Environmental Impact Assessment

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Project Number: 51077-003
December 2019

MLD: Greater Malé Waste-to-Energy Project – Waste to Energy Plant (PART E)

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

I. Introduction

1. The ADB Safeguard Policy Statement (ADB 2009) requires assessment of whether the project is planned in an area that may qualify as Critical Habitat or Natural Habitat. This assessment followed more detailed guidance in International Finance Corporation Performance Standard 6 and its recently updated accompanying guidance note (IFC 2012, 2019).

2. ADB SPS requires that any projects financed by ADB shall not implement project activities and components in area of critical habitat/s, unless (i) there are no measurable adverse impacts on the critical habitat that could impair its ability to function, (ii) there is no reduction in the population of any recognized endangered or critically endangered species, and (iii) any lesser impacts are mitigated. If a project is located within a legally protected area, ADB requires that the project implement additional programs to promote and enhance the conservation aims of the protected area. In an area of natural habitats, there must be no significant conversion or degradation, unless (i) alternatives are not available, (ii) the overall benefits from the project substantially outweigh the environmental costs, and (iii) any conversion or degradation is appropriately mitigated. ADB SPS further requires the use of precautionary approach in the use, development, and management of renewable natural resources.

3. In order to assess whether the Greater Malé Waste-to-Energy Project (WTE project) is located in a critical habitat, an initial screening was undertaken using the Integrated Biodiversity Assessment Tool (IBAT).[1] Results show that the location of the WTE project is likely a critical habitat. Therefore, a critical habitat assessment is needed to confirm the results.

4. This biodiversity and critical habitat assessment is applicable to the WTE project. Apart from the information from the IBAT screening, this report is also based on the baseline information provided in the EIA for the WTE project, which was supported with literature review and field data collection.

II. Definition of Critical Habitat

5. Critical habitat is defined in ADB SPS (2009) as a subset of both natural and modified habitat that deserves particular attention. Critical habitat includes areas with high biodiversity value, including (i) habitat required for the survival of critically endangered or endangered species; (ii) areas having special significance for endemic or restricted-range species; (iii) sites that are critical for the survival of migratory species; (iv) areas supporting globally significant concentrations or numbers of individuals of congregatory species; (v) areas with unique assemblages of species or that are associated with key evolutionary processes or provide key ecosystem services; and (vi) areas having biodiversity of significant social, economic, or cultural importance to local communities.

[1] The Integrated Biodiversity Assessment Tool (IBAT) is a multi-institutional programme of work involving BirdLife International, Conservation International, IUCN, and UNEP-WCMC. IBAT provides a basic risk screening on biodiversity. It draws together information on globally recognised biodiversity information drawn from a number of IUCN's Knowledge Products: IUCN Red List of Threatened Species, Key Biodiversity Areas (priority sites for conservation) and Protected Planet/The World Database on Protected Areas (covering nationally and internationally recognised sites, including IUCN management categories I–VI, Ramsar Wetlands of International Importance and World Heritage sites).

III. Areas of analysis

6. Critical Habitat and Natural Habitat assessment ideally takes place across sensible ecological or political units that are sufficiently large to encompass all direct and indirect impacts from the project. These areas of analysis (AoAs) are thus often much broader than the direct project footprint. AoAs may be separate or combined, depending on the ecology of the biodiversity concerned.

7. Considering the extent of potential impacts on aquatic biodiversity from the Project an aquatic AoA was identified as the 50-km study area to make consistent with the default range in the IBAT Screening. This area is approximately within the Zone 3 of Maldives, within which common biological communities and/or management issues exist (Figure 1).

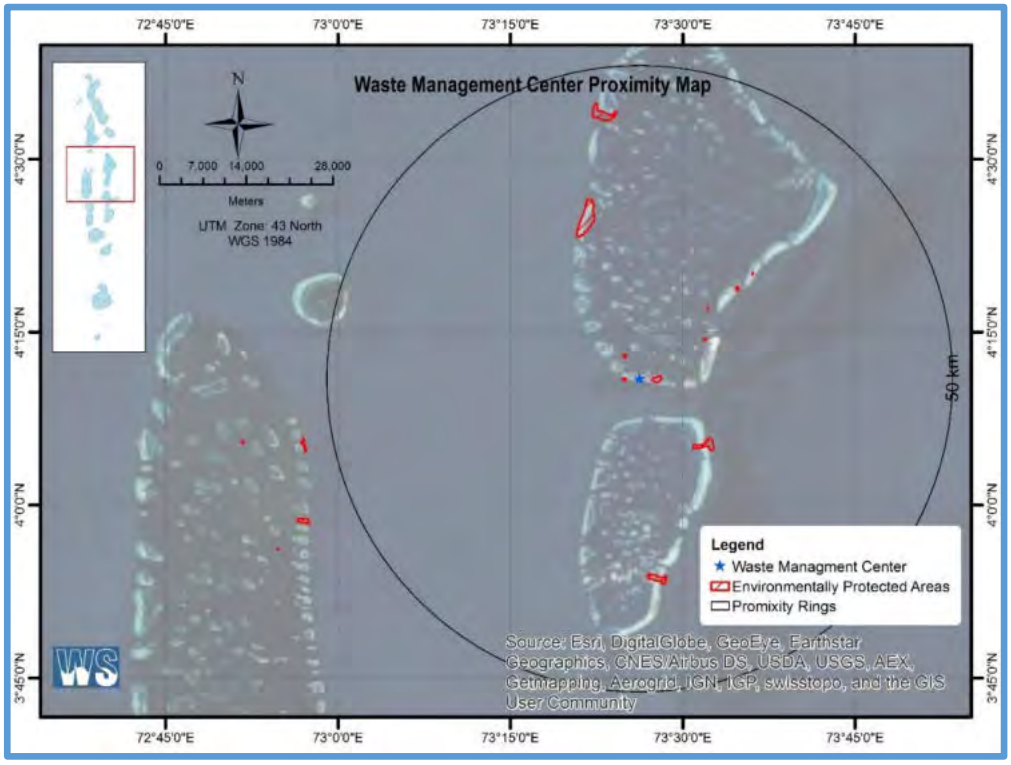


Figure 1: 50km buffer zone from project site at Thilafushi

8. Identification of AoAs does not mean that the project has any obligations across them. The aim of this Critical Habitat Assessment is to identify whether the broad units qualify as Critical Habitat and, if so, for which biodiversity features. This information helps to prioritize impact assessment and to focus mitigation efforts.

IV. Thresholds of Critical Habitat

1. To identify if a certain species can qualify the project AoA as Critical Habitat, the IFC Guidance Note 6 (2019)[2] has been used.

V. Critical Habitat Screening and Assessment

2. Critical habitat screening considered critical habitat-qualifying biodiversity candidates identified within the EIA as actually or potentially present. In each case, reasons are identified for each biodiversity feature likely meeting or not meeting Critical Habitat. IBAT was used as the initial screening for critical habitat values. Performance Standard 6 (PS6) defines these values for critical habitat (PS6: para. 16) and legally protected and internationally recognized areas (PS6: para. 20). The IBAT was used to screen for known risks within a standard 50km buffer of the project area at Thilafushi (see **Error! Reference source not found.**).

VI. Criteria 1 – 3: Critically Endangered or Endangered Species, Endemic and/or Restricted-range species Migratory or Congregatory Species

3. Habitat of significant importance to priority species can trigger critical habitat status. IBAT was used to create a preliminary list of priority species that could occur within the AoA. This list is drawn from the IUCN Red List of Threatened Species (IUCN RL). Due to the uncertainty surrounding the assessment at this preliminary stage, the list of species for which Critical Habitat may be triggered is still provisional and will require further analysis as reiterated in the conclusion.

4. The justification for the assessment has been provided in Table 1.

5. It should be noted that this list is preliminary and other species not currently included or poorly represented such as birds, fish, and invertebrates may come to light and require inclusion following monitoring and field surveys, continued desk study, and stakeholder engagement during project implementation.

[2] https://www.ifc.org/wps/wcm/connect/5e0f3c0c-0aa4-4290-a0f8-4490b61de245/GN6_English_June-27-2019.pdf?MOD=AJPERES&CVID=mRQjZva

Table 1: Critical Habitat Screening Assessment

Species Name	Criteria 1 CR or EN Species	Criteria 2 Endemic / Restricted Range Species	Criteria 3 Migratory / Congregatory Species	Rationale
Mammals				
Blue Whale *Balaenoptera musculus*	EN	-	M	About 5,000 individuals of this species survive today in three populations: North Atlantic, North Pacific, and the Southern Hemisphere. According to interviews with local people, there has been only few sightings of Blue Whales in Maldives waters and is regarded as an uncommon visitor to the Maldives. There is no recorded information that can confirm the regular occurrence of this species in the AoA. It is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs, at least seasonally. *Balaenoptera musculus* does not appear to qualify the Project area as Critical Habitat.
Birds				
Matsudaira's Storm-petrel *Oceanodroma matsudairae*	-	RS	M	Population is only known to breed on the Volcano Islands in southern Japan. After breeding the species move south across equatorial belt and then winters in the equatorial belt. Only recorded in Ha. Atoll (Anderson & Baldock 2001), which is not within the AoA. There is a possibility that the species could occur near the coast in the Project AoA. This is, however, unlikely given degradation and development in that area. Based on the available information, <10% of the species' range overlap the terrestrial AoA, and there is low likelihood that suitable habitat exists in the Project area. *Oceanodroma matsudairae* does not appear to qualify the Project area as Critical Habitat.

Species Name	Criteria 1 CR or EN Species	Criteria 2 Endemic / Restricted Range Species	Criteria 3 / Migratory Congregatory Species	Rationale
Odonata				
Enallagma maldivense	CR	RS	-	*Enallagma maldivensis* is a species of damselfly. There is insufficient data available for this species. No data is available on its population size in the AoA nor population size for the entire country. Dragonflies normally are found in freshwater habitats. No information is available on the presence of freshwater habitats (e.g. ponds) in the AoA. On a precautionary basis, it is possible that the terrestrial AoA holds more than 0.5% of the global population of this globally Critically Endangered damselfly. As such, *Enallagma maldivense* qualifies the project AoA as Critical Habitat.
Fishes				
Pondicherry Shark *Carcharhinus hemiodon*	CR	-	-	The Pondicherry Shark is a rare shark found on the continental and insular shelves of the eastern Indian Ocean and the western Pacific, from India to New Guinea. Thought to be extinct, recently found near a seasonal fishing village in Sri Lanka. There have been no recorded sightings in Maldives. It is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Carcharhinus hemiodon* does not appear to qualify the Project area as Critical Habitat.
Bowmouth Guitar shark *Rhina ancylostoma*	VU*	-	-	Although this shark is found throughout coastal areas across the Indian Ocean, sightings of this species in Maldives is rare. There is no recorded information that can confirm the regular occurrence of this species in the AoA. There is no reason to suspect that the AoA holds disproportionately high or low populations. The Project only occupies a small percentage of the AoA and is not predicted to have broad-scale impacts. Without further information, it thus seems unlikely that the Project could have impacts on this shark that would impact it to a level that it would become Endangered. As such, *Rhina ancylostoma* does not qualify the Project area as Critical Habitat.

Species Name	Criteria 1 CR or EN Species	Criteria 2 Endemic / Restricted Range Species	Criteria 3 Migratory / Congregatory Species	Rationale
Bottlenose Wedge shark *Rhynchobatus australiae*	CR	-	-	The Bottlenose Wedgefish inhabits inshore waters on the continental shelves, specifically enclosed bays, estuaries, and coral reefs. It is found in South-East Asia and Australia. Although this shark is also found throughout coastal areas across the Indian Ocean, sightings of this species in Maldives is rare. There is no recorded information that can confirm the regular occurrence of this species in the AoA. It is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Rhynchobatus australiae* does not appear to qualify the Project area as Critical Habitat.
Whale Shark *Rhincodon typus*	EN	-	-	Whale sharks are commonly found within Maldives. A possible resident population exists in ADh. Atoll which is outside the AoA. Sightings are rare within the AoA. It is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Rhincodon typus* does not appear to qualify the Project area as Critical Habitat.
Shortfin Mako Shark *Isurus oxyrinchus*	EN	-	M	The Shortfin Mako is an offshore littoral and epipelagic species found occurring in tropical and warm-temperate waters of all oceans. It is a highly migratory species making extensive journeys of over 3,000 kilometers. This species is found throughout Maldives. However, occurrence close to the atolls is very rare. There is no recorded information that can confirm the regular occurrence of this species in the AoA, It is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Isurus oxyrinchus* does not appear to qualify the Project area as Critical Habitat.

Species Name	Criteria 1 CR or EN Species	Criteria 2 Endemic / Restricted Range Species	Criteria 3 Migratory / Congregatory Species	Rationale
Great Hammerhead *Sphyrna mokarran*	EN	-	-	*Sphyrna mokarran* is a coastal-pelagic and semi-oceanic tropical hammerhead occurring close inshore and well offshore, over the continental shelves, island terraces, and in passes and lagoons of coral atolls, as well as over deep water near land. Sightings are seasonal during the start of North-east Monsoon. According to diver community, southern atolls have the most likelihood of sightings which fall outside the AoA. The great hammerhead ranges widely throughout the tropical waters of the world. For this reason, it is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Sphyrna mokarran* does not appear to qualify the Project area as Critical Habitat.
Ornate Eagle Ray *Aetomylaeus vespertilio*	EN	-	-	The Ornate Eagle Ray has a sporadic distribution in the Indo-West Pacific, including Maldives. It occurs on the inner continental shelf to depths of 110 m over soft sandy substrate. Rarely seen and one sighting at Landaa Giraavaru, Baa Atoll, Maldives was recorded on February 2018. This area is outside the AoA. It is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Aetomylaeus vespertilio* does not appear to qualify the Project area as Critical Habitat.
Longfin Mako *Isurus paucus*	EN	-	-	The Longfin Mako is widespread in tropical and warm temperate waters, and likely occurs in all oceans, although its distribution is poorly recorded. Sightings of this species in Maldives is rare. It is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Isurus paucus* does not appear to qualify the Project area as Critical Habitat.

Species Name	Criteria 1 CR or EN Species	Criteria 2 Endemic / Restricted Range Species	Criteria 3 Migratory / Congregatory Species	Rationale
Sky Emperor *Lethrinus mahsena*	EN	-	-	This species is found in coral reef habitats and adjacent sandy and seagrass areas. Commercially fished in most of its habitat, but there are no evidences that it happens in the Maldives as well. It is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Lethrinus mahsena* does not appear to qualify the Project area as Critical Habitat.
Echinoderms				
Golden Sandfish *Holothuria scabra;* Golden Sandfish *Holothuria lesson;* Black Teatfish *Holothuria nobilis*	EN	-	-	All these holothurian species are fished commercially, with some local populations in sharp decline due to overexploitation. All three species have a wide range across Indo-Pacific tropical seas. No information is available about the presence and abundance of these species in the project AoA; however, it is very unlikely that the Project AoA holds >0.5% of the global population of this species, and >5 pairs. *Holothuria spp.* do not appear to qualify the Project area as Critical Habitat.
Corals				
Acropora rudis	EN	-	-	This species is found in the northern Indian Ocean and the central Indo-Pacific. Found also in the Maldives, however, data lacks on population size. The AoA is already impacted and not all the reefs are in pristine conditions, and this species was also not found during the underwater surveys. It is extremely unlikely the Project AoA holds >0.5% of the global population of this species. *Acropora rudis* does not appear to qualify the Project area as Critical Habitat.

CR – Critically Endangered under IUCN Red List; EN – Endangered under the IUCN Red List; RS – Restricted Range Species under IUCN; M – migratory.
*- Recently changed to vulnerable status in IUCN Red List

VII. Criterion 4: Unique assemblages of species that are associated with key evolutionary processes

6. As is the case for the majority of Indo-Pacific islands, the Maldives Archipelago has been subject to long and extreme isolation that has allowed evolutionary processes to generate unique, endemic flora and fauna. Beyond this general context, however, there is no reason to believe that the terrestrial or aquatic AoA host particularly unusual or key evolutionary processes. Unique assemblages of species associated with key evolutionary processes thus do not qualify the Project area as Critical Habitat.

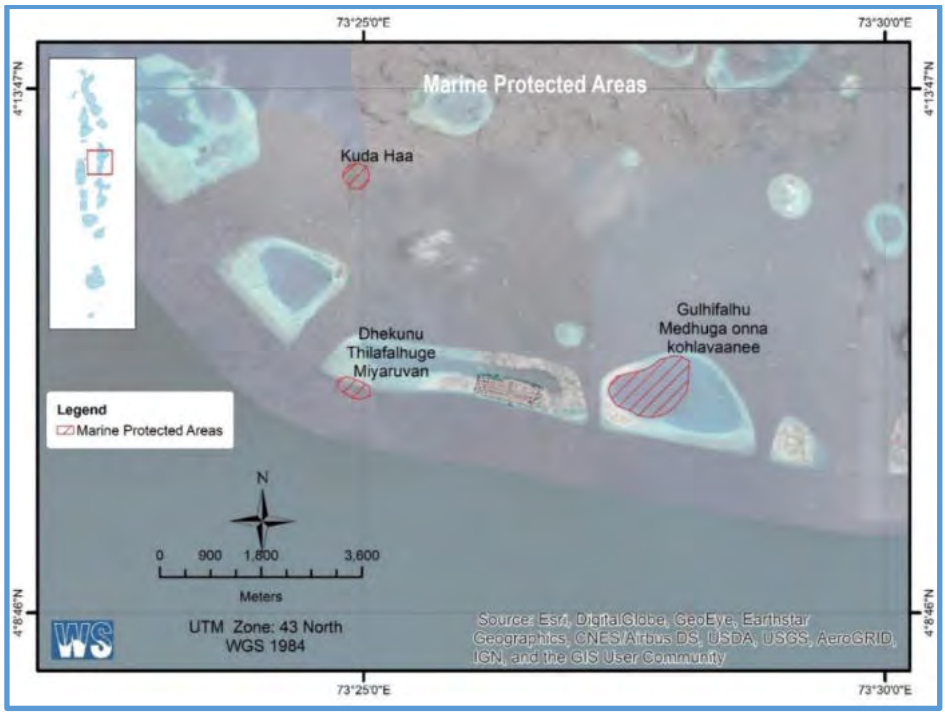
VIII. Criterion 5: Areas having biodiversity of significant social, economic, or cultural importance to local communities (including ecosystem services)

7. This additional assessment considers the ecosystem services from biodiversity in general. The assessment of significance of ecosystem services to local communities is assessed retrospectively in line with the consultation with local dive communities.

8. Ecosystem services affected by the project are prioritized when all three of the following criteria are met: (i) the project might affect the ability of others to benefit from the service; (ii) the affected service is important to beneficiaries' well-being; and (iii) beneficiaries do not have viable alternatives for that service.

9. The limited information presented does not give reason to believe that the Project terrestrial or aquatic AoA are sufficiently important to local people that they represent Critical Habitat under this criterion. However, it is beyond the scope of this assessment to collect additional information on ecosystem services, and then to assess which may qualify the project area as Critical Habitat.

Figure 2. 5km buffer zone from project site at Thilafushi



IX. Legally protected areas and internationally recognized areas

10. There are some areas near to the Project. The nearest MPA to the WTE project site is the "*Lions Head*" (Dhekunu Thilafalhuge Miyaruvani), around 1 km from the proposed plant. Additionally, as a precautionary approach, a more focused habitat assessment was conducted for this MPA. Results show that none of the IUCN species categorized as critically endangered species, endangered species or vulnerable species is found within this MPA. Results also show that none of nationally protected species is found within this MPA either. A complete assessment of the Lions Head is attached as Annex 2.

24. Following IFC (2019), none of the protected areas found in the Project AoA meets the thresholds for Critical Habitat for some species for which it was designated. For this reason, none of the protected areas found in the AoA qualify the Project area as Critical Habitat.

X. Conclusion and Recommendations

25. The WTE project will be established in Maldives, a country rich in biodiversity. Based on the initial screening using IBAT, the project site is likely to be a critical habitat at least for a terrestrial insect.

11. In the course of project implementation, it is highly recommended that continuous marine underwater monitoring be undertaken around Thilfushi island to confirm the extent of biodiversity in various seasons of the year, including assessment of features pertinent to critical habitats. In cases when future information determines the existence of critical habitat within the study area, the WTE project should be able to demonstrate that:

(i) It does not lead to measurable adverse impacts on those biodiversity values for which the critical habitat was designated, and on the ecological processes supporting those biodiversity values;
(ii) It does not lead to a net reduction in the global and/or national/regional population of any Critically Endangered or Endangered species over a reasonable period of time; and
(iii) It has integrated into its management program a robust, appropriately designed, and long-term biodiversity monitoring and evaluation program.

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Annex 1: IBAT assessment report

IBAT

Integrated Biodiversity Assessment Tool

WORLD BANK GROUP BIODIVERSITY RISK SCREEN

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Project Name: Thilafushi WTE

Location: [4.2, 73.4]

Overlaps with:

Protected Areas	11
Key Biodiversity Areas	0
IUCN Red List	15
Critical Habitat	Likely

Displaying project location and buffers: 10.0 km, 50.0 km

WORLD BANK GROUP

This report is based on IFC Performance Standard 6 (PS6) but applies to World Bank Environmental and Social Standard 6 (ESS6)

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About this report

IBAT provides initial screening for critical habitat values. Performance Standard 6 (PS6) defines these values for critical habitat (PS6: para. 16) and legally protected and internationally recognized areas (PS6: para. 20). PS6 will be triggered when IFC client activities are located in modified habitats containing "significant biodiversity value," natural habitats, critical habitats, legally protected areas, or areas that are internationally recognized for biodiversity. References to PS6 and Guidance Note 6 (GN6) are provided to guide further assessment and detailed definitions where necessary. Please see https://www.ifc.org/ps6 for full details on PS6 and GN6.

The report screens for known risks within a standard 50km buffer of the coordinates used for analysis. This buffer is not intended to indicate the area of impact. The report can be used to:

- Scope risks to include within an assessment of risks and impacts
- Identify gaps within an existing assessment of risks and impacts
- Prioritize between sites in a portfolio for further assessment of risks and impacts
- Inform a preliminary determination of critical habitat
- Assess the need for engaging a biodiversity specialist
- Identify additional conservation experts or organizations to inform further assessment or planning

WARNING: IBAT aims to provide the most up-to-date and accurate information available at the time of analysis. There is however a possibility of incomplete, incorrect or out-of-date information. All findings in this report must be supported by further desktop review, consultation with experts and/or on-the-ground field assessment as described in PS6 and GN6. Please consult IBAT for any additional disclaimers or recommendations applicable to the information used to generate this report.

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IBAT

Priority Species

Habitat of significant importance to priority species will trigger critical habitat status (See PS6: para 16). IBAT provides a preliminary list of priority species that could occur within the 50km buffer. This list is drawn from the IUCN Red List of Threatened Species (IUCN RL). This list should be used to guide any further assessment, with the aim of confirming knownor likely occurrence of these species within the project area. It is also possible that further assessment may confirm occurrence of additional priority species not listed here. It is strongly encouraged that any new species information collected by the project be shared with species experts and/or IUCN wherever possible in order to improve IUCN datasets.

IUCN Red List of Threatened Species - CR & EN

The following species are potentially found within 50km of the area of interest.
For the full IUCN Red List please refer to the associated csv in the report folder.

Species name	Common name	IUCN Category	Group
Carcharhinus hemiodon	Pondicherry Shark	CR	CHONDRICHTHYES
Rhina ancylostoma	Bowmouth Guitarfish	CR	CHONDRICHTHYES
Rhynchobatus australiae	Bottlenose Wedgefish	CR	CHONDRICHTHYES
Ensillagma maldivense		CR	INSECTA
Balaenoptera musculus	Blue Whale	EN	MAMMALIA
Rhincodon typus	Whale Shark	EN	CHONDRICHTHYES
Isurus oxyrinchus	Shortfin Mako	EN	CHONDRICHTHYES
Sphyrna mokarran	Great Hammerhead	EN	CHONDRICHTHYES
Aetomylaeus vespertilio	Ornate Eagle Ray	EN	CHONDRICHTHYES
Isurus paucus	Longfin Mako	EN	CHONDRICHTHYES
Acropora rudis		EN	ANTHOZOA

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Biodiversity features which are likely to trigger Critical Habitat

Protected Areas

The following protected areas are found within 10.0 km and 50.0 km of the area of interest.
For further details please refer to the associated csv file in the report folder.

Area name	Distance	Recommendation
Giravaru Kuda Haa	10.0 km	Assess for biodiversity risk
Hans Hass Plave (Gulhi Falhu)	10.0 km	Assess for biodiversity risk
Lions Head (Thilafalhu Miyaruvani)	10.0 km	Assess for biodiversity risk
Banana reef (Gaathu Giri)	50.0 km	Assess for biodiversity risk
Embudhoo Kanduolhi	50.0 km	Assess for biodiversity risk
Guraidhoo Kandu	50.0 km	Assess for biodiversity risk
Huraa Mangrove	50.0 km	Assess for biodiversity risk
Makunudhoo Kandu	50.0 km	Assess for biodiversity risk
Nassimo Thila (Lankan Thila)	50.0 km	Assess for biodiversity risk
Rasfari	50.0 km	Assess for biodiversity risk
Thanburudhoo Thila (HP Reef)	50.0 km	Assess for biodiversity risk

Key Biodiversity Areas

IBAT

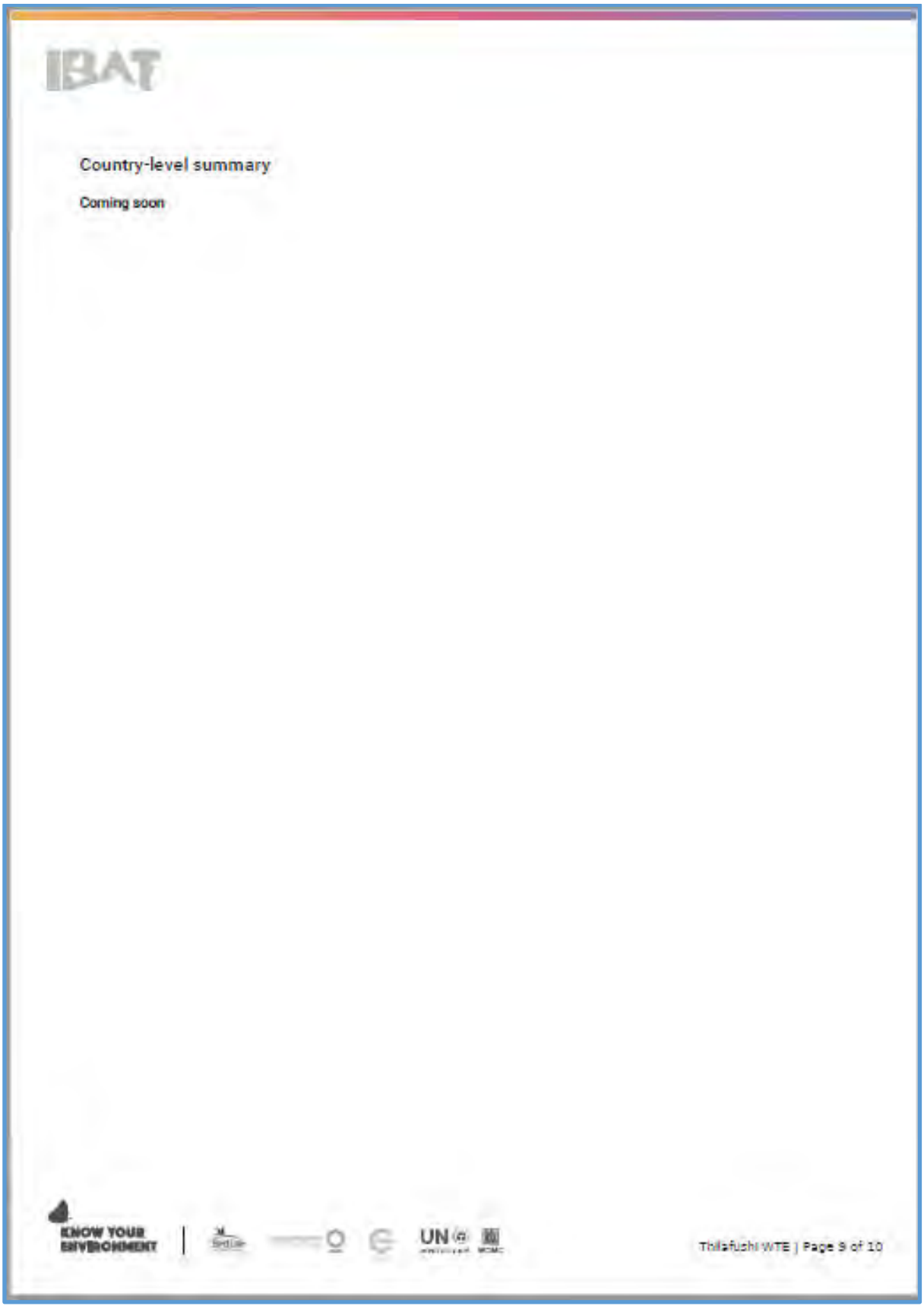
The following key biodiversity areas are found within 10.0 km and 50.0 km of the area of interest.
For further details please refer to the associated csv file in the report folder.

Area name	Distance	Recommendation

Species with potential to occur

Area Taxonomic group	Total assessed species	Total (CR, EN & VU)	CR	EN	VU	NT	LC	DD
CHONDRICHTHYES	28	19	3	5	11	2	4	3
INSECTA	1	1	1	0	0	0	0	0
MAMMALIA	10	1	0	1	0	0	7	2
ANTHOZOA	124	23	0	1	22	40	53	8
HOLOTHUROIDEA	31	5	0	3	2	0	15	11
ACTINOPTERYGII	656	3	0	1	2	3	628	22
REPTILIA	2	1	0	0	1	0	1	0
AVES	36	2	0	0	2	4	30	0
MAGNOLIOPSIDA	5	0	0	0	0	0	5	0
AMPHIBIA	1	0	0	0	0	0	1	0
HYDROZOA	2	0	0	0	0	0	2	0
MALACOSTRACA	8	0	0	0	0	0	7	1
LILIOPSIDA	3	0	0	0	0	0	3	0

Area Taxonomic group	Total assessed species	Total (CR, EN & VU)	CR	EN	VU	NT	LC	DD
POLYPODIOPSIDA	1	0	0	0	0	0	1	0
GASTROPODA	66	0	0	0	0	0	65	1
BIVALVIA	1	0	0	0	0	0	1	0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Country-level summary
Coming soon
KNOW YOUR ENVIRONMENT
UN
Thilafushi WTE | Page 9 of 10

IBAT

Recommended Experts and Organizations

For projects located in critical habitat, clients must ensure that external experts with regional expertise are involved in further assessment (GN6: GN22). Clients are encouraged to develop partnerships with recognized and credible conservation organizations and/or academic institutes, especially with respect to potential developments in natural or critical habitat (GN6: GN23). Where critical habitats are triggered by priority species, species specialists must be involved. IBAT provides data originally collected by a large network of national partners, while species information is sourced via the IUCN Red List and affiliated Species Specialist Groups. These experts and organizations are listed below. **Please note that this is not intended as a comprehensive list of organizations and experts. These organizations and experts are under no obligation to support any further assessment and do so entirely at their discretion and under their terms. Any views expressed or recommendations made by these stakeholders should not be attributed to the IFC or IBAT for IFC partners.**

Relevant national or regional organizations

IBAT integrates information developed by a global network of conservation agencies, organizations and experts. These efforts are coordinated by the IBAT Alliance (BirdLife International, Conservation International, IUCN and UNEP-WCMC) who compile and maintain this information as globally standardized databases. The local partners most relevant to the area of analysis are:

Wild Bird Society of Japan Address: Maruwa Building, 3-9-23 Nishi-Gotanda, Shinagawa-ku, Tokyo 141-0031, JapanWeb: http://www.wbsj.org/

BirdLife Asia Regional Office Address: 354 Tanglin Road, #01-16/17, Tanglin International Centre, Singapore 247672 Email: singapore.office@birdlife.org Web: http://www.birdlife.org/asia

Directory for Species Survival Commission (SSC) Specialist Groups and Red List Authorities

URL: http://www.iucn.org/about/work/programmes/species/who_we_are/ssc_specialist_groups_and_red_list_authorities_directory/

Annex 2: Critical Habitat Assessment for Lions Head MPA

LIVE&LEARN
MALDIVES

FINAL REPORT

Baseline Socio Economic Survey in
Thilafushi and Gulhifalhu

TA 9327 - Greater Male' Environmental Improvement and Waste Management Project

August – September2019

Table of Contents

1. Introduction

Asian Development Bank (ADB) requested and received assistance through the Ministry of Environment and Energy (MEE) for the services of Live and Learn Environment Education to carry out the baseline socio-economic survey of the residents of Thilafushi and Gulhifalhu which was a requirement of the Greater Male' Environmental Improvement and Waste Management Project.

The overall objective of this consultancy was to ascertain baseline socio economic profile of the residents in Thilafushi and Gulhifalhu islands. The survey also aimed to determine the current waste disposal practices, the needs and willingness of the companies operating in the islands to pay for waste management services. The results of the survey will be used for evidence-based planning and designing needs based socially inclusive strategies to maximize project benefits.

This document reports a summary of the purpose, methodology, sampling frame and strategy, data collection and analysis process, key findings of the study, limitations of the study and general recommendations.

2. Methodology

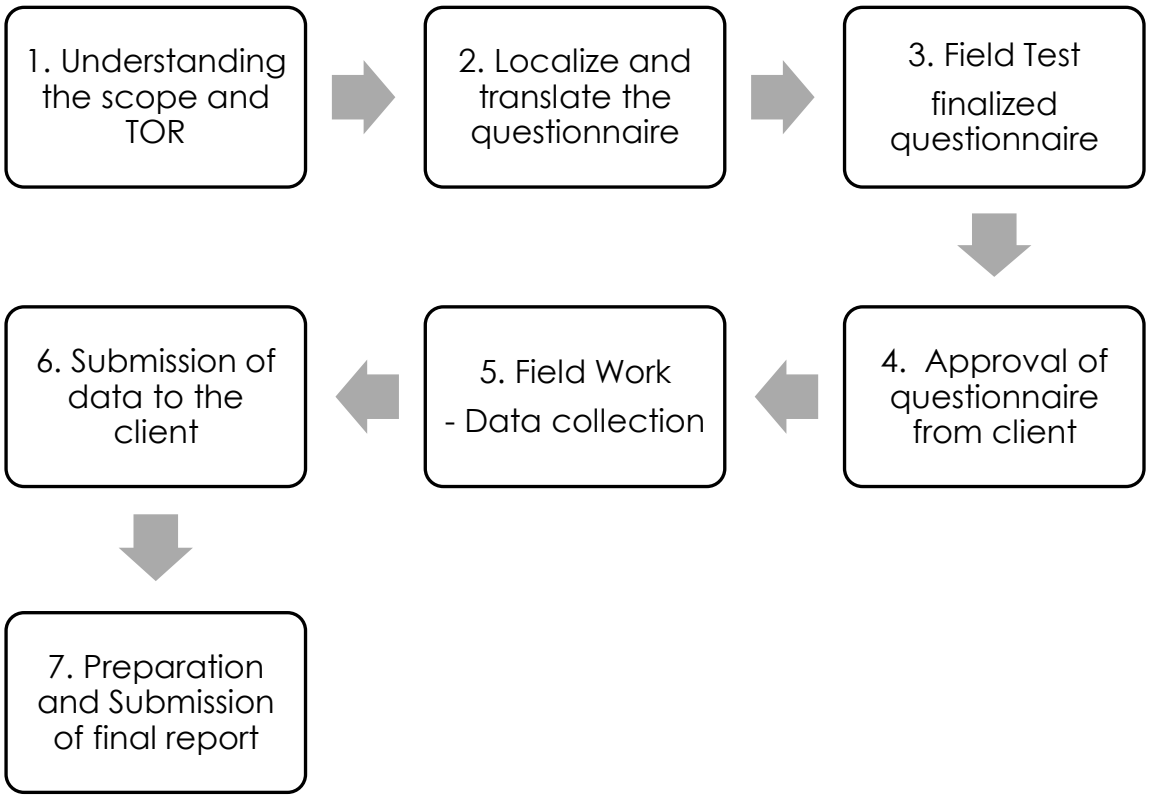
2.1 Objectives

The aim of this study was to ascertain baselines with regards to poverty and development indicators that included a set of socio- economic variables such as, education, occupation, economic status, access to basic services- including access to healthcare, accommodation, clean drinking water and food, and waste management. The survey targeted residents living and/or working in all areas in Thilafushi and Gulhifalhu islands.

