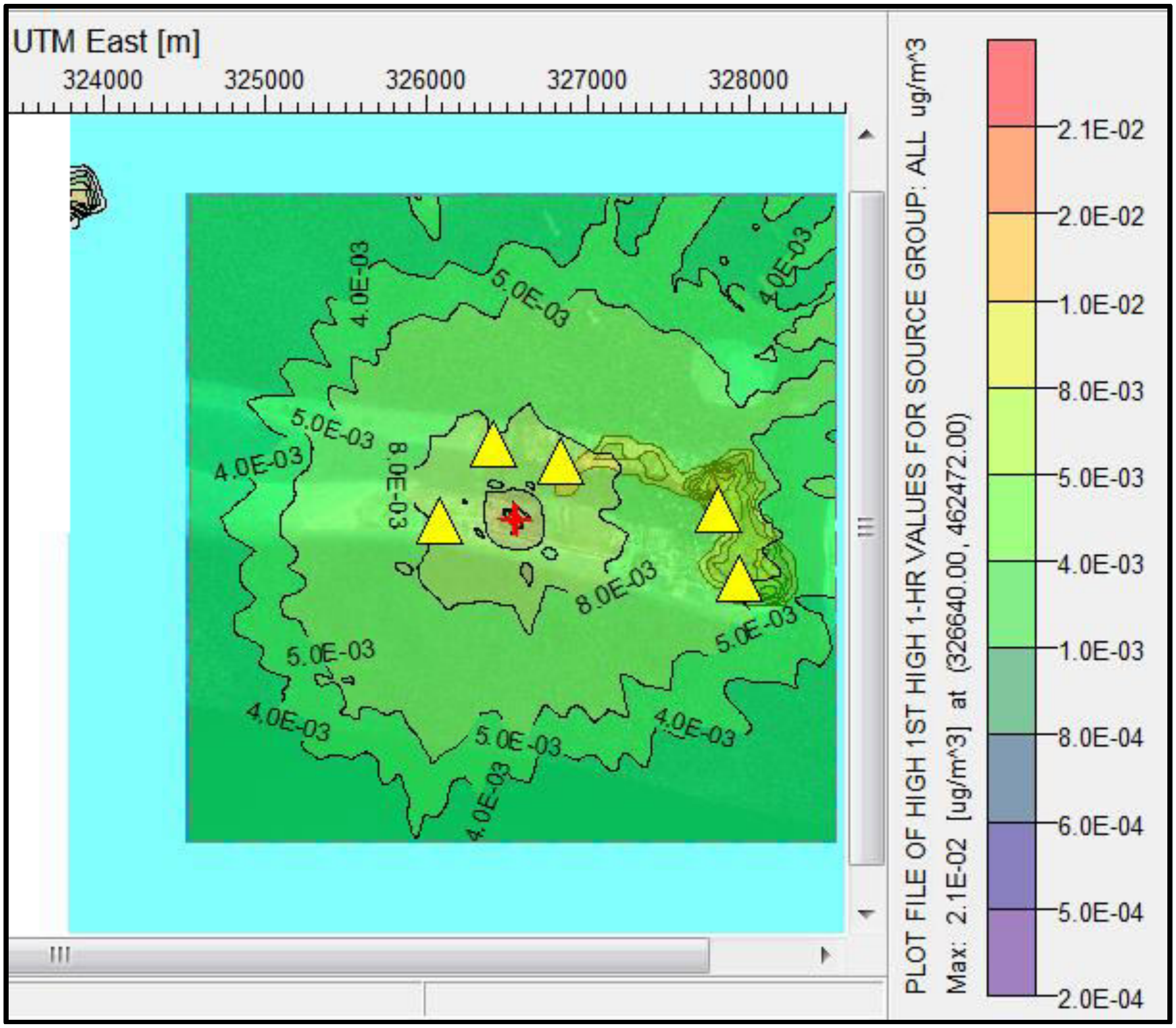


Figure 45: Dioxin and Furans 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

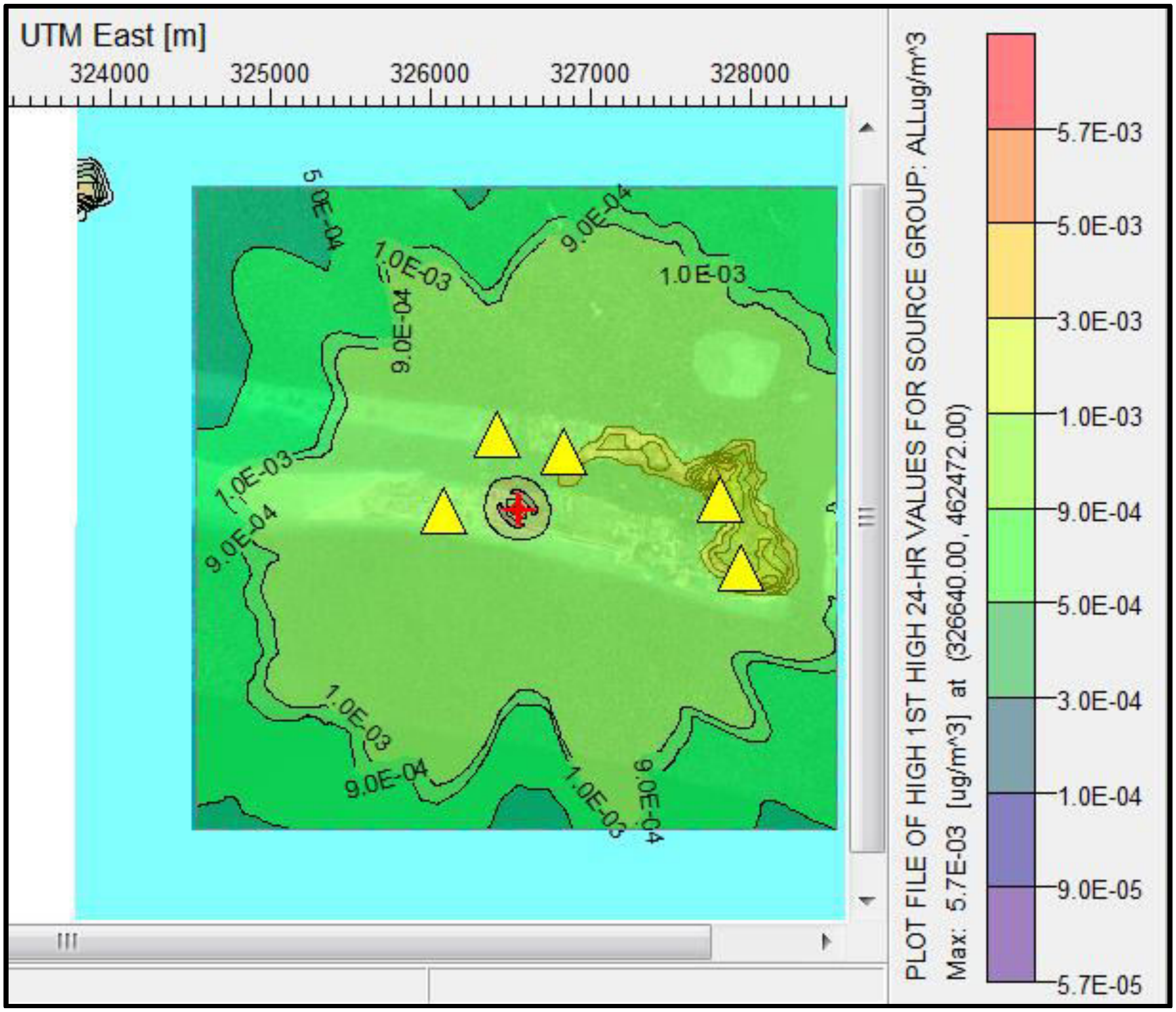


Figure 46: Dioxin and Furans 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

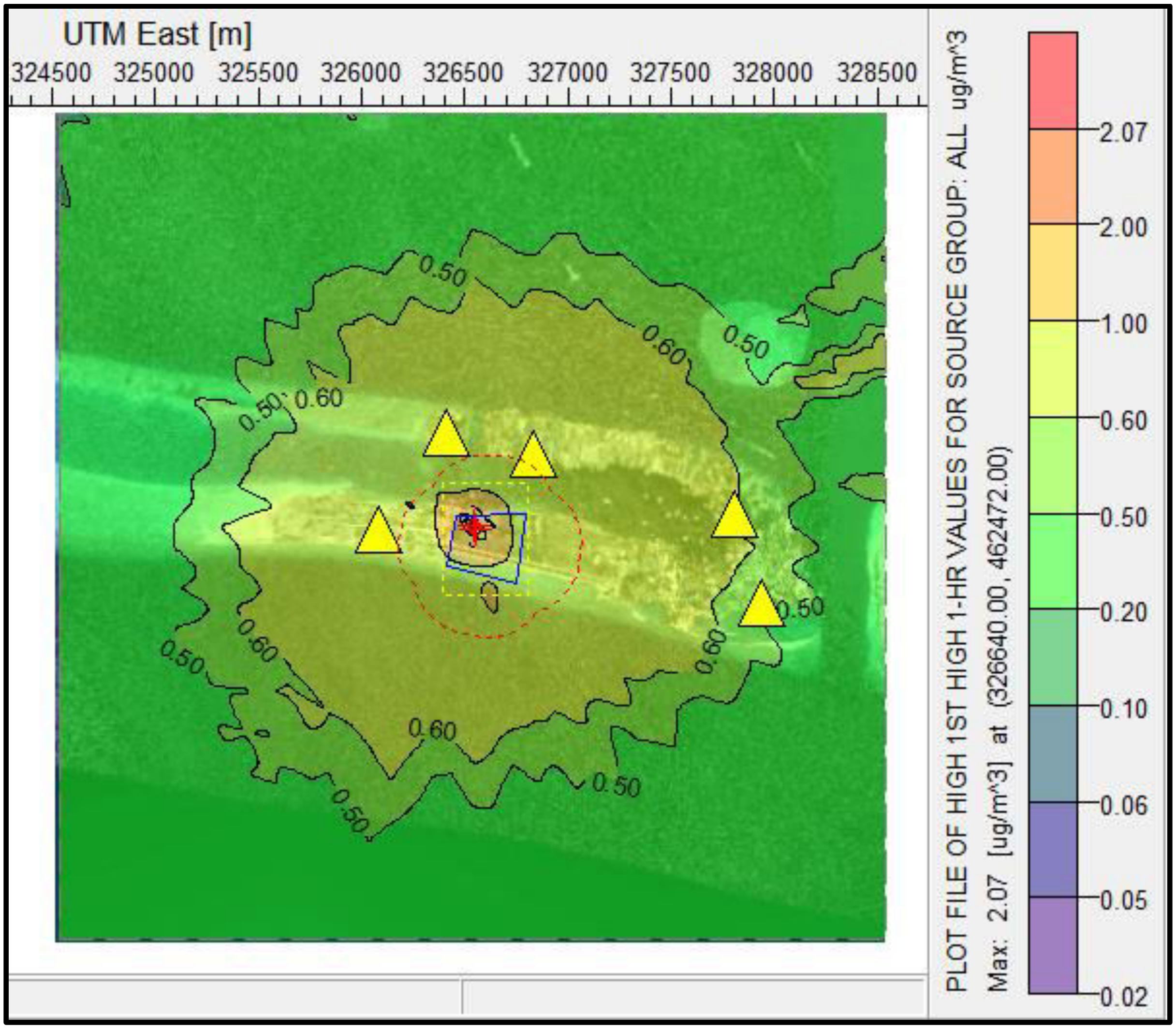


Figure 47: HCl 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

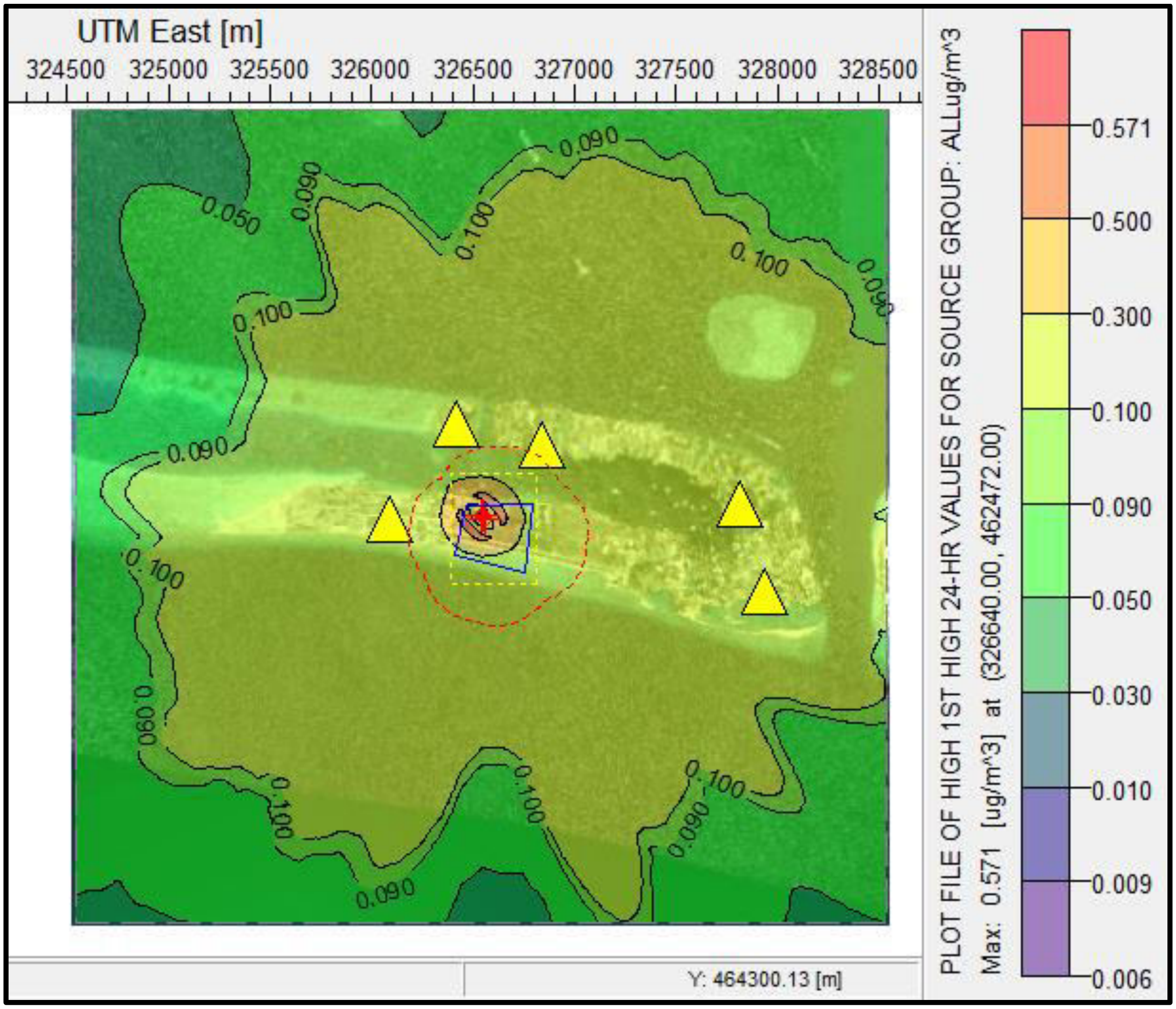


Figure 48: HCl 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

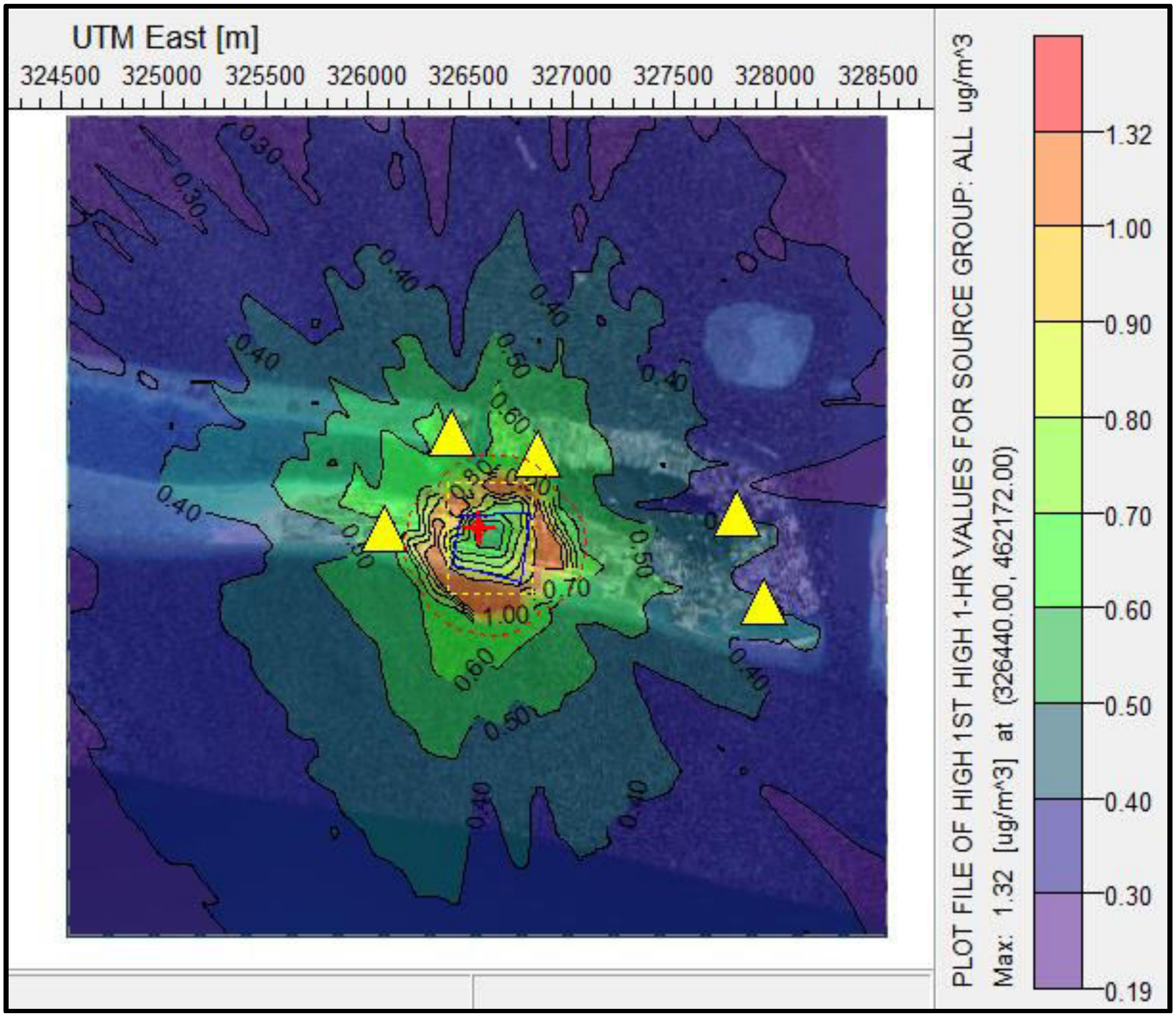


Figure 49: Sb 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs

Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

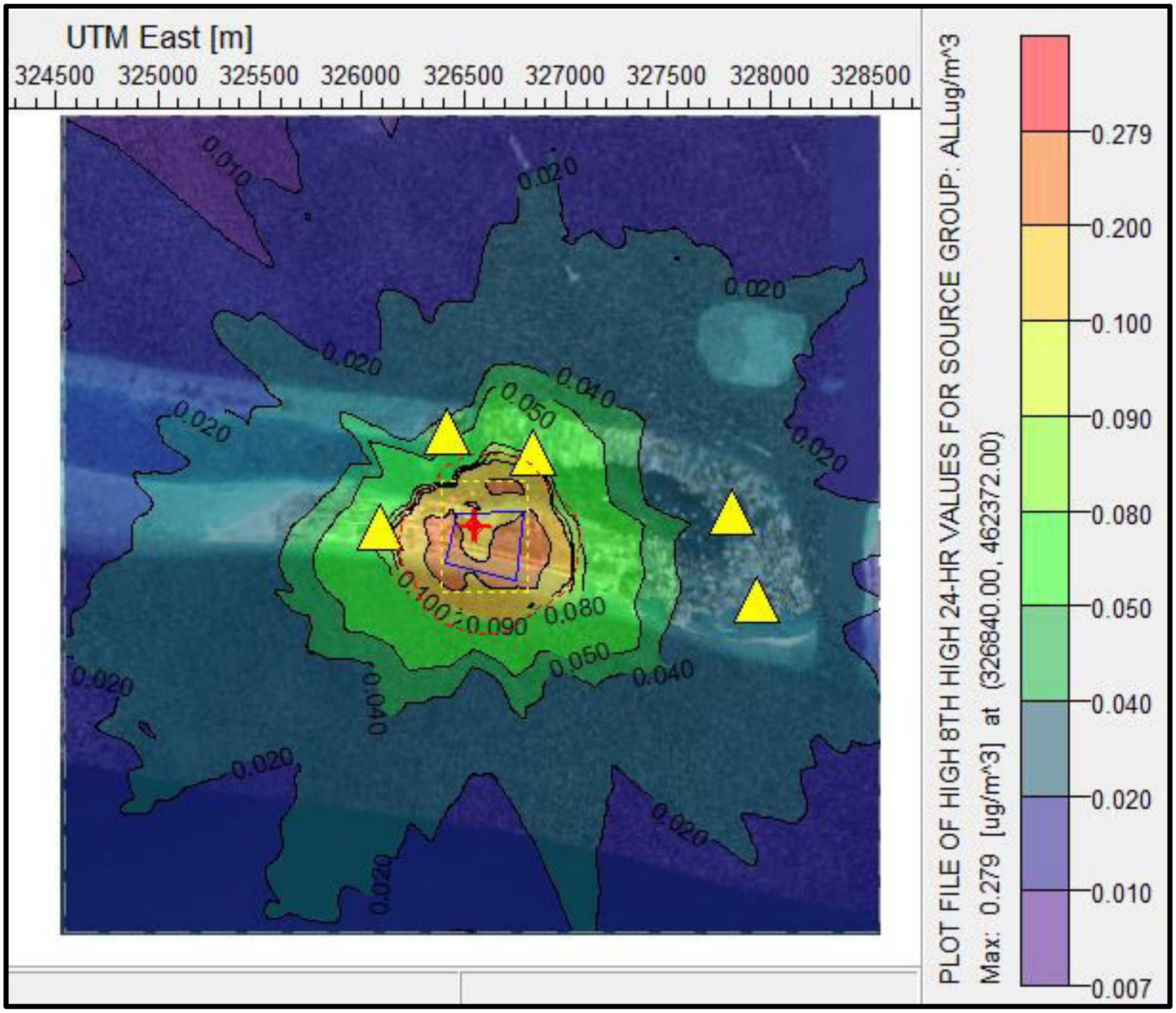


Figure 50: Sb 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

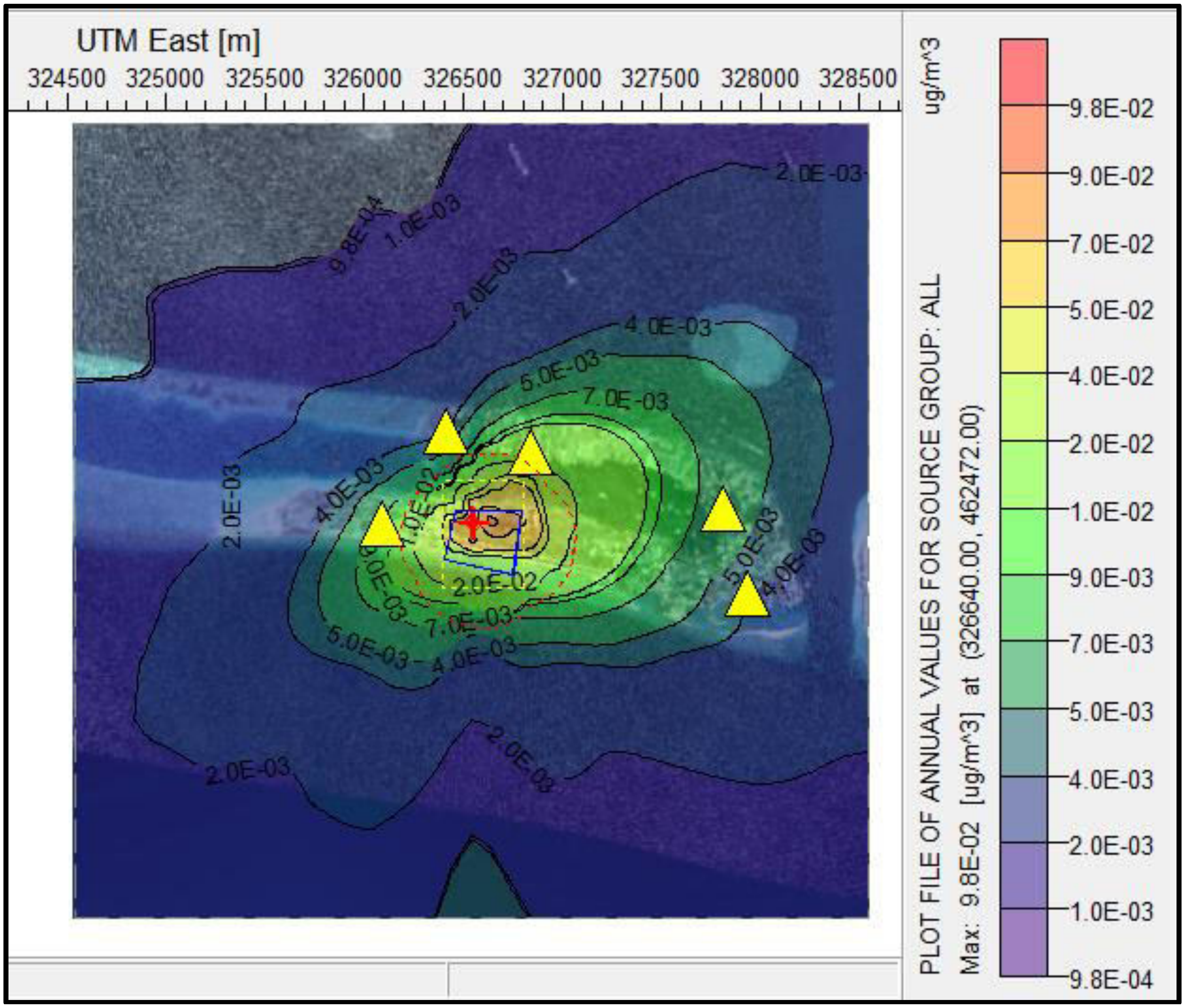


Figure 51: Sb 1 YR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