2.2 Approach

The following schematic diagram summarizes the key steps of the approach that was followed to carry out the assignment.

Figure 1: Schematic diagram showing the work methodology



2.3 The Sampling Frame and Sampling Strategy

The survey was carried out in Thilafushi and Gulhifalhu islands. The survey was based on a core sets of information, an updated list of tenants obtained from Greater Male' Industrial Zone Limited (GMIZL) and estimated number of workers on site. The survey sample represented a cross-section of the individuals working and/or residing in Thilafushi and Gulhifalhu Islands and the companies based in these two islands.

During the inception phase, Live and Learn identified the survey locations, sampling methodology and sample size. The sample size was based on instructions provided by the client. Specific instructions were provided to survey about 200 individuals living/ and or working in areas or sites that are close in proximity to the waste management site in Thilafushi. Survey locations were finalized with guidance from Thilafushi and Gulhifalhu management office, the Greater Male' Industrial Zone Limited (GMIZL). According to the information received, not many companies were in areas close to the waste management site in Thilafushi. GMIZL highlighted that there are discrepancies in utility services available in the different zones of the island, that the "old Thilafushi" identified in the map as "silver plots" did not have water and sanitation services available. They also guided the survey team to identify the size and type of tenants in the different zones of the islands. Care was taken to ensure that the sample represented residents living/ and working in sites near all areas/ zones in the islands. To maximize on the quality, a comprehensive list of tenants was obtained from GMIZL. See *Appendix A* for the list of tenants located in Thilafushi, obtained from GMIZL and *Appendix B* for maps of Thilafushi and Gulhifalhu with the surveyed companies located.

2.4 Data Collection

2.4.1 Questionnaire

The survey was carried out using two questionnaires based on socio economic variables - one for individuals working and/ or residing in Thilafushi and Gulhifalhu and the other for companies based in Thilafushi and Gulhifalhu Islands. The sample covered 430 individuals (Thilafushi 374; Gulhifalhu 56) and 35 companies (Thilafushi 32; Gulhifalhu 3).

The questionnaires were developed to elicit the most important quantifiable data for this assessment. The questionnaires included various research questions that intended to get information for the research areas, specifically,

a. Provision and accessibility to basic services including;
   - Accommodation
   - Food
   - Healthcare

b. Expenses on basic needs and savings
c. Waste management
d. Factors influencing waste management practices
e. Readiness to use improved waste management services

The questionnaires were modified in line with the societal norms, adapted to the local context and was translated in Dhivehi. The questionnaires were field-tested and refined based on the experience gained by the field test. The modified questionnaires are included in *Appendix C.*

2.5 Data Analysis

2.5.1 Data entry, analysis, synthesis and interpretation

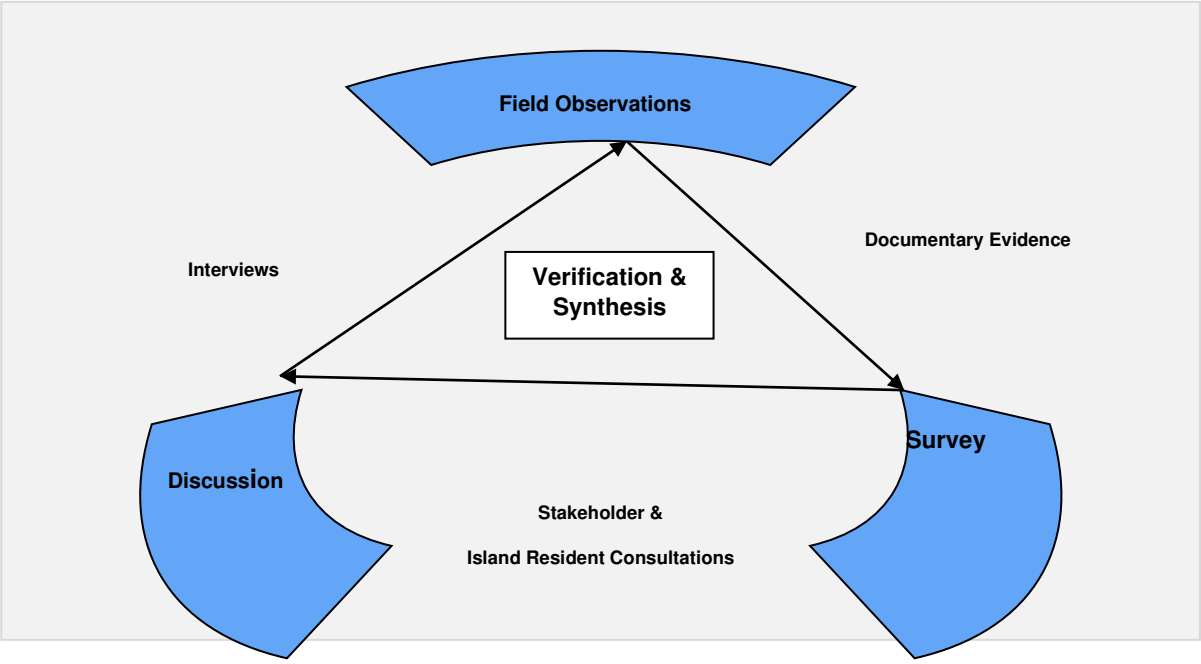
The questionnaires were filled by trained enumerators using tablet computers or smart phones in order to ensure efficiency and accuracy. The data were automatically entered, coded and fed into a central data base.

Data analysis and tabulation were carried out using a set of tables prepared by the Consultant's Team and shared with the client for feedback and comments.

2.5.2 Integration of Different Information Gathering Processes

Findings of field research were triangulated and documented to ensure their credibility and validity. Information gathered from the different sources were checked through comparisons and verification discussions. For example, information from surveys was cross checked with information gathered from discussions with client, project documents and observations. Consultant compared data mainly from these three sources prior to making conclusions and reporting. Evidence from secondary sources including stakeholder consultation and interviews were used as supplementary sources of information to support the findings gathered from the above three key sources. Following figure illustrates the triangulation process of data that was gathered from various methods under this study.

Figure 2: Triangulation of raw data collected from different methods



3. Key Findings

3.1 General Information

The survey respondents comprised of 1 female and 429 males. The respondents' ages ranged from 18 to 67 and are mostly Muslims (81%) and from Bangladesh (66%). The length of stay of the respondents in Maldives ranged from less than one year to more than 35 years. 78 percent of the respondents stated that they had a work visa or permit, 18 percent did not have a work visa or work permit and 3 percent did not want to respond to the question. Note that Maldivians (15%) do not need a permit to work in Thilafushi and Gulhifalhu. Hence, out of the 85 percent of foreign respondents, approximately 66 percent had a work visa or permit.

The education level of the respondents' showed that 9 percent did not have any education, 12 percent had basic literacy skills, 25 percent completed primary and 39 percent completed secondary education (secondary school and O'level), 7 percent have completed A'level and 4 percent have completed degree and above.

The education level was reflected in the job titles that the respondents hold as 54 percent of the respondents were unskilled labourers, 35 percent skilled workers, 7 percent at supervisor level, 1 percent at managerial level and 3 percent of the respondents' held jobs that were not categorized in any of the above mentioned categories.

The key points that emerged from the study are;

3.2 Income, Expenditure and Savings

- The self-assessed economic status showed that 24 percent respondents perceived themselves to be poor. The proportion of respondent who felt that they were in the lower middle-income level to middle income level constituted approximately 70 percent. Two percent respondents believed that they are rich.

- The highest expenditure for the respondents was estimated to be on communication (phone and internet) and the average monthly spent monthly ranged from MVR 500 to MVR 1500. The monthly expenditure on accommodation and basic needs such as utilities, food and drinks, and health care were borne by the employers and respondents had to spend minimal amount on these (Refer Table 1 below).

Table 1: Summary of expenditure

Expenditure (MVR)	Number of people who spent on:						
	B2.Food & Drinks	B3. House Rent	B4. House Maintenance	B5. Healthcare	B6. Electricity	B7. Water	B8. Communication
0-499	253	395	404	396	402	403	149
500-999	40	1	7	14	9	13	205
1000-1499	47	3	3	10	5	2	45
1500-1999	36	3	2	1	3	1	14
2000-2499	15	1	3	4	5	6	11
2500-2999	1	1	2	0	1	0	0
3000-3499	13	2	2	1	0	1	2
3500-3999	2	1	1	0	0	2	0
4000-4499	5	1	1	0	1	1	2
Above 5000	18	22	5	4	4	1	2

- The respondents stated that their average savings would be about 60 to 80 percent of the monthly income and 78 percent of the respondents send their savings to their families in respective countries.

Table 2: Summary of Income

No. of respondents' – Summary of Income (MVR)

Place of Residence	Below poverty line (<2000 MVR)	2001-4000	4001-6000	>6000
Male'	2	7	3	40
Thilafushi	19	46	140	119
Gulhifalhu	5	14	19	14
Boat	0	0	2	1
Other	1	0		2
Total	**27**	**67**	**164**	**176**

- Note: As indicated in the initial communications with the client, it was anticipated that a lot of people would hesitate to provide accurate data for income and expenditure, since the state is preparing to decree income tax. It appears that the data on expenditure and savings have errors and inconsistencies due to this. The main observation is that the lowest incomes estimated from the data received range from MVR200 to MVR500, some of whom are local and foreign nationals serving as technical/skilled employees. No local would work on a full-time job for a salary that is less than MVR5000, specifically in this job category. Additionally, the lowest income for foreign laborers will not be less than USD200, i.e., approximately 3000 per month.

3.3 Housing, Infrastructure and Basic Services

- Majority of the respondents lived in Thilafushi (74%) and the rest of the respondents lived in Male' (12%), Gulhifalhu (12%) and in a boat or a dhoni (1%).

- 46 percent of the respondents lived in shared rooms, 37 percent in living quarters, 14 percent in single rooms and 3 percent at the project worksite.

- In the majority of the accommodation that respondents lived, the walls are built with concrete blocks plastered with cement (60%) and the rest corrugated iron (25%), wood (12%) and stone (2%); and the roofs are mostly built with corrugated iron (87%).

- 58 percent of the respondents had a separate kitchen in their living premises and out of that 50% use cooking gas for cooking.

- Main sources of drinking water were house/building service connection (34%), public tap water from treated source (30%), bottled water (28%) and rainwater (4%). Similarly the source of water used for washing and bathing include house/building service connection (53%), public tap water from treated source (41%), and rainwater (2%)

- On average it was reported that respondents shared a toilet among 5 to 10 people and 96 percent of the toilets they used were flush latrine connected to piped sewer system. 15 respondents stated that they use alternated toilets and out of which 3 respondents used public toilets.

- For the question on whether respondents were aware of their rights, 39 percent said "Yes" and 61 percent said "No". In terms of respondents perception on what their basic rights were, majority said right to accommodation (33%) and the rest said right to food (30%), salary (29%), healthcare (29%), leave (26%), safe water and sanitation (26%) and number of working hours (23%).

3.4 Health Condition and Healthcare Services

- 68 percent of the respondents surveyed had a health insurance and 46 percent had a health issue past six months. The common issues reported were fever (65%) and cold (9%). Other issues reported include asthma, breathing problems, throat pain and other body aches and pains.

- 94 percent of those who reported sick saw a doctor and 96 percent went to a health facility in Male'. This could be because a health facility was opened in Thilafushi only recently (July 2019) and with limited facilities and services.

Table 3: Disease Incidence Summary

	No. of respondents'			
Place of Residence	**Asthma/Lung related/Allergies/Cold, cough, fever**	**Water-borne diseases**	**Vector-borne diseases**	**Skin diseases**
Male'	16	0	2	0
Thilafushi	125	0	6	5
Gulhifalhu	5	0	0	0
Boat	0	0	0	0
Other (Villimale and Hulhumale)	0	0	0	0
Total	**146**	**0**	**8**	**5**

Note: Records of water and air borne diseases are not available.

3.5 Solid Waste Management

- Majority of the respondents (66%) and companies (76%) highlighted that they are aware of the health issues related to garbage while 32 percent of the respondents' 24 percent of the companies said that they are not aware of such issues.

- 46 percent of the respondents believed that garbage is a huge problem in their locality, 19 percent of the respondents believed that it is a problem while 8 percent of the respondents reported that they rarely have issues and 25 percent respondents said not an issue at all. Similarly, 46 percent of the companies believed that garbage is a huge problem in their locality, 43 percent believed that it is a problem while 3 percent reported that they rarely have issues and 6 percent said not an issue at all.

- 67 of the respondents and 83 percent of the companies reported that the present practice of waste disposal in Thilafushi, including burning caused health issues and majority of the respondents said main problem was health problems due to air pollution and smoke (59%). Other problems stated include problems due to flies (4%) and problems due to contamination of lagoon (1%).

Solid waste management survey was mostly focused on to the companies based in Thilafushi and Gulheefalhu Islands and hence the key findings stated below in this section are based on the company responses.

- 69 percent reported that they segregate waste while 29 percent said that they do not. The companies who segregate waste reported that they segregate waste into plastics (31%), organics (32%), paper (14%) and metal (51%).

- 6 percent of the companies have received training on waste management while the majority 94 percent reported that they have not received any training in this area.

However, 71 percent companies stated that training on solid waste management will be beneficial.

- 37 percent companies said that they sell recyclable materials, while the majority 63 percent said that they do not sell recyclable waste materials.

- 29 percent of companies had door to door waste collection service and 71 percent opted for private arrangement. The frequency of waste collection or disposal services include: daily (9%), weekly (12%), monthly (3%) and irregular (6%).

- 9 percent of the companies reported that they use WAMCO's services for waste disposal. 91 percent said that they made private arrangements. This was evident from the responses as 71 percent of the companies stated that they were poorly satisfied with the present waste collection mechanism.

- 62 percent of the companies said they pay for waste collection and 38 percent said that they did not pay. The amount, companies who were paying for waste disposal, range from MVR 500 – MVR 40,000.

- From the companies currently not using the services of WAMCO for waste disposal, 85 percent stated that they will shift to WAMCO if services were improved and 9 percent said they did not want. In addition, 91 percent companies are willing to pay a reasonable amount to WAMCO if waste disposal practices were improved.

- Most companies (65%) were not aware about Government's program on Solid Waste Management (SWM) improvement through Ministry of environment and WAMCO.

3.6 Other Issues

Other socioeconomic issues, problems and concerns raised by the individual respondents and companies during the survey included:

- No electricity and water services available in some parts of Thilafushi
- No regulations on road safety and parking.
- No regular ferry services were available, hence, the residents had to hire speedboats if there was an emergency medical issue.
- Smoke inhalation is the main problem. Some days smoke becomes so thick that you will not be able to see the person standing next to you.
- No banks and other facilities available on the Islands and therefore, have to go to Male' to send money home.
- Currently, government charging a very high amount for waste disposal.
- Waste management is a hazard. Hope the government solves this problem soon

See *Appendix D* and *Appendix E* for graphical representation of data obtained from individual survey and company survey respectively.

4. Limitations

- Time constraints – Since the timeframe for data collection was about 4 days, data collection process was rushed and enumerators may have missed some information given by the respondents. In addition, had to seek permission from the companies to conduct the survey and since most of the companies' heads were based in Male, it was difficult to contact them within the time frame and hence, was not able to get some data such as number of employees from all the companies surveyed.
- Communication – The translators were briefed about the survey. However, even translators were not able to comprehend some questions such as "Are you aware of your rights?" and explain to respondents. One reason for this could be that translators competency in formal Dhivehi language may be limited.
- Reluctant or refused to give information on certain questions such as salary and company assets.

5. Recommendations

- Conduct regular assessments of the risk factors involved for residents of Thilafushi and Gulheefalhu and establish mechanisms to reduce risk factors including health hazards.
- Enhance health facility at Thilafushi with improved services to deal with emergency at all times.
- Have schedule ferries at night.
- Develop and improve the current waste management system used
  - Regular collection of waste
  - Create awareness and provide training on proper waste management and individual responsibility
  - Establish a system to collect payment based on the amount of garbage
  - Enact laws and regulations. Penalize those do not abide by the regulations
  - Train WAMCO staff on customer care and establish a grievance procedure and an efficient complaints system
  - Manage waste and abolish burning of waste to minimize health hazards.

APPENDICES

APPENDIX A: List of Tenants Located in Thilafushi

TENANT REGISTRY SHEET| GREATER MALE' INDUSTRIAL ZONE LIMITED

#	TENANT NAME	ZONE	LOCATION	TYPE OF WORK
1	Aasandha Company Limited	Silver	Thilafushi 01	File Storage
2	Waste Management Corporation Limited	-	-	Waste management
3	Villa Hakatha Pvt Ltd	Platinum Plot	Thilafushi 02	LPG storage and refilling plant, bulk cement station, cement packing plant, cement storage, diesel petrol kerosene storage tank, LPG and oxygen, sale of cement and oil, warehousing and All works allowed in Thilafushi
4	Heavy Load Maldives Pvt Ltd			Loading and unloading harbor, warehousing and labor accomodation
5	MTCC	Platinum Plot	Thilafushi 02	Warehousing and slipway
6	MTCC	Gold Plot	Thilafushi 02	Boat building and boat repair
7	Silver Sands Pvt Ltd	Gold Plot	Thilafushi 01	Boat repair and slipway
8	Yacht Tours Maldives	-	-	Slipway work
9	Nalahiya Tradings Pvt Ltd	Platinum Plot	Thilafushi 02	Warehouse of construction materials Shop (by letter no: TCL-PRJ/PRIV/2018/005)
10	State Trading Organization Plc Ltd	Gold Plot	Thilafushi 02	Warehousing
11	Fuel Express Maldves Pvt Ltd	Platinum Plot	Thilafushi 01	Vessel building and servicing fiber glass work
12	Fuel Express Maldves Pvt Ltd	Platinum Plot	Thilafushi 01	Vessel building and servicing fiber glass work
13	Maldives Ports Limited	Platinum Plot	Thilafushi 01	Boat building and boat repair
14	Maldive Gas Pvt Ltd	Platinum Plot	Thilafushi 01	LPG refilling
15	Villa Shipping & Trading Co. Pvt Ltd	Gold Plot	Thilafushi 02	Cooking gas, cement, oxygen tank, diesel, petrol, kerosene storage and sale ,warehousing , boat building and repair ,slipway, engine repair and maintenance workshop for land and sea vessel and labor accommodation
16	Apollo Holdings Pvt Ltd	Platinum Plot	Thilafushi 02	All Works allowed in Thilafushi
17	Sun Transport Pvt Ltd	TIZ	TIZ	Boat Yard
18	Maldive Gas Pvt Ltd	Platinum Plot	Thilafushi 01	LPG
19	Gulf Craft Service Centre Maldives Pvt Ltd	Gold Plot	Thilafushi 02	Speed boat building and repair

20	Gulf Craft Service Centre Maldives Pvt Ltd	Gold Plot	Thilafushi 02	Vessel work
21	Nalahiya Tradings Pvt Ltd	Gold Plot	Thilafushi 02	Warehouse of construction materials
22	Universal Enterprises Pvt Ltd	Platinum Plot	Thilafushi 01	Boat repair
23	Ahmed Luthfee	Platinum Plot	Thilafushi 01	Fiber glass speed boat & fishing boat building and boat repair
24	R.K.L Group Pvt Ltd	Platinum Plot	Thilafushi 01	Warehousing and related works, Cement brick and related works, heavy vehicle parking and repairing related works, land and sea vessel building and repairing and related works
25	Coastline Investments Pvt Ltd	Platinum Plot	Thilafushi 01	Warehousing
26	Al Shaali Marine Maldives Pvt Ltd	Platinum Plot	Thilafushi 01	Vessel repair
27	Coastline Investments Pvt Ltd	Platinum Plot	Thilafushi 01	Vessel repair, all works allowed in Thilafushi, diesel storage tank and warehousing
28	VA Pvt Ltd	Platinum Plot	Thilafushi 02	Warehousing
29	Nalahiya Construction Material	platinum Plot	Thilafushi 02	Warehousing
30	Agas Maldives Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing & land and sea vessel building
31	Uniforce Investment Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing and land and sea vessel building
32	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	Vessel repair
33	Fuel Supplies Maldives Pvt Ltd	Platinum Plot	Thilafushi 01	Vessel building and repair, workshop, labor accommodation and warehousing
34	State Trading Organization Plc Ltd	-	-	N/A
35	Maldives Structural Products Pvt Ltd	Gold Plot	Thilafushi 02	Production of metal sheet
36	Static Company Pvt Ltd	Gold Plot	Thilafushi 01	RO plant workshop (diselination plant manafuacturing), workshop (welding, lathing, engineering and repair works, pannel making), fiber works, warehousing and labor accommodation
37	Villa Hakatha Pvt Ltd	Gold Plot	Thilafushi 02	All works allowed in Thilafushi
38	Waste Management Corporation Limited	-	-	warehousing, accommodation block, parking, garage, recycle facility and office building
39	Tommy Engineering Pvt Ltd			Boat Yard
40	Ministry of Defence and National Security	-	-	MNDF works

41	State Electric Company Ltd	Silver Plot	Thilafushi 02	Electricity sevices to Thilafushi
42	Apollo Holdings Pvt Ltd	Gold Plot	Thilafushi 02	All Works allowed in Thilafushi
43	Apollo Holdings Pvt Ltd	Gold Plot	Thilafushi 02	All Works allowed in Thilafushi
44	Timber House Pvt Ltd	Silver Plot	TIZ	Wood storage and other works
45	The Hawks Pvt Ltd	Platinum Plot	Thilafushi 01	Retail shop, oil supply, brick work, café and boat building
46	Secure Bag (Maldives) Pvt Ltd	Gold Plot	Thilafushi 01	-
47	Muni Enterprises Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
48	A.H. Brothers Pvt Ltd	Silver	Thilafushi 01	Warehousing
49	Alia Investments Pvt Ltd	TIZ	TIZ	Auto Mobile/ Motor Vehicle
50	Amin Construction Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and Carpentry work
51	Apollo Holdings Pvt Ltd	Gold Plot	Thilafushi 02	All Works allowed in Thilafushi
52	Ego Maldives Pvt Ltd	TIZ	TIZ	Warehousing and Carpentry work
53	Marine Export & Trading Company Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and vehicle repair
54	Rainbow Aluminum Pvt Ltd	Gold Plot	Thilafushi 02	Construction work and aluminum works
55	Rainbow Enterprises	Gold Plot	Thilafushi 02	Warehousing, Furniture production and related works
56	Vimla Construction and Trade Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing, carpentry and labor accommodation
57	Alia Investments Pvt Ltd	TIZ	TIZ	Industrial Equipments/ Marine Power Generation
58	Moosa Kaleem	Silver Plot	-	Warehousing of construction materials, hardware materials GI pipe and structural beam
59	Heavy Dockyard Maldives Pvt Ltd	Platinum Plot	Thilafushi 01	All Works allowed in Thilafushi
60	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
61	Universal Enterprises Pvt Ltd	Platinum Plot	Thilafushi 01	Warehousing
62	Mild Steel Maldives Pvt Ltd	Gold Plot	Thilafushi 01	Boat yard
63	Sonee Hardware Pvt Ltd	TIZ	TIZ	General harware and Warehousing
64	Sonee Hardware Pvt Ltd	TIZ	TIZ	General harware and Warehousing
65	Sonee Hardware Pvt Ltd	TIZ	TIZ	General harware and Warehousing
66	Mafhaa Private Limited	Gold Plot	Thilafushi 01	Boat building and boat repair
67	Coastline Investments Pvt Ltd	Platinum Plot	Thilafushi 01	Warehousing
68	Heavy Dockyard Maldives Pvt Ltd	Platinum Plot	Thilafushi 01	All Works allowed in Thilafushi
69	Aima Construction Pvt Ltd	TIZ	TIZ	brick works

70	Umet Construction Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and construction work
71	Mohamed Manik	Gold Plot	Thilafushi 01	Warehousing
72	Sunfront Pvt Ltd	-	-	Warehousing
73	MWSC	TIZ	TIZ	Water production and distribution system
74	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
75	Apollo Holdings Pvt Ltd	Platinum Plot	Thilafushi 02	All Works allowed in Thilafushi
76	Maldive Gas Pvt Ltd	Platinum Plot	Thilafushi 01	Buffer zone
77	Sunfront Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing
78	Far Horizon Pvt Ltd	Silver Plot	Thilafushi 01	Fish processing plant, ice plant, aquaponics, fiber tub construction, boat construction and boat repair
79	Maziya Service Pvt Ltd	TIZ	TIZ	fabrication and wood work
80	Maldives Ports Limited	-	-	Vehicle storage
81	Sun Transport Pvt Ltd	TIZ	TIZ	Godown ,carpentary , fiber glass works and workshop
82	Abdul Latheef	TIZ	TIZ	Alluminium Workshop
83	Maldives Petroleum Link Pvt Ltd	Platinum Plot	Thilafushi 01	Warehousing and oil works
84	Vermillion International Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing, boat building, machanicale engineering and brick production
85	Simdi Company Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing
86	Nazaki Aluminium Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and aluminum workshop
87	Heavy Load Maldives Pvt Ltd	Silver Plot	Thilafushi 01	All works allowed in Thilafushi
88	Marine Export & Trading Company Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
89	Leo Trading Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing, parking , vehicle repair and temporary labor accommodation
90	Beach Marine Pvt ltd	TIZ	TIZ	Workshop
91	Aaru Pvt Ltd	Silver	Thilafushi 01	Warehousing
92	Abbas Abdulla	Gold	Thilafushi 02	Warehousing of Construction Materials
93	Agas Maldives Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing
94	Ahmed Mujah	Silver Plot	Thilafushi 01	Warehousing, Work shop and live fish
95	Aima Construction Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing & Carpentry
96	Ali Abdulla	Gold Plot	Thilafuhsi 2	Warehousing/Construction Materials
97	Ali Muththalib	TIZ	TIZ	Warehousing, fiber works & workshop
98	Al Shaali Marine Maldives Pvt Ltd	Platinum Plot	Thilafushi 01	Vessel repair
99	Apollo Holdings Pvt Ltd	Platinum Plot	Thilafushi 02	All Works allowed in Thilafushi
100	Aries Enterprises Pvt Ltd	TIZ	TIZ	Warehousing

101	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
102	FW Construction Company Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and workshop
103	Fuel Supplies Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Oil works
104	Maldives Petroleum Link Pvt Ltd	Platinum Plot	Thilafushi 01	Workshop and oil works
105	Heavy Force Pvt Ltd	Gold Plot	Thilafushi 01	Vehicle repair
106	Ibrahim Abdul Latheef	-	-	Workshop
107	Ismail Shafeeu	Silver Plot	Thilafushi 01	Warehousing
108	M.T Hojgaard Pvt Ltd	TIZ	TIZ	Concrete work, carpentry, welding and boat repair
109	Nakachafushi Island Resort	Silver Plot	Thilafushi 01	Warehousing
110	Nalahiya Tradings Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
111	Olhahali Investment Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing
112	Reollo Enterprise Pvt Ltd	TIZ	TIZ	Warehousing and workshop
113	Sunfront Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing
114	Sunfront Pvt Ltd	Gold Plot	Thilafushi 01	Warehousing
115	Sunland Trading Company Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
116	Tep Construction Pvt Ltd	TIZ	TIZ	Warehousing of Construction Materials
117	Vista Investments Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and construction work
118	Amin Construction Pvt Ltd	TIZ	TIZ	Warehousing
119	Ahmed Luthfee	Silver Plot	Thilafushi 01	Fiber glass speed boat & fishing boat building and boat repair
120	Moosa Kaleem	Silver Plot	Thilafushi 01	Warehousing
121	Adam Ibrahim	Silver	Thilafushi 01	Warehousing
122	Alia Construction Pvt Ltd	TIZ	TIZ	Warehousing, workshop, carpentry, labor quarter,vessel building, garage and parking zone
123	Umar Zahir	Silver Plot	Thilafushi 01	Warehousing
124	Sandcays Pvt Ltd	TIZ	TIZ	Warehousing and labor accommodation
125	Mohamed Ahmed Abdulla	Silver Plot	Thilafushi 01	Warehousing
126	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	Vessel repair and vessel building
127	Hussain Mohamed Fulhu	Silver Plot	Thilafushi 01	All works allowed in Thilafushi
128	Marine Coral Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
129	Mohamed Moosa	Silver Plot	Thilafushi 01	Warehousing
130	Ibrahim Rasheed Ali	Silver Plot	Thilafushi 01	Wood warehousing and wood works
131	Waste Management Corporation Limited	-	-	warehousing, accommodation block, parking, garage, recycle facility and office building

132	Mass Enterprises Pvt Ltd	Silver Plot	Thilafushi 01	Wood warehousing and wood works
133	Aima Construction Pvt Ltd	TIZ	TIZ	Vehicle and Barge repair
134	Ali Naashid	Silver Plot	Thilafushi 01	Wood warehousing & wood works
135	Alia Investments Pvt Ltd	Silver Plot	Thilafushi 01	Wood warehousing and wood works
136	FW Construction Company Pvt Ltd	Silver Plot	Thilafushi 01	Wood warehousing and wood works
137	Far Horizon Pvt Ltd	Silver Plot	Thilafushi 01	Wood warehousing and wood works
138	Ibrahim Hassan	Silver Plot	Thilafushi 01	Wood warehousing and wood works
139	Onus Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
140	Sunfront Pvt Ltd	-	-	Warehousing and Carpentry work
141	Timber House Pvt Ltd	Silver Plot	Thilafushi 01	Wood storage and other works
142	Timber Trade Pvt Ltd	Silver Plot	Thilafushi 01	Wood storage and other works
143	Ali Shareef	Silver Plot	Thilafushi 01	Warehousing
144	Ahmed Sinah	Platinum Plot	Thilafushi 01	Dockyard
145	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	All works allowed in Thilafushi
146	Maldives Petroleum Link Pvt Ltd	Platinum Plot	Thilafushi 01	Warehousing
147	Heavy Load Maldives Pvt Ltd	Silver Plot	Thilafushi 01	All works allowed in Thilafushi, except works stated in clause 12 of the agreement.
148	Aaru Pvt Ltd	Silver	Thilafushi 01	Warehousing
149	Hello Maldives Pvt Ltd	Gold Plot	Thilafushi 01	Fish processing plant, ice plant, aquaponics, fiber tub construction, boat construction and boat repair
150	Silver Sands Pvt Ltd	Gold Plot	Thilafushi 01	All works allowed in Thilafushi
151	Bio Diversity Education and Awareness Maldives (BEAM)	-	-	Collecting, segregating and bailing ocean plastic
152	Marine Coral Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and brick works
153	Damas Company Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and workshop
154	Leo Trading Pvt Ltd	Gold Plot	-	Warehousing and workshop (Heavy vehicle maintenance and services)
155	Mild Steel Maldives Pvt Ltd	-	-	Warehousing
156	Maldives Structural Products Pvt Ltd	Gold Plot	Thilafushi 02	Warehousing
157	Island Engineering Services and Supplies Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
158	Static Company Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
159	Damas Company Pvt Ltd	Silver Plot	Thilafushi 01	Vehicle repair and vehicle storage

160	The Hawks Pvt Ltd	Silver Plot	Thilafushi 01	Bric work, fiber work and carpentry
161	Hussain Khalid	Silver Plot	Thilafushi 01	Warehousing, hotel, shop and labor accommodation
162	Ismail Adil	Silver Plot	Thilafushi 01	Warehousing
163	Hassan Haleem	Silver Plot	Thilafushi 01	Brick work
164	Mohamed Sameer	Silver Plot	Thilafushi 01	Brick work
165	Tep Construction Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing of Construction Materials
166	Monaza Contracting Company Pvt Ltd	Silver Plot	Thilafushi 01	Carpentry, staff accommodation, café, workshop and saloon
167	Mohamed Majid	Silver Plot	Thilafushi 01	Warehousing and Tailor work
168	Saroof Naazim	TIZ	TIZ	Non Flammable works
169	Aaru Pvt Ltd	Silver	Thilafushi 01	Labor Accommodation
170	Agas Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
171	Ahmed Sameeru	Silver Plot	Thilafushi 01	Warehousing
172	Ahmed Sinah	TIZ	TIZ	Warehousing
173	Ahmed Zareer	TIZ	TIZ	Warehousing
174	Aima Construction Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
175	Aima Construction Pvt Ltd	Silver Plot	Thilafushi 01	All works allowed in Thilafushi
176	Ali Ibrahim Rashid	TIZ	TIZ	Warehousing
177	Apollo Holdings Pvt Ltd	Platinum Plot	Thilafushi 02	All Works allowed in Thilafushi
178	Asian Power Investment Pvt Ltd	TIZ	TIZ	Warehousing and workshop
179	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and vehicle repair
180	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
181	Dhivehi Meysthiri Pvt Ltd	Silver Plot	Thilafushi 01	All Works allowed in Thilafushi
182	Dhivehi Meysthiri Pvt Ltd	Silver Plot	Thilafushi 01	Carpentry
183	Dynamic Construction and Trading Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and brick works
184	Farifeyran Pvt Ltd	Silver Plot	Thilafushi 01	Brick work, warehousing, cement works, carpentry, workshop, metal works, fiber works, sale of wood and hardware construction work
185	Faunu Enterprises Pvt Ltd	Gold Plot	Thilafushi 01	Vessel repair Shop (by letter no: TCL-LEGAL/PRIV/2018/025)
186	Haajaraa Workshop	Silver Plot	Thilafushi 01	Warehousing and machinery repair
187	Maldives Petroleum Link Pvt Ltd	TIZ	TIZ	Warehousing, labor accommodation and maintences work
188	Maldives Petroleum Link Pvt Ltd	TIZ	TIZ	Warehousing, labor accommodation and maintences work

189	Ibrahim Majid	TIZ	TIZ	Warehousing and Compact works of steel and plastic
190	Ilyas	Silver Plot	Thilafushi 01	Workshop
191	Ismail Hilmy	Silver Plot	Thilafushi 01	Warehousing
192	Ismail Zahir	TIZ	TIZ	Vessel repair
193	Ives Pvt Ltd	TIZ	TIZ	Warehousing and workshop
194	Jausa Holdings Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
195	LuckyHiya Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and Carpentry work
196	Maldives Road Development Corporation Limited	Silver Plot	Thilafushi 01	Brick works site office
197	Mohamed Moosa	Silver Plot	Thilafushi 01	Brick work, warehousing, cement works, carpentry, workshop, metal works, fiber works, sale of wood and hardware construction work
198	Mohamed Naasih	Silver Plot	Thilafushi 01	Vehicle repair
199	Mohamed Shareef	TIZ	TIZ	Warehousing and services
200	Muaz Mohamed	TIZ	TIZ	Warehousing
201	Muni Enterprises Pvt Ltd	TIZ	TIZ	Carpentry
202	MWSC	Platinum Plot	Thilafushi 01	Water plant and other water related works
203	MWSC	Platinum Plot	Thilafushi 01	Water supply for Thilafushi
204	Ocean Brilliant Sea Food International Pvt Ltd	TIZ	TIZ	Fish processing
205	Prop Pvt Ltd	-	-	N/A
206	Rasheed Carpentry & Construction Pvt Ltd	Silver Plot	Thilafushi 01	Carpentry
207	Rasheed Carpentry & Construction Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and Carpentry work
208	The Hawks Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing, vehicle repair, brick work, oil storage, retail business, boat building and café
209	Universal Enterprises Pvt Ltd	Silver Plot	Thilafushi 01	Labor Acommodation
210	Vantha Pvt Ltd	TIZ	TIZ	Warehousing, labor accommodation and boat building and repair
211	Villa Hakatha Pvt Ltd	Platinum Plot	Thilafushi 02	Warehousing
212	Villa Hakatha Pvt Ltd	Gold Plot	Thilafushi 02	All works allowed in Thilafushi
213	Damas Company Pvt Ltd	Silver Plot	Thilafushi 01	All Works allowed in Thilafushi
214	Maziya Service Pvt Ltd	TIZ	TIZ	Warehousing
215	Hassan Jawhary	Silver Plot	Thilafushi 01	Warehousing
216	Damas Company Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
217	Sirius Enterprises Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
218	Ahmed Lilal			building material storage
219	Sirius Enterprises Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
220	Eye Care Pvt Ltd	TIZ	TIZ	Warehousing, workshop and café