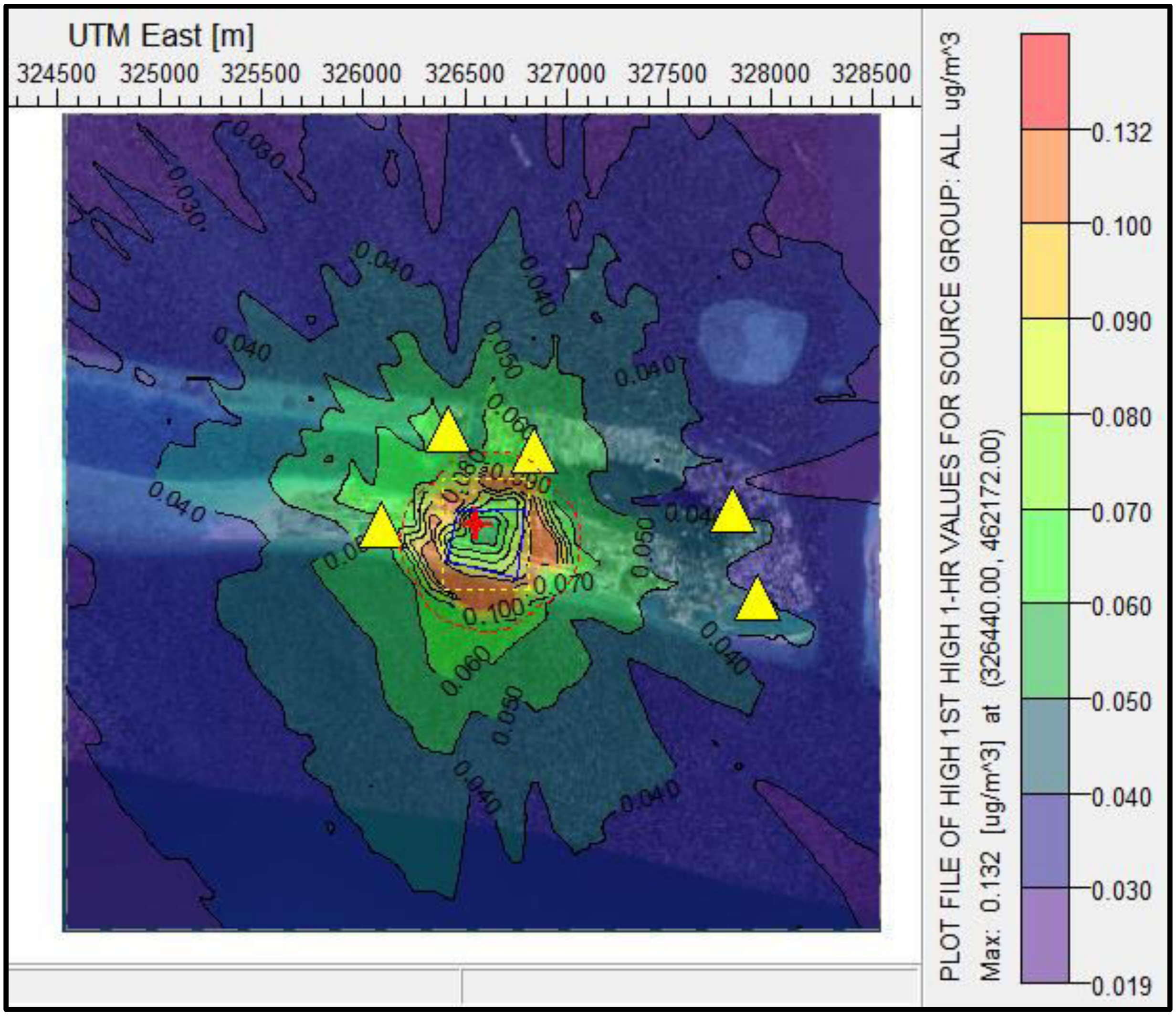


Figure 52: As 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

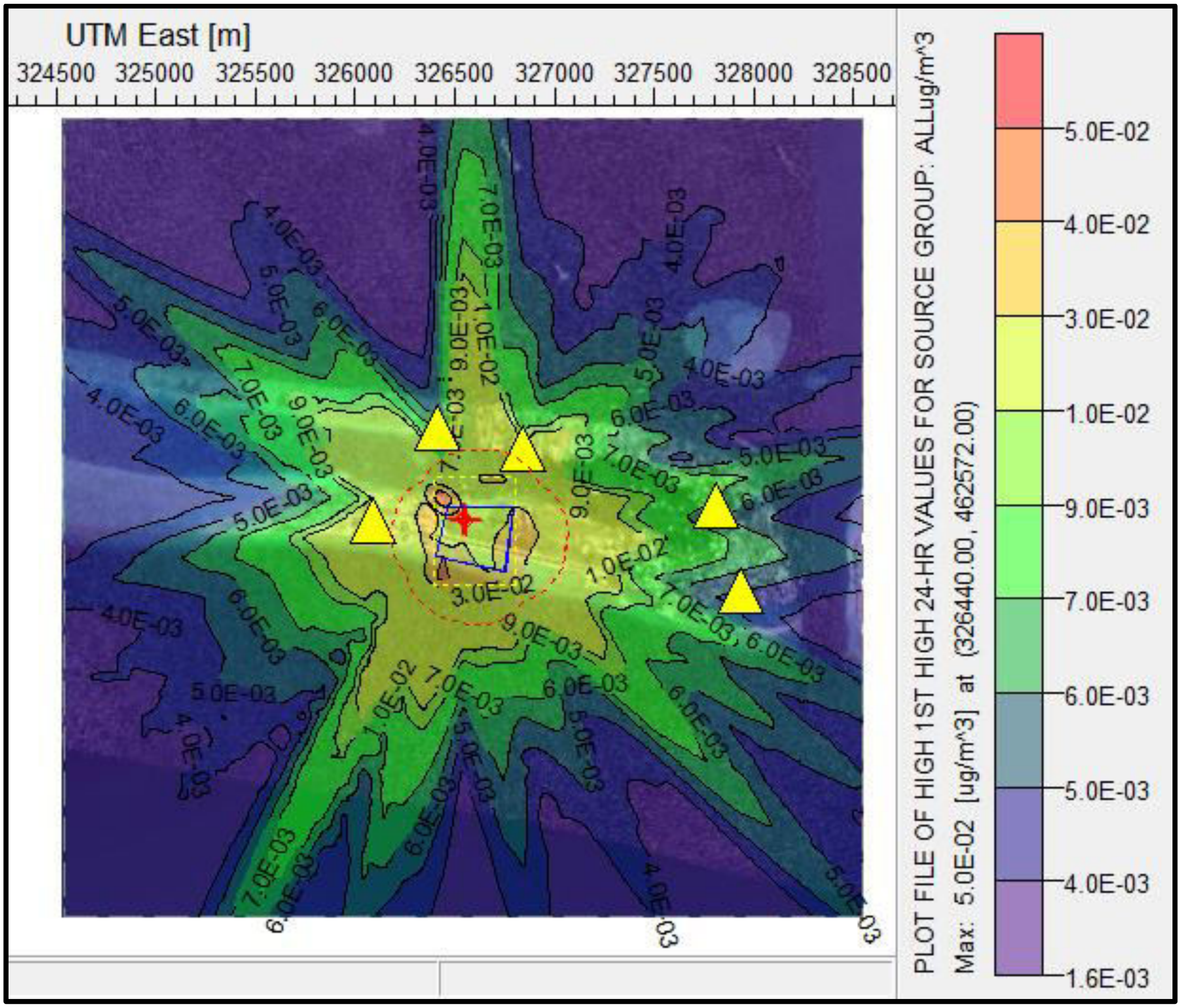


Figure 53: As 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs

Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

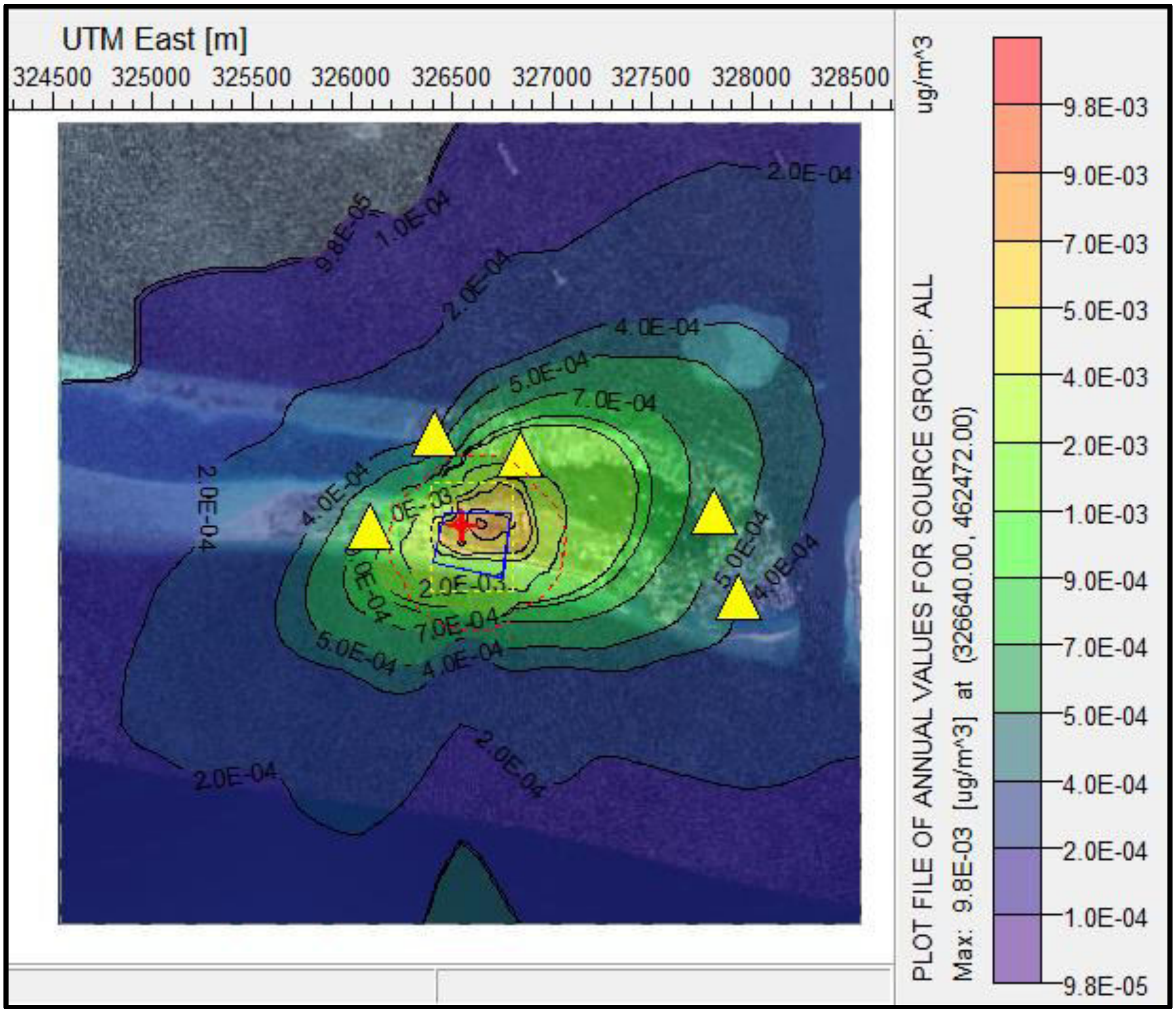


Figure 54: As 1 YR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

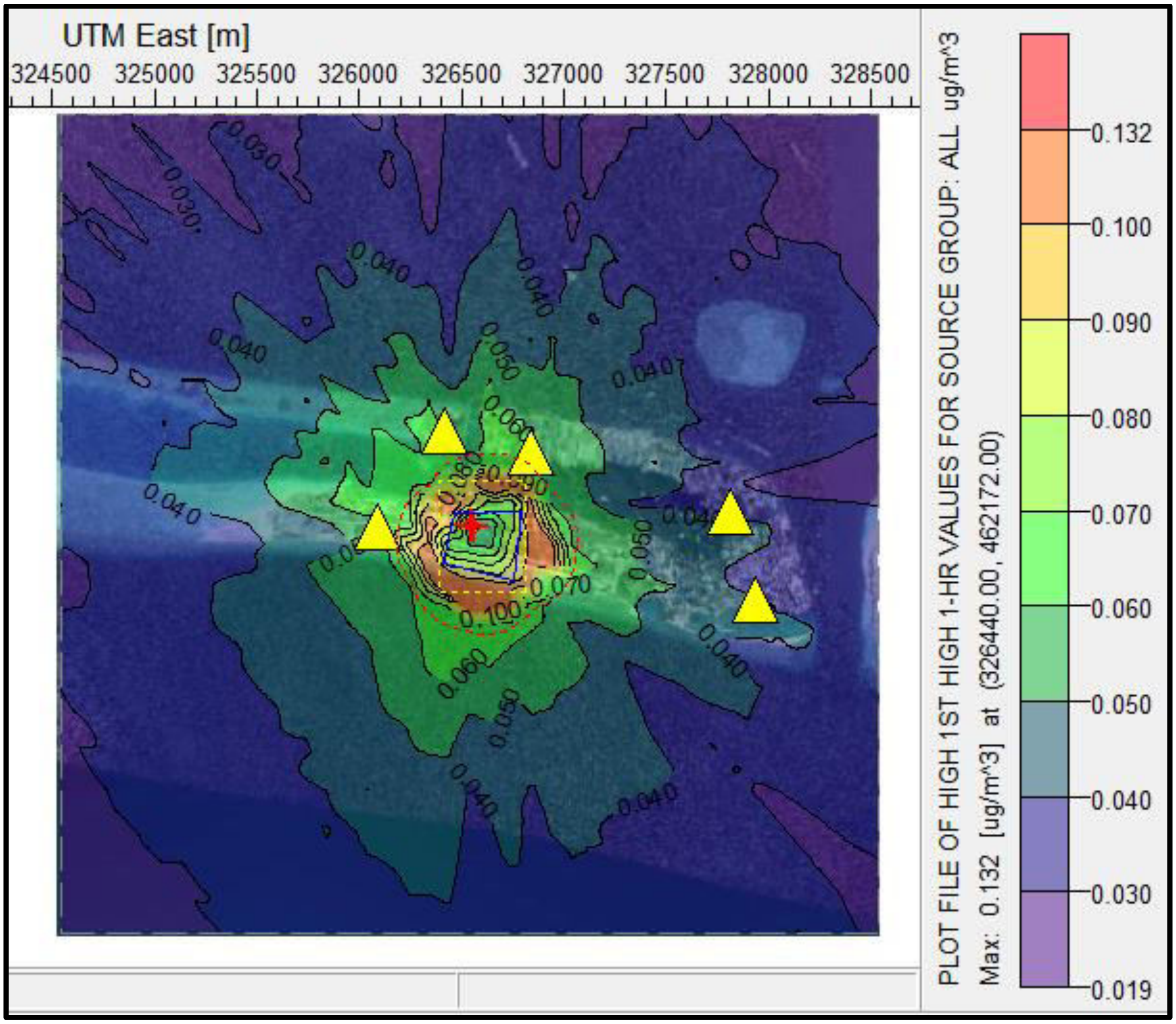


Figure 55: TI 1 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

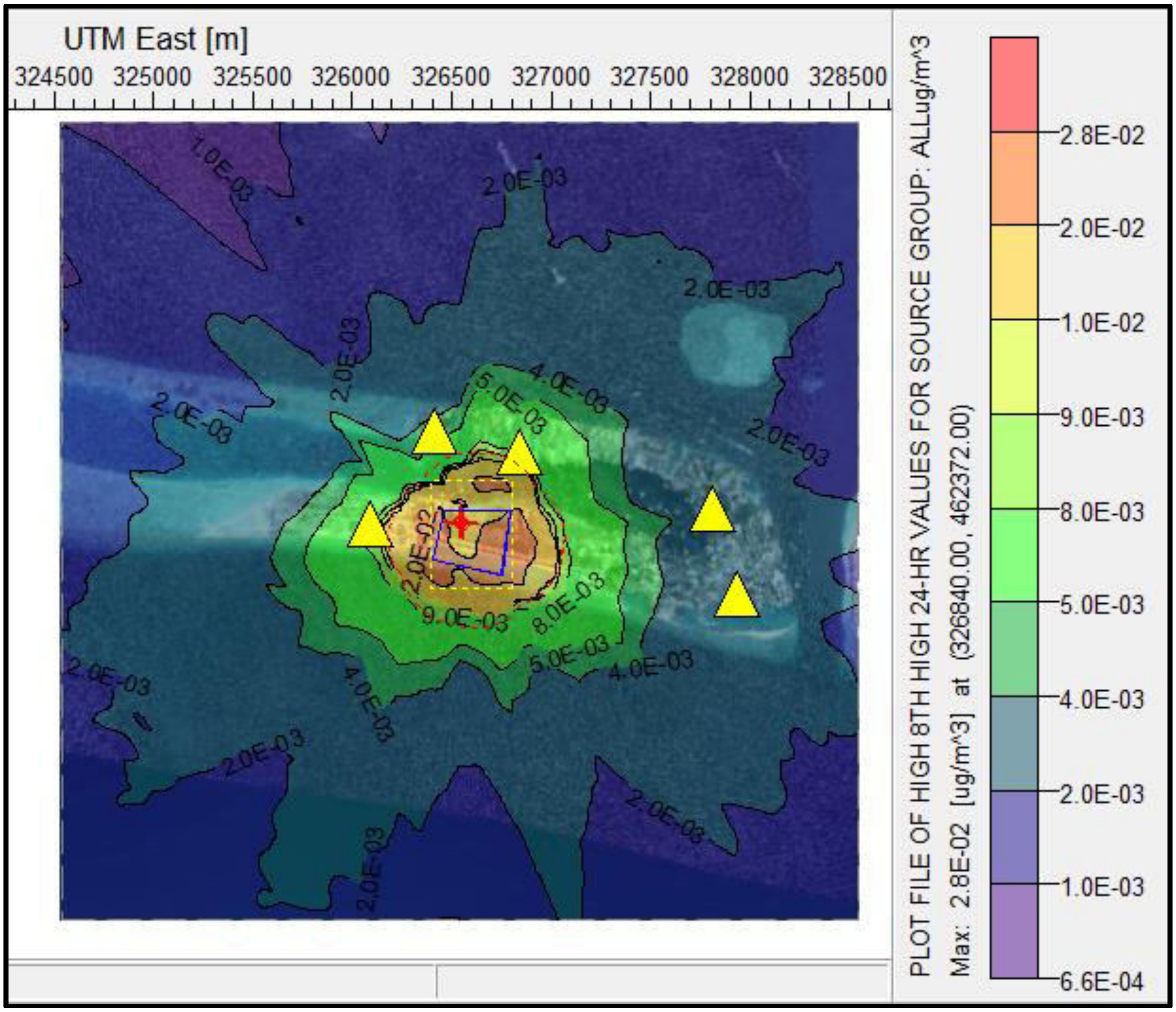


Figure 56: TI 24 HR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

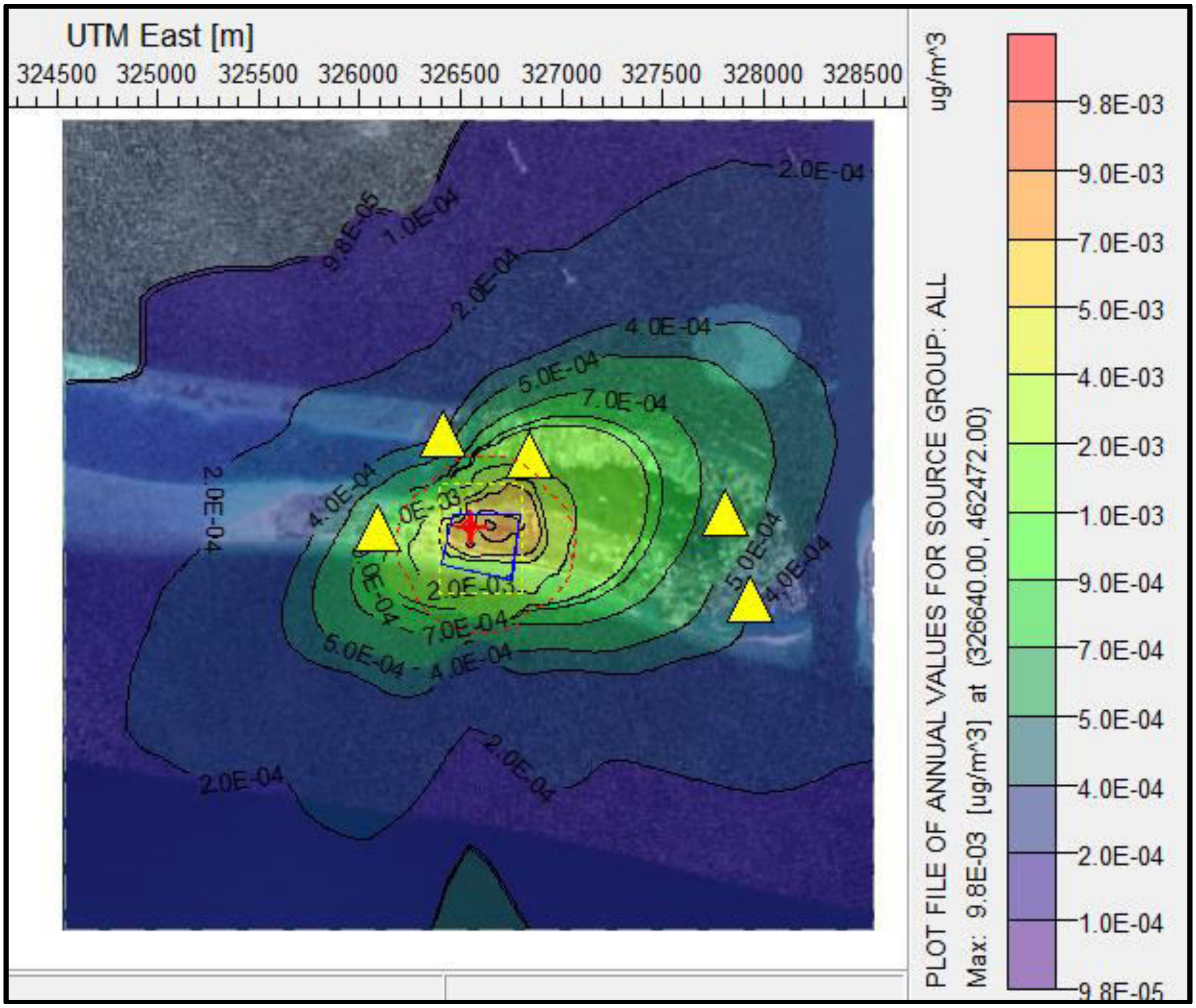