221	Ahmed Sameeru	Silver Plot	Thilafushi 01	Warehousing and Vessels/Vehicle repair
222	Thoha Mohamed	TIZ	TIZ	Warehousing and Carpentry work
223	Abdul Muhsin Hussain	Gold	-	Warehousing
224	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	N/A
225	Marine Coral Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
226	Marine Coral Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
227	Meridium Services Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and oil works
228	Tennssor Holdings Pvt Ltd	TIZ	TIZ	Warehousing and workshop
229	Wheel Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and workshop
230	Asian Power Investment Pvt Ltd	TIZ	TIZ	Vessel repair and production of machine
231	Mario Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Construction work
232	Haneefa Exzim Investment	Silver Plot	Thilafushi 01	Warehousing
233	Ahmed Sameeru	Silver Plot	Thilafushi 01	Warehousing and Workshop
234	Asir Nizar	Silver Plot	Thilafushi 01	Workshop
235	The Wiz Company Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing
236	Mohamed Yoosuf	TIZ	TIZ	Warehousing and brick works
237	Ali Ahmed	TIZ	TIZ	Warehousing, Café, Shop & Workshop
238	The Hawks Pvt Ltd	Silver Plot	Thilafushi 01	Retail shop, oil supply, brick work, café and boat building
239	Ahmed Luthfee	Silver Plot	Thilafushi 01	Fiber glass speed boat & fishing boat building and boat repair
240	LoneStar Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing, workshop and labor accommodation
241	Maldives Petroleum Link Pvt Ltd	TIZ	TIZ	Warehousing, labor accommodation and maintences work
242	Mohamed Waheed Hassan	TIZ	TIZ	Warehousing, shop, café and workshop
243	Rayline Services Pvt Ltd	TIZ	TIZ	Warehousing
244	Mario Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Construction work
245	The Hawks Pvt Ltd	Silver Plot	Thilafushi 01	Retail shop, oil supply, brick work, café and boat building
246	Denicon Construction & Trading Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and construction work
247	Ahmed Naseer	TIZ	TIZ	Warehousing
248	Rishtha Company Pvt Ltd	TIZ	TIZ	Warehousing and brick works
249	Tennssor Holdings Pvt Ltd	TIZ	TIZ	Heavy machinery storage and services
250	Abdulla Abdul Sattar	Silver	Thilafushi 01	Workshop
251	Abdulla Salih	TIZ	TIZ	Warehousing & Workshop
252	Afeef Mohamed	TIZ	TIZ	Labor Accommodation & Café Fiber Glass Work (Allowed through letter)

253	Ahmed Amir	Silver	Thilafushi 01	All Works allowed in Thilafushi
254	Ahmed Mujah	TIZ	TIZ	Warehousing
255	Ali Abdulla	Silver Plot	Thilafushi 01	Workshop
256	Ali Ahmed	TIZ	TIZ	Warehousing, Café, Shop & Workshop
257	Ali Rasheed	Silver Plot	Thilafushi 01	Warehousing
258	Alia Investments Pvt Ltd	TIZ	TIZ	Warehousing and workshop
259	Alia Investments Pvt Ltd	TIZ	TIZ	Warehousing and workshop
260	Alia Investments Pvt Ltd	TIZ	TIZ	Warehousing and workshop
261	Bric Construction	TIZ	TIZ	Workshop and warehouse
262	Coastline Investments Pvt Ltd	Silver Plot	Thilafushi 01	Warehouse
263	Denicon Construction & Trading Pvt Ltd	Silver Plot	Thilafushi 01	Labor Accommodation and shop
264	Dhiraagu	Silver Plot	Thilafushi 01	Mobile antenna
265	Gasim Mahmood	TIZ	TIZ	Workshop
266	Heavy Force Pvt Ltd	Gold Plot	Thilafushi 01	Engineering works
267	Hussain Khalid	TIZ	TIZ	Warehousing & labor accommodation
268	Hussain Nazeeh	Silver Plot	Thilafushi 01	Warehousing
269	Hussain Rasheed	TIZ	TIZ	Warehousing
270	Hussain Shiyam	TIZ	TIZ	Warehousing
271	Hussain Waheed	TIZ	TIZ	Workshop
272	Ibrahim Ali	TIZ	TIZ	Carpentry
273	Jiaz Maldives Pvt Ltd	Silver Plot	TIZ	Warehousing and labor accommodation
274	Meridium Services Pvt Ltd	Silver Plot	Thilafushi 01	Oil works
275	Misraab Trading Co Pvt Ltd	TIZ	TIZ	Warehousing
276	Mohamed Abdul Sattar	Silver Plot	TIZ	Warehousing
277	Mohamed Haleel	Silver Plot	-	Warehousing and workshop
278	Mohamed Musthag	TIZ	TIZ	Warehousing and workshop
279	Mohamed Naasih	-	-	Warehousing
280	Mohamed Rasheed Ahmed	Silver Plot	TIZ	Warehousing, café, workshop and shop
281	Mohamed Rasheed Hussain	TIZ	TIZ	Warehousing, workshop, brick work and machine production
282	Mohamed Shakir	Silver Plot	Thilafushi 01	Vehicle and engine repair
283	Mohamed Shareef	TIZ	TIZ	Metal sheet storage
284	Musthafa Fareed	TIZ	TIZ	Warehousing
285	Naadira Jameel	TIZ	TIZ	Show room and workshop
286	Nasrullah Abdul Waahid	TIZ	TIZ	Warehousing
287	Ocean Logistics Pvt Ltd	TIZ	TIZ	Warehousing of Construction Materials
288	Ooredhoo Maldives Pvt Ltd	Silver Plot	Thilafushi 01	Antenna
289	Pool Chemicals and Services Maldives Pvt Ltd	TIZ	TIZ	Radio station
290	Prestige Group Maldives Pvt Ltd	TIZ	TIZ	Warehousing

291	Relax Maldives Pvt Ltd	TIZ	TIZ	Warehousing, brick work and café
292	Relax Maldives Pvt Ltd	TIZ	TIZ	Warehousing, brick work and café
293	Relax Maldives Pvt Ltd	TIZ	TIZ	Brick work and workshop
294	Riffathulla Ali	TIZ	TIZ	Warehousing, café, workshop and shop
295	Riznee Mohamed	TIZ	TIZ	Warehousing, labor accommodation and hydroponics agriculture
296	Shen Maldives Raufa Construction Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing and labor accommodation
297	Standard and Origin Pvt Ltd	TIZ	TIZ	Warehousing and workshop
298	Standard and Origin Pvt Ltd	TIZ	TIZ	Warehousing and workshop
299	Tennssor Holdings Pvt Ltd	TIZ	TIZ	Heavy machinery storage and services
300	Tennssor Holdings Pvt Ltd	TIZ	TIZ	Heavy machinery storage and services
301	Try On Maldives Pvt Ltd	TIZ	TIZ	Marine engineering workshop
302	Umar Zahir	Silver Plot	Thilafushi 01	Clinic
303	Urban Investment Pvt Ltd	TIZ	TIZ	Warehousing
304	Well Land Investment Pvt Ltd	TIZ	TIZ	Warehousing and making of name board
305	Ahmed Nizar	Silver Plot	Thilafushi 01	Garage
306	B Company Pvt Ltd	TIZ	TIZ	Godown
307	Hussain Musthaq	Silver Plot	Thilafushi 01	Warehousing
308	Sunfront Pvt Ltd	Silver Plot	Thilafushi 01	Warehousing of Construction Materials
309	Wheel Pvt Ltd	Silver Plot	Thilafushi 01	Workshop
310	Equalise Investment Pvt Ltd	TIZ	TIZ	Auto Repair and maintenance services
311	Aboobakuru Jauhary	TIZ	TIZ	Vehicles Paintings and cleaning works
312	Moosa Ali	TIZ	TIZ	metal fabrication
313	Aujaz Hassan	TIZ	TIZ	Workshop and brick work
314	Department of Public Health	Silver Plot	Thilafushi 01	Warehousing
315	Department of Public Health	Silver Plot	Thilafushi 01	Warehousing
316	State Electric Company Ltd	Silver Plot	Thilafushi 02	Electricity sevices to Thilafushi
317	State Electric Company Ltd	Silver Plot	Thilafushi 02	Electricity sevices to Thilafushi
318	State Electric Company Ltd	Silver Plot	Thilafushi 02	Electricity sevices to Thilafushi
319	State Electric Company Ltd	Silver Plot	Thilafushi 02	Electricity sevices to Thilafushi
320	Greater Male' Industrial Zone Limited		Thilafushi	Overall administration and management of Thilafushi and Gulhifalhu

APPENDIX B: Maps of Thilafushi and Gulhifalhu with the surveyed individuals and companies located

INDIVIDUALS LOCATIONS

COMPANIES LOCATIONS

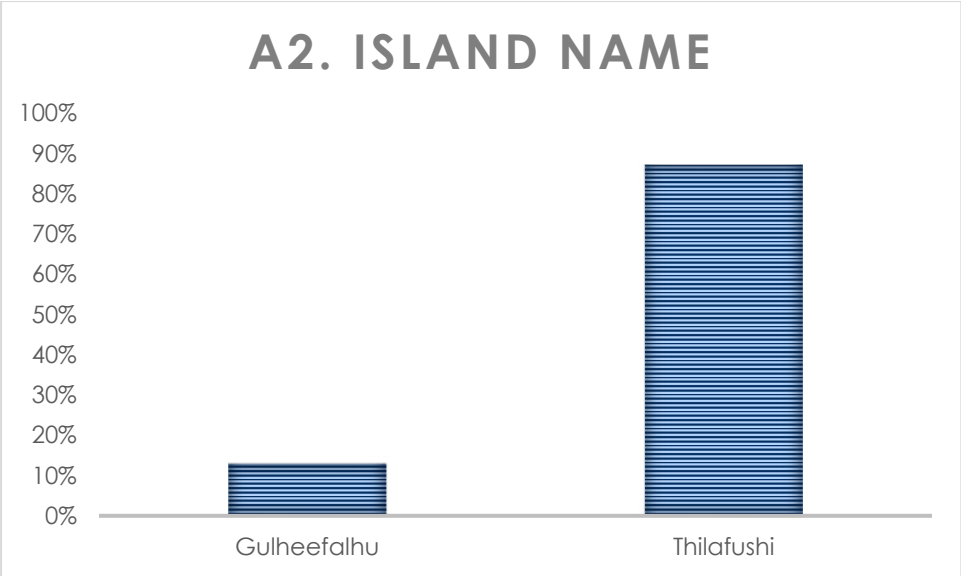
APPENDIX C: Questionnaires for Individual and Company Surveys

(Attached as a separate file)

APPENDIX D: Graphical representation of data obtained from individual survey

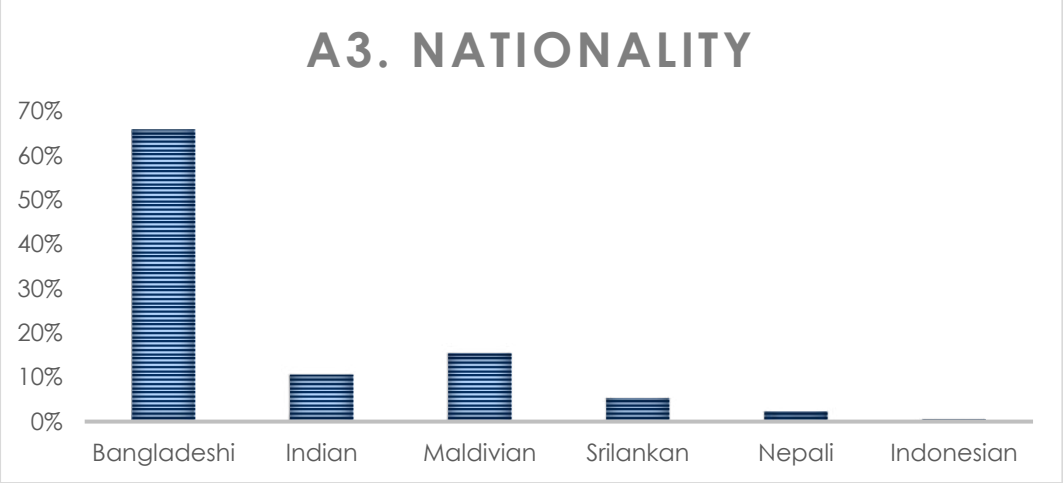
A. GENERAL INFORMATION: RESPONDENT

A2. Island Name



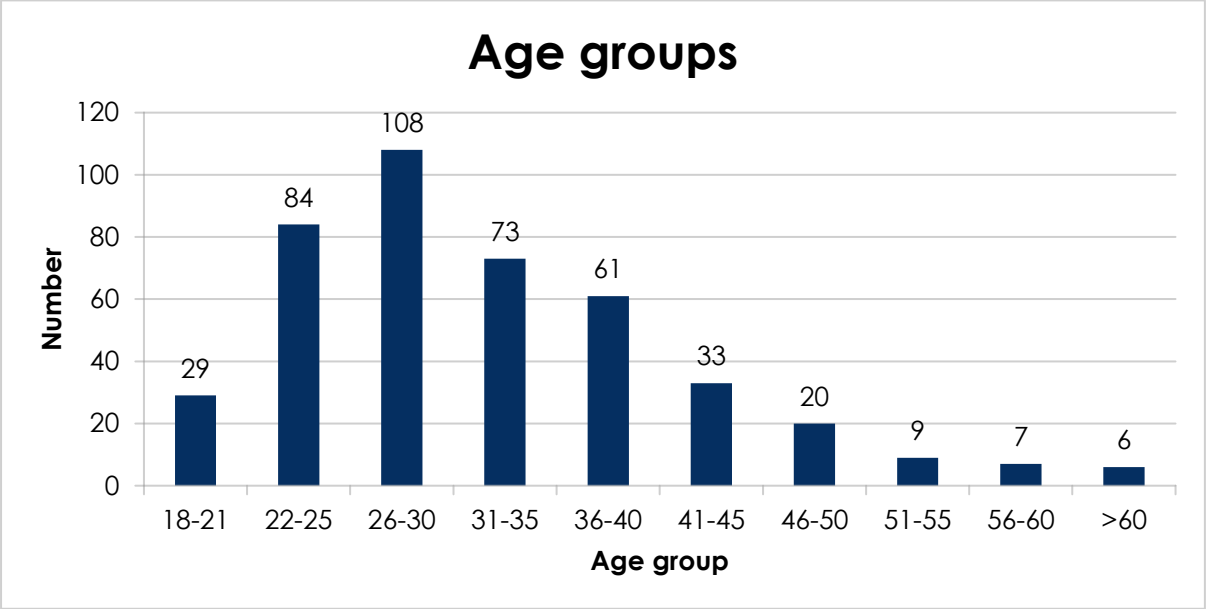
Gulheefalhu	56	13%
Thilafushi	378	87%

A3/A4. Nationality



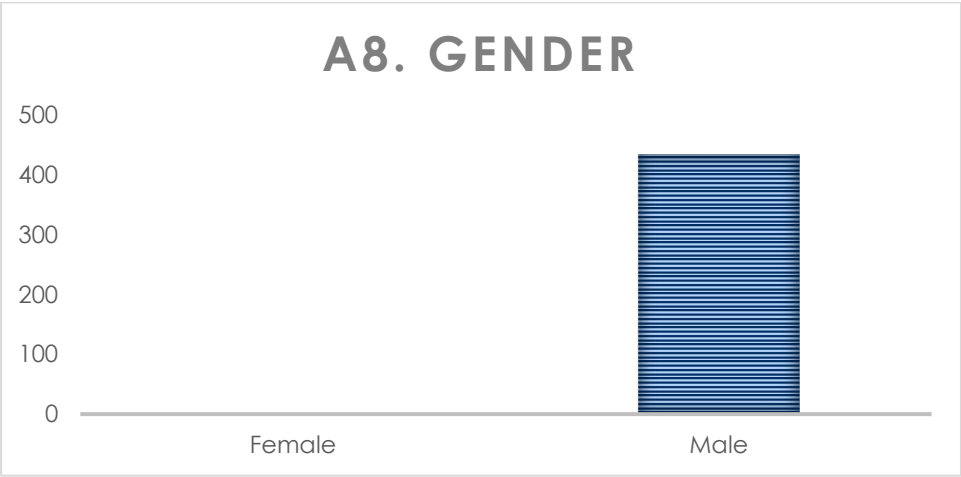
Bangladeshi	286	66%
Indian	46	11%
Maldivian	67	15%
Srilankan	23	5%
Nepali	10	2%
Indonesian	2	0%

A7. Age group



Age group	Count
18-21	29
22-25	84
26-30	108
31-35	73
36-40	61
41-45	33
46-50	20
51-55	9
56-60	7
>60	6
	430

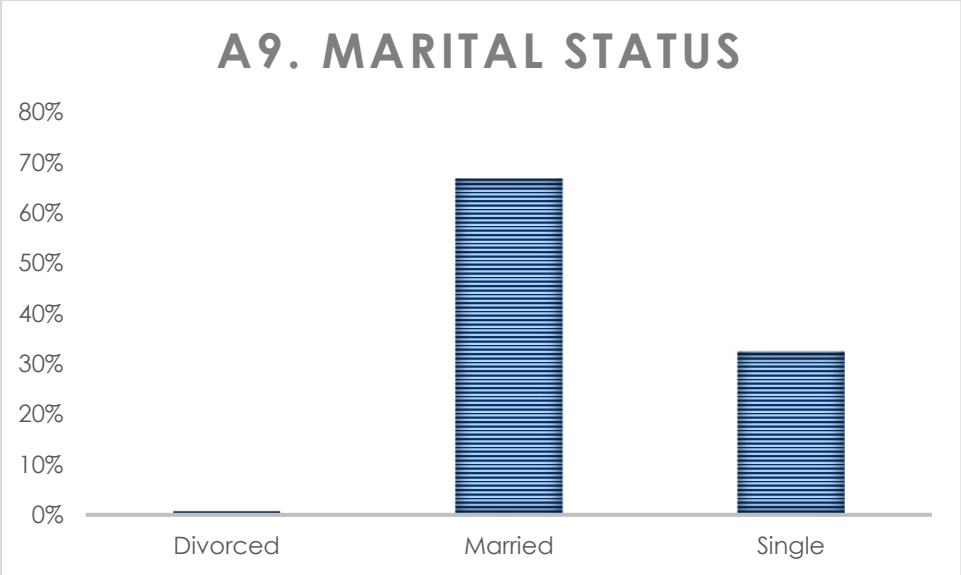
A8. Gender



Female	1

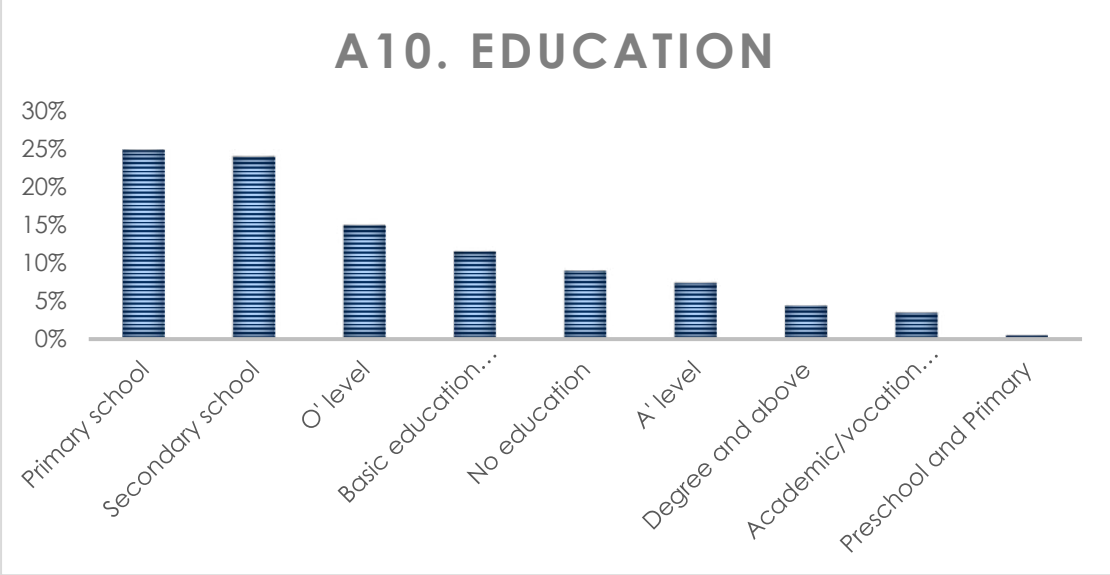
Male	429

A9. Marital Status



Divorced	3	1%
Married	290	67%
Single	141	32%

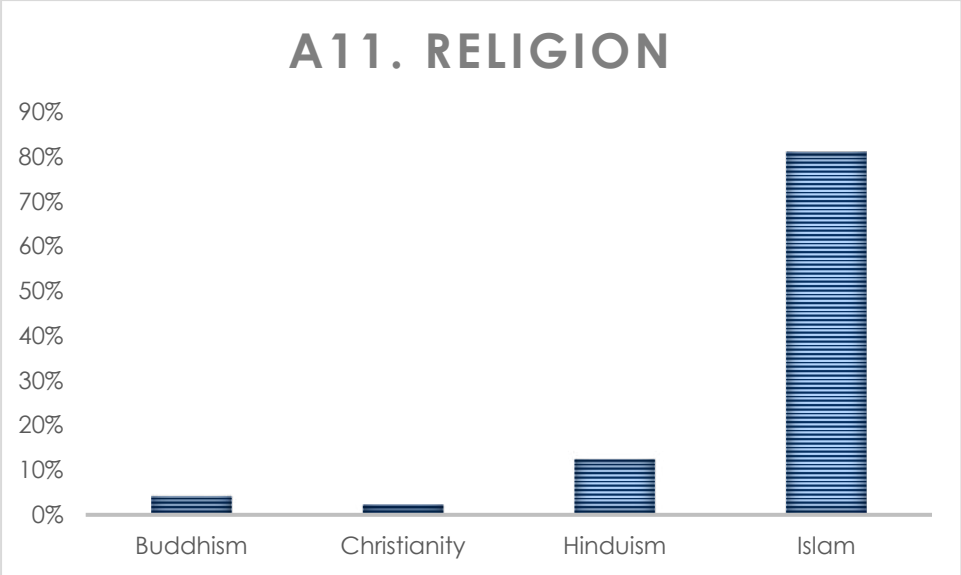
A10. Education



Primary school	108	25%
Secondary school	104	24%
O' level	65	15%
Basic education (basic literacy)	50	12%
No education	39	9%
A' level	32	7%

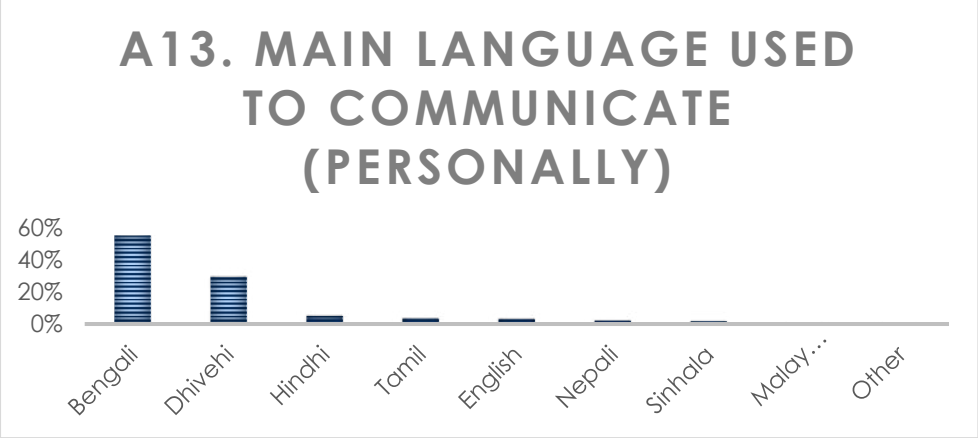
Degree and above	19	4%

A11/A12. Religion



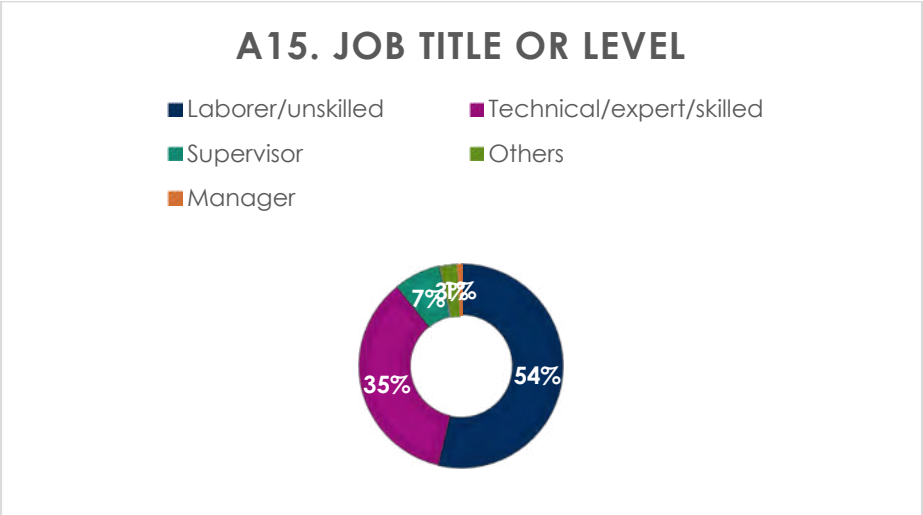
Buddhism	18	4%
Christianity	10	2%
Hinduism	54	12%
Islam	352	81%

A13/A14. Main Language used to communicate



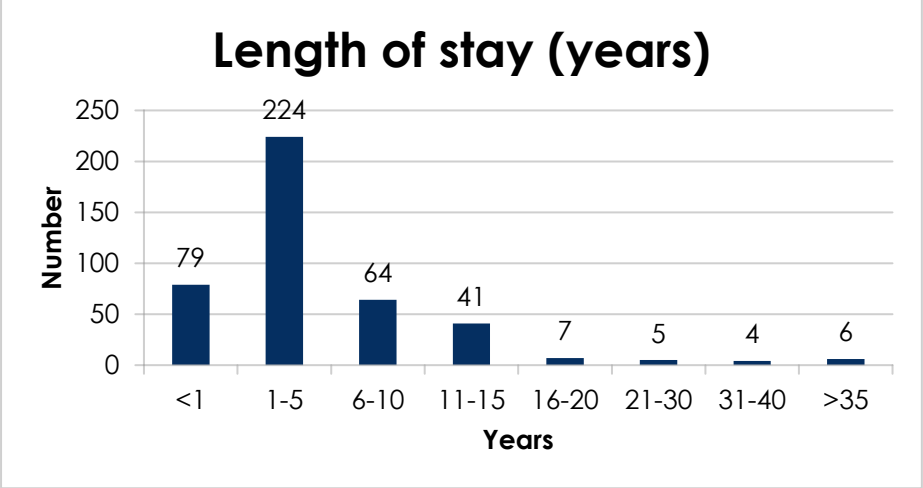
Bengali	239	55%
Dhivehi	127	29%
Hindhi	22	5%
Tamil	15	3%
English	13	3%
Nepali	9	2%
Sinhala	7	2%
Malayalam	1	0%

A15. Job Title/ or Level



Laborer/unskilled	233	54%
Technical/expert/skilled	154	35%
Supervisor	32	7%
Others	12	3%
Manager	3	1%

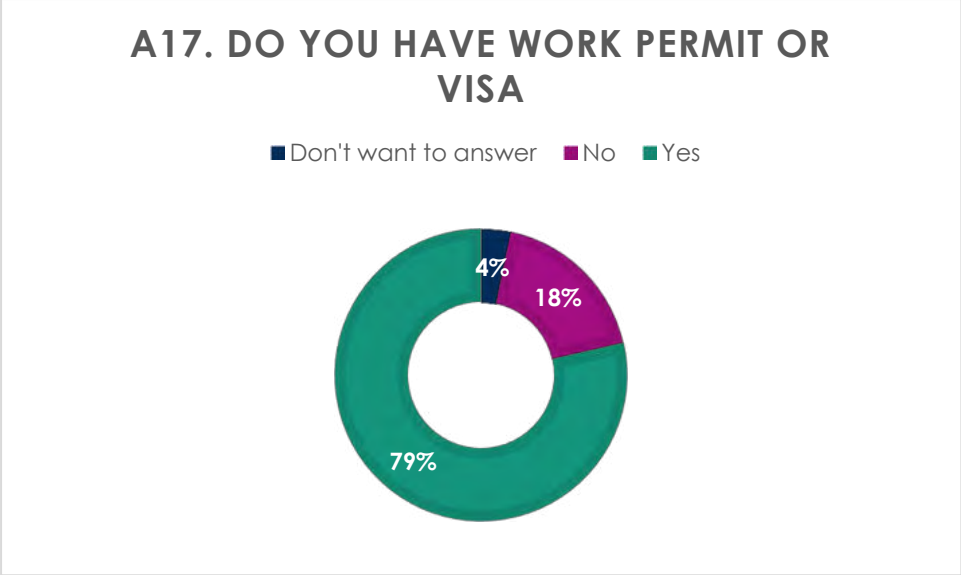
A16. Length of Stay



Length of stay (years)	Count
<1	79
1-5	224
6-10	64
11-15	41
16-20	7
21-30	5
31-40	4

>35	6
	430

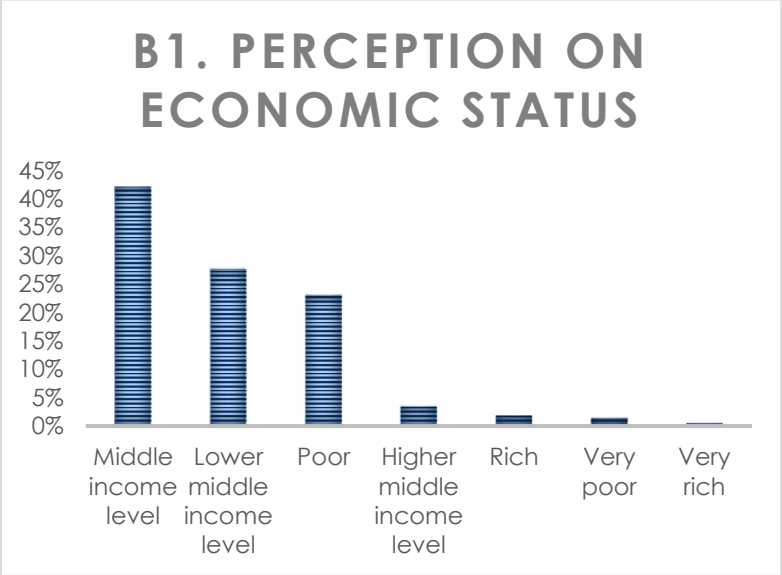
A17. Do you have a work permit?



Don't want to answer	15	4%
No	78	18%
Yes	337	78%

B. INCOME, EXPENDITURE AND SAVINGS

B1. Perception on Economic status

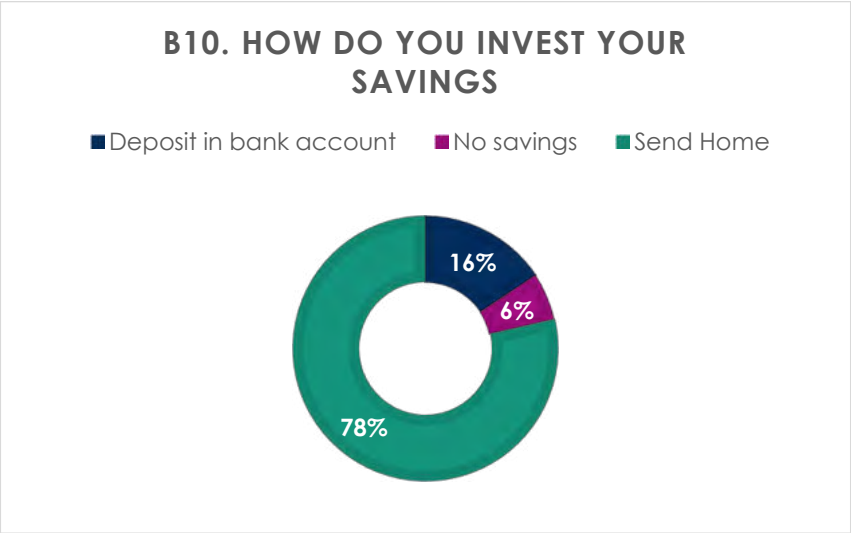


Middle income level	183	42%
Lower middle income level	120	28%
Poor	100	23%
Higher middle income level	15	3%
Rich	8	2%
Very poor	6	1%
Very rich	2	0%

B2/B3/B4/B4/B6/B7/B8. Estimated monthly expenditure

Expenditure (MVR)	Number of people who spent on:						
	B2.Food & Drinks	B3. House Rent	B4. House Maintenance	B5. Healthcare	B6. Electricity	B7. Water	B8. Communication
0-499	253	395	404	396	402	403	149
500-999	40	1	7	14	9	13	205
1000-1499	47	3	3	10	5	2	45
1500-1999	36	3	2	1	3	1	14
2000-2499	15	1	3	4	5	6	11
2500-2999	1	1	2	0	1	0	0
3000-3499	13	2	2	1	0	1	2
3500-3999	2	1	1	0	0	2	0
4000-4499	5	1	1	0	1	1	2
Above 5000	18	22	5	4	4	1	2

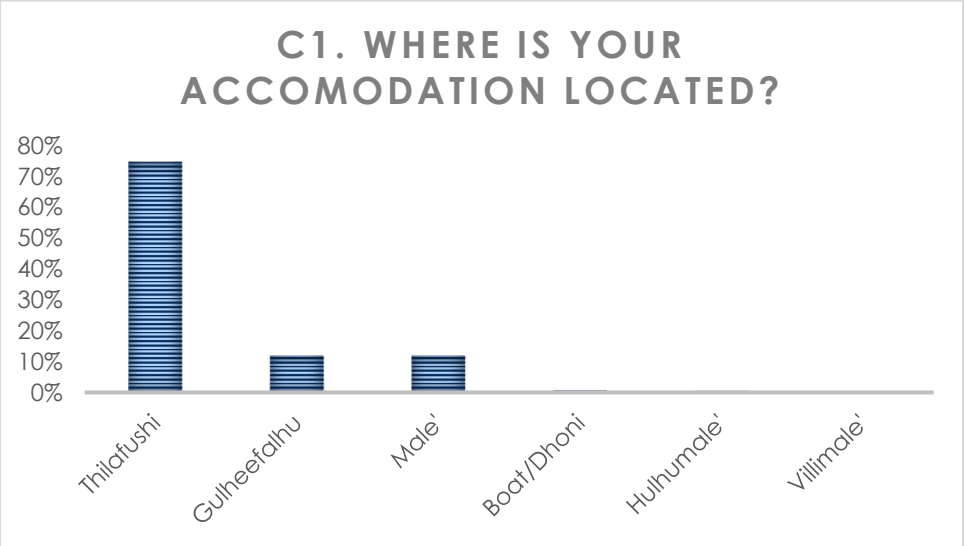
B10. How do you invest your savings?



Deposit in bank account	68	16%
No savings	25	6%
Send Home	341	78%

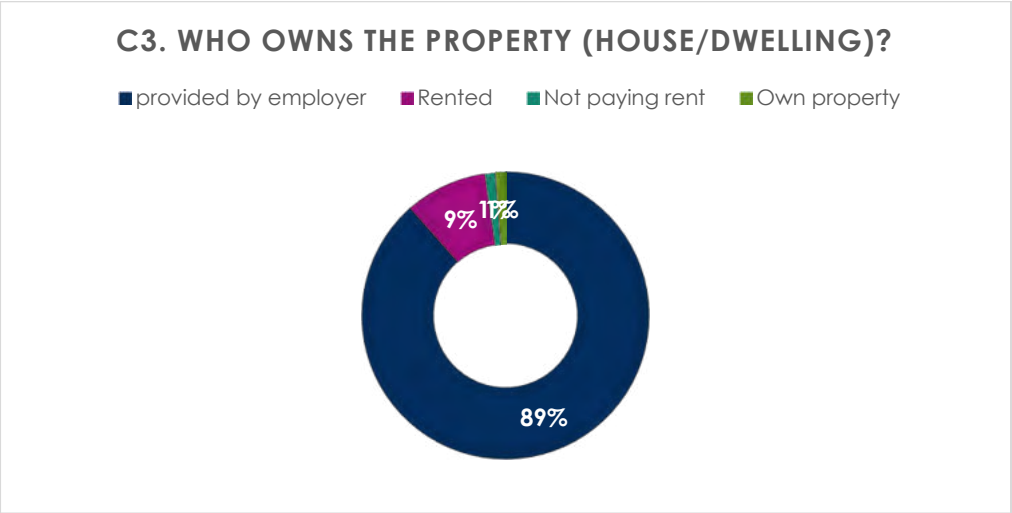
C. HOUSING, INFRASTRUCTURE AND BASIC SERVICES

C1/C2. Where (which island) is your accommodation located?



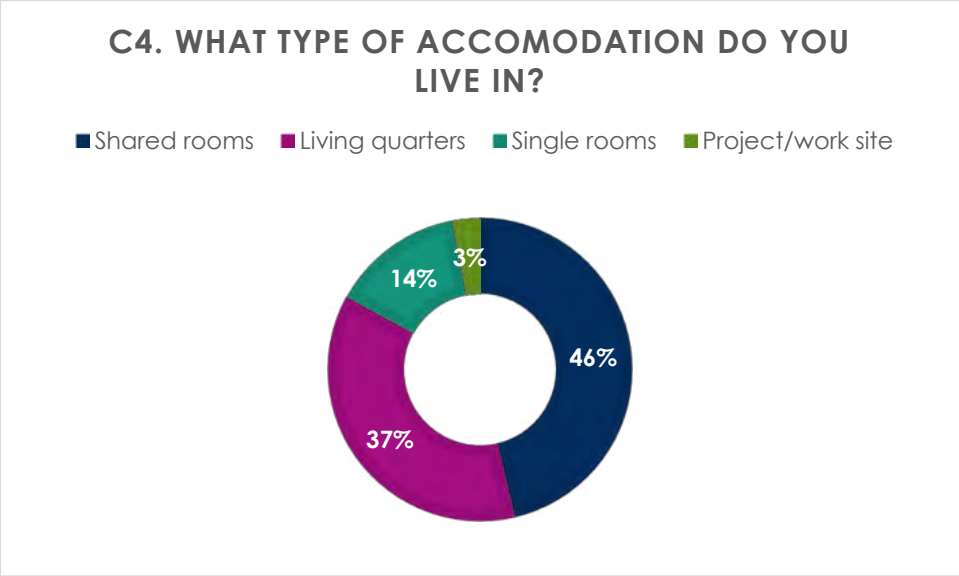
Thilafushi	320	74%
Gulheefalhu	52	12%
Male'	52	12%
Boat/Dhoni	3	1%
Hulhumale'	2	0.47%
Villimale'	1	0.23%

C3. Who owns the property (House/dwelling)?



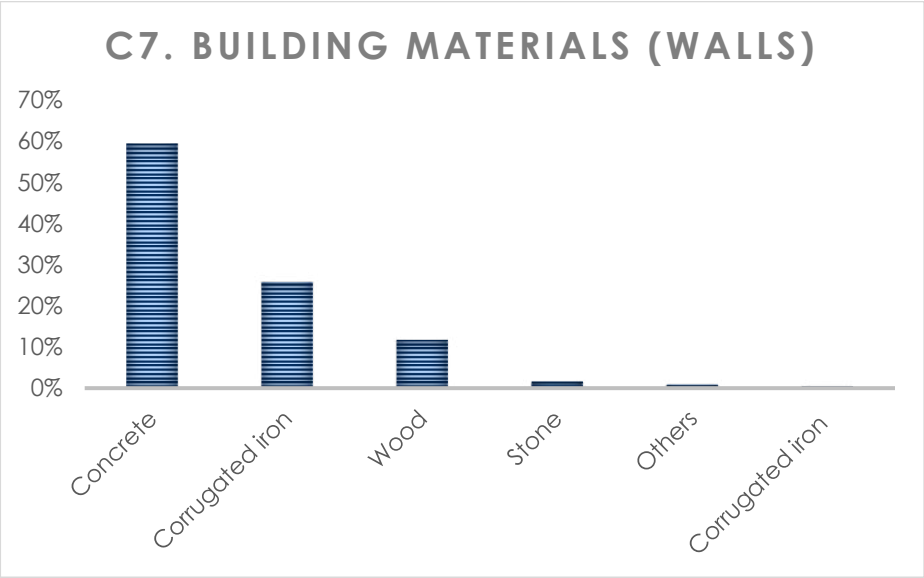
provided by employer	384	88%
Rented	40	9%
Not paying rent	5	1%
Own property	5	1%

C4. What type of accommodation do you live in?



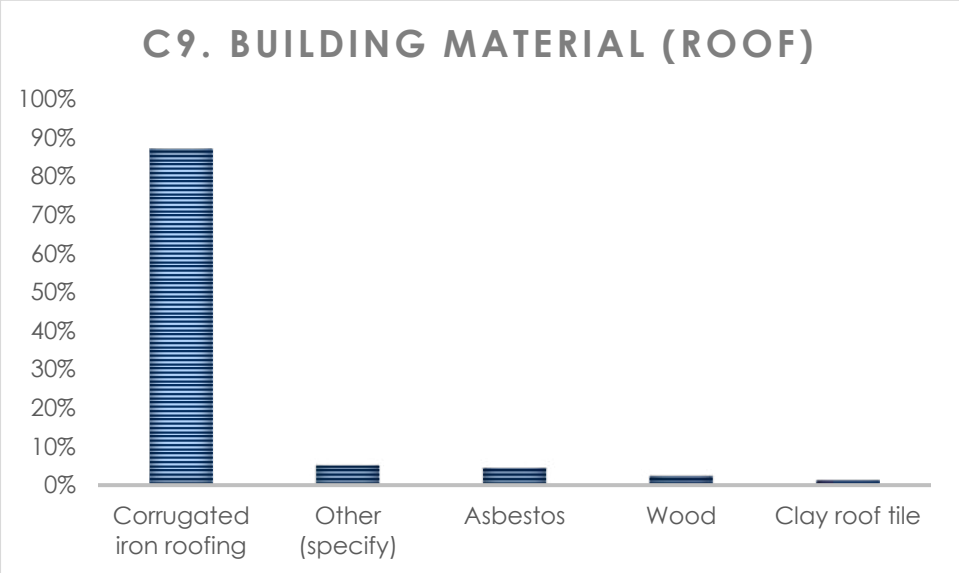
Shared rooms	201	46%
Living quarters	159	37%
Single rooms	61	14%
Project/work site	13	3%

C7/C8. Building material (Walls)



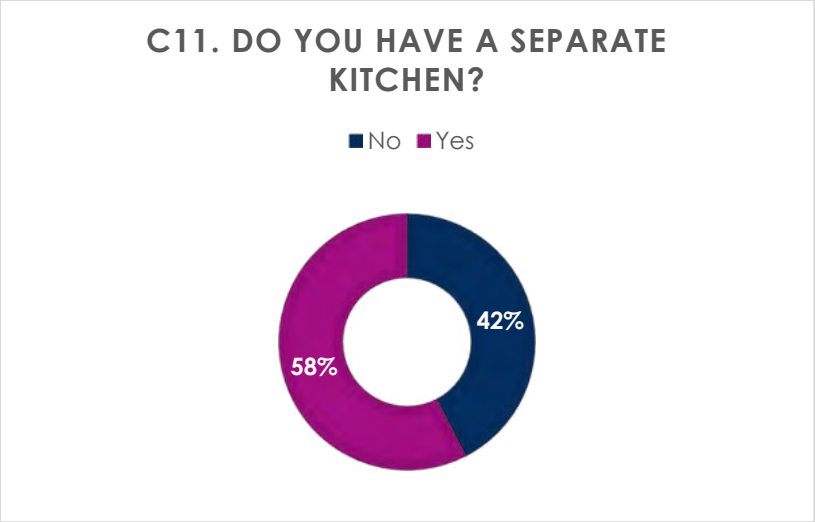
Concrete	258	60%
Corrugated iron	108	25%
Wood	51	12%
Stone	7	2%
Others	4	1%
Corrugated iron	2	0%

C9/C10. Building material (Roof)



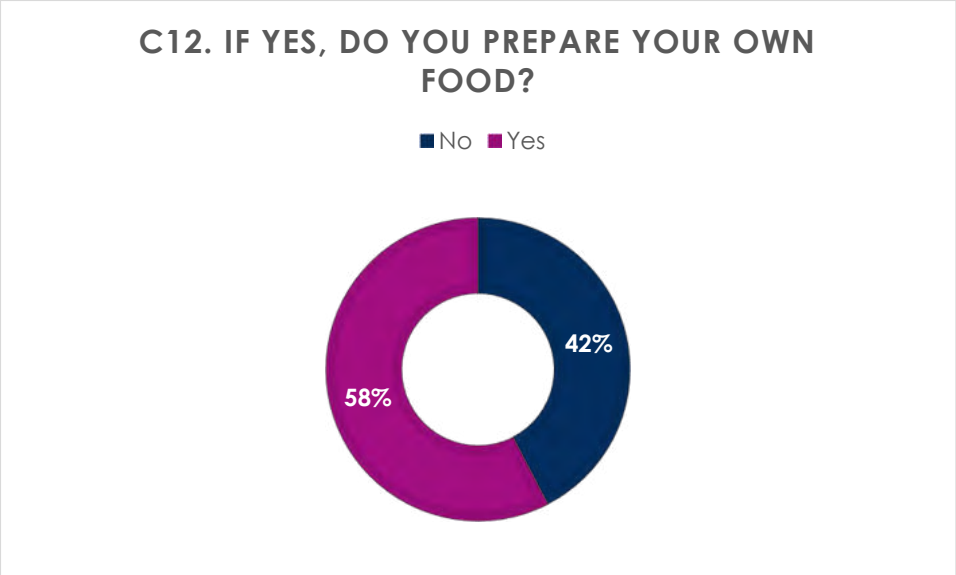
Corrugated iron roofing	378	87%
Other (specify)	22	5%
Asbestos	19	4%
Wood	10	2%
Clay roof tile	5	1%

C11. Do you have a Separate kitchen?



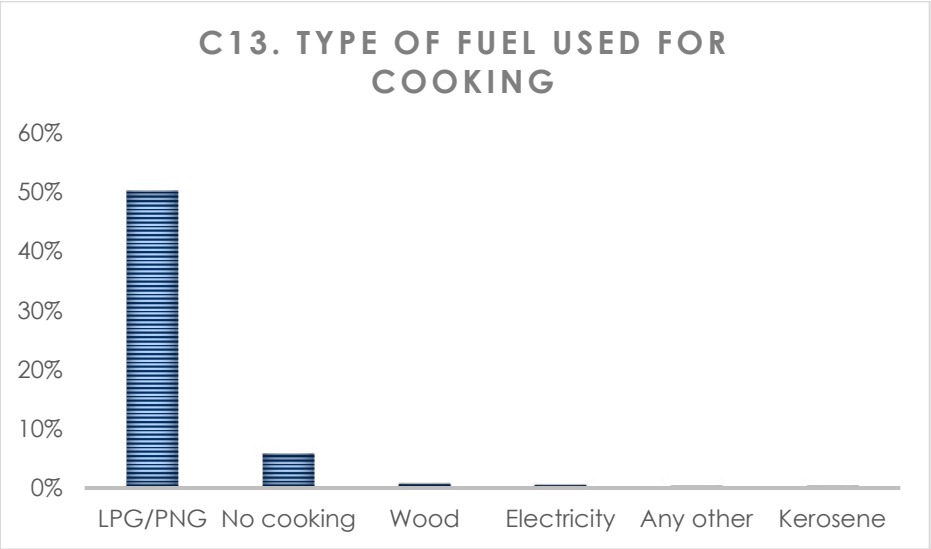
No	184	42%
Yes	250	58%

C12. If yes, do you prepare your own food?



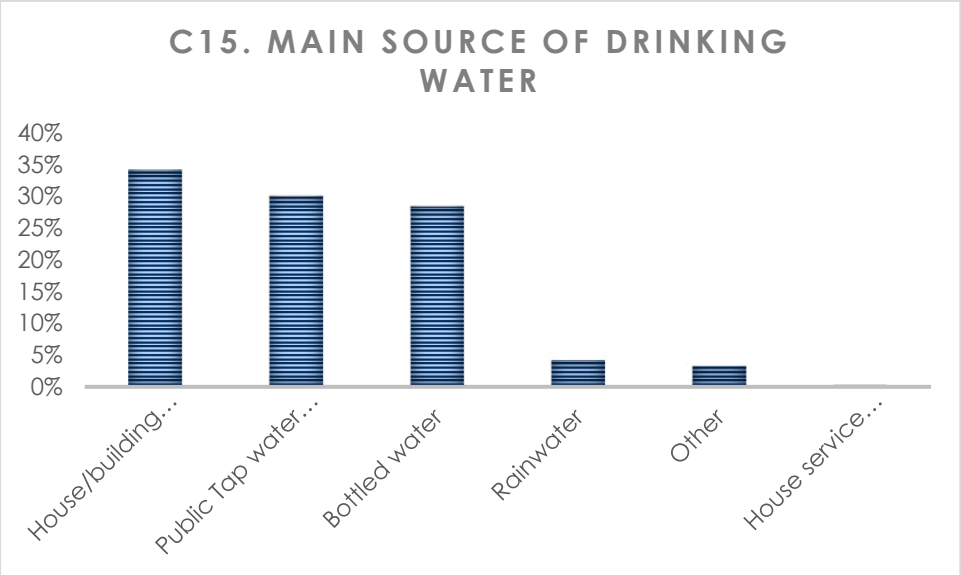
No	106	42
Yes	144	58

C13/C14. What type of fuel is used for cooking?



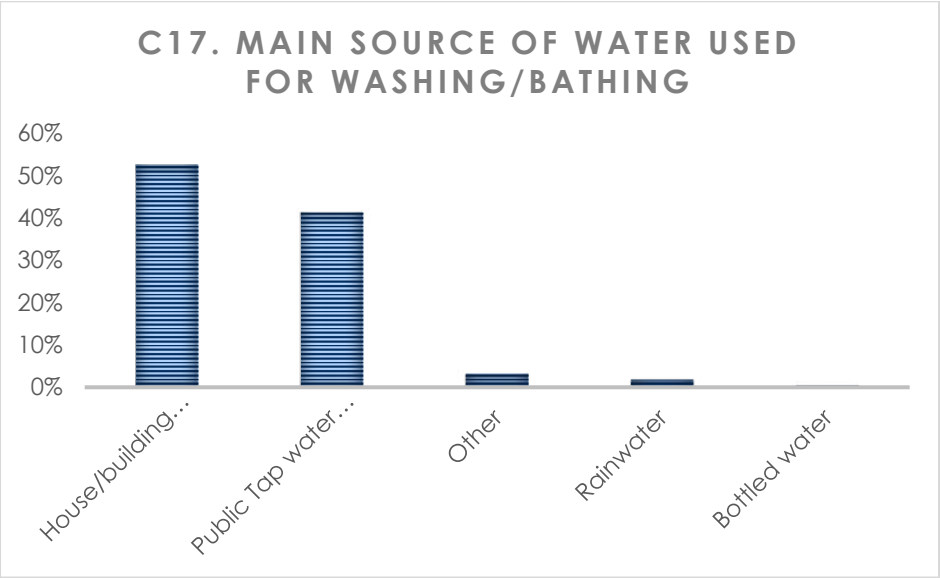
LPG/PNG	218	50%
No cooking	25	6%
Wood	3	1%
Electricity	2	0%
Any other	1	0%
Kerosene	1	0%

C15/C16. Main source of drinking water



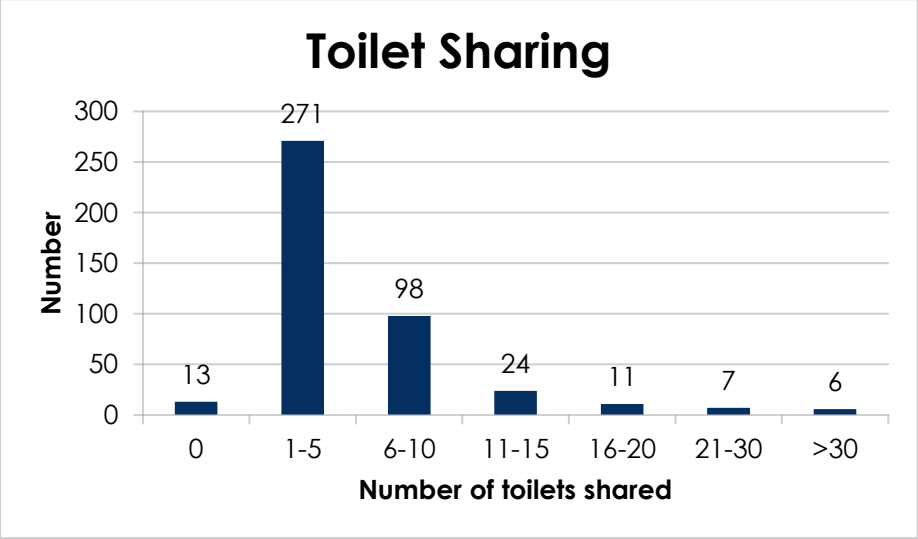
House/building service Connection	148	34%
Public Tap water from treated source	130	30%
Bottled water	123	28%
Rainwater	18	4%
Other	14	3%
House service Connection	1	0%

C17/C18. Main source of water used for washing/ bathing



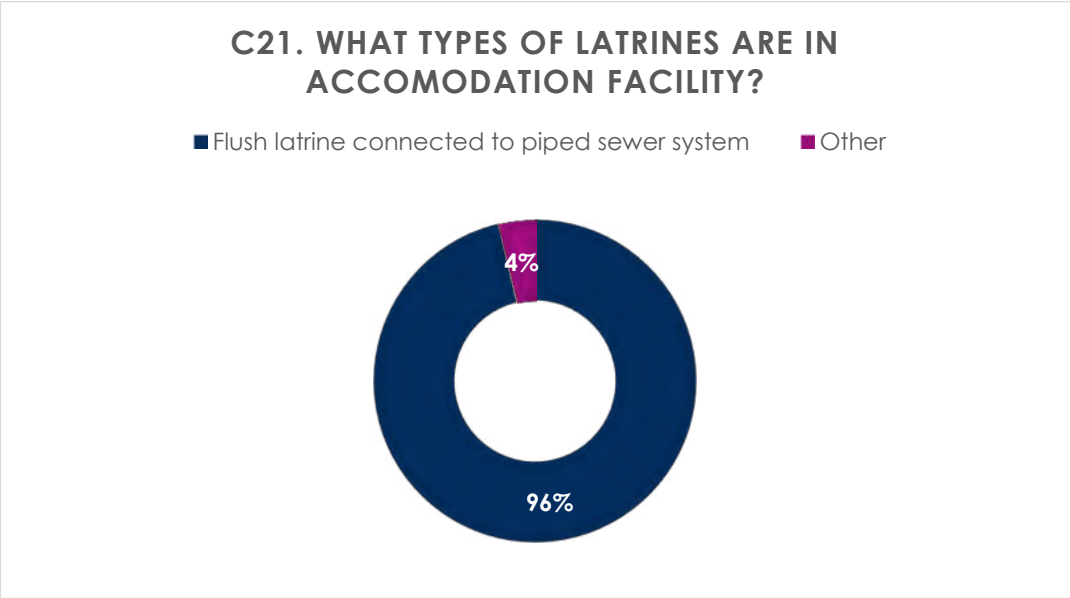
House/building service Connection	228	53%
Public Tap water from treated source	179	41%
Other	14	3%
Rainwater	8	2%
Bottled water	2	0%

C20. Number of toilets shared



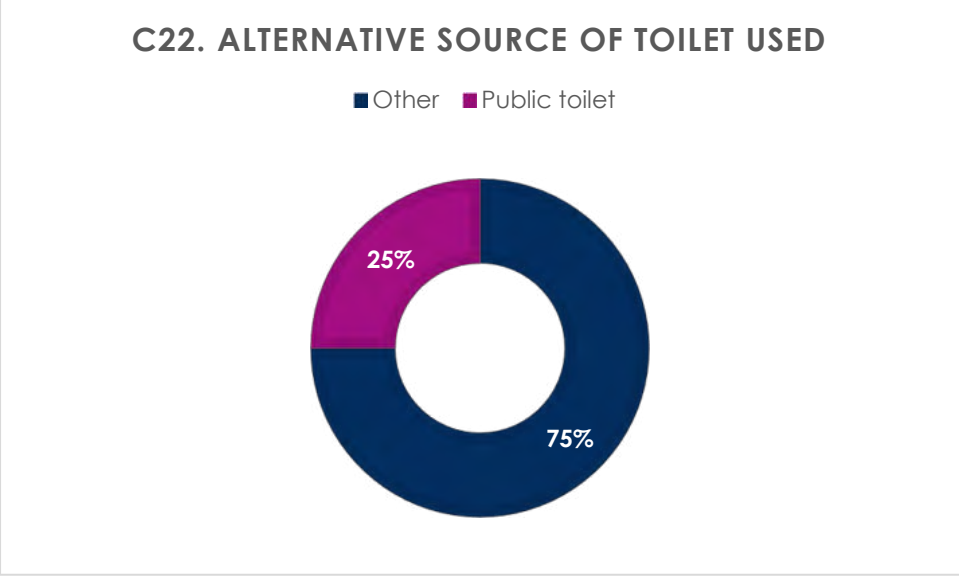
Number of toilets shared	Count
0	13
1-5	271
6-10	98
11-15	24
16-20	11
21-30	7
>30	6
	430

C21. What Types of Latrines are in the accommodation facility?



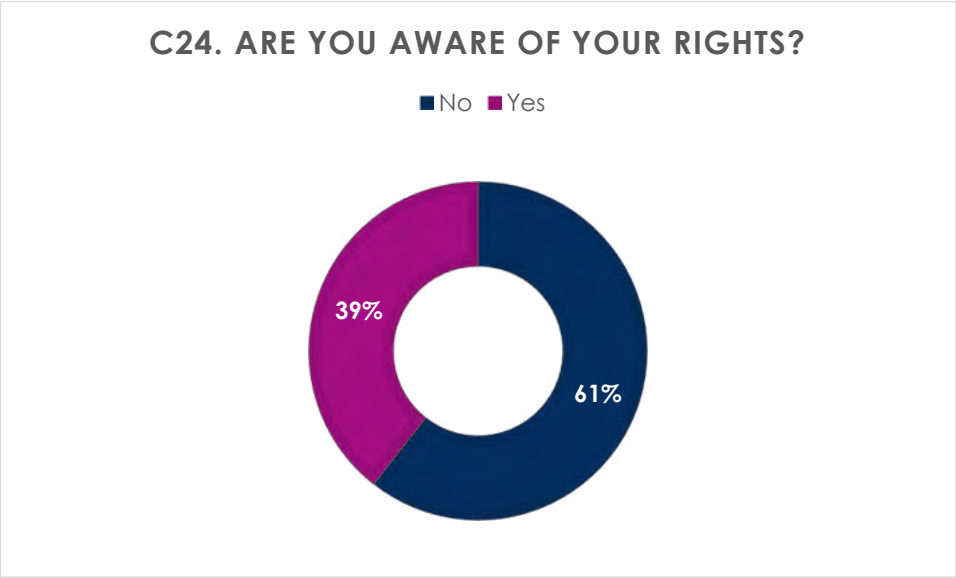
Flush latrine connected to piped sewer system	414	96%
Other	16	4%

C22/C23. Alternate source of toilet used



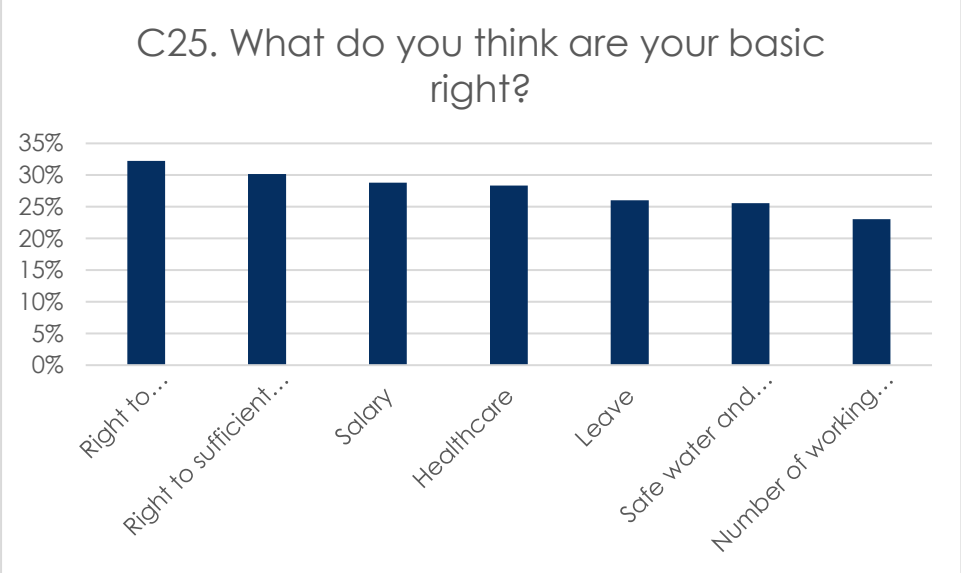
Other	15	83%
Public toilet	3	17%

C24. Are you aware of your rights?



No	263	61%
Yes	167	39%

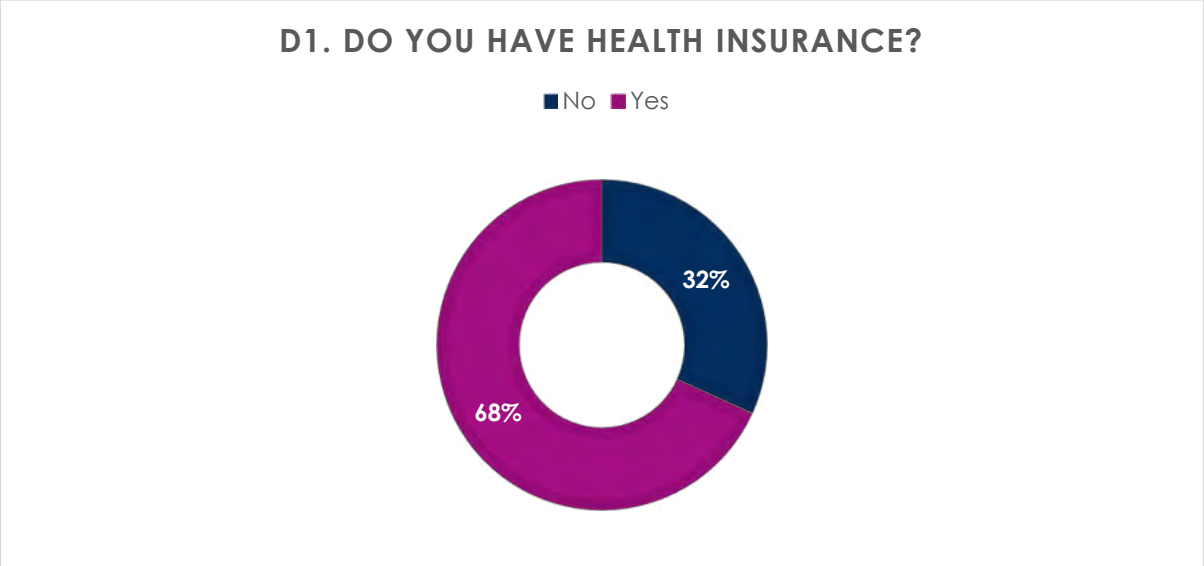
C25.What do you think are your basic rights?



Right to accommodation	140	32%
Right to sufficient foods/meals	131	30%
Salary	125	29%
Healthcare	123	28%
Leave	113	26%
Safe water and sanitation	111	26%
Number of working hours	100	23%

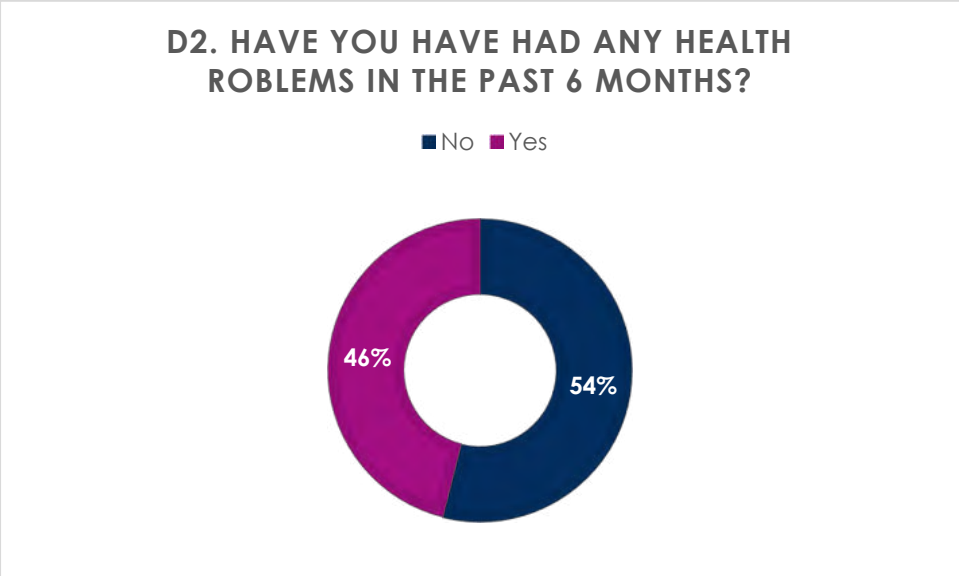
D. HEALTH CONDITION AND HEALTH CARE SERVICES

D1. Do you have health insurance?



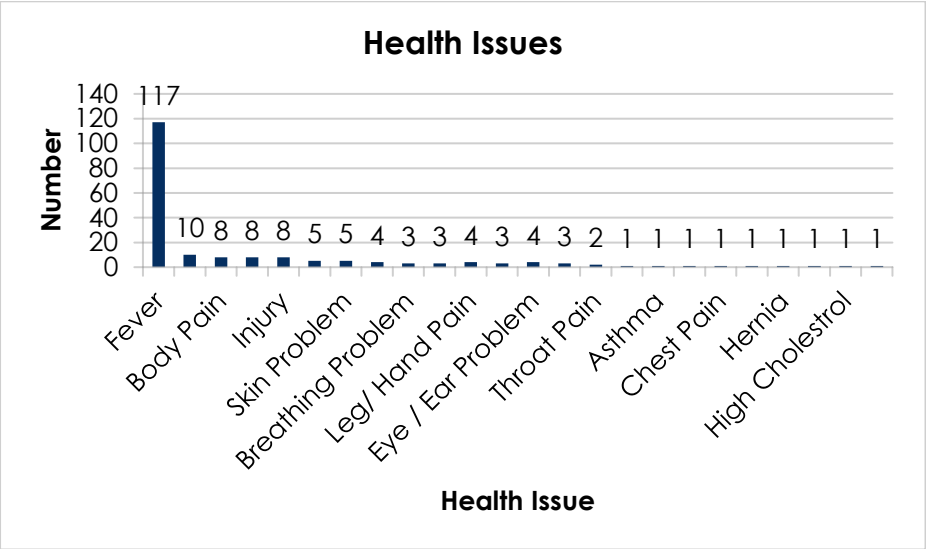
No	138	32%
Yes	296	68%

D2. Have you have had any health problems in the past 6 months?



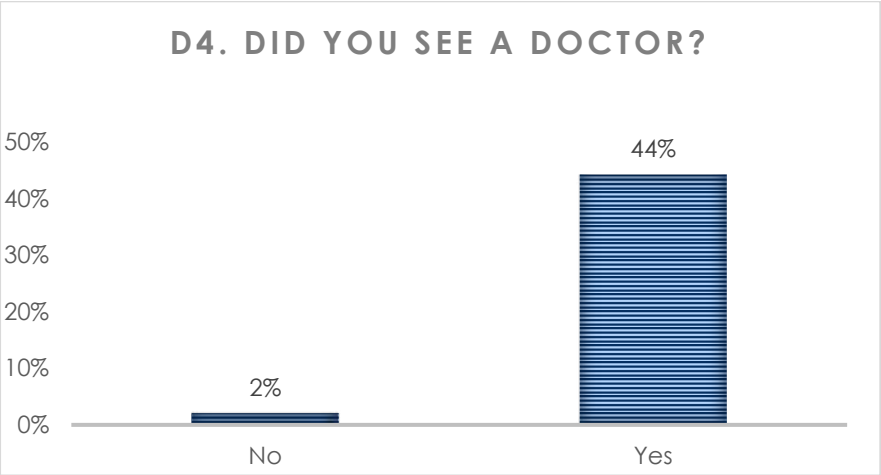
No	234	54%
Yes	200	46%

D3. Health Issues



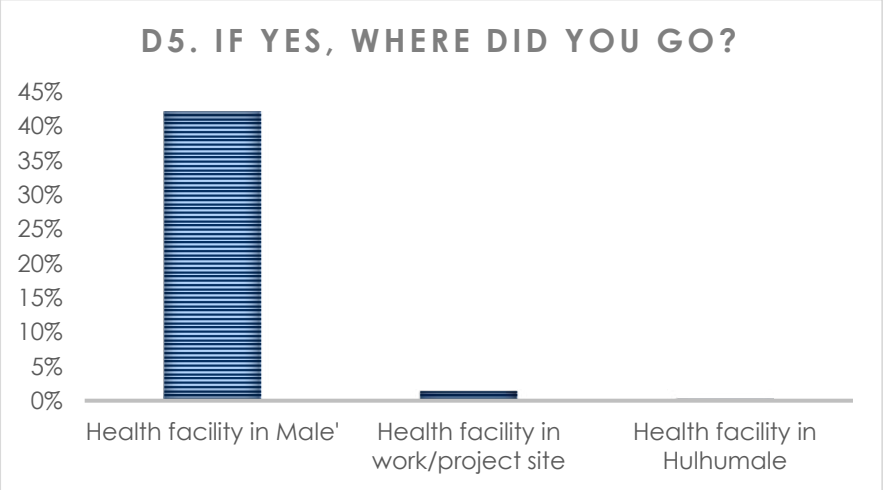
Health Issue	Count
Fever	117
Fever & Cold	10
Body Pain	8
Cold	8
Injury	8
Chikungunya	5
Skin Problem	5
Dengue	4
Breathing Problem	3
Headache	3
Leg/ Hand Pain	4
Tooth Pain	3
Eye / Ear Problem	4
Stomach Pain	3
Throat Pain	2
Allergy	1
Asthma	1
Back Pain	1
Chest Pain	1
Diabetics	1
Hernia	1
High Blood Pressure	1
High Cholestrol	1
Other	1
	196

D4. **Did you see a doctor?**



No	9	2%
Yes	192	44%

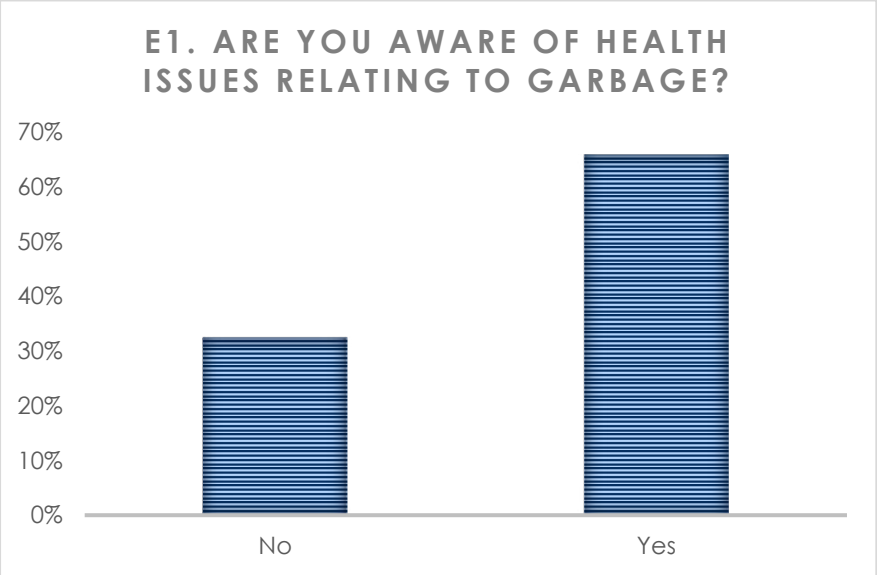
D5. If yes, where did you go?



Health facility in Male'	183	42%
Health facility in work/project site	6	1%
Health facility in Hulhumale	1	0%

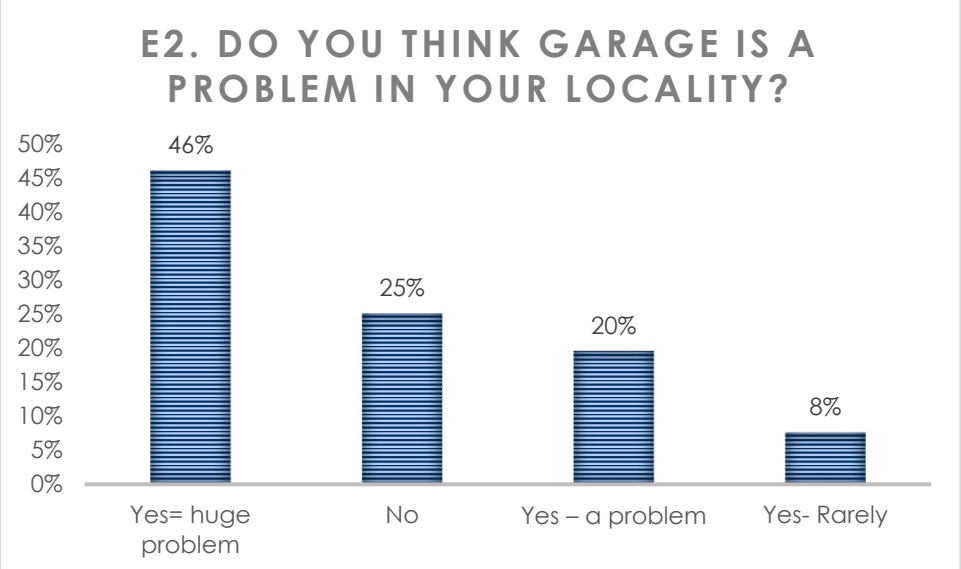
E. SOLID WASTE MANAGEMENT

E1. Are you aware of any health issues relating to garbage/ waste management?