Figure 57: TI 1 YR (Isopleth in microgram/m3)

LEGEND: Yellow Triangles refer to identified ASRs
Area Sensitive Receptor (ASRs)

	Long	Lat
ASR1	327812	462536
ASR2	327938	462105
ASR3	326839	462822
ASR4	326087	462455
ASR5	326416	462929

10. DISCUSSION OF RESULTS

10.1 AERMOD VER.9.1 MODEL RUN USING TIER 3 MET DATA (MALDIVES METEOROLOGY)

Figures 24 to 48 are the results of the predictive peak values of emission dispersion modeling presented in 2 dimensional graphs: 4000 m (4km) X 4000 m (4 km). Dispersion model results are presented in 2-dimension graphical presentation Distance (X-axis) and Concentration ug/Ncm (Y-axis). Raw data of results are in output files presented in the following Nomenclature: (x=distance from source, km), conc=ground-level centerline concentration, ug/m3), (sigmay=dispersion coefficient in Y direction, dimensionless) , (sigmaz=dispersion coefficient in Z direction, dimensionless), (xf=distance to final plume rise, km) , (h=plume height, m).

10.2 TOTAL DUST (TD)

Predicted short term (1 hour) for controlled[14] total dust (TD) maximum ground level concentrations is 7.60 ug/m3 located 280 meters ENE from the center of the domain. The 24 hour controlled total dust (TD) maximum ground level concentrations is 3.188 ug/m3 located 608 meters ENE from the center of the domain. Simulated concentrations for maximum ground level concentration for 1 hour total dust (TD) are generally very low. There is no available the Ambient Air Quality Standards for total dust in the Austal2000 Report. For the total dust (TD) deposition, AERMOD results shows 0.00754 g/m2 for 1 hour, 0.038505 g/m2 for 24 hr, and 0.43394 g/m2 for 1 year deposition. Deposition simulations are all below the TALuft precipitation limit of 0.35 g/m2-d. There are no applicable USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at Universal Transverse Mercator (UTM) coordinates Easting 326540 and Northing 462472.