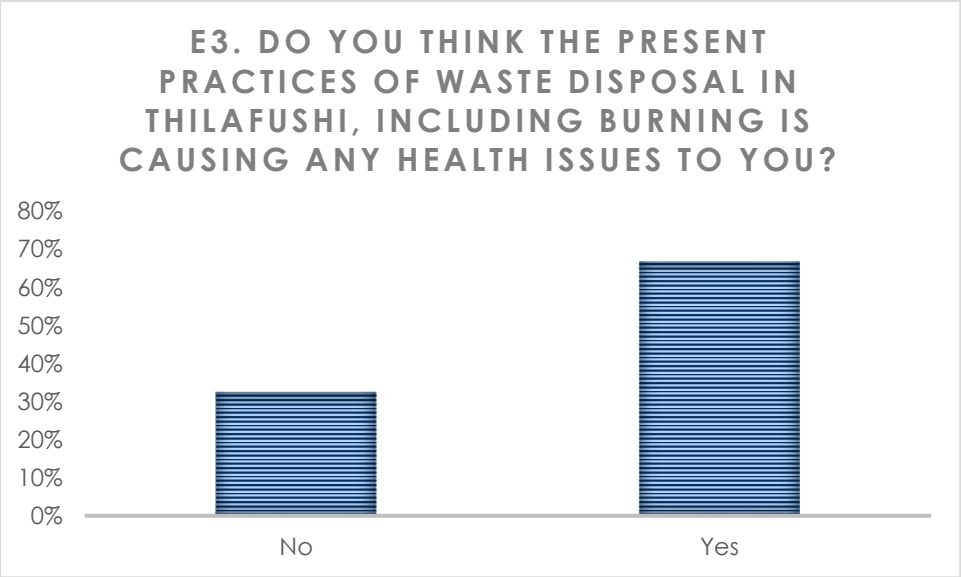
No	141	32%
Yes	286	66%
(blank)	7	2%

E2. Do you think garbage is a problem in your locality?



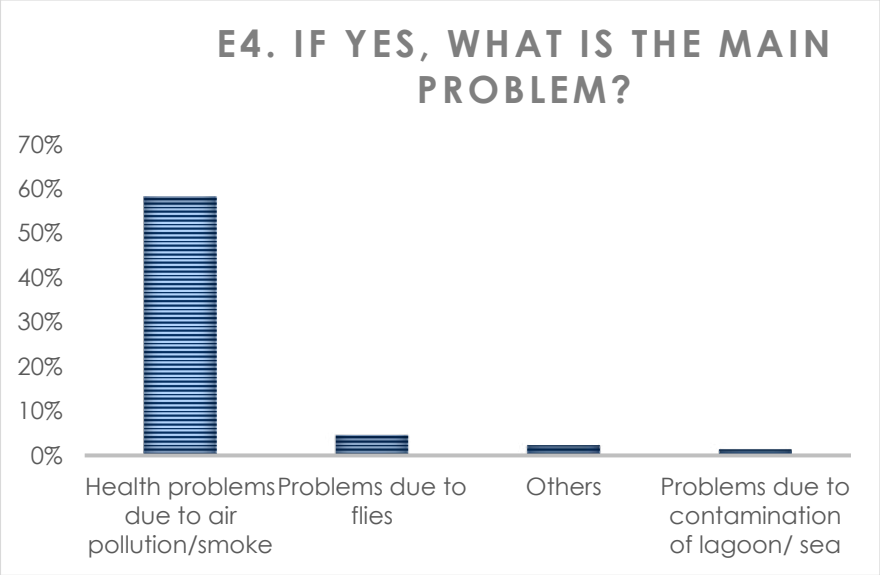
Yes= huge problem	200	46%
No	109	25%
Yes – a problem	85	20%
Yes- Rarely	33	8%
(blank)	7	2%

E3. Do you think the present practices of waste disposal in Thilafushi, including burning is causing any health issues to you?



No	141	32%
Yes	290	67%
(blank)	3	1%

E4/E5. If yes, what are the problems?



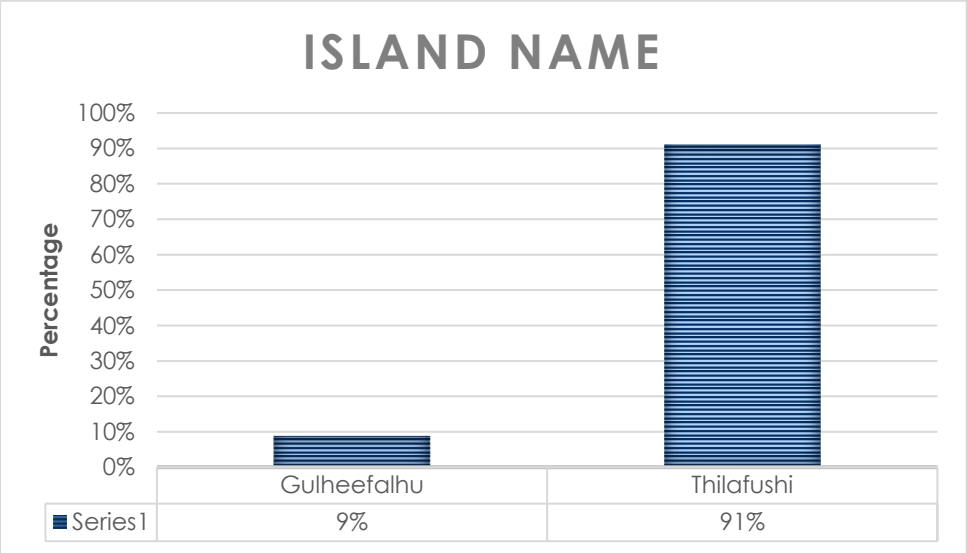
Health problems due to air pollution/smoke	253	58%
Problems due to flies	20	5%
Others	10	2%
Problems due to contamination of lagoon/ sea	6	1%
(blank)	145	33%

APPENDIX E: Graphical representation of data obtained from company survey

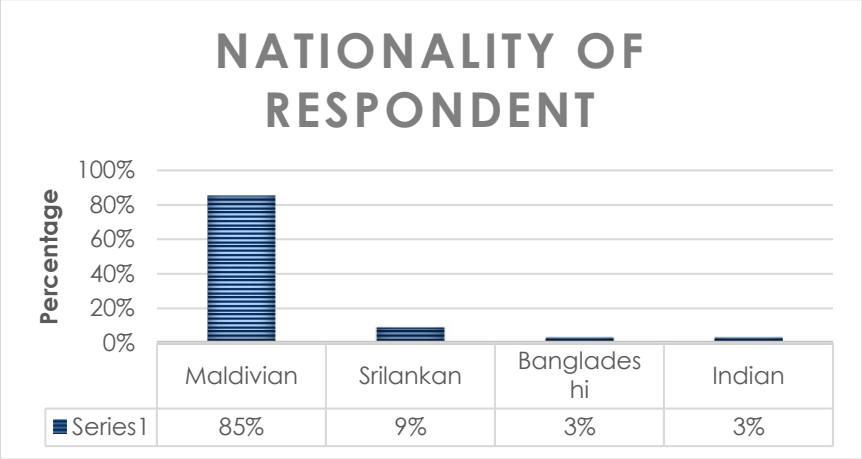
DATA AND GRAPHS – COMPANY SURVEY

A. GENERAL INFORMATION

A2. Island Name



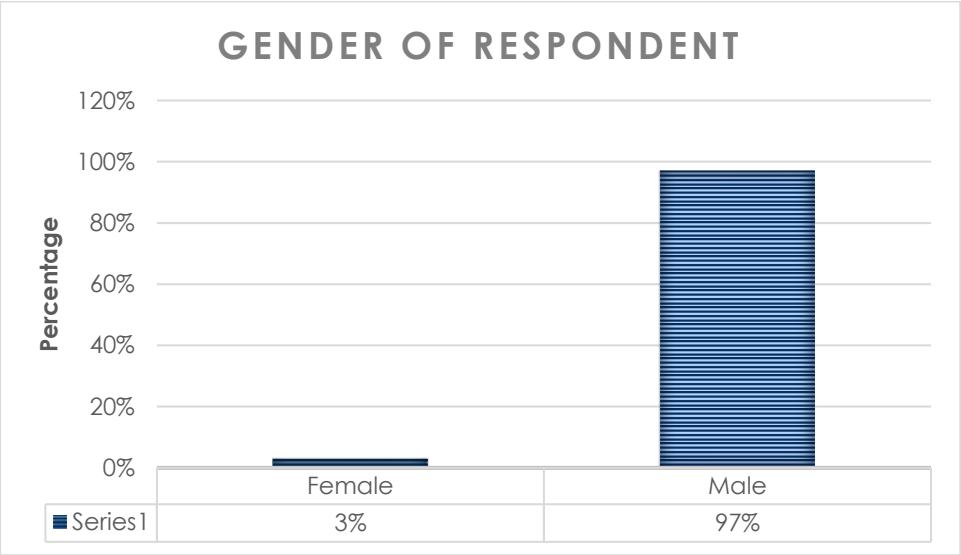
A3 & A4 Nationality (of respondent)



A5. Name of Respondent

(Data not to be disclosed)

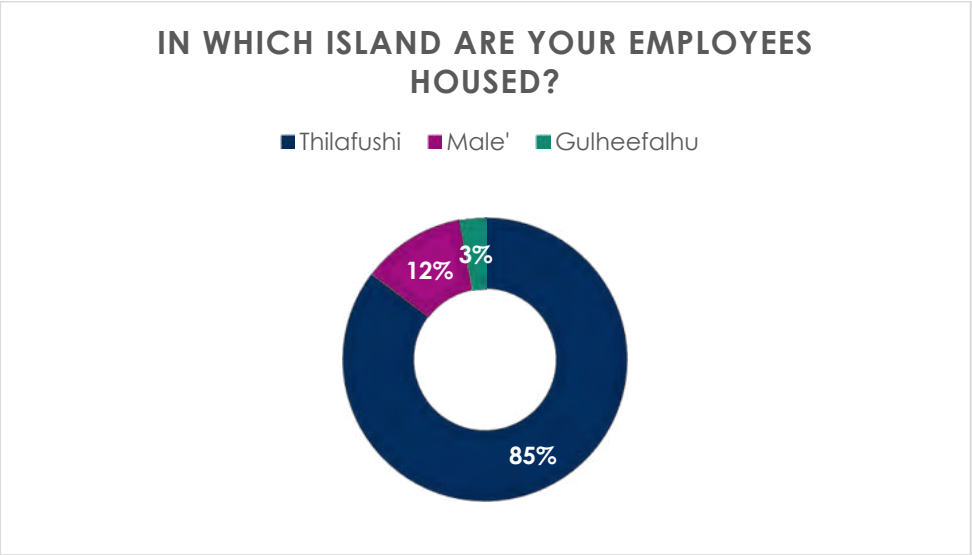
A6. Gender (of respondent)



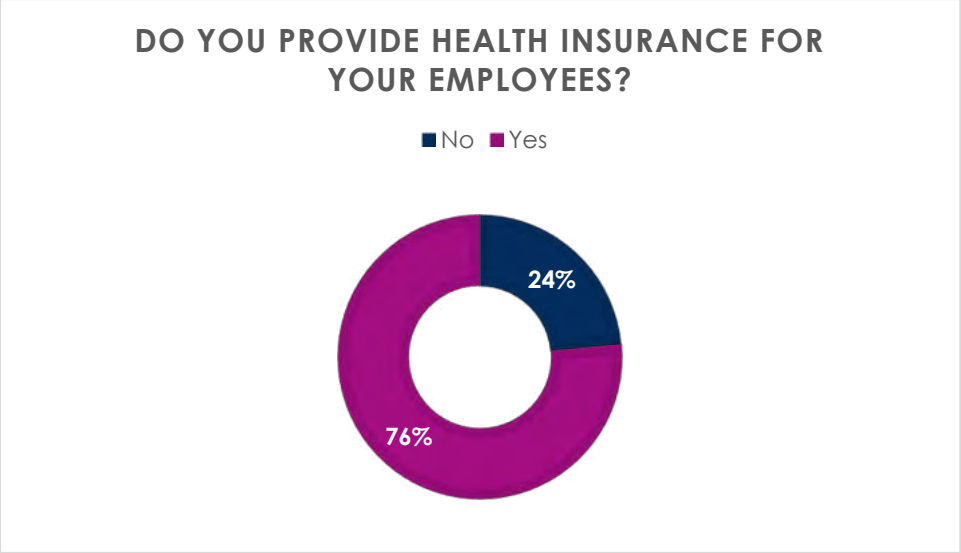
A7, A8 and A9. Company Name, Key Activities and Total Number of Employees

#	A2. Island Name	A7. Company Name	A8. What are the key Activities conducted by the company?	A9. Number of employees?	Gender
1	Thilafushi	Villa Hakatha	Delivery, gas, cement petrol and diesel	130	men
2	Thilafushi	Villa Hakatha F n B	Food and Beverage services, restaurant services	24	men
3	Thilafushi	Batch construction PVT LTD	Warehouse, storing metal, wood and electrical supplies	15	men
4	Thilafushi	Wheel pvt ltd	Leasing tugboats, excavators etc., Repairing and maintenance of vehicles and vessels, Taking projects such as land reclamation	10	men
5	Thilafushi	Mtcc	Warehouse and slipway, boat building and boat repair	180	men
6	Thilafushi	IZ	Workshop	No information	
7	Thilafushi	Eve garment	All works allowed in Thilafushi	No information	
8	Thilafushi	Leo trading	In Thilafushi they have mechanical and technical staff as the main work done there is the maintenance of assets such as landing craft, excavators etc.	47	men
9	Thilafushi	Sony hardware	Warehouse, storing and packaging	200	men
10	Thilafushi	Lafarge Maldives	Cement Factory	No information	
11	Thilafushi	MALDIVE GAS	LPG filling	29	men
12	Thilafushi	WAMCO	Solid waste management services, conduct clean up programs	150	men
13	Thilafushi	Mpl thilafushi	Boat building and boat repair, vehicle garage	35	men
14	Thilafushi	Dhamas	warehouse and workshop, vehicle repair and garage, warehouse	No information	
15	Thilafushi	Nalahiya trahiya trading pvt ltd	Warehouse for constuction materials	200	men
16	Thilafushi	Maldives Structural Product MSP	manufacturing roofing products, corrugated iron sheets	15	men
17	Thilafushi	Raajje logistics pvt ltd	Logistics Work, Transportaion sea and land	33	men
18	Thilafushi	Leo Trade	Logistics work	33	men
19	Thilafushi	Sunfront	Repairing boats and logistics	25	men
20	Thilafushi	Static company (aqua reef)	Water plant and electrical work	19	men
21	Thilafushi	The Hawks	Oil supplier; boatyard for loading, unloading and repair; port harbour; workshop,	120	men
22	Thilafushi	Metco	Garage	5	men
23	Thilafushi	Thilafalhu cafe	Tea shop	7	men
24	Thilafushi	Heavy Force	Repair n maintenance of heavy vehicles, Precast Yard.	35	men
25	Thilafushi	Antrac (maldives petroleum	Heavy vehicles are rented out, sell diesel oil, have 3 landing crafts	28	men
26	Thilafushi	Gulf craft	Boat building n repair	130	1 woman
27	Thilafushi	Maldives police services	Serve and protect	25	men
28	Thilafushi	Best dives ptv ltd	Boat yard, engine repair	12	men
29	Thilafushi	Build Maldives Company	Ship Repair and maintenance	24	men
30	Gulheefalhu	Stelco	Provide electricity	6	men
31	Gulheefalhu	GMIZ	Manage all services related to tenants including municipal services such as road maintenance, land lease, and conflict resolution. Tree plantation to make the island green	35	men
32	Gulheefalhu	Litus	Storage and workshop	15	men
33	Thilafushi	Apollo	Loading and unloading cargo	230	men
34	Thilafushi	GMIZ	Tenants related all municipal service including road works; Conflict resolution; land leasing and monitoring	155	men

A10. In which island are your employees housed?



A11. Do you provide health insurance for your employees?

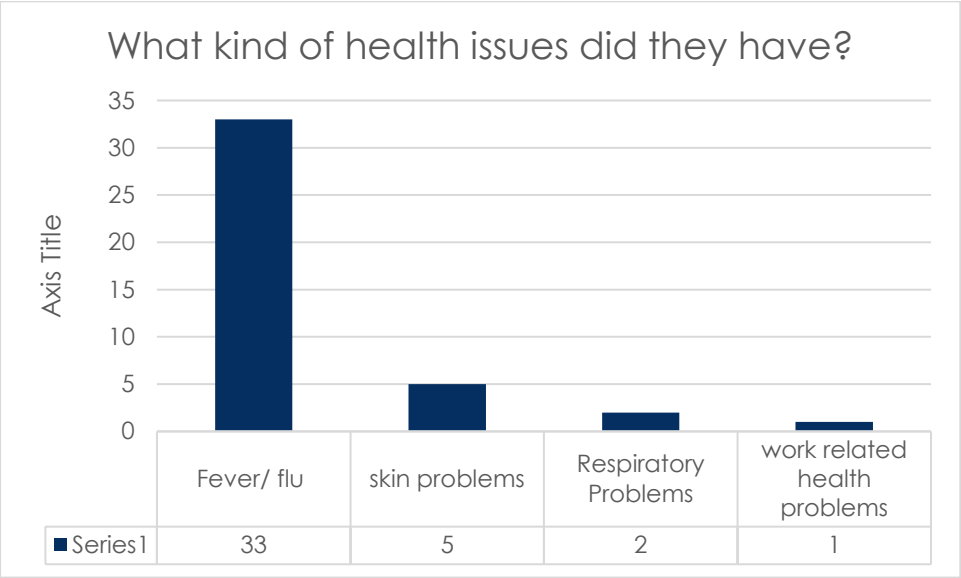


Note: Maldivian Nationals have access to the Government Health Insurance Scheme – Aasandha.

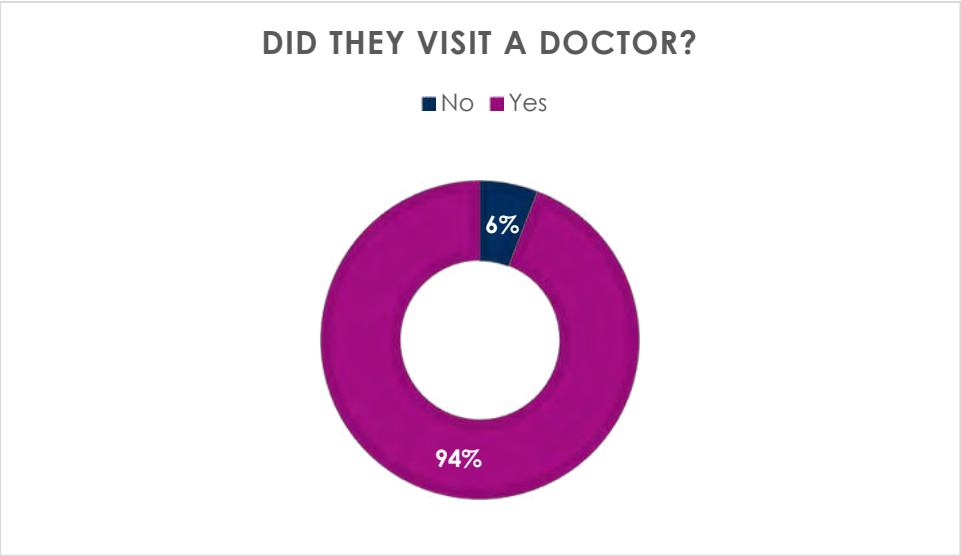
A12. How many of your employees have reported sick in the past year?

	A2. Island Name	A7. Company Name	A9. Total number of employees?	A12. How many of your employees have reported sick in the past year?
1	Thilafushi	Villa Hakatha	130	60
2	Thilafushi	Villa Hakatha F n B	24	10
3	Thilafushi	Batch construction PVT LTD	15	1
4	Thilafushi	Wheel pvt ltd	10	25
5	Thilafushi	Mtcc	180	6
6	Thilafushi	IZ	no information provided	2
7	Thilafushi	Eve garment	no information provided	20
8	Thilafushi	Leo trading	47	10
9	Thilafushi	Sony hardware	200	60
10	Thilafushi	Lafarge Maldives	no information provided	2
11	Thilafushi	MALDIVE GAS	29	3
12	Thilafushi	WAMCO	150	25
13	Thilafushi	Mpl thilafushi	35	3
14	Thilafushi	Dhamas	no information provided	11
15	Thilafushi	Nalahiya trahiya trading pvt ltd	200	4
16	Thilafushi	Maldives Structural Product MSP	15	5
17	Thilafushi	Raajje logistics pvt ltd	33	5
18	Thilafushi	Leo Trade	33	25
19	Thilafushi	Sunfront	25	25
20	Thilafushi	Static company (aqua reef)	19	16
21	Thilafushi	The Hawks	120	36
22	Thilafushi	Metco	5	25
23	Thilafushi	Thilafalhu cafe	7	5
24	Thilafushi	Heavy Force	35	10
25	Thilafushi	Antrac (maldives petroleum	28	4
26	Thilafushi	Gulf craft	130	80
27	Thilafushi	Maldives police services	25	24
28	Thilafushi	Best dives ptv ltd	12	4
29	Thilafushi	Build Maldives Company	24	20
30	Gulheefalhu	Stelco	6	6
31	Gulheefalhu	GMIZ	35	10
32	Gulheefalhu	Litus	15	2
33	Thilafushi	Apollo	230	90
34	Thilafushi	GMIZ	155	60

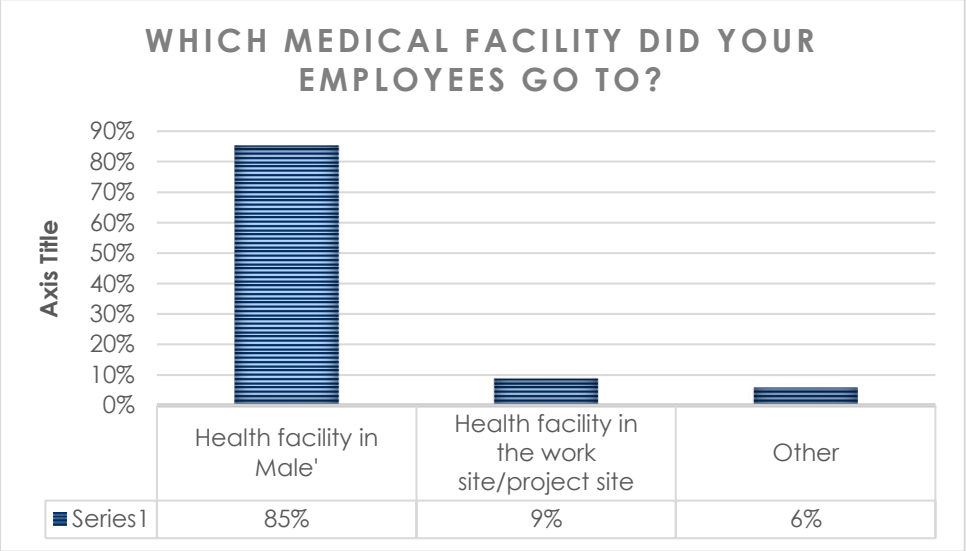
A13. What kind of health issues did they have? (please provide a list if you have one)



A14. Did they visit a doctor?



A15. If yes to A14, Where did they go?



A16. What is the average annual cost for healthcare services for your employees? (in MVR)

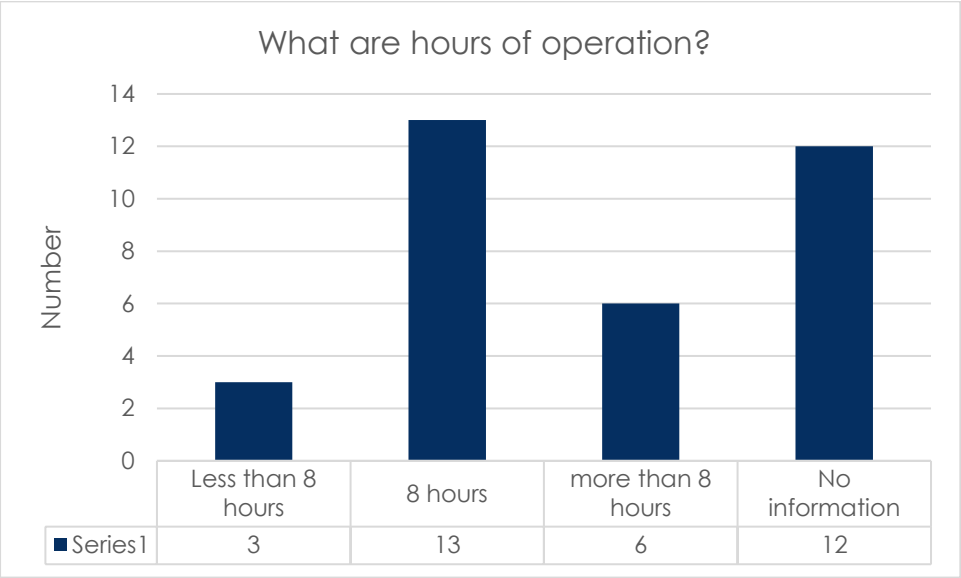
This information was provided by 8 companies.

	Island Name	Company Name	Annual cost for healthcare
1	Thilafushi	Wheel pvt ltd	45000
2	Thilafushi	Leo trading	300000 to 400000
3	Thilafushi	Sony hardware	400000
4	Thilafushi	MALDIVE GAS	66700
5	Thilafushi	Nalahiya trahiya trading pvt ltd	8400
6	Thilafushi	Maldives Structural Product MSP	8250
7	Thilafushi	Heavy Force	350000
8	Thilafushi	Antrac (maldives petroleum	28000 (company pays MVR1000 per person) employee pays MVR1000 (annually)

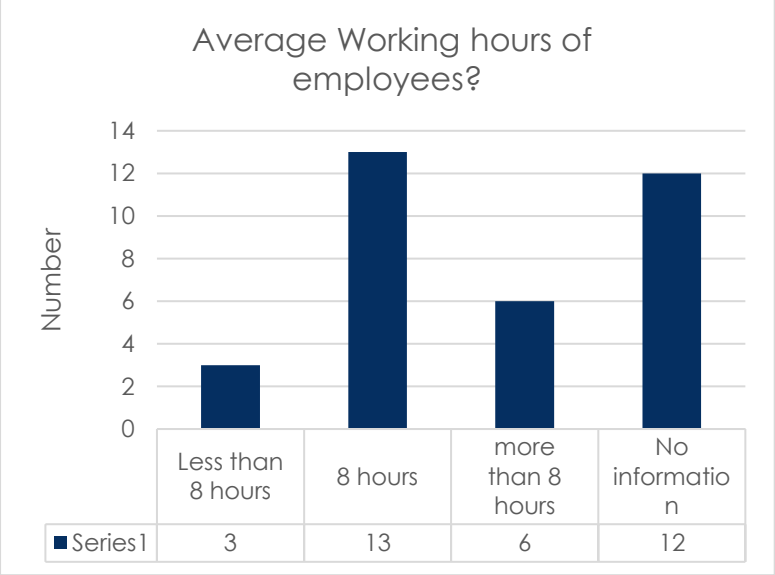
A17. What are the range of salaries of your employees?

None of the companies provided this information

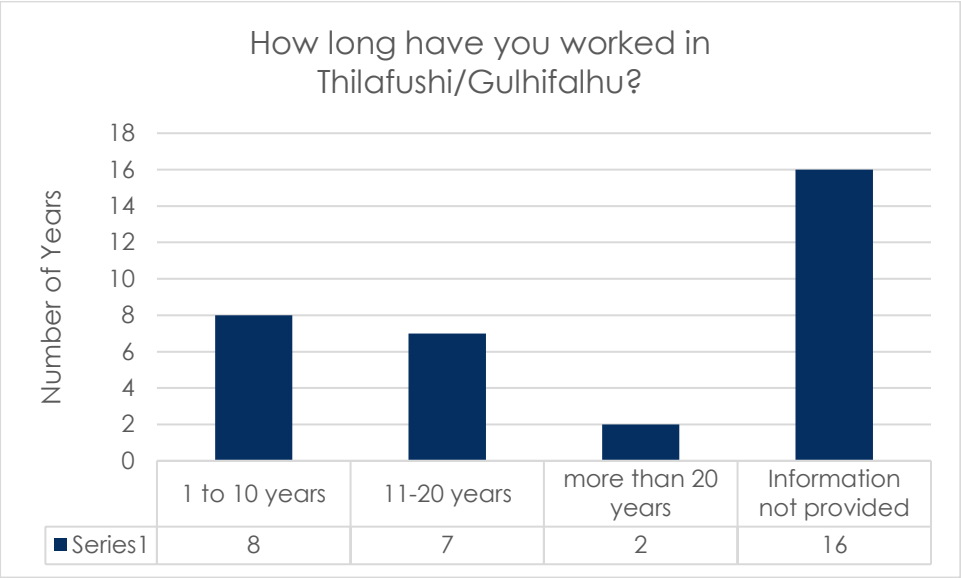
A18. What are the hours of operation?



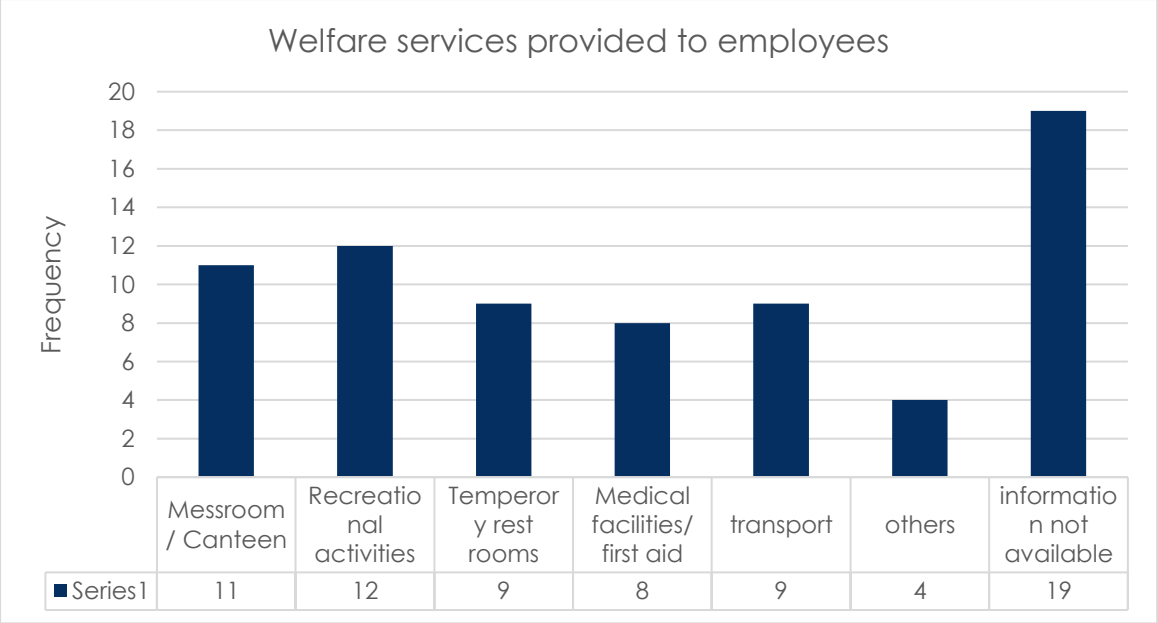
A19. What are the average working hours of your employees?



A20. When did you start operations in Thilafushi/ Gulhifalhu?



A21. Specify the types of employee welfare facilities provided by your company



A22. Do you provide your employees with life insurance?

None of the companies provide life insurance to their employees

A23. Do you provide your employees with disability insurance?

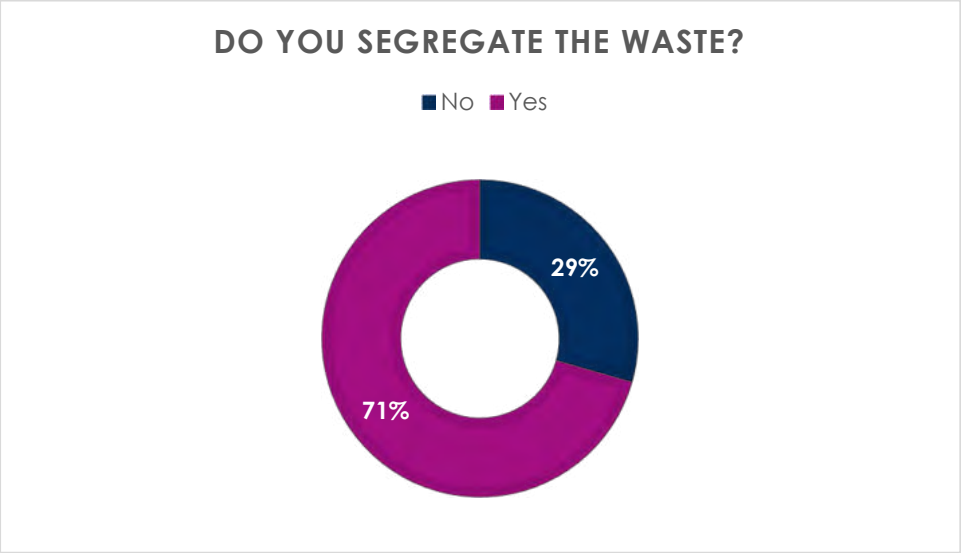
None of the companies provide disability insurance to their employees

A24. What are the company's main assets? Can you provide details?

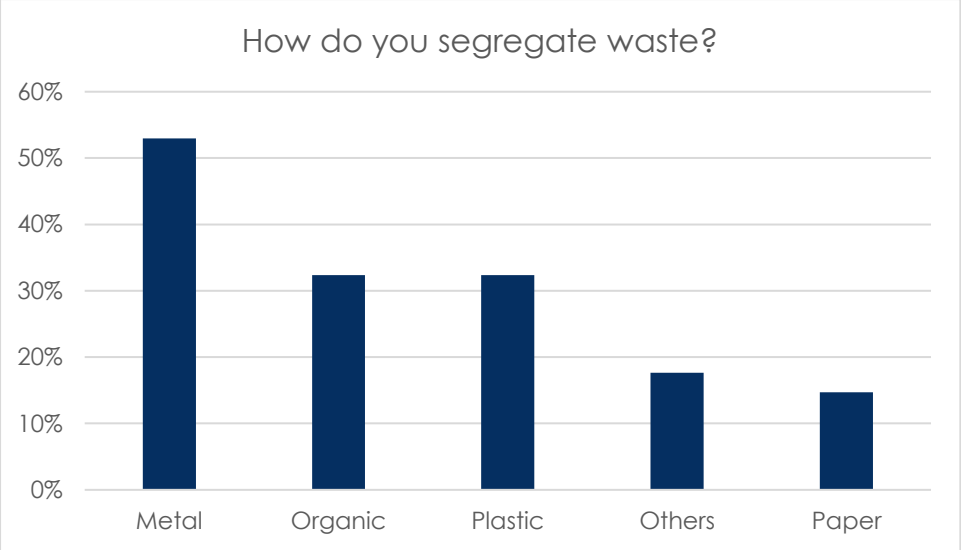
Only two companies provided details

F. SOLID WASTE MANAGEMENT

B1. Do you segregate the waste?



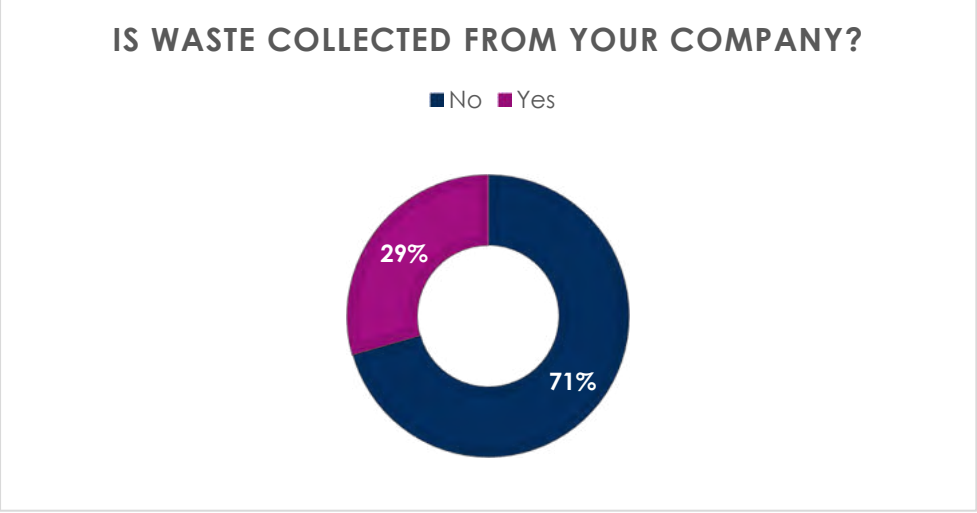
B2 and B3 How do you segregate waste?



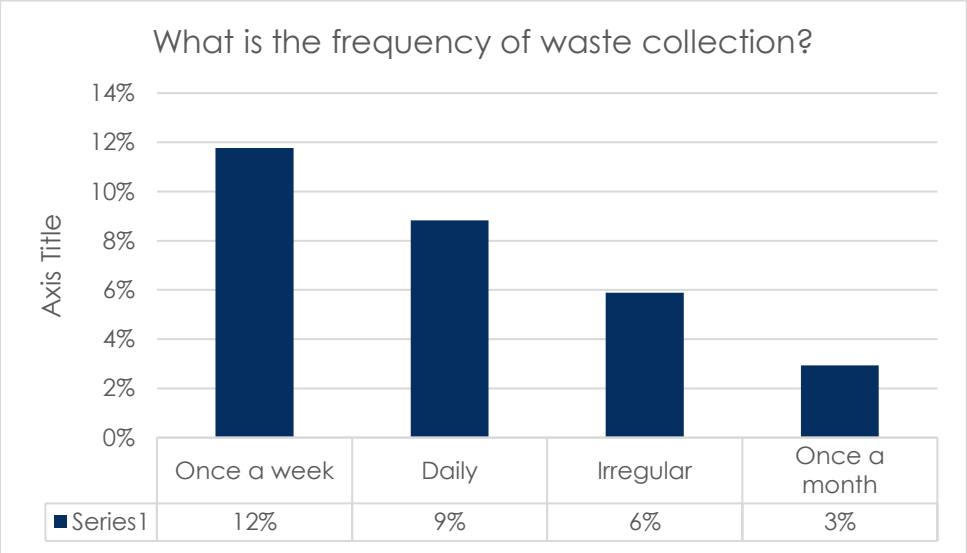
B4. Have you received any training and assistance in waste segregation?

B6. Do you sell recyclable waste?

B7. Is waste collection door to door/ from the company premises?



B8. If yes to B7, what is the frequency of waste collection?



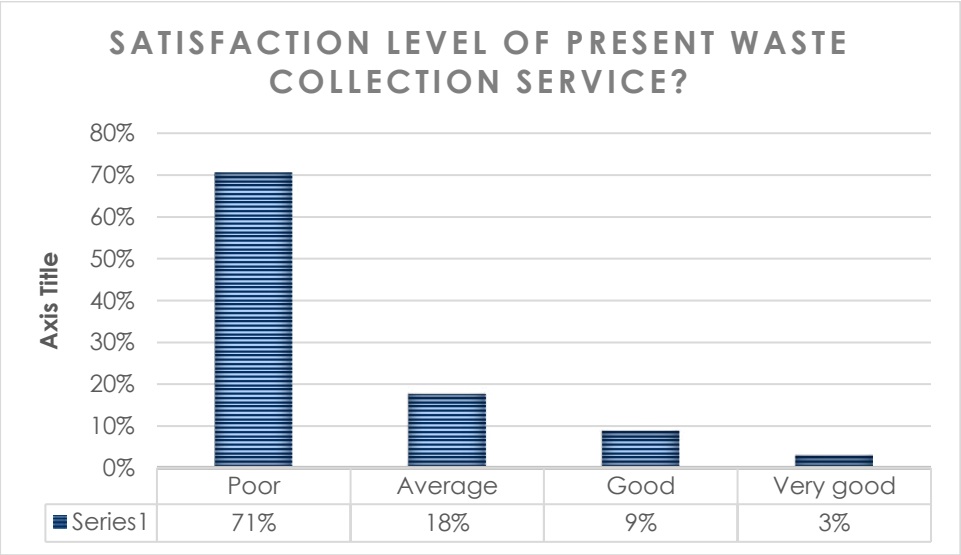
B9 and B10. Who is responsible for waste collection?

B11. Do you pay for waste collection/ disposal service?

B12. How much do you pay for monthly waste collection (in MVR)

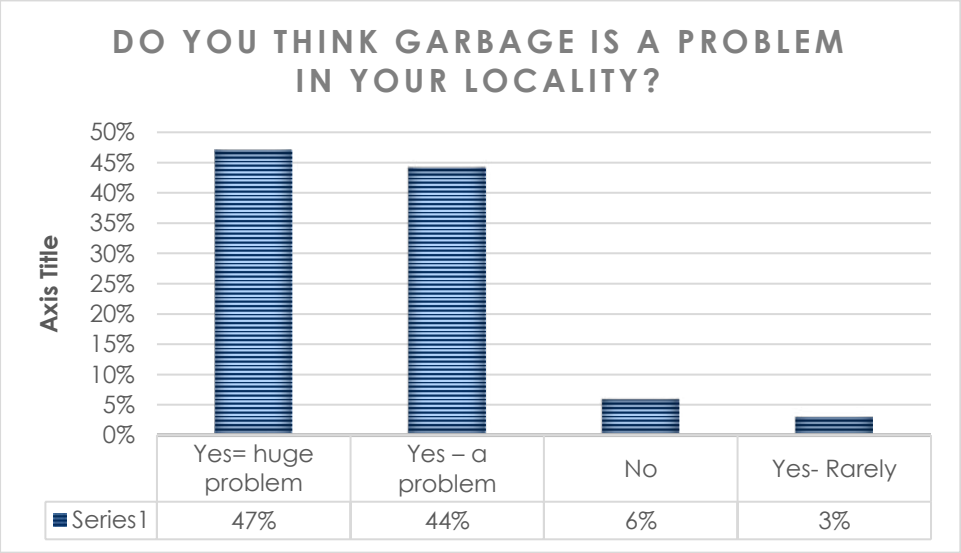
Amount in MVR	Sum of Count
(blank)	1
0-499	14
500-999	2
1000-1499	1
1500-1999	4
2000-2499	5
2500-2999	2
4000-4499	1
6000-6499	1
7000-7499	1
14000-14499	1
19000-19499	1
19500-20000	1
	35

B13. Satisfaction level of present waste collection/ management service?

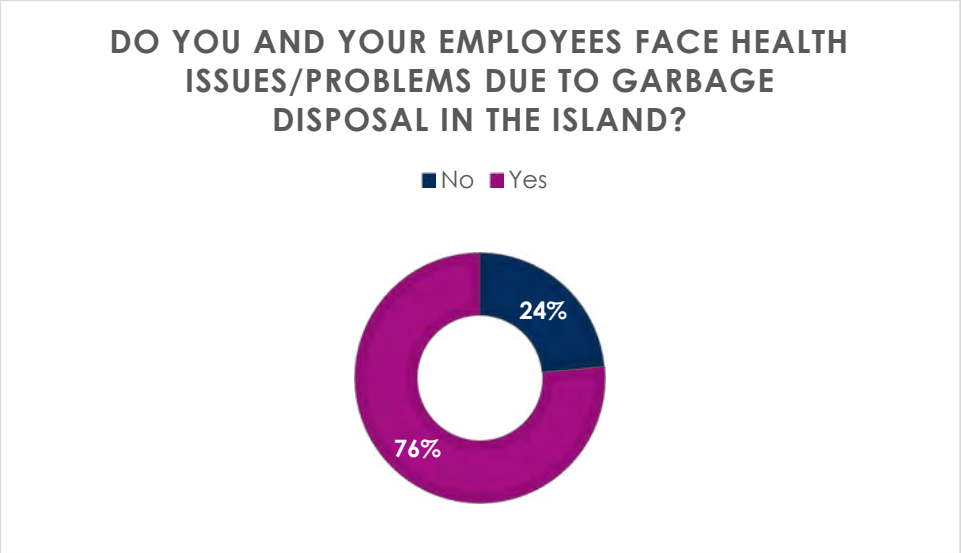


B14. Do you feel the present monthly charge for waste collection is:

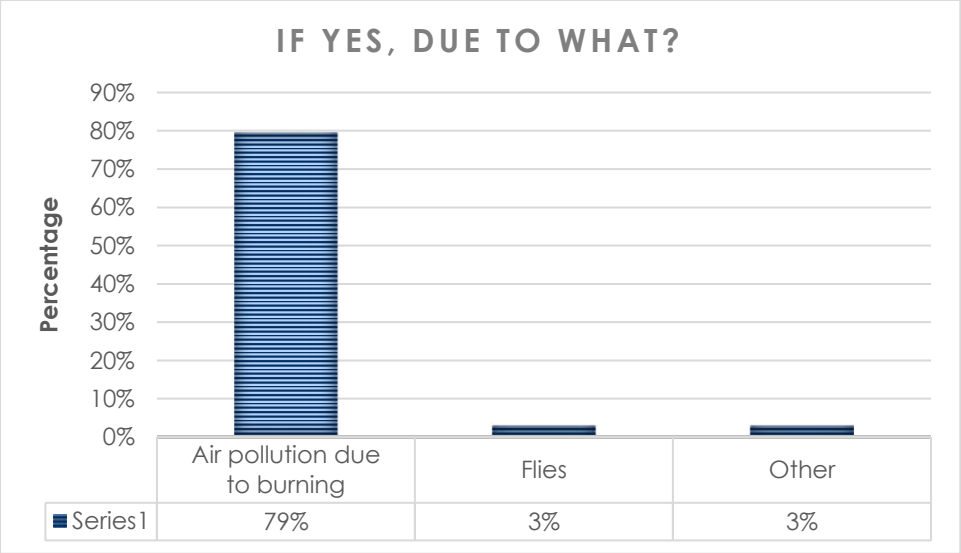
B15. Do you think garbage is a problem in your locality?



B16 and B17. Do you and your employees face health problems/ issues due to the present practices of waste disposal in Thilafushi, including burning?

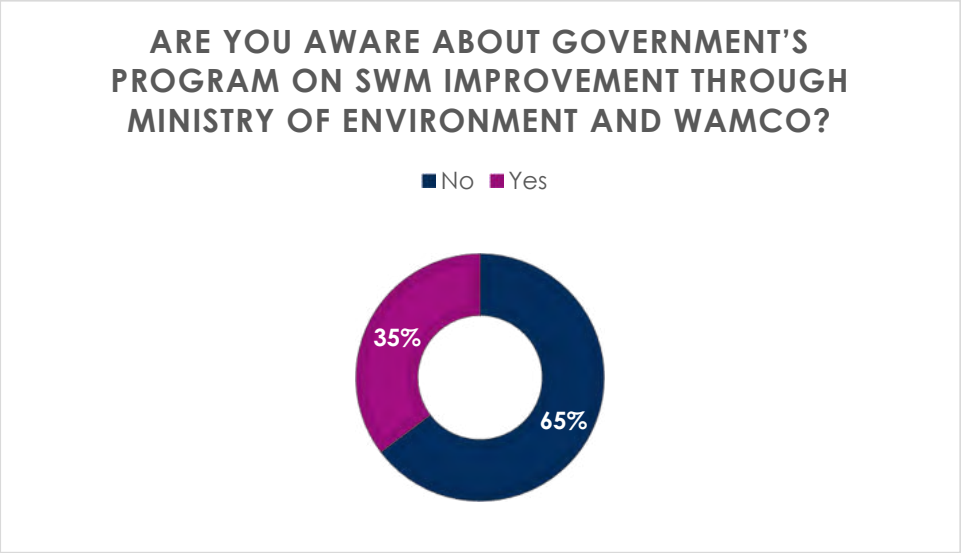


If yes to B16, due to what?

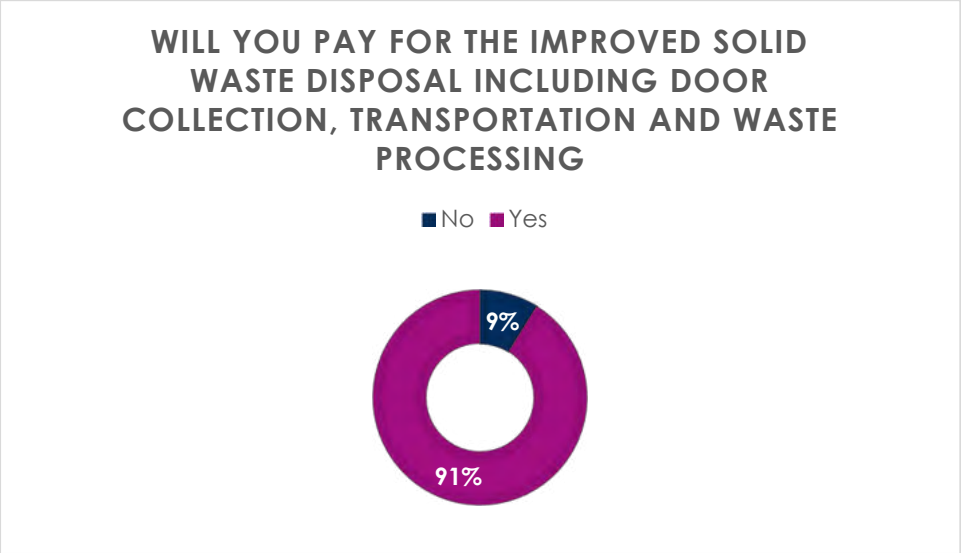


B18. Do you think community level trainings in solid waste management will be beneficial?

B19. Are you aware about Government's program on SWM improvement through Ministry of environment and WAMCO?



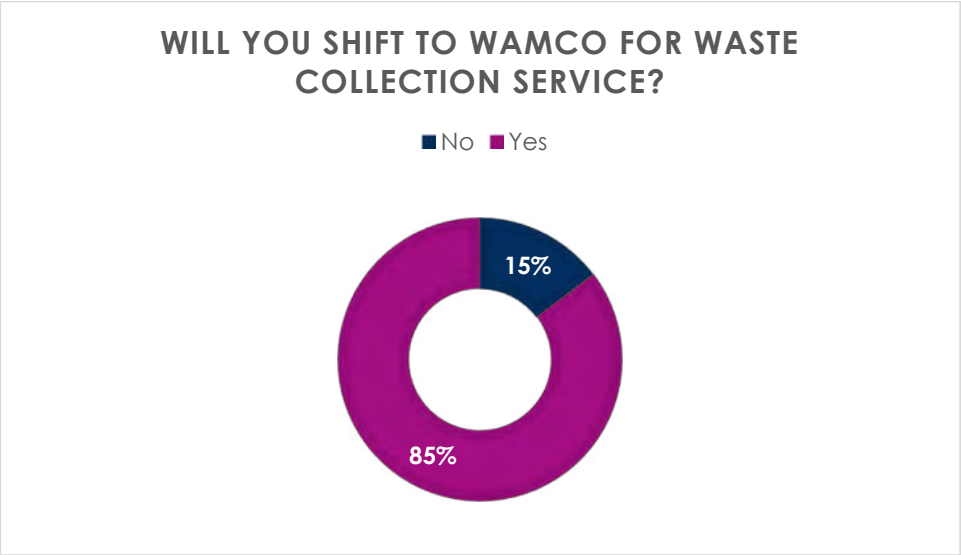
B20. Will you pay for improved solid waste disposal including door collection, transportation and waste processing?



B21. If yes to B20, how much would you be willing to pay for improved waste collection and waste management services?

Amount in MVR	Sum of Count
<0 or (blank)	19
0-499	3
500-999	3
1000-1499	4
1500-1999	1
2000-2499	2
5000-5499	2
39500-40000	1
Grand Total	**35**

B22 and B23. Will you shift to WAMCO for waste collection service?



B24. What are the socio-economic problems face by your employees? Any other suggestions/ comments?

	Island Name	Company Name	What are the socio-economic problems faced by your employees? Any other suggestions or comments?
1	Thilafushi	Villa Hakatha	No comments
2	Thilafushi	Villa Hakatha F n B	Conduct surveys annually to assess
3	Thilafushi	Batch construction PVT LTD	Health issues
4	Thilafushi	Wheel pvt ltd	No comments
5	Thilafushi	Mtcc	No comments
6	Thilafushi	IZ	No water and electricity
7	Thilafushi	Eve garment	No comments
8	Thilafushi	Leo trading	No comments
9	Thilafushi	Sony hardware	Yes. Food services are not so good, no regulations on road safety, parking
10	Thilafushi	Lafarge Maldives	No comments
11	Thilafushi	MALDIVE GAS	No comments
12	Thilafushi	WAMCO	No comments
13	Thilafushi	Mpl thilafushi	Heard about possible other issues. But no choice. Need to work here
14	Thilafushi	Dhamas	Infrastructure, roads, no lights at night. No security fo vehicles, parking space, abandoned vehicles, rule of law and order.
15	Thilafushi	Nalahiya trahiya trading pvt ltd	Healh services only recently established, road conditions
16	Thilafushi	Maldives Structural Product MSP	Ferry schedule regularly; taxi services; garbage per tonne of the lorry
17	Thilafushi	Raajje logistics pvt ltd	Waste disposal while transferring loads
18	Thilafushi	Leo Trade	Smoke I inhalation is their main problem, no proper sewage, poor road conditions during rainy season
19	Thilafushi	Sunfront	Waste disposal into the sea can be quite problematic as difficult for boats to come near the jetty for loading n unloading goods
20	Thilafushi	Static company (aqua reef)	Mainly smoke inhalation is their main concern
21	Thilafushi	The Hawks	Fighting;Illegal ppl; drinking; Banking problem; emergency ferry/boat system;;emergency med
22	Thilafushi	Metco	No comments
23	Thilafushi	Thilafalhu cafe	No comments
24	Thilafushi	Heavy Force	Smoke, roads, emergency transport
25	Thilafushi	Antrac (maldives petroleum	No electricity no water or sewage system at the present moment, the road conditions are bad, staff live in newly reclaimed land area and no electricity from main grid is not available, company provides generators and water is carried to site for staff to use. Smoke from burning waste is the main issue.
26	Thilafushi	Gulf craft	Waste gets washed from the ocean into our facility. Seasonal problems are there, during one season flies would be a hazard. During some days smoke is so thick the person standing next to you is not visible.
27	Thilafushi	Maldives police services	Nil
28	Thilafushi	Best dives ptv ltd	Nil
29	Thilafushi	Build Maldives Company	No infrastructure, road lights, road building not provided
30	Gulheefalhu	Stelco	Ferry timing a d the transportation is quite difficult
31	Gulheefalhu	GMIZ	Wamco to pick garbage twice monthly
32	Gulheefalhu	Litus	No comments
33	Thilafushi	Apollo	Waste management is a hazard! The governemnt should solve it as soon as possible
34	Thilafushi	GMIZ	Waste management is a hazard; WAMCO should not charge government for waste management as they have been allocated a plot of land; maybe a nominal fee; drug and prostitution was a problem but not that we have Police and they are patrolling 24/7 problems are minimised; should be given risk allowance for people working here

Republic of Maldives

Ministry of Environment and Energy

Consultancy Services for Feasibility Study for an Integrated Solid Waste Management System for Zone III (including Greater Male') and Preparation of Engineering Design of the Regional Waste Management Facility at Thilafushi

Saafu Raaje Zone III Integrated Waste Management System

Environmental and Social Impact Assessment for the Regional Solid Waste Management Facility (RSWMF) Thilafushi

Chapter on Air quality (2nd revision of 18.09.2019)

Date:	18/09/2019
Prepared by:	Ahmed Jameel
Checked by:	Chakir Kasdarli

Revision History

Revision	Details	Date	Initial
01	Completion of section 7.4 and 9	12/09/2019	AJ
02	Revised version after ADB comments of 16.09.2019	18/09/2019	AJ

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List of units, abbreviations and acronyms

Abbreviations and acronyms	
ADB	Asian Development Bank
ADM	Air dispersion modelling
AQMA	Air Quality Management Area
AQO	Air Quality Objective
As	arsenic
Cd	cadmium;
CO	carbon monoxide
Cr	chromium
CrVI	chromium VI
Cu	copper
DBO	Design-Build-Operate
GOM	Government of Maldives
GM	Greater Male’
EAL	Environmental Assessment Level
ELV	Emissions Limit Value
EU	European Union
HCl	hydrogen chloride
HF	hydrogen fluoride
Hg	mercury
HSE	Health, Safety, Environment
IED	Industrial Emissions Directive
IFC	International Finance Corporation
IWM	Integrated waste management
MOE	Ministry of Environment
MSL	Mean Sea Level
MSW	Municipal Solid waste
NH3	ammonia
Ni	nickel
NO2	nitrogen dioxide

NOx	nitrogen oxides
Pb	lead
PM_{10}	fine airborne particulate matter with an aerodynamic diameter of less than 10 micrometers
$PM_{2.5}$	fine airborne particulate matter with an aerodynamic diameter of less than 2.5 micrometers
RSWMF	Regional Solid Waste Management Facility
Sb	antimony
SBD	Standard Bidding documents
SO2	sulphur dioxide
SWM	Solid Waste Management
TA Luft	First General Administrative Regulation Pertaining the Federal Immission Control Act (Technical Instructions on Air Quality Control in the following document as *"TA Luft"*
TOC	Total Organic Carbon
TPD	Tonnes Per Day
V	vanadium
VDI	Verein Deutscher Ingenieure (German Engineer Association)
VOCs	Volatile Organic Compounds;
WHO	World Health Organisation
WTE	Waste to Energy
Units	
µm	micrometre: 1 µm = 0.001 mm
mm	millimetre: 1 mm = 0.001 m
m	metre: 1 m = 0.001 km
km	kilometre
m^2	square metre
ha	hectare: 1 ha = 10,000 m^2
l	litre: 1 l = 0.001 m^3
m^3	cubic metre
ng	nanogram: 1 ng = 0.001 µg
µg	microgram: 1 µg = 0.001 mg
mg	milligram: 1 mg = 0.001 g

g	gram: 1 g = 0.001 kg
kg	kilogram: 1 kg = 0.001 Mg (t)
Mg	megagram (same as t: tonne)
s	second
h	hour
d	day (calendar day)
a	year
°C	degrees Celsius
K	Kelvin
Pa	pascal: 1 Pa = 0.01 mbar (millibar)
kPa	kilopascal: 1 kPa = 1,000 Pa
MPa	megapascal: 1 MPa = 1,000,000 Pa
kJ	kilojoule
kWh	kilowatt hour: 1 kWh = 3,600 kJ
MW	megawatt
OU	odour unit
OU/m3	odorous substances concentration
LU	livestock unit (1 livestock unit equals an animal live weight of 500 kg)

Glossary

Immissions	Immissions shall be air pollutants affecting humans, animals, plants, soil, water, the atmosphere, cultural assets and any other property. Immissions shall be indicated as follows: a) Mass concentration, as mass of air pollutant per unit volume of polluted air; for gaseous substances, mass concentrations are to be referenced to 293.15 K and 101.3 kPa. b) Deposition, as mass of pollutant per unit area of ground per unit time. Synonym of immission : Ambient air quality
Immission Indicators,	Immission indicators describe the initial load, the additional load or the total load of the respective air pollutant. The initial load shall describe the pre-existing load of a pollutant. The additional load shall characterise the concentrations, which can be expected to be caused (for planned installations) or which are actually caused (for existing installations) by the planned project. With respect to planned installations, the indicator for the total load shall be calculated on the basis of the initial load plus the additional load indicators. With respect to existing installations, this indicator equals the initial load.
Assessment Points,	Assessment points shall be those points in the vicinity of an installation for which immission indicators, indicative of the total load, are determined.
Grid Points	Grid points shall be those points in the vicinity of an installation for which the additional load is calculated (immission projection).
Immission Values also known as immission rate or ambient air values	The annual immission value shall be the concentration or deposition value of a substance averaged over one year. The daily immission value shall be the concentration value of a substance averaged over one calendar day, taking into account the respective frequency limit for excess values (number of days) over one year. The hourly immission value shall be the concentration value of a substance, averaged over a whole hour (e.g., from 8 a.m. to 9 a.m.), taking into account the respective frequency limit for excess values (number of hours) over one year.
Waste Gas Volume and Waste Gas Volumetric Flow Rate	Waste gases shall be carrier gases with solid, liquid or gaseous emissions. any data regarding the waste gas volume and the waste gas volumetric flow rate are referenced to standard conditions (273.15 K and 101.3 kPa) after subtraction of the water vapour content unless explicitly indicated otherwise
Emissions	Emissions shall be air pollutants originating from an installation. Emissions shall be indicated as follows: a) mass of substances or groups of substances emitted as related to the volume (mass concentration) aa) of waste gas under standard conditions (273.15 K and 101.3 kPa) after subtraction of the water vapour content, bb) of waste gas (wet) under standard conditions (273.15 K and 101.3 kPa) before subtraction of the water vapour content, b) mass of substances or groups of substances emitted per unit time as a mass flow (emitted mass flow); the mass flow is the total emission occurring in one hour of normal operation of an installation under operating conditions which are most unfavourable to the maintenance of air quality;

	c) quantity of fibres emitted (fibre dust concentration), as related to the volume of waste gas under standard conditions (273.15 K and 101.3 kPa) after subtraction of the water vapour content; d) ratio of the mass of emitted substances or groups of substances to the mass of products generated or processed or to stocking density (emission factor); the mass ratio shall take into account the total emissions from the installation occurring over one day of normal operation of such installation under operating conditions most unfavourable to the maintenance of air quality; e) amount of Odour Units of odorous substances emitted, as related to the volume (odorous substances concentration) of waste gas at 293.15 K and 101.3 kPa before subtraction of the water vapour content; the odorous substances concentration is the olfactometrically-measured ratio of volume flows when diluting a waste gas sample with neutral air down to the odour threshold, indicated as a multiple to the odour threshold.
Emission Ratio	The emission ratio shall be the ratio of the mass of an air pollutant emitted in waste gas to the mass of supplied fuels or input materials; it shall be provided as a percentage.
Emission Reduction Ratio	The emission reduction ratio shall be the ratio of the mass of an air pollutant emitted in waste gas to its mass supplied in crude gas; it shall be provided as a percentage. The odour reduction ratio is an emission reduction ratio.
Emission Standards and Emission Limits	Emission standards shall provide the basis for emission limits. The emission limits shall be established in the letter of permit or in a subsequent order as a) permissible fibre dust, odorous substances or mass concentrations of air pollutants in waste gas provided that aa) any daily mean values do not exceed the established concentration level and bb) any half-hourly mean values do not exceed twice the established concentration level, b) permissible mass flows, as related to one hour of operation, c) permissible mass ratios, as related to one day (daily mean values), d) permissible emission ratios, as related to one day (daily mean values), e) permissible emission reduction ratios, as related to one day (daily mean values), or f) any other requirements to provide precaution against harmful effects of air pollutants on the environment.

Consultation/Comments & answers matrix

Following the ADB mission held in Male' between the 04-08.08.2019 the following questions and comments have been addressed to the consultant:

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
AQ1	Need for robust baseline data to inform air quality modelling and to confirm airshed status	(new comments)	Update: Further air quality monitoring is reported as being currently in progress ('Air quality and air dispersion modelling report 190828' page 41), which is welcomed. The measurements made during this period should be analysed and assessed against the relevant limit values to determine background conditions and whether the location should be treated as a degraded airshed.	Please see updated Chapter 7.4. It could not be clearly determined whether the location should be treated as a degraded airshed or not. The site is clearly influenced by the adjacent dumpsite and its open burning. (see Chapter 7.4)
AQ2	Impact of the proposed facility on air quality	(new comments)	Update: AQ2 comments remain valid. The new report 'Air quality and air dispersion modelling report 190828' is unfinished, but does not refer to the EHS requirement for the contribution from a facility to account for less than 25% of the air quality standard/guideline. When baseline air quality data are available, the assessment results should be reinterpreted in the light of these requirements.	Please see Chapter 8.4. It is obvious that new facilities emissions are far below the EHS requirements. The main problematic is the ambient baseline condition which is mainly influenced by the dumpsite and which contributes to a temporary degraded airshed.
AQ3	Required assessment of average emission limit values for heavy metals	(new comments)	Update: these substances are now all listed in Table 6 (p44). These substances have been considered in the assessment, at least at the preliminary screening stage. The assessment states (p51) that "In the calculation, the heavy metal nickel was considered representative of the group of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel". The reason for limiting the assessment to nickel is not explained. The assessment for all substances listed above should be clearly set out. The new report also states that: 'For ammonia and hydrogen chloride (5.2.4 Class III TA Luft), for carbon	For the calculation at the assessment point the emission value for Nickel was considered as 0,5 mg/m³ which is the emission threshold value for all heavy metals (Antimony, chromium, copper, margan, vanadium, tin, lead, cobalt and nickel) which means we are considering a worst case.

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
			monoxide, for organic substances (expressed as total C) as well as dioxins and furans no minor mass flow are set in the regulations therefore there is no need to undertake a detailed dispersion modelling for these parameters either.' These substances should in principle be included in the assessment. It is likely that no significant impacts would be identified for ammonia or hydrogen chloride. However, emissions of dioxins and furans should be modelled and, as a screening approach, evaluated against the WHO guideline of Air concentrations of 0.3 pgTEQ/m3 which is used to identify local emission sources that need to be identified and controlled	
AQ4	Confirmation of stack height	(new comments)	The revised assessment confirms the proposed stack height of 50 metres, which would be adjacent to a building of height 43 metres. This appears to be relatively low for a facility of this nature. AQ4 remains valid.	This comment is wrong. The building height is 30 m (and not 43 m). There is no reference in the report that the building is 43 m high. The statement relatively low is not clear enough. If ADB experts has another formula how to calculate the stack height than please do it and provide us with a clear height
AQ5	Reliability of model results	(new comments)	The new report 'Air quality and air dispersion modelling report 190828' states: 'The results have been checked again and are considered as right and robust. The model used is a state of the art, accepted model by the German Ministry of Environment. It reaches it best performances in flat environment and poor database which is the case in the Maldives. The comparison with plants in the UK which has provenly different ambient and environmental conditions could not be considered as appropriate.' The consultant is correct: the situation in the Maldives is different to the UK, and different dispersion characteristics would be expected. However, our experience is based on the use of ADMS	The Consultant is unable to run another model as the one presented in this report. As far as there is no mandatory requirement to use AERMOD or ADMS in the national ToR as well in the EHS guidelines, the consultant estimate to use an internationally recognized ADM. Rationale for using this model has been presented.

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
			and AERMOD for modelling assessments worldwide, not just in the UK. This comment remains valid. In the context of assessing mercury, the report states "[As] pre-pollution with air pollutants at the site is not known (baseline), so it is assumed that the calculated values represent the total load." This seems to imply that the assessment has been carried out by assuming that there is no baseline contribution due to mercury. This is not a conservative approach to the assessment, and the assessment should take account of baseline levels of air pollutants.	This text has been changed. The additional represents the "process contribution" from the WtE. Considering this source as a single standing source, the results from the calculations shows that increase of pollutants in the atmosphere is far below the requirements of IFC. The combination of process contribution and baseline unfortunately not (for the parameter PM, SO_2, NO_2). This is mainly related to the influence of the dumpsite.
AQ6	Calculation of emission mass flows for nitrogen oxides (nitrogen monoxide and nitrogen dioxide), specified as nitrogen dioxide	(new comments)	Further clarification has been provided which indicates that there may be a further factor of 90% involved in calculating nitrogen dioxide concentrations. This is not clearly explained, and does not account for the discrepancy, but the difference is small and not likely to significantly affect the study conclusions.	OK
AQ7	Responses provided to questions from ADB Experts			
1	Air quality assessment to be undertaken following international good practice, for which ADB would usually refer to IFC EHS Guidelines. Since German approach has been utilized and ADB is not familiar with this, it needs to be demonstrated how this is consistent with international good practice, notably in stack height calculation, scoping out potential air quality impacts, and in terms of the dispersion model used, the EIA should also include the justification for using the German approach	See Chapter 4 "Methodology"	The report explains the background to the German method, but does not relate this to the IFC EHS methodology which is specified for use in the ADB Safeguard Policy Statement (2009). See AQ1 and AQ2 above.	It is not very clear for the consultant, what the ADB experts wants more. Concerning AQ1 and AQ2 we completed the report accordingly. The German approach does not differs from other approaches which is : • Considering Regulatory requirements (in this case due to non availability of Maldivian regulation, we used German regulations and International standards

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
				• Significance of the source (detailed description of WtE facility was provided in the document • Location of the emitting facility relative to other sources (Macro, Meso and Microlocation presented) • Location of sensitive receptors (done) • Existing ambient air quality, and potential for degradation of the airshed from a proposed project (The airshed is allready temporary degraded due to the dumpsite and is tending to be better after the dumpsite closure) • Technical feasibility and cost effectiveness of the available options for prevention, control, and release of emissions (part of the complete EIA)
2	in any case, as ADB is used to seeing assessments undertaken against terminology of IFC EHS Guidelines, the results of German approach should be presented in that context in EIA and avoid using German specific terminologies.	Whether it was possibly terminology has been harmonized additional glossary was presented on page 1-2	The glossary is useful, but terminology has not been harmonized. E.g. sections 8.1.2 and 8.2.1.2 use the German terminology throughout.	Terminology has been harmonized. Whether it was not possible to use another terminology the glossary can be used.
3	Specifically German approach ambient air quality standards are based on WHO interim targets, rather than the WHO	For baseline assessment table 1.1.1 of IFC HSE guidelines (WHO guidelines was used) for emission values German	The WHO guidelines or EU standards should be used throughout the assessment (not just for baseline assessment) rather than using the approach based on	The German standards are mainly similar to EU standards, for certain parameters even more stringent.

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
	guidelines; the EIA is to also discuss results in context of latter.	standards have been used which are more stringent than EU IED standards presented in the IFC EHS sector guidelines for MSW treatment facilities (see Chapter 4 "metjodology)	German standards. See also AQ2 Reference to emission standards is not relevant	
4	The status of the airshed does need to be reported, for this baseline ambient air quality monitoring at Thilafushi is required	Thilafushi Island airshed is actually highly influenced by the uncontrolled burning of the illegal dumpsite. Once the dumpsite fires have been stopped (latest with the operation of the WtE), there is no further emission source like the dumpsite. The fires and smokes are temporary and with actual basline aire monitoring no significant pollution has been detected. If there was a similar source (after extinguishing the fires on Thilafushi) the concerns about the degraded air-shed would be reasonable. Actually on Thilafushi the dispersion of any potential pollutant that yet may be produced is unrestricted.	Report is incomplete. The issue of open burning can be addressed when considering the results of baseline air quality monitoring. The report could explain why baseline levels are considered likely to be negligible: this would need to take account of existing industrial and other activity in the local area.	Based on the updated baseline chapter and its results we did an assessement of the airshed. Baseline monitoring have been done on 4 locations at 3 different periods: • June 2018 • March 2019 • August 2019 Covering main parameters as per ToR with a monitoring and recording frequency which able to develop baseline parameters comparable to WHO guidelines for ambient air quality. See chapter 7.4

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
5	Monitoring should include NO_2, SO_2, PM_{10} and $PM_{2.5}$ as well as all parameters listed in national TOR including CH_4, CO, Cd, Pb, Hg, HC which do not yet appear to have been monitored (or it needs to be explained why the cannot be, but if mercury has more than negligible impact it should have baseline).			NO_2, SO_2; PM_{10}; $PM_{2,5}$ done at all survey points. CH_4, CO done at selected survey points. Pb, Cd, Hg and HC could not be done due to the non-availability of adequate equipment. Additional paramaters done : CO_2, H_2S See Chapter 7.4
6	Monitoring should enable the ambient air quality to be clearly established by reference to WHO guidelines: 1 hour averages for NO_2, 10 minute and 24 averages for SO_2, and 24 hour averages for PM_{10} and $PM_{2.5}$. Monitoring program should be done over a period of two weeks, i.e. not just a one off and undertaken in different seasons (second season can be added to EIA at later date) to reflect changes in wind direction etc.	Done see page 42.	Report incomplete	Done see Chapter 4 methodology and Chapter 7.4 Baseline
7	The ambient air quality data already collected needs to be adequately presented with averaging period, units etc.They also need to be compared to the WHO guidelines to determine if the airshed is degraded.	Done see page p 42	Report incomplete	Done see Chapter 7.4 Baseline
9	The assessment to include consideration of all the parameters in the EU IED even if it is just to scope out they have a negligible impact	Done	All pollutants now included. Assessment of metals needs to be further explained; assessment of dioxins & furans is required. See AQ3.	