10.3 PARTICULATE MATTER 10 (PM-10)

Predicted short term (1 hour) for controlled particulate matter 10 (PM-10) maximum ground level concentrations is 0.102 ug/m3 located 100 meters E from the center of the domain. The 24-hour controlled PM-10 maximum ground level concentrations is 0.02844 ug/m3 located 100 meters E from the center of the domain. Simulated concentration for maximum ground level concentration for 24 hour PM10 is below the 35 ug/m3 TA Luft standards. There is no available Ambient Air Quality Standards for PM-10 in the Austal2000 report. For the PM-10 deposition, AERMOD results shows 0.00037 g/m2 for 1 hour, 0.0007g/m2 for 24 hour and 0.025 g/m2 for 1 year deposition. There is no TALuft limit for PM10 for 1-hour in the Austal2000 report. Results are below TA Luft and WHO Air Quality Guideline Values. There are no USEPA standards in ug/Nm3 unit, the values used are converted from parts per billion by volume (ppbv). The results show insignificant increase of 0.51% for 1-hour, 0.06% for 24-hour, and 0.01% for 1-year. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.4 SULFUR DIOXIDE (SO2)

Predicted short term (1 hour) for controlled sulfur dioxide (SO_2) maximum ground level concentrations is 10.34 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled SO_2 maximum ground level concentrations is 2.85 ug/m3 located 100 meters E from the center of the domain. For 1-year averaging time, results of maximum concentration is 0.25302 ug/m3. Results for maximum ground level concentration for 1 hour, 24 hour and 1 year SO_2 are all below the TA Luft standards of 350 ug/m3 for 1 hour, 125 ug/m3 for 24 hr and 50 ug/m3 for 1 year respectively. There are no USEPA standards in ug/Nm3 unit, the values used are converted from parts per billion by volume (ppbv). The results show insignificant increase of 4.88% for 1-

[14] Controlled emission parameters refer to post-air pollution control devices. For the WtE, each stack will include baghouse and electostatic precipitators.

hour, 14.29% for 24-hour, and 0.32% for 1-year. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.5 NITROGEN OXIDES (NOX)

Predicted short term (1 hour) for controlled NO_2 maximum ground level concentrations is 48.91 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled NO_2 maximum ground level concentrations is 14.16 ug/m3 located 100 meters E from the center of the domain. For 1 year averaging time, results of maximum NO_2 concentration is 2.1 ug/m3. Simulated concentration for maximum NO_2 ground level concentration for 1 year is below the TA Luft standards of 40 ug/m3. There are no USEPA standards in parts per billion by volume (ppbv) therefore cannot be converted to ug/Nm3 unit. The results show increase of 24.46% for 1-hour, and 5.25% for 1-year if compared to WHO Air Quality Guidelines. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.6 MERCURY (HG)

Predicted short term (1 hour) for controlled mercury (Hg) maximum ground level concentrations is 0.00643 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled Hg maximum ground level concentrations is 0.00178 ug/m3 located 100 meters E from the center of the domain. For 1 year averaging time, results of maximum concentration is 0.0057 ug/m3. There are no TA Luft, USEPA standards and WHO Air Quality Guideline Values. The results show insignificant increase of 0.18% for 24-hour and 3.14% for 1-year using TA Luft standards. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.7 AMMONIA (NH3)

Predicted short term (1 hour) for controlled ammonia (NH_3) maximum ground level concentrations is 2.066 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled NH_3 maximum ground level concentrations is 0.57123 ug/m3 located 100 meters E from the center of the domain. There are no NH_3 TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.8 HYDROGEN CHLORIDE (HCL)

Predicted short term (1 hour) for controlled hydrogen chloride (HCl) maximum ground level concentrations is 2.066 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled NH_3 maximum ground level concentrations is 0.57123 ug/m3 located 100 meters E from the center of the domain. There are no HCl TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.9 HYDROGEN FLOURIDE (HFL)

Predicted short term (1 hour) for controlled hydrogen fluoride (HFl) maximum ground level concentrations is 2.066 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled HFl maximum ground level concentrations is 0.57123 ug/m3 located 100 meters E from the center of the domain. There are no HFl TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.11 DIOXINS AND FURANS (D/F)

Predicted short term (1 hour) for controlled Dioxins and Furans maximum ground level concentrations is 0.0258 ug/m3 located 100 meters E from the center of the domain. The 24 hour controlled Dioxins and Furans maximum ground level concentrations is 0.00569 ug/m3 located 100 meters E from the center of the domain. There are no Dioxins and Furans TA Luft standards in the Austal2000 report. There are no USEPA standards and WHO Air Quality Guideline Values. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.12 SUM OF HEAVY METALS AND THEIR COMPONENTS: ANTIMONY, CHROMIUM,COPPER, MANGANESE, VANADIUM, TIN, LEAD, COBALT, NICKEL (TA LUFT CLASS II AND III)

Predicted short term (1 hour) for the Sum of heavy metals and their components: antimony, chromium,copper, manganese, vanadium, tin, lead, cobalt, nickel (TA Luft class II and III) ground level concentrations is 1.3161 ug/m3 located 316 meters NorthNorthEast (NNE) from the center of the domain. The 24 hour controlled total sum of metals maximum ground level concentrations is 0.4954 ug/m3 located 141 meters NorthWest (NW) from the center of the domain. For 1 year averaging time, results of maximum concentration is 0.0982 ug/m3. Simulated concentrations for maximum ground level concentration for both 1, 24 hours & 1 Year averaging which are generally very low. Results are generally lower than US RSLs for combined 24 hr averaging for Cu, Vn,Cr and Mn of 0.152 ug/m3 and the 3 month NAAQS for Lead of 0.15 ug/m3. There is no available the Ambient Air Quality Standards for said metals in the Austal2000 Report. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.13 ARSENIC / CADMIUM AND ITS COMPOUNDS (EXPRESSED AS AS AND CD), BENZO (A) PYRENE, WATER-SOLUBLE COBALT COMPOUNDS (EXPRESSED AS CO), CHROMIUM (VI) COMPOUNDS (EXPRESSED AS CR) (TA LUFT CLASS I)

Predicted short term (1 hour) for the Sum of heavy metals and their components: Arsenic / cadmium and its compounds (expressed as As and Cd), benzo (a) pyrene, water-soluble cobalt compounds (expressed as Co), chromium (VI) compounds (expressed as Cr) (TA Luft Class I) ground level concentrations is 0.13161 ug/m3 located 316 meters NorthNorthEast (NNE) from the center of the domain. The 24 hour controlled total sum of metals maximum ground level concentrations is 0.049 ug/m3 located 141 meters NorthWest (NW) from the center of the domain. For 1 year averaging time, results of maximum concentration is 0.00982 ug/m3. Simulated concentrations for maximum ground level concentration for both 1, 24 hours & 1 Year averaging which are generally very low. Results are generally lower than the available ESL for Arsenic of 3 ug/m3 and 0.067 ug/m3 for 1 year. There is no available the Ambient Air Quality Standards for said metals in the Austal2000 Report. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.14 THALLIUM AND ITS COMPOUNDS (TA LUFT CLASS I) CADMIUM

Predicted short term (1 hour) for the Sum of heavy metals and their components: Thallium and its compounds (TA Luft class I) cadmium ground level concentrations is 0.13161 ug/m3 located 316 meters NorthNorthEast (NNE) from the center of the domain. The 24 hour controlled total sum of metals maximum ground level concentrations is 0.049 ug/m3 located 141 meters NorthWest (NW) from the center of the domain. For 1 year averaging time, results of maximum concentration is 0.00982 ug/m3. Simulated concentrations for maximum ground level concentration for both 1, 24 hours & 1 Year averaging which are generally very low. There is no available the Ambient Air Quality Standards for said metals in the Austal2000 Report and in the USEPA NAAAQS, ESLs and RSLs. Reference center of the domain is the location of the Boiler Stack-1 at UTM coordinates Easting 326540 and Northing 462472.

10.15 OVERALL RESULTS

AERMOD validation of the Austal2000 model results shows slightly higher results than the Austal2000 report but still within TA Luft Standards, USEPA Standards and WHO Air Quality Guideline Values. For the deposition results, Total Dust, SO2, NO2 and Hg are confirmed to be way below the 1 year TA Luft precipitation standards. Toxic heavy metal parameters such Ni, Ti, As,Cd, and Pb was excluded in the validation model due to absence of design emission data. For all the above parameters, controlled emissions have been validated to be in compliance with the TA Luft Standards as provided in the Austal2000 Report and with the USEPA standards.

Based on the design emission of the proposed WTE plant, proposed stack height of 50 meters in the Austal2000 report was found to be favorable considering all predicted ground level concentrations in the AERMOD validation model are below the TA Luft and USEPA standards.