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
10	Under German approach, mercury is reported to have more than a negligible impact. It needs to be clarified why in terms of input data used, ideally to support that WtE is clean technology preferable if mercury levels were negligible. It may raise concerns why mercury is flagged, as perhaps it relates to burning of unsegregated hazardous waste?	The 17th ordinance for the implementation of the Federal Immission control Act (Ordinance on Incineration Plants for municipal waste and similar combustible cubstances) has defined an maximum emission value of 0,03 mg/m³. This value is monitored and controlled at the stack To respect this value active carbon is used in the flue gas cleaning in order to deposit the mercury. The problematic with mercury is that it is difficult to identify the source in the waste. Therefore it is a venture that the mercury is provided by hazardous waste. With the maximum flue gas volume flow and maximum allowed mercury concentration we have a mass flow which is over the threshold value. Therefore an air dispersion model is needed (made with Astral200). This was made an the expert (sub-contractor) came to the conclusion that there is	Provided issues with the air quality assessment can be addressed (AQ1, AQ2, AQ4, AQ5), the evaluation of mercury is acceptable.	OK

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
		no critical additional pollution		
11	Consultant has modelled the parameters in Table 10, whilst not required under German legislation it is important to ADB the EIA clearly demonstrates the air quality impacts of the WtE plant on a spatial basis and, given what is currently degraded airshed, that maximum project contribution impact is not significant. Thus dispersion plots for all the modelled parameters should be provided,	Done	The assessment does not clearly demonstrate the air quality impacts of all pollutants: see comments AQ1 to AQ6 above. Dispersion plots were provided for some parameters: these are a mix of airborne concentration and deposition plots.	Please precise what ADB experts understand under "clearly". The assessment is saying that parameters below minor mass flow have a negligible impact, for those over the minor mass flow an ADM has to be conducted to see "the dispersion effect" of this parameter and consequently its impact. Dispersion plots have been provided upon request of the ADB expert after on site mission. Most of the plots show clearly that the impacts are low at the receiving sensitive points
12	Also confirm the maximum ground level concentration (additional load in German terms) that the model has predicted. Note the maximum ground level concentration may not be at the same location as ANP1 receptor point included in the model by consultant. The dispersion modelling is required by the national TOR.	Ambiant air quality baseline measures have not been done actually for Mercury. ADB is right that maximum ground level concentration may not be at the same location as ANP 1. On the ANP1 we have factories with people working 8-10 h permanetly exposed to hazards. On our experts opinion it makes less sense to undertake an extensive Mercury baseline survey: Actually Mercury is released in a diffuse form	This comment refers to model outputs, not to ambient air quality measurements. The consultant's response does not address the question.	We confirm these figures as it was mentioned in the report received from our sub-consultant. If ADB experts identified a mistake then please advice then we could check with the data set. But a first cross check does not show any discrepancies

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
		from the old dumpsite on fire. This releasing will be stopped as soon as the dumpsite is closed and rehabilitated. Mercury baseline surveys are complex and costly because of the surveying of vaporous gaz and of particle-bound mercury. In order to meet the requirements of ADB it is necessary to have a narrow mesh of measurement points. Also the analytics is very expensive.		
13	Confirm the basis for 8,000 hours operation, as 8,200 hours availability is also mentioned. Is it possible it could operate for more hours? Though WtE plant will not operate all the time, dispersion modelling is usually done for 8,760 hours since it is not known exactly which days of the year (under what met conditions) will be operational or not.	We confirm that ADM was made on the communicated operation hours of 8,000 hrs. There are mandatory yearly revisions imposed to the contractor so it is not expected that it could be operated longer	The response addresses the question, and confirms that the assessment is not conservative in respect of operating hours. This should be taken into account when interpreting the results.	The WtE facility needs mandatory yearly revision and maintenance time where the facility is shut down or working partially. These are mandatory requirements to the DBO contractor. So it is almost impossible that the WtE facility will operate at all thime and therefore a realistic operation time of 8,000 is considered as realistic for the conclusion of the outcome of this report
14	The consultant needs to check the results of the model, as per our technical advisor the emissions of NO_2, SO_2 and PM_{10} appear to be relatively low for a WtE plant of this scale. At the minute the impacts are not significant, but this raises a concern they have been underestimated. Need to confirm the	The results have been checked again and are considered as right and robust. The model used is a state of the art, accepted model by the German Ministry of Environment. It reaches	The consultant is correct: the situation in the Maldives is different to the UK, and different dispersion characteristics would be expected. Our experience is based on the use of ADMS and AERMOD for modelling assessments worldwide, not just in the UK. Our comment AQ5 remains valid.	There are more than 140 models developed and accepted only in Europe. As per National ToR and also as per IFC performance standard it is not mandatory to use a specific ADMS or AERMOD. As a German consultants we have used Austal 2000 which is the

N°	ADB experts Comments	Answer/Reference after 1st draft comments	Comments of ADB expert team (Ricardo) from 16.09.2019	Consultant's answers
	model inputs are appropriate and were correctly inputted and why model concentrations can be considered as robust. This issue may relate to either input data or the type of model used which does not follow same principles as more frequently used ADMS or AERMOD.	it best performances in flat environment and poor database which is the case in the Maldives. The comparaison with plants in the UK which has provenly different ambient and environmental conditions could not be considered as appropriate		official reference model of the German Regulation on Air Quality Control, listed as an accepted model by the European Environment agency and the 11th International Conference on Harmonization within Atmospheric Dispersion Modeling for Regulatory Purposes, held in Cambridge, England. The model is considered as robust and has been runned two times.The model running (including additional parameters) costs 8,000 EUR. The consultant cannot afford to use a second model for consistency check anymore. If ADB experts are not convinced about the results we suggest to engage a special consultant for consistency check with AERMOD or other ADM model

AIR QUALITY REPORT WtE THILAFUSHI

1 Introduction

The ambient air quality status of Maldives is currently unknown due to the lack of monitoring data. It 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. Aside from the increased land and sea vessels, diesel power generation, and construction, open burning in Thilafushi is also a significant source of air pollution in the region.

The proposed WtE Facility will treat approximately 500 TPD of municipal waste (Household waste and similar to Household waste) based on the estimated throughput at design point, generating as a "by-product", electricity. This air quality repor for the proposed facility was carried out as follows:

a) Outline review of the policy context for air quality.
b) Assessment of baseline air quality
c) Identification of potentially sensitive locations
d) Calculation of the minimum stack height
e) Identification of potential parameters which needs a more detailed dispersion modelling
f) Evaluation of forecast levels of released substances against relevant standards, guidelines, critical levels and critical loads
g) Dispersion modelling study of emissions to forecast air concentrations and deposition rates at potentially sensitive locations
h) Conclusions

The main focus of the air quality assessment was the evaluation of modelled levels against relevant standards and guidelines. Levels of relevant substances were forecast at sensitive receptors to enable an assessment of the effects on air quality with regard to human health risks and environment to be evaluated.

As the Maldives did not have a wide range of air quality survey network, therefore baseline assessment have been done through temporary field measures.

The proposed development is forecast to have no significant effects on air quality during abnormal operating conditions or due to road traffic emissions, and no significant cumulative effects are forecast to occur. No amenity issues such as odours or dusts would be expected to arise outside the site boundary, and emissions to air from the proposed facility are forecast to have no significant effects on the local environment.

The proposed facility will have no significant adverse effects on air quality. Consequently, it was concluded that no further mitigation is necessary, other than the extensive mitigation and control measures already built into the proposed facility.

2 Scope of work

2.1 ToR for air modelling consultant

For this special purposes of establishing a detailed and reliable air quality report (as part of a complete EIA), Water solutions and Kocks Consult GmbH hired The Engineer Company Ulbricht GmbH from Germany a specialised consultant in the field of environmental consultancy, permitting procedures and noise abatement.

The scope of work was to undertake:

- the stack height calculation
- The calculation and assessment of air pollutants emission

According First General Administrative Regulation Pertaining the Federal Immission Control Act (Technical Instructions on Air Quality Control – TA Luft).

For the purpose of this work Water Solutions and Kocks Consult GmbH have submitted the following documentation to the consultant

[1] The emission values according Industrial Emissions Directive (IED) (2010/ 75/ EU, 2010) and 17th Ordinance for the implementation of the Federal Immission control Act (Ordinance on Incineration Plants for municipal waste and similar combustible cubstances (the more stringent had to be used, dioxins and furans according IED)

[2] The data set for Thilafushi from the National Maldives meteoroligcal service

[3] The dimensioning parameter for WtE, particularly the flue gas cleaning

3 Policy and Guidance

3.1 National legislation

The proposed SWM project will be governed by the laws of the Government of Maldives and the implementing regulations promulgated in accordance with such laws. As summarized below, the legal and regulatory framework for the protection and preservation of the environment of the Maldives with respect to solid waste management is currently evolving to conform to international standards within the unique context of the Maldivian natural environment. In light of the development of a comprehensive national solid waste management program including establishment of facilities to provide state of the art solid waste disposal, recycling and resource recovery, it is expected that certain existing proposed laws, draft regulations and temporary guidelines concerning solid waste management will be significantly revised and promulgated in binding final form during the course of the project. To the extent that Maldivian laws and regulations become final they shall be binding upon the project proponents superseding analogous standards referenced herein.

At present, Maldives does not have a national air quality policy or a national ambient air quality standard. However there are legislations and programmes to prevent air pollution such as Environmental Protection and Preservation Act (4/93), Draft Waste Incineration Guideline, Concrete Batch Plant Guideline and the Vehicular Emission Standard (MEE, 2017).

The Environmental Protection and Preservation Act (eppa) 1993

The Environmental Protection and Preservation Act (EPPA) of the Maldives (Law No. 4/93) is an umbrella law that provides statutory powers regarding environmental regulation and enforcement.

The relevant components of the EPP Act 1993 are:

Environmental Guidance

Article (2) The concerned government authorities shall provide the necessary guidelines and advise on environmental protection in accordance with the prevailing conditions and needs of the country. All concerned parties shall take due considerations of the guidelines provided by the government authorities.

Environmental Protection and Conservation

Article (3) The Ministry of Environment shall be responsible for formulating policies, rules and regulations for protection and conservation of the environment in areas that do not already have a designated government authority already carrying out such functions.

Protected Areas and Natural Reserves

Article (4) The Environment Ministry shall be responsible for identifying and registering protected areas and natural reserves and drawing up of rules and regulations for their protection and preservation.

Environmental Impact Assessment

Article (5) (a) An EIA shall be submitted to the Environment Ministry before implementing any developing project that may have a potential impact on the environment.

The EIA process in the Maldives is coordinated by the Environment Protection Agency (EPA) in consultation with relevant government agencies and National Commission for the Protection of the Environment (NCPE). The first step in environmental assessment process involves screening of the project to be classified as one that requires an Initial Environmental Examination (IEE) or one that requires a full Environmental Impact Assessment (EIA). Based on this decision, the Ministry then decides the scope of the EIA which is discussed with the proponent and the EIA consultants in a "scoping meeting". The consultants then undertake the EIA starting with baseline studies, impact prediction and finally reporting the findings with impact mitigation and monitoring plan. The EIA report is reviewed by EPA following which an EIA Decision Note is given to the proponent who will have to implement the Decision Note accordingly. As a condition of approval, appropriate environmental monitoring may be required and the proponent will have to report monitoring data at required intervals to the Ministry.

Environmental Impact Assessment regulation, 2007

The Environment Ministry issued the EIA Regulation in May 2007, which guides the process of undertaking the Environmental Impact Assessment in the Maldives. This Regulation provides a comprehensive outline of the EIA process, including the application to undertake an EIA, details on the contents, format of the IEE/EIA report, the roles and responsibilities of the consultants and the proponents as well as minimum requirements for consultants undertaking the EIA.

The objective of the Maldivian Environmental Impact Regulations, 2007 is to serve as a decision making tool for stakeholders in assessing the potential significant environmental impacts of a development proposal at the same time providing required guidance in obtaining environmental approval for such projects in the form of Environmental Decision Statement.

The Table of Contents for Initial Environmental Examination or EIA as specified in Schedule E of the EIA Regulations requires the proponent to furnish a detailed description of the natural, economic and human environment. This includes

- description of site characteristics including soil type, relief, landforms, present land use and drainage system
- type of flora and fauna, rare or endangered species, sensitive habitats of ecological importance including wetlands and mangroves
- marine environment including rocky bottom, coral reefs and sea grass beds
- beach systems; composition; stability; current; tide and wave dynamics
- description of surrounding infrastructure including utilities
- socio-economic characteristics including demographic profile, economic activities, housing and utilities, employment statistics and available skills, labour availability, unique cultural characteristics
- other attributes of the locality e.g. amenities and recreational values

The proposed WtE and landfill project is categorized under "Schedule D" list of projects requiring an EIA study.

Post EIA monitoring, auditing and evaluation

The EIA Regulations 2007 provides a guideline of the environmental monitoring programme that should be included in EIA reports as monitoring is a crucial aspect of the EIA process.

Accordingly, the monitoring programme shall outline the objectives of monitoring, the specific information to be collected, the data collection program and managing the monitoring programme. Managing the monitoring programme requires assigning institutional responsibility, enforcement capability, requirements for reporting and ensuring that adequate resources are provided in terms of funds, skilled staff and the like.

Solid waste management regulation

The main objective of the regulation is to implement the National Solid Waste Management Policy and through that protect the environment by;

- minimizing the impact of waste on the environment including, in particular, the impact of waste so far as it directly affects human health;
- Establishing an integrated framework for minimizing and managing waste in a sustainable manner; and putting in place uniform measures to seek to reduce the amount of waste that is generated, and where waste is generated, to ensure that waste is reused, recycled and recovered in an environmentally sound manner before being safely treated and disposed.

The regulation also takes note in detail accounts of the following fields in its enactment.

Waste management measures - Waste Management Standards, Plans, Protocols of declaration of priority wastes, Extended producer responsibilities, Prohibition of unauthorized disposal of waste, Littering, Container standards for collection of waste in public places, Waste Collection standards in sea vessels, Waste collection facilities standards in ports, Protocols in Reduction, re-use recycling and recovery of waste, Waste Management activities list and Protocols of restrictions on provision of waste management services.

Waste Management Licenses – Basic requirements for licensing, key standards, the validity period of the license, transfer protocols of a license, protocols for surrendering a license, license fees and governance of a license register.

Transportation of Waste - Duties of personnel transporting the waste, protocols of exporting and transboundary transfer of hazardous wastes, protocols of transportation of waste from one island to another, duties of receivers of waste and accidentals protocols at sea

Monitoring, Inspection , Auditing and Enforcement - Duty to furnish information, duty to reporting, Notice from the Administering Authority requiring a review of activities carried out under a license, Revocation of a license, Defrayal of Administering Authority costs, Register of fines and administrative actions, Inspectors, Establishment of national waste information system, National Waste Management Status Reports.

Clause 18 of this regulation restricts provision of waste management services without obtaining a licence for the following activities:

- Operate a waste management facility
- Operate waste collection and transportation services
- Waste recycling services
- Operation of landfills

Waste management policy

Former MHTE (Now MoE) has published a National Solid Waste Management Policy for the Maldives. The aim of the waste management policy is to formulate

and implement guidelines and means for solid waste management in order to maintain a healthy environment. The developer shall follow any guidelines /regulations on waste management that the government may introduce.

Waste management during construction and operation of the proposed project will be guided by the relevant laws, regulations and policies related to waste in Maldives.

Review of the Maldivian regulatory framework during the course of the baseline monitoring exercise revealed that there exists limited regulations/standards which are appropriate to the present study and can be referred for compliance to the environmental components being monitored. Hence an attempt has been made in accordance with IFC PS requirements to identify the internationally recognized standards viz. WHO which has been referred to review conformance with the baseline values of the various environmental parameters being monitored. The list of such international standards has been provided below.

WHO air quality guidelines, 2005

the WHO Air quality guidelines as revised in 2005 (Refer Annex 3.7) represent the most widely agreed and up- to-date assessment of health effects of air pollution, recommending standards for air pollutants viz. PM10, PM2.5, SO2, NOx and Ozone at which the public health risks are significantly reduced. Necessary efforts has therefore been made by the proponent to compare the baseline air pollutant values monitored with the WHO air quality standards to establish any possible deterioration in ambient air quality and subsequent impact on worker health due to emissions that are resulting from open burning of solid wastes. Significant improvement in ambient air quality, if any due to implementation of the proposed waste management facility will also be verified based on the WHO standards.

Male' declaration on control and prevention of air pollution and its likely transboundary effects for South Asia

The objectives of Male' Declaration includes:

Assessing and analyzing the origin and causes, nature, extent and effects of local and regional air pollution,

Developing and/or adopting strategies to prevent and minimize air pollution

Setting up monitoring arrangements beginning with the study of sulphur and nitrogen and volatile organic compounds emissions, concentrations and deposition.

The proposed project will minimize the air pollution caused by the existing waste management practices of open burning of mixed waste in Thilafushi.

3.2 European legislation

The Industrial Emissions Directive (IED) (2010/ 75/ EU, 2010) brings together seven existing directives, including the Waste Incineration Directive, into one piece of legislation. The IED outlines total emission limit values (ELVs) for a number of pollutants typically emitted during waste incineration. These are NOx, CO, total dust, HCl, HF, SO2, organic substances, trace metals, and dioxins and furans. The design and operation of all new waste incinerations facilities must ensure compliance with the ELVs.

3.3 German legislation (as basis for the ADM)

First General Administrative Regulation Pertaining the Federal Immission Control Act (Technical Instructions on Air Quality Control – TA Luft) published in the Joint Ministerial Gazette from 30 July 2002 (English translation)

At the national level in Germany, the Act on the Prevention of Harmful Effects on the Environment Caused by Air Pollution, Noise, Vibration and Similar Phenomena (Federal Immission Control Act - BImSchG) is at the core of the body of statutory instruments that makes up immission control legislation. It has in the meantime received significant reinforcement in the form of numerous statutory instruments and two significant administrative provisions – Technical Instructions on Air Quality Control (TA Luft) and Technical Instructions on Noise Abatement (TA Lärm). The TA Luft is a comprehensive air pollution control regulation that includes:

- A discussion of the scope of the TA Luft application, which is to review applications for licenses to construct and operate new industrial facilities (or altered existing facilities) and to determine whether the proposed new or altered facilities will comply with the requirements of the TA Luft and the requirements of other air pollutant emission regulations promulgated under the Federal Pollution Control Act.
- Air pollutant emission limits for dust, sulfur dioxide, nitrogen oxides, hydrofluoric acid and other gaseous inorganic fluorine compounds, arsenic and inorganic arsenic compounds, lead and inorganic lead compounds, cadmium and inorganic cadmium compounds, nickel and inorganic nickel compounds, mercury and inorganic mercury compounds, thallium and inorganic thallium compounds, ammonia from farming and livestock breeding operations, inorganic gases and particulates, organic substances and others.
- Emission limits may also be set for hazardous, toxic, carcinogenic or mutagenic substances as part of the TA Luft review procedures.
- Other limits or requirements related to stack heights (for flue gases or other process vents) and for storing, loading or working with liquid or solid substances.
- Various requirements for sampling measuring and monitoring emissions.
- Listing of the industries subject to the requirements of the TA Luft, such as mining, electric power generation, glass and ceramics, steel, aluminum and other metals, chemical plants, oil refining, plastics, food, and others.

Annex 3 is devoted to guidelines on: how the atmospheric dispersion modeling required during the TA Luft review is to be performed, and the acceptable type of dispersion model to be used. In essence, the modeling must be in accordance with the VDI Guidelines 3782 Parts 1 and 2, 3783 Part 8, 3784 Part 2, and 3945 Part 3.

17th Ordinance for the implementation of the Federal Immission control Act (Ordinance on Incineration Plants for municipal waste and similar combustible cubstances

The 17th Ordinance for the implementation sets the regulatory framework for the special case of the municipal waste incinerators based on the general requirement of the Federal immission control Act and the TA Luft. The Air emissions standards which have been set as the basis for the project (DBO) are *similar to the EU-IED and in some cases more stringent*

VDI (German Engineer Association) Guideline 3945 part 3 "Environmental meteorology/Atmospheric dispersion models –Particle model" of September 2000

The Commission on Air Pollution Prevention of the VDI and DIN – Standards Committee, which includes experts from science, industry and administration, acting independently, establish VDI guidelines and DIN standards in the field of environmental protection. These describe the state of the art in science and technology in the Federal Republic of Germany and serve as a decision-making aid in the preparatory stages of legislation and the application of legal regulations and ordinances. KRdL's working results are also considered as the common German point of view in the establishment of technical rules at the European level by CEN (the European Committee for Standardization) and at the international level by ISO (the International Organization for Standardization). This guideline describes a numerical model for simulating the dispersion and calculating the concentrations of trace species in the atmosphere. Data required for the model include the mean wind field, turbulence parameters, emission data and, depending on the specific case, further application-specific input data.

3.4 Guidance note

Latest IFC General EHS Guideline, page 3-17 "Air emission and ambient air quality"

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP). These General EHS Guidelines are designed to be used together with the relevant Industry Sector EHS Guidelines which provide guidance to users on EHS issues in specific industry sectors. The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Page 3-17 applies to facilities or projects that generate emissions to air at any stage of the project life-cycle. It complements the industry-specific emissions guidance presented in the Industry Sector Environmental, Health, and Safety (EHS) Guidelines by providing information about common techniques for emissions management that may be applied to a range of industry sectors. This guideline provides an approach to the management of significant sources of emissions, including specific guidance for assessment and monitoring of impacts. It is also intended to provide additional information on approaches to emissions management in projects located in areas of poor air quality, where it may be necessary to establish project-specific emissions standards.

Latest IFC EHS Guideline for Waste management facilities page 8-10 and 29-30

The proposed WtE will involve a state of the art management of MSW generated from the Zone III waste catchement area (GM and other atolls and resorts) through waste incineration and sanitary landfill disposal of residual waste and is likely to be driven by IFC Sector EHS Guidelines on Waste Management Facilities. The guideline outlines significant EHS issues associated with waste management facilities during operations and decommissioning phases along with recommendations for mitigating the identified impacts. The applicability of these guidelines with respect to specific waste management operation including the current waste management practices has been discussed in details below.

Presently waste received at the Thilafushi is dumped in an uncontrolled manner with intentionally or non-intentionally burning leading to emission of pollutants (VOCs, dioxins & furans, particulate matter, acid fumes, SOx, NOx, etc.) which are expected to result in the deterioration of ambient air quality and occupational health. Hence in line with IFC Sectoral EHS requirements the ambient air quality needs to be periodically monitored by the proponent to check conformance with WHO Ambient Air Quality Guidelines, 2005.

Air pollutant emissions are also envisaged during the operation of waste incineration to be commissioned as an integral part of the proposed Thilafushi WtE.Carbon dioxide, Sulfure dioxide, particulate matter etc. have been identified as the key air pollutants that are likely to be released by waste incineration. High temperature maintained within the combustion furnace of the plant generally limits/restricts the formation of toxic substances viz. dioxins/furans, NOx, SOx and CO. Hence in accordance to the provision of the IFC EHS Guidelines it is necessary to undertake periodic monitoring of such emissions to review the performance of these proposed waste management systems against national & internationally recognized standards. However in absence of specific standards catering to emissions from Incineration plants in Maldives, project will be designed and operated in accordance with the substantive provisions of the following guidelines:"Air Emission Standards for MSW Incinerators in the EU & US" (Refer Appendix 4.1) and respective EU and german legislation. These regulations establish the minimum standards that must be met by facilities; specifically, emission levels for various pollutant materials: organics (dioxins, furans), metals (cadmium, lead and mercury), particulate matter (opacity), acid gases (hydrogen chloride, sulfur dioxide, nitrogen dioxide) and fugitive gas emissions.

IFC Performance standard

This section specifies the environmental monitoring requirements and assesses the compliance to the applicable national and international EHS guidelines/standards with respect to the current waste management practices and proposed Thilafushi RWMF as defined under relevant provisions of the applicable IFC Performance Standards.

PS3: pollution prevention & abatement

PS3 identifies the contribution of industrial activity and urbanization towards increased levels of pollution to air, water, and land that may threaten people and the environment at the local, regional, and global level. This performance standard therefore aims towards avoidance and minimization of the adverse impacts on human health and environment by addressing the pollution from project activities.

Paragraph 9 of the PS requires the proponent to undertake periodic monitoring of pollutants appropriate to the nature and scale of the potential impacts to demonstrate compliance with applicable national regulations and evaluate project environmental performance to determine corrective actions, if any. For project involving pollutant emissions Paragraph 26 and 27 of the PS requires the proponent to evaluate whether the existing background ambient levels are in compliance with the relevant national or internationally recognized ambient quality guidelines and/or standards so that adequate control measures can be put in place to prevent significant deterioration of environment quality and demonstrate continual improvement.

As the proposed Thilafushi Waste Management Project will involve emissions of air pollutants (CO2, CO, NOX, SOx, PM, VOCs, dioxins/furans, etc.) and noise from operation of the plant and vehicles involved in waste handling and

transportation, generation of leachate landfill facilities there may exist potential risks on ambient environment, occupational and community health from such operations if not properly managed. Hence it is imperative that a monitoring framework is developed and implemented during the project operations stage to periodically assess and evaluate the performance of key HSE indicators to regularly check conformance with applicable national and international standards/guidelines *(WHO Ambient Air Quality Standards*, IFC Waste Management Facility EHS Guidelines, etc.) for necessary corrective action, if any.

Further in line with provisions of PS1, primary monitoring has been undertaken for physical components (ambient air) to establish the baseline environment and check for any possible deterioration in ambient environment.

4 Methodology

This air quality report was carried out in accordance with the TA Luft and established good practice for air quality modelling and assessment. The study considered emissions from the WtE stack and the Diesel Genset controlled under the 17th Ordonance of the German Federal Imission Control act and the Industrial Emissions Directive (2010/75/EU). In summary, the substances to be assessed are set out in the table below. For the sake of clarity a comparaison table with Table 1 of the IFC HES sector guideline for MSW facilities (standard guideline for ADB) has been developed. The values in blue are the values used for this project.

Table 1 Air emission standards for MSW Incinerators in the EU and US as per IFC EHS sector guideline Waste management Facilities page 29			17. Ordinance for the Implementation of the Federal Immission Control Act (Germany)
Parameter	EU	USA[a]	
Total Suspended particulates (PM_{10})	10 mg/m³ [24 hr average]	20 mg/dscm	5 mg/m³ [24 hr average] 20 mg/m³ [0,5 hr average]
Total Carbon (C)			10 mg/m³ [24 hr average] 20 mg/m³ [0,5 hr average]
Sulfur Dioxide (SO_2)	50 mg/m³ [24 hr average]	30 ppmv (or 80% reduction)	50 mg/m³ [24 hr average] 200 mg/m³ [0,5 hr average]
Oxides of Nitrogen (NO_x)	200-400 mg/m³ [24 hr average]	150 ppmv [24 hr average]	150 mg/m³ [24 hr average] 400 mg/m³ [0,5 hr average]
Opacity	n/a	10%	n/a
Hydrochlorid Acid (HCl)	10 mg/m³	25 ppmv (or 95% reduction)	10 mg/m³ [24 hr average] 60 mg/m³ [0,5 hr average]
Dioxins and furans	0,1 ng TEQ/m³ [6-8 hr average]	13 ng/dscm (total mass)	n/a
Cadmium*	0,05-0,1 mg/m³ [0,5-8 hr average]	0,010 mg/dscm	n/a
Carbon Monoxide (CO)	50-150 mg/m³	50-150 ppmv[c]	50 mg/m³ [24 hr average] 100 mg/m³ [0,5 hr average]

Table 1 Air emission standards for MSW Incinerators in the EU and US as per IFC EHS sector guideline Waste management Facilities page 29			17. Ordinance for the Implementation of the Federal Immission Control Act (Germany)
Parameter	EU	USA[a]	
Lead (Pb)*	See total metals below	0,140 mg/dscm	n/a
Mercury (Hg)	0,05-0,1 mg/m³ [0,5-8 hr average]	0,050 mg/dscm (or 85% reduction)[b]	0,03 mg/m³ [24 hr average] 0,05 mg/m³ [0,5 hr average]
Total metals*	0,5-1 mg/m³ [0,5-8 hr average]	n/a	n/a
Hydrogen Fluoride (HF)	1 mg/m³	n/a	1 mg/m³ [24 hr average] 4 mg/m³ [0,5 hr average]
Ammonia (NH_3)	n/a	n/a	10 mg/m³ [24 hr average] 15 mg/m³ [0,5 hr average]

[a] All values corrected to 7% oxygen [b] Whichever is less stringent

*Actually as there were no requirements for heavy metals (including lead) and cadmium this was not considered. The Consultant has contacted his sub-contractor due undertake additional assessment of these pollutants

It could be seen that values considered in this report for PM_{10}, NO_x, Mercury (Hg) are more stringent than EU-IED values. Additional parameters like Ammonia (NH_3), Total Carbon (C) *(in the TA luft but not in the IED)* and dioxin and furans *(in the IED but not in the TA Luft)* have been considered.

4.1 Ambiant air quality/Existing conditions

Actually the Maldives does not have an Air quality monitoring surveying network. Therefore ambient air quality has been assessed through a temporary field survey.

Baseline Air quality monitoring was conducted at four locations: 3 locations at Thilafushi (AQ1, AQ2, and AQ3) and one location at Villingili (AQ4) by Water Solutions. In 2018, air quality monitoring was carried out at AQ3 at Thilafushi from 20th to 26th June 2018. In 2019, air quality monitoring was carried out at AQ4 at Villingili from 3rd to 9th March 2019, at AQ1 from 19th to 25th March 2015. Additional air quality monitoring was carried at AQ2 from 20th to 25th August 2019 and at AQ3 from 25th to 31st August 2019.

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. The additional station at Vilingili was selected as a control site.

The instrument used for taking air quality for baseline is the Aeroqual series 500 monitors and sensors. Aeroqual is a portable monitor suited for surveying common indoor and outdoor pollutants compatible with over 30 different sensors. The Series 500 can be deployed for short term fixed monitoring by

adding an optional outdoor enclosure. The Aeroqual Series 500 is also highlighted as the leading instrument for measuring ozone, nitrogen dioxide and carbon monoxide by the United States Environmental Protection Agency (US EPA).

Figure 1: Air Quality monitoring station with two Aeroqual Series 500 monitors

Predominant wind direction is an important criteria in selection of the air quality sampling stations as gaseous and particulate emissions from the project activities have a greater chance of dispersal along the predominant wind direction and affect the downwind human habitations. The monitoring network for ambient air quality was developed based on the following key criteria;

- Regional meteorology (primarily wind speed and direction)
- Important receptor locations (e.g. nearby inhabitation);
- Proposed project activities
- Logistics for operating the air monitoring equipment

The predominant wind directions in Maldives are dependent on the NE and SW monsoons. The wind directions for all seasons recorded at the National Meteorological Centre, Maldives reveal that apart from the winter months (when winds primarily blow from NW-NE), winds predominantly blow from the west.

The ambient air quality monitoring locations are shown in and rationale for selection of the locations is presented in Table 1.

Table 1: Locations for ambient air quality monitoring

Station Name	Station Coordinates	Monitoring rationale
Thilafushi Downwind (AQ1)	4°10'56.6 N 73°26'53.3 E	This downwind station with respect to the proposed facility has been selected to establish the baseline that could be compared with the monitoring to be undertaken during the construction and operational phases of the project to detect actual project imprints to the air quality of the nearest receptor.
Thilafushi crosswind (AQ2)	4°10'57.3 N 73°25'59.4 E	The cross wind station with respect to the proposed facility has been selected to establish the general baseline of the island, for comparison with the downwind station at the time of project activities

Station Name	Station Coordinates	Monitoring rationale
Thilafushi crosswind (AQ3)	4°11'07.6 N 73°26'37.4 E	The cross wind station with respect to the existing dumpsite at the Thilhafushi has been selected to establish the general baseline of the island
Viligili Island (AQ4)	4°10'26.4 N 73°28'59.9 E	The cross wind station with respect to Thilhafushi has been selected as a control site and to detect project imprints to air quality of the nearest receptor due to trans-island transportation of pollutants

The exact location of the ambient air stations were selected by WS/Kocks on site personnel to ensure the stations experience free air flow and are established at height between 1.5-5 meters and comply with the rationale of the monitoring program.

Selection of the sampling stations was based on the general climatological data obtained from the National Meteorological Center, Maldives. Also, data for the predominant wind directions for the sampling period was obtained from the National Meteorological Centre Maldives. As the direction of flow of exhaust air will be affected with changing wind directions, predominant exhaust air directions were noted down several times during the sampling program.

Because of the location of the island, strong gusts and variations of wind directions were noted which have the potential to influence the dispersion and in turn affect the air sampling. As a result it was thought pertinent to systematically record wind direction and strong gust.

Summary of the parameters measured:

Station	Parameters	Date	Frequency of recording
AQ 1	PM_{10}	19.03.2019-20.03.2019	Minutely (24 hrs)
	$PM_{2,5}$	19.03.2019-20.03.2019	Minutely (24 hrs)
	NO_2	20.03.2019-21.03.2019	Minutely (24 hrs)
	CO	22.03.2019-23.03.2019	Minutely (24 hrs)
	CH_4	21.03.2019-22.03.2019	Minutely (24 hrs)
	CO_2	19.03.2019-20.03.2019	Minutely (24 hrs)
	H_2S	20.03.2019-21.03.2019	Minutely (24 hrs)
	SO_2	22.03.2019-23.03.2019	Minutely (24 hrs)
	VOC	21.03.2019-22.03.2019	Minutely (24 hrs)
AQ2	CO_2	25.08.2019-26.08.2019	Every 15 min (24 hrs)
	CO	26.08.2019-27.08.2019	Every 15 min (24 hrs)
	NO_2	27.08.2019-29.08.2019	Every 15 min (24 hrs)
	$PM_{2,5}$	25.08.2019-26.08.2019	Every 15 min (24 hrs)
	PM_{10}	25.08.2019-26.08.2019	Every 15 min (24 hrs)

Station	Parameters	Date	Frequency of recording
AQ 3	PM_{10}	20.06.2018-24.06.2018	Every 10 min (96 hrs)
	$PM_{2,5}$	20.06.2018-24.06.2018	Every 10 min (96 hrs)
	SO_2	20.06.2018-24.06.2018	Every 10 min (96 hrs)
	CO_2	25.08.2019-26.08.2019	Every 15 min (24 hrs)
	CO	26.08.2019-27.08.2019	Every 15 min (24 hrs)
	NO_2	28.08.2019-29.08.2019	Every 15 min (24 hrs)
	PM_{10}	25.08.2019-26.08.2019	Every 15 min (24 hrs)
	$PM_{2,5}$	25.08.2019-26.08.2019	Every 15 min (24 hrs)
AQ 4	SO_2	06.03.2019-10.03.2019	Minutely (96 hrs)
	NO_2	06.03.2019-10.03.2019	Minutely (96 hrs)
	PM_{10}	06.03.2019-10.03.2019	Minutely (96 hrs)
	$Pm_{2,5}$	06.03.2019-10.03.2019	Minutely (96 hrs)
	CH_4	06.03.2019-10.03.2019	Minutely (96 hrs)
	CO	06.03.2019-10.03.2019	Minutely (96 hrs)

Figure 2: Location of Ambiant air quality monitoring station (Source Google earth)

4.2 Air dispersion modelling (ADM)

4.2.1 Rationale

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.* (Available as a free download at https://www.umweltbundesamt.de/themen/luft/regelungen-strategien/ausbreitungsmodelle-fuer-anlagenbezogene/austal2000n-download)

AUSTAL2000 is a steady-state dispersion model that is designed for long-term sources and continuous buoyant plumes. AUSTAL2000 is also capable of using multiple point, area, volume, and line sources. This model includes dry deposition algorithms and considers the conversion of nitric oxide (NO) to nitrogen dioxide (NO2). It is also able to make predictions about the frequency of odour nuisance.