10.16 AERMOD VER.9.1 MODEL MAXIMUM GROUND LEVEL CONCENTRATIONS IN AREA SENSITIVE RECEPTORS (ASR-GLCMAX)

Results of the dispersion model in Table 8 shows highest predicted ground level concentrations (GLC) in ASRs for TSP, CO SO2 and NO2 for 1-hour and 24-hour period. Predicted peak values for 1 year are below 0.00000 ug/Ncm and considered not significant. GLCs for 1-hour and 24-hour period are all below applicable ambient air quality standards.

Table 8: TABLE OF NOTEABLE PEAK VALUES IN AREA SENSITIVE RECEPTORS AREAS (ASRs)

Receptor ID	Receptor Description		UTM Coordinates		PARAMETERS (ug/Ncm)											
		Direction	Easting (m)	Northing (m)	TD 1 hour	TD 24 hour	PM10 1 hour	PM10 24 hour	NO2 1 hour	NO2 24 hour	SO2 1 hour	SO2 24 hour	Hg 1 hour	Hg 24 hour	D/F 1 hour	D/F 24 hour
Applicable Standards					-	-	20	50	200	-	212	20	-	-	-	-
ASR 1	Industrial	1273.25	327812	462536	0.444	0.188	0.031	0.009	16.672	6.623	3.111	0.922	0.019	0.006	0.023	0.007
ASR 2	Industrial	1445.55	327938	462105	0.395	0.159	0.027	0.008	14.967	5.577	2.712	0.790	0.017	0.005	0.020	0.006
ASR 3	Industrial	459.87	326839	462822	0.656	0.213	0.045	0.014	23.098	7.466	4.537	1.379	0.028	0.009	0.034	0.010
ASR 4	Industrial	453.28	326087	462455	0.634	0.217	0.041	0.014	22.492	7.298	4.144	1.370	0.026	0.009	0.031	0.010
ASR 4	Industrial	473.64	326416	462929	0.713	0.216	0.043	0.012	24.549	7.393	4.351	1.206	0.027	0.008	0.032	0.009

11. RECOMMENDATIONS

The WTE Boilers should be regularly maintained and structure of the stack, ducts should be regularly checked up to avoid fugitive dusts sources and particulate accumulation. Biomass and municipal fuel should have an acceptance criteria such as moisture content and toxic characterization. Waste should be dried to eliminate moisture which is a precursor to incomplete combustion which is among major contributors to Particulate Matter (PM) and Carbon Monoxide (CO) emission. Control device such as the Dry scrubber and Baghouse is also recommended for regular check-up and maintenance.

Other control measures outside the facility are also recommended which include, periodic watering of roads for, minimizing generation and resuspension of dust particles. Forestation and plantation in perimeter-buffer areas are other effective controls. These areas will be protected by vegetation walls from dispersion of air pollutants. Other cleaner production measures are recommended.

Regular Ambient Air quality monitoring should be conducted in hot spots and impacts areas based on the results of this modelling report. Actual ambient monitoring may be treated as validation of model results. Every modification and installation of new sources should be considered by proponent as additional contribution to emission of the Power plant, hence modelling updates should also be conducted to determine assimilative carrying capacity of the area based on the impacts of the plant to the environment. These efforts will contribute to recommendations of the plant's overall management efforts to abate air pollution thus performing corporate responsibility to the environment and natural resources. It recommended to (i) retain the four (4) ambient monitoring stations used in conducting ambient air quality in Thillafushi island for the EIA study; and (ii) put up additional ambient monitoring stations in ASR 2, ASR 3 and ASR 5 areas due to industrial facilities with workers quarters.

According to WHO best practices in WTE plant, proper combustion design is among the important factor in reduction of emission. Proper design and operation of incinerators should achieve desired temperatures, residence times, and other conditions necessary to destroy pathogens, minimize emissions, avoid clinker formation and slagging of the ash (in the primary chamber), avoid refractory damage destruction, and minimize fuel consumption. Good combustion practice (GCP) elements also should be followed to control dioxin and furan emissions (Brna and Kilgroe 1989)[15]. Regardless of how well equipment is designed, wear and tear during normal use and poor operation and maintenance practices will lead to the deterioration of components, a resultant decrease in both combustion quality, an increase in emissions, and potential risks to the operator and public. Operation and maintenance also affect reliability, effectiveness and life of the equipment. Essentially all components of small-scale incinerators are prone to failure and require maintenance. Maintenance on an hourly to semi-annual schedule is required (EPA 1990). See Annex 1 and 2.

Background ambient air quality was not accounted in the modeling run. However given there are no potential significant sources of air pollution (such as mobile, area, line sources, community and other air-pollutant emitting industries) near the WTE plant, the results of both the Austal2000 and AERMOD models are generally acceptable and can be seen as below TA Luft and USEPA Standards. However, it is highly recommended to conduct a validation run after 1 to 3 months during operations stage using actual CEMS, stack testing, and ambient air monitoring results.

[15] WHO Best Practices in Incineration, EPA (1990), UNDP (2003), and De Montfort literature.

12. RECOMMENDED AMBIENT AIR QUALITY MONITORING STATIONS

Recommended to put up addition Monitoring stations in the ASR 2, ASR 3 and ASR 5 areas. Below is the receptor map of with identified Area Sensitive Receptor primary impact areas and location of Existing Ambient Air Quality Monitoring Stations . In cases of exceedance, these areas are likely to be affected.

Figure 58: Recommended monitoring sites.

ANNEXES

ANNEX-1: WHO Best Practice in WTE plant - Recommended Operating Parameters

Table 2 Recommendations of key design/operating parameters for small-scale intermittent incinerators.

Derived in part from EPA (1990), UNDP (2003), and De Montfort literature.

Type	*Parameter*	*Recommendation*
Capacity	Destruction rate, safety boxes capacity	District/subdistricts in Taylor (2003) that regularly used incinerators destroyed an average of 58 safety boxes per month, about 14 per week, equivalent to ~12 kg/week. Remote areas may only generate 1 kg per month. Proper sizing is important. Ideally, unit should burn for long periods (~4 hrs) to save fuel. (De Montfort units are not suitable for short sharp burns without a warm up period, though this appears to be common practice).
Temperatures	Primary chamber Secondary chamber Gas entering air pollution control devices, if any	540 to 980 C 980 to 1200 C (EPA 1990 recommendations) >850/1100* C (S. African and EU standards) >1000/1100* C (Indian and Thai standards) * more than 1% chlorinated organic matter in waste <230 C
Residence times	Gas (secondary chamber)	>1 s
Air flows	Total combustion air Supply and distribution of air in the incinerator Mixing of combustion gas and air in all zones Particulate matter entrainment into flue gas leaving the incinerator	140 – 200% excess Adequate Good mixing Minimize by keeping moderate air velocity to avoid fluidization of the waste, especially if high (>2%) ash waste is burned.
Controls & Monitoring	Temperature and many other parameters	Continuous for some, periodic for others
Waste	Waste destruction efficiency	>90% by weight
	Uniform waste feed Minimizing emissions of HCl, D/F, metals, other pollutants Load/charge only when incinerator operating conditions are appropriate	Uniform waste feed, and avoid overloading the incinerator Avoid plastics that contain chlorine (polyvinyl chloride products, e.g., blood bags, IV bags, IV tubes, etc. Avoid heavy metals, e.g., mercury from broken thermometers etc. Pre-heat incinerator and ensure temperatures above 800 C. Avoid overheating.
Enclosure	Roof	A roof may be fitted to protect the operator from rain, but only minimum walls.
Chimney	Height	At least 4 – 5 m high, needed for both adequate dispersion plus draft for proper air flow
Pollution control equipment	Installing air pollution control devices (APCD)	Most frequently used controls include packed bed, venturi or other wet scrubbers, fabric filter typically used with a dry injection system, and infrequently electrostatic precipitator (ESP). Modern emission limits cannot be met without APCD.

ANNEX-2: WHO Best Practice in WTE plant - Typical Maintenance Schedule for Incinerators

Table 4. Typical maintenance schedule for incinerators (derived in part from EPA 1990).

Activity Frequency	*Component*	*Procedure*
Hourly	Ash removal	Inspect and clean as required
Daily	Temperature, pollution monitors, if any	Check operation
	Underfire air ports	Inspect and clean as required
	Door seals	Inspect for wear, closeness of fit, air leakage
	Ash pit	Clean after each shift
Weekly	Latches, hinges, wheels, etc.	Lubricate if applicable
Monthly	External surfaces of incinerator and chimney (stack)	Inspect external hot surfaces. White spots or discoloration may indicate loss of refractory
	Refractory	Inspect and repair minor wear with refractory cement
	Upper/secondary combustion chamber	Inspect and remove particulate matter accumulated on chamber floor
Semi-annually	Hot external surfaces	Inspect and paint with high temperature paint as required
	Ambient external surfaces	Inspect and paint as required