It also available in English version as it is used by *other EU-member states*

The program system AUSTAL2000 calculates the spread of pollutants and odours in the atmosphere. It is an extended implementation of Annex 3 of the German regulation TA Luft (Technical Instruction on Air Quality Control) demands for dispersion calculations a Lagrangian particle model in compliance with the German guideline VDI 3945 Part 3. The modelling work was carried out by Ulbricht Consulting (Germany). The dispersion modelling report is attached as an Annex to this report.

Steady-state Gaussian plume models assess pollutant concentrations and/or deposition fluxes from a variety of sources associated with an industrial source complex. *Unlike the Gaussian models* commonly used, this flexible modelling procedure used in AUSTAL2000 *provides realistic results even when buildings and uneven terrain influence flue gas dispersion*. The model calculates the contribution of specified air pollutants from a given point source to the background concentrations present in the ambient air at ground level in the area surrounding the source.

4.2.2 Comparaison AUSTAL2000 vs AERMOD[1]

Unlike the Gaussian dispersion model AERMOD, AUSTAL2000 is a Lagrangian dispersion model that simulates the dispersion of air pollutants by utilizing a random walk process. According to Sawford[2] a Lagrangian simulation *has greater potential for application* as it mimics the behaviour of particles. The direction and velocity of dispersion are estimated by wind field vectors. Additionally, the vector of the turbulent velocity is randomly varied for every particle by using a Markov process. The random element varies with the intensity of turbulence. The concentration is determined by counting the particles in a given volume[3]

[1] Christian Langner & Otto Klemm (2011) A Comparison of Model Performance between AERMOD and AUSTAL2000, Journal of the Air & Waste Management Association, 61:6,640-646, DOI: 10.3155/1047-3289.61.6.640

[2] Sawford, B.L. Lagrangian Statistical Simulation of Concentration Mean and Fluctuation Fields; J. Climate Appl. Meteorol. 1985, 24, 1152-1166.

[3] Guideline 3945, Part 1. Environmental Meteorology—Atmospheric Dispersion Models—Particle Model; Verein Deutscher Ingenieure: Düsseldorf, Germany, 2000.

Like AERMOD, AUSTAL2000 is capable of calculating terrain and contains its own algorithm to assess the effects of building downwash[4]. AUSTAL2000 does not differentiate between rural or urban areas. AUSTAL2000 requires *less meteorological* information than AERMOD: z0, wind measurement height, wind direction, wind speed, and the stability classes according to Klug–Manier. The Klug–Manier classes represent the German standard stability classification for the atmosphere, similar to the Pasquill stability classes[5] in the United States. All of these meteorological data come from ground-based measurements and no information from upper air soundings is utilized. The wind measurement height and z0 are provided in the input file. If z0 is not provided by the user, AUSTAL2000 will calculate it using an internal database of roughness lengths and the coordinates of the area.AUSTAL2000 uses the register of roughness lengths and the integrated wind field component TALdia, which creates wind field libraries for complex terrain and for cases with buildings.

AERMOD generally predicted concentrations closer to the field observations. AERMOD and AUSTAL2000 performed considerably better when they included the emitting power plant building, indicating that the downwash effect near a source is an important factor. Both models performed acceptable for a no buoyant volume source. AUSTAL2000 had difficulties in stable conditions, resulting in severe underpredictions. This analysis indicates that AERMOD is the stronger model compared with AUSTAL2000 in cases with complex and urban terrain.

Generally speaking, the analysis indicates that AERMOD is the stronger model compared with AUSTAL2000 in complex and urban terrain. *In cases with simple terrain*, both models lead to acceptable results. Given the specific conditions and scope of the investigation, a model user has to evaluate whether he/she can get the meteorological data required to operate AERMOD. *For cases of poor meteorological data coverage, AUSTAL2000 could be an alternative*

4.2.3 Comparaison AUSTAL2000 vs CALPUFF[6]

Given the same quality of meteorological data, the performance of AUSTAL is similar to that of CALPUFF when using the Kincaid data set. The AUSTAL predictions tend to be conservative, usually overestimating the Kincaid GLC by roughly a factor two. AUSTAL performance is strongly affected by the choice of "quality factor" parameter, which controls the stochastic variability through the number of particles released. AUSTAL also tends to underestimate the wind speed at elevated levels, but AUSTAL predictions *are greatly improved when wind data at an elevated level* (close to the elevated source) is provided. AUSTAL predictions are improved when the thermal properties of exhausted gas from a power plant are described by the *VDI thermal flux equation*.

4.2.4 Conclusion

The computer program AUSTAL2000 is a reference implementation developed on behalf of the German Federal Environmental Agency. It is also used by other EU-state members and is a state of the art model following international good practice. AUSTAL2000 is is a Lagrangian dispersion model that simulates the

[4] AUSTAL2000—Program Documentation of Version 2.4; Janicke Consulting: Dunum, Germany, 2009.
[5] Pasquill, F. The Estimation of the Dispersion of Windborne Material; Meteor. Mag. 1961, 90, 33-49
[6] Ka-Hing Yau, Robert W. Macdonald & Jesse L. Thé (2011), inter-comparison of the austal2000 and calpuff dispersion models against the kincaid data set, 9th Int. Conf. on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes

dispersion of air pollutants by utilizing a random walk process, with a particular strong performance in simple terrain and with poor meteorological data coverage. The model requires less meteorological information than similar models (AERMOD, etc.) which, given the circumstances and the environment in Maldives, makes it probably more suitable to generate a reliable output.

4.2.5 Grid

The stack height of has been set for the ADM to min 46 m (Worst case/see stack height calculation). Therefore the ADM area has a radius of at least 2,300 m (50 times the stack height). The grid for the calculation of concentration and deposition shall be selected in accordance with Chapter 7 (2) of Annex 3 of the Technical Instruction "Air" so that the location and contribution of the maximum emission can be determined with sufficient certainty. This is usually the case when the horizontal mesh size does not exceed the stack height. At source distances greater than 10 times the height of the stack, the horizontal mesh size can be selected proportionally larger. The calculations and assessments were carried out in an area of 3.2 x 2.6 km and a grid with mesh sizes of 5 to 20 m.

4.2.6 Potential sensitive locations/Assessment points

In the examination area, two asessement points were determined for the calculations. The location of these points can be found in Annex 3. BUP 1 (west) is the point with the maximum load. ANP 1 (East) has been considered for additional mercury load dispersion calculation. These points are also nearby the baseline ambient air survey points.

4.2.7 Level of uncertainity

The resulting statistical uncertainty (in %) was taken into account in the evaluation. The calculation was performed with the quality level "2". To assess the emissions, the calculated value is increased by the statistical uncertainty.

4.2.8 Meteorology

4.2.8.1 *Rainfall, Temperature, atmospheric pressure*

The rainfall over the Maldives varies during the two monsoon periods with more rainfall during the southwest monsoon. These seasonal characteristics can be seen from *Figure 3*, which shows the mean monthly rainfall observed for central atolls.

The average annual rainfall for the archipelago is 2,124 mm. There are regional variations in average annual rainfall: southern atolls receive approximately 2,280 mm, and northern atolls receive approximately 1,790 mm annually (MEE, 2015). Mean monthly rainfall also varies substantially throughout the year with the dry season getting considerably less rainfall. This pattern is less prominent in the southern half, however. The proportions of flood and drought years are relatively small throughout the archipelago, and the southern half is less prone to drought (UNDP, 2006).

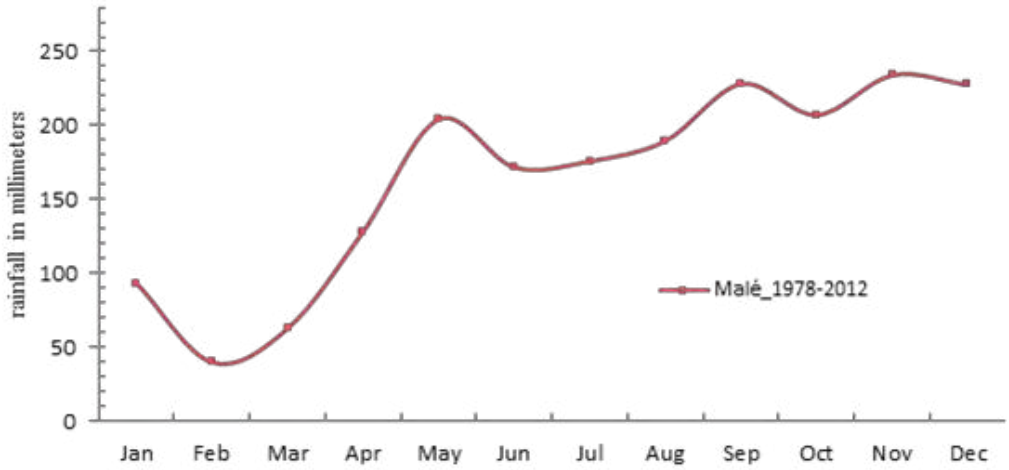


Figure 3: Long term average rainfall for the central atolls (Source: Maldives Meteorological Service, 2016)

For the ADM the following meteorological data have been acquired and used

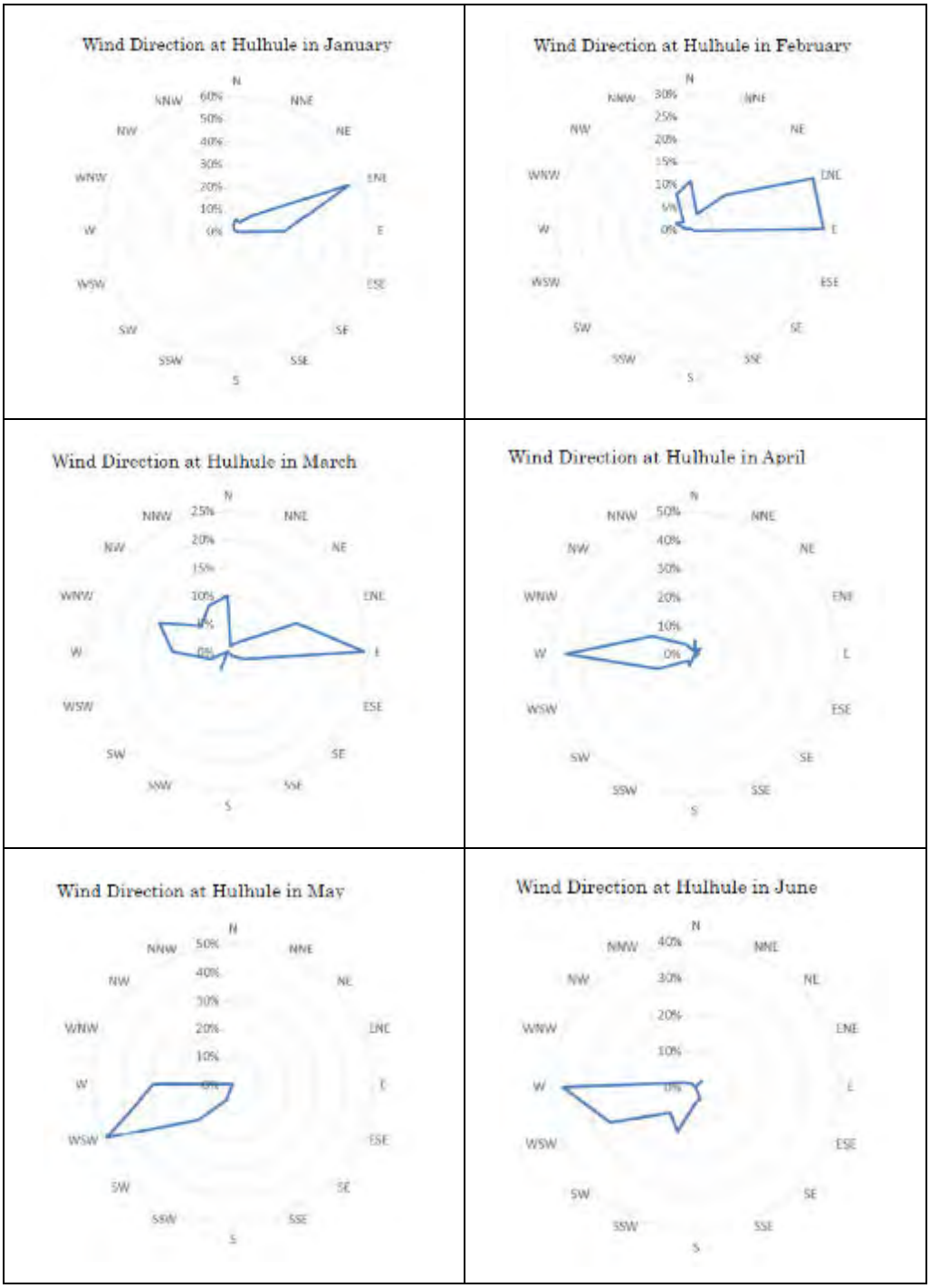
Rainfall data set (daily)	Source : Maldives Meteorological service Location : Weather station Hulhule' (Airport) at 10 km East of Thilafushi Data set: from 08.1974-12.2017
Temperature data set (daily)	Source : Maldives Meteorological service Location : Weather station Hulhule' (Airport) at 10 km East of Thilafushi Data set: from 01.-12.2017
Atmospheric pressure data set (daily)	Source : Maldives Meteorological service Location : Weather station Hulhule' (Airport) at 10 km East of Thilafushi Data set: from 01.-12.2017

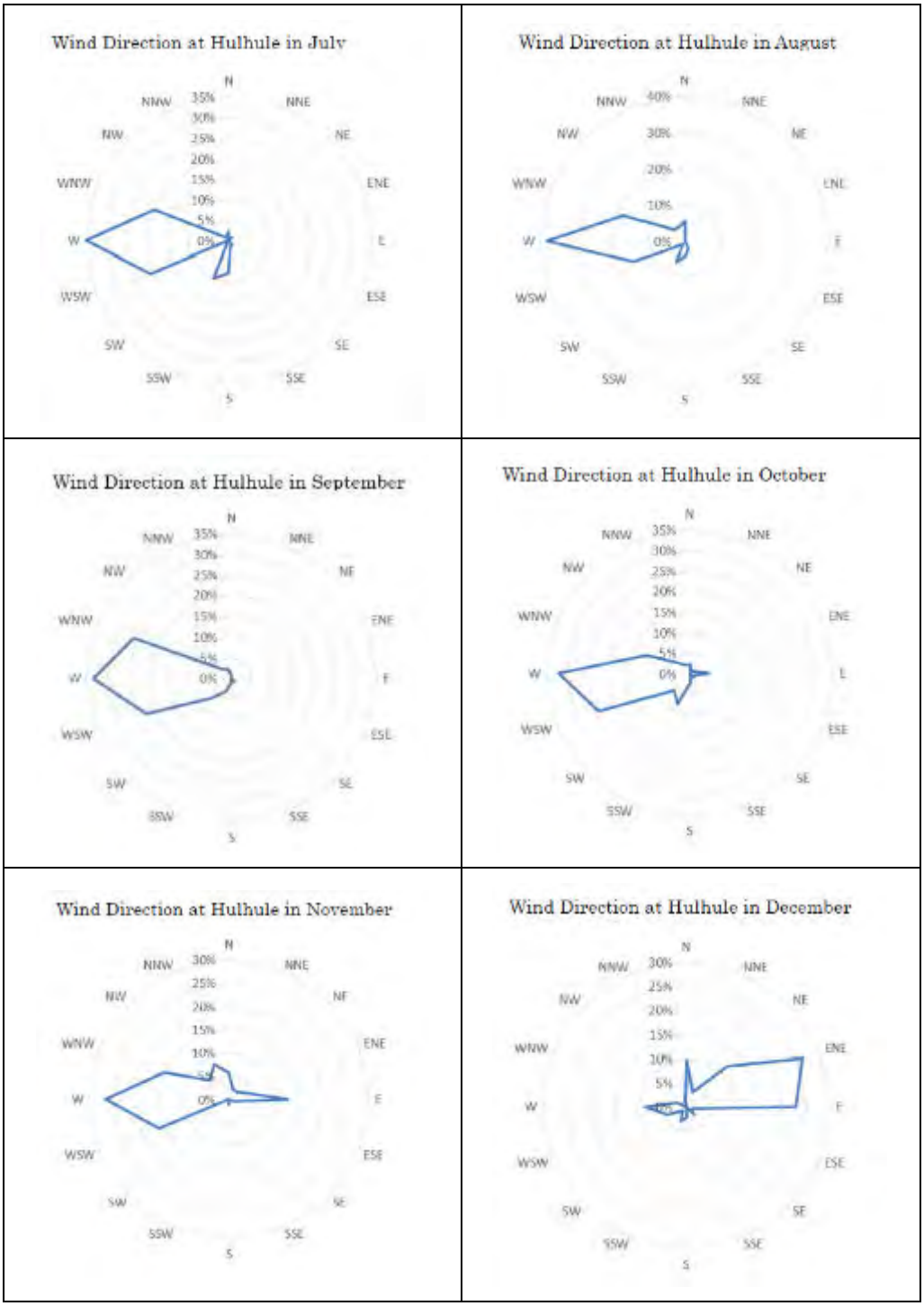
The data set have bee provided in Excel format and have been computed for the purpose of the model in AKterm format.

4.2.8.2 *Wind*

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 *Figure 4*.

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.


Wind Direction at Hulhule in January
Wind Direction at Hulhule in February
Wind Direction at Hulhule in March
Wind Direction at Hulhule in April
Wind Direction at Hulhule in May
Wind Direction at Hulhule in June


Wind Direction at Hulhule in July
Wind Direction at Hulhule in August
Wind Direction at Hulhule in September
Wind Direction at Hulhule in October
Wind Direction at Hulhule in November
Wind Direction at Hulhule in December
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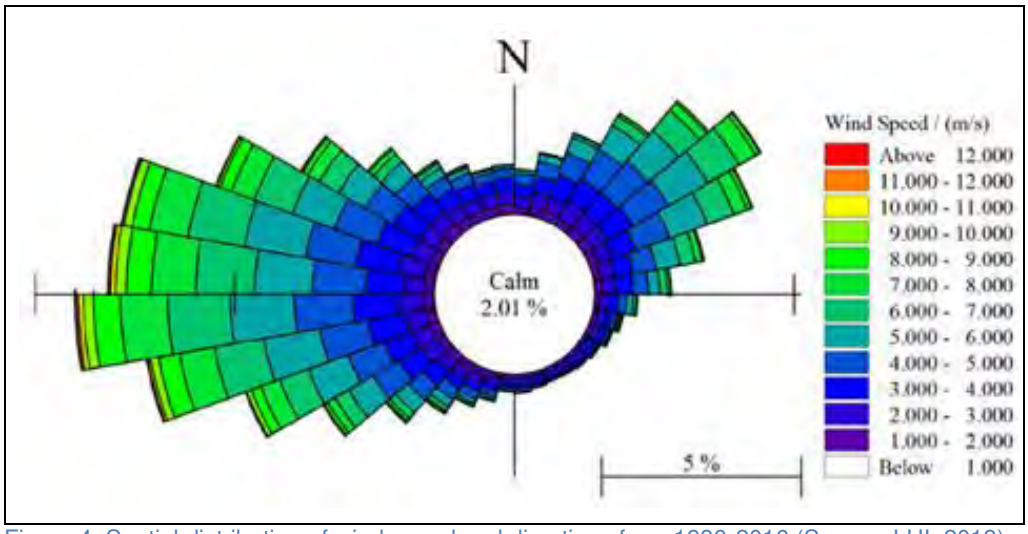


Figure 4: Spatial distribution of wind speed and directions from 1986-2016 (Source: LHI, 2018)

Figure 5 illustrates clearly wind the distribution pattern in terms of direction and frequency. The length of the "slices" represents the percentage of occurrence while the colour code illustrates wind speed. Furthermore, Table 15 shows the occurrence of wind by values in different directions and various speeds. According to the analysis, two dominant wind directions can be observed; i.e. West and North-East. The wind from the South-East quadrant is negligible. Significantly, calm conditions are rare, occurring 2.01% of the time.

Dir (Deg.N) / Speed (m/s)	0 – 10	10 – 20	20 – 30	30 – 40	40 – 50	50 – 60	60 – 70	70 – 80	80 – 90	90 – 100	100 – 110	110 – 120	120 – 130	130 – 140	140 – 150	150 – 160	160 – 170	170 – 180	180 – 190	190 – 200	200 – 210	210 – 220	220 – 230	230 – 240	240 – 250	250 – 260	260 – 270	270 – 280	280 – 290	290 – 300	300 – 310	310 – 320	320 – 330	330 – 340	340 – 350	350 – 360	Total
0 – 1	0.03	0.06	0.06	0.05	0.06	0.07	0.06	0.04	0.09	0.03	0.03	0.05	0.04	0.06	0.05	0.04	0.05	0.08	0.03	0.06	0.07	0.08	0.06	0.06	0.07	0.07	0.11	0.03	0.06	0.07	0.08	0.06	0.07	0.06	0.06	0.03	2.07
1 – 2	0.17	0.24	0.20	0.21	0.24	0.26	0.21	0.19	0.20	0.14	0.14	0.14	0.10	0.12	0.10	0.10	0.11	0.12	0.11	0.16	0.19	0.10	0.24	0.21	0.23	0.24	0.30	0.23	0.30	0.23	0.27	0.29	0.27	0.24	0.23	0.10	7.07
2 – 3	0.29	0.38	0.43	0.48	0.44	0.45	0.43	0.35	0.34	0.23	0.19	0.16	0.15	0.14	0.13	0.11	0.11	0.13	0.12	0.17	0.19	0.28	0.32	0.49	0.51	0.53	0.64	0.53	0.64	0.54	0.48	0.45	0.39	0.34	0.31	0.29	12.16
3 – 4	0.31	0.40	0.57	0.67	0.67	0.72	0.60	0.49	0.42	0.24	0.19	0.16	0.13	0.10	0.09	0.09	0.09	0.08	0.08	0.16	0.22	0.27	0.44	0.65	0.73	0.98	1.10	0.95	1.13	0.92	0.77	0.58	0.41	0.38	0.35	0.28	16.39
4 – 5	0.26	0.39	0.58	0.86	1.03	1.05	0.90	0.61	0.37	0.20	0.10	0.08	0.07	0.03	0.04	0.04	0.05	0.09	0.08	0.13	0.20	0.31	0.48	0.75	0.97	1.28	1.48	1.36	1.31	1.11	0.82	0.55	0.38	0.29	0.21	0.19	18.62
5 – 6	0.10	0.19	0.42	0.68	0.99	1.13	1.00	0.59	0.30	0.16	0.06	0.05	0.03	0.03	0.03	0.01	0.04	0.05	0.04	0.07	0.11	0.21	0.41	0.70	1.07	1.40	1.63	1.45	1.51	1.15	0.75	0.48	0.23	0.14	0.09	0.08	17.39
6 – 7	0.02	0.04	0.09	0.26	0.69	0.90	0.72	0.39	0.19	0.08	0.05	0.03	0.02	0.01	0.00	0.01	0.02	0.01	0.03	0.04	0.08	0.11	0.20	0.40	0.76	1.24	1.58	1.19	1.13	0.96	0.57	0.25	0.12	0.07	0.03	0.02	12.89
7 – 8	0.00	0.01	0.03	0.08	0.23	0.47	0.35	0.18	0.08	0.03	0.03	0.02	0.01	0.01				0.01	0.02	0.02	0.02	0.06	0.09	0.21	0.50	0.90	1.18	1.07	0.98	0.62	0.33	0.15	0.05	0.03	0.00	0.01	7.70
8 – 9		0.00	0.03	0.02	0.05	0.12	0.11	0.04	0.01	0.01	0.02	0.00							0.01	0.00	0.01	0.02	0.04	0.09	0.25	0.57	0.85	0.62	0.48	0.30	0.14	0.04	0.03	0.02			3.60
9 – 10				0.02	0.04	0.05	0.03	0.00	0.00	0.00	0.00										0.00	0.01	0.01	0.02	0.12	0.21	0.24	0.28	0.21	0.08	0.04	0.01	0.00				1.39
10 – 11						0.00	0.01															0.01	0.00	0.01	0.03	0.06	0.13	0.12	0.06	0.02	0.02	0.00				0.47
11 – 12																									0.01	0.02	0.06	0.04	0.02	0.01	0.00	0.01				0.18
12 – 13																									0.01	0.01	0.04	0.01	0.01	0.01	0.00					0.09
13 – 14																								0.00			0.01	0.01								0.02
14 – 15																											0.00									0.00
15 – 16																												0.00								0.00
Total	1.18	1.70	2.42	3.33	4.44	5.22	4.42	2.86	2.00	1.12	0.81	0.69	0.54	0.51	0.44	0.41	0.47	0.58	0.51	0.81	1.08	1.53	2.28	3.60	5.26	7.42	9.13	8.22	8.09	6.03	4.27	2.89	1.95	1.56	1.28	1.06	100

Figure 5: Directional Distribution of Wind Statistics (% Occurrence for Wind Speed vs. Wind Direction)

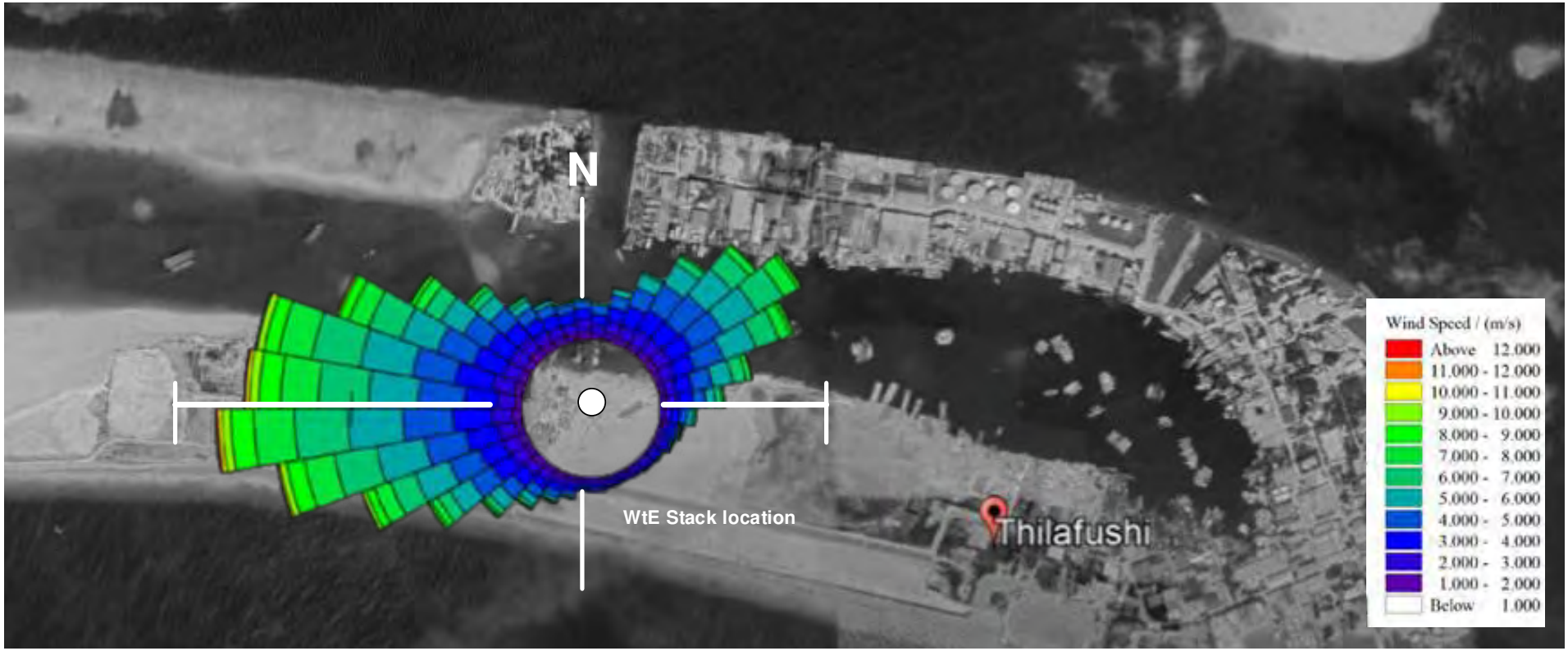


Figure 6: average Wind rose over project location

Besides the annual monsoonal wind variations, there are occasional tropical storms in the central region of the Maldives which increases wind speeds up to 110 km/h, precipitation to 30 to 40 cm over a 24 hour period and storm surges up to 3 m in the open ocean (UNDP, 2006).

For the ADM the following hourly wind data set have been acquired and used

Wind data set (hourly)	Source : Maldives Meteorological service Location : Weather station Hulhule' (Airport) at 10 km East of Thilafushi Data set: from 01.-12.2017 (24 hrs/day) Wind measurement height z_o : 11,5 m over ground level
Dispersion class time series	The wind direction distribution and the wind speeds were modelled with a dispersion class time series for the year 2017[7].

The data set have bee provided in Excel format and have been computed for the purpose of the model in AKterm format.

4.2.9 Topography

All islands of the Maldives are very low lying; more than 80% of the land area is less than 1 m above mean high tide level (MEEW, 2005). Combined with the small size of the islands, this means that accelerated sea level rise will have devastating effects on the islands and threatens the very existence of all the islands of the Maldives.

The proposed site for the establishment of the WtE was reclaimed in 2018. 15 hectares of land was reclaimed from the shallow lagoon which was located on either side of the link road that was constructed at Thilafushi. The materials for the reclamation was borrowed from North Male' Atoll with a radius of 10 km from Thilafushi using a Trailing Suction Hopper Dredger (TSHD). The dredger borrowed the material for the reclamation from borrow sites were within a depth range of 40-50m. The material from the dredger was discharged to the reclamation area via a floating pipe line which ran from the sea floor to the reclamation area, which was bunded with sand bunds, from southern side of the reclamation area.

The site has been reclaimed to a height of +1.5 m from MSL from an average depth of -1.5 m above the sea floor. The sand grains are angular to sub-angular in shape with gravel size varies from 20 – 30 mm in diameter and fairly uniformly graded. It can be described as loosely packed, silty, coral sand with pieces of corals and shells. Since the area had been recently reclaimed, the site does not have humus topsoil which is found on typical tropical islands. The soils have very high permeability for water. Much of the rainfall occurs as intense storms but no signs of erosion is observed, confirming high infiltration capacity.

The entire Island and the project location are mainly on the main level over MSL and don't present any substantial elevation (only the actual dumpsite is culminating at approx. 15 m over MSL). The following figure present the actual site configuration

[7] Wind data provided by Maldives Meteorological Services

Figure 7: areal picture of reclaimed area for WtE Facility

Ground roughness	The ground roughness of the terrain is described by an average roughness length z0. It is determined according to the land use classes of the CORINE Cadastre. The roughness length was chosen within the calculation to be z0 = 0.2. This value should be considered as representative for the area of calculation.
Terrain and slope	It is a flat terrain. In the computing area, no gradients of more than 1:20 or even more than 1: 5 occur.

4.2.10 Building effects

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 facility.

WtE dimensions: Approx. Length x width x height [m]: 100 x 70 x 30

Sourrounded 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.

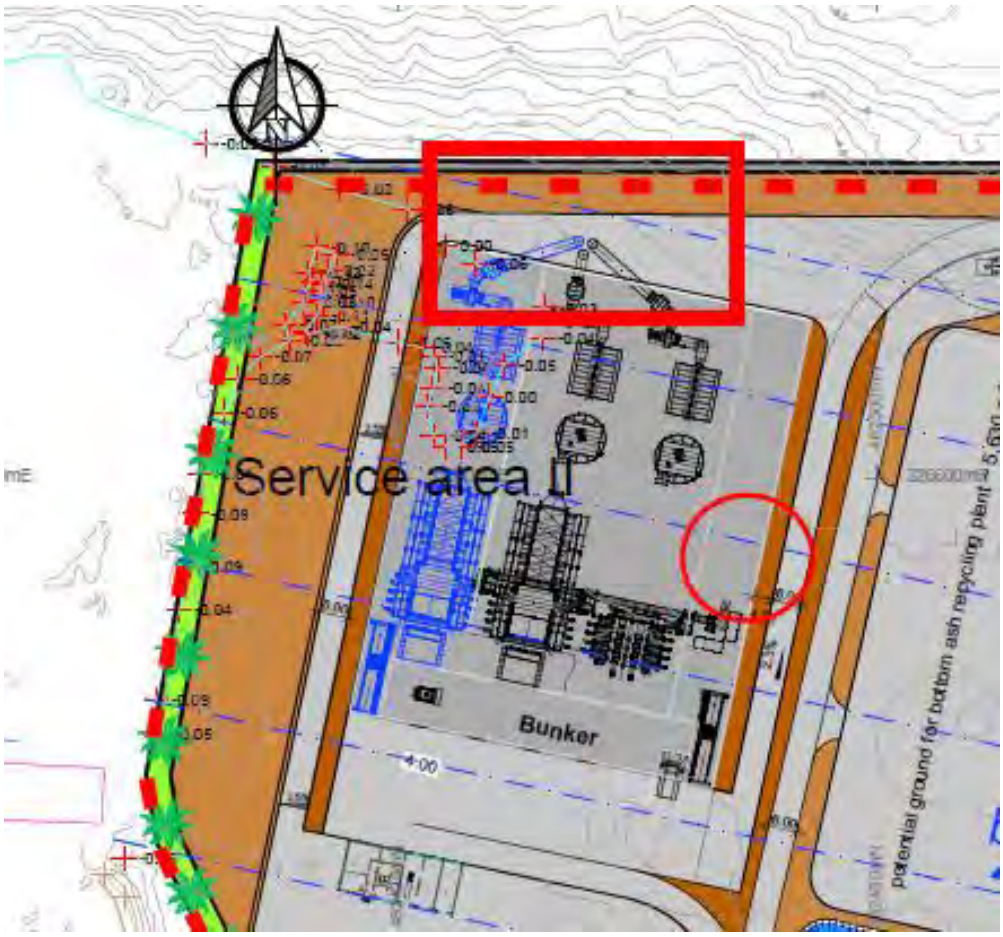


Figure 8: tentative Location of the WtE, the stack (square) and the genset (circle)

4.2.11 Emissions

The following parameter have been provided to the consultant for the ADM

Location of the stack	4.183004 N; 73.437155 E	
Number of stacks	2	
Stack height above ground level	46 m for ADM (Stack height will be fixed to 50 m for DBO)	
Distance between stacks	7 m (to be considered as 1 single source)	
Equivalent diameter	2.12 m	
Operation hrs WtE/Stack	8,000 hrs/year	
Flue gas volume flow	Stack 1	Stack 2
	57,856 m³/h	57,856 m³/h
Flue gas temperature	180°C	
Location of Genset	4.182394 N; 73.437370 E	
Number of Genset	1	

Distance between Genset and stack	Approx. 150 m
Operation hours Genset	760 h/year (only emergency/Island mode)
Flue gas volume flow Genset	12.470 Nm³
Emissions (based on 11% O_2 in the flue gas)	
Total dust	5 mg/Nm³
PM_{10}	0,5 mg/Nm³
Total carbon	10 mg/Nm³
HCl	10 mg/Nm³
Hf	1 mg/Nm³
SO_2	50 mg/Nm³
NO_x	150 mg/Nm³
Hg	0,03 mg/Nm³
CO	50 mg/Nm³
NH_3	10 mg/Nm³
Dioxin/furan	0,1 ng/Nm³

5 Assessment criteria

5.1 Criteria to protect human health

The Technical Instruction provides Immison rate/ambient air concentration values for the concentration of substances above which risks to human health are expected (paragraph 4.2) or they cause considerable nuisance or considerable disadvantages (Section 4.3). significant drawbacks, in particular protection of vegetation and ecosystems (Section 4.4) and harmful environmental effects by pollutant depositions (section 4.5) as well as irrelevant additional burdens, the compliance of which, according to Number 4.1 the TA Luft, can eliminate the determination of the total load, if the threshold are not respected

The following tables show the Immison rate/ambient air concentration values specified in the TA Luft as well as the irrelevant additional loads for the WtE plant relevant pollutants.

Table 2: Immission rate/ambient air concentration values and irrelevant values according Nr. 4.2 of the TA Luft

Substance/group of substances	Immison rate/ambient air concentration values	Average period	Allowed exceeding frequency per year	Irrelevant additional load
Protection of human health - Emission values according N° 4.2 TA Luft				
Aerosol (PM_{10})	40 µg/m³	year	-	1.2 µg/m³
	50 µg/m³	24 hours	35	-
Sulfur dioxide (SO_2)	50 µg/m³	year	-	1.5 µg/m³
	125 µg/m³	24 hrs	3	-
	350 µg/m³	1 hr	24	-
Nitrogen dioxide (NO_X)	40 µg/m³	year	- 18	1.2 µg/m³
	200 µg/m³	1 hr		-

5.2 Criteria to protect ecological sites

Table 3: Immison rate/ambient air concentration values and irrelevant values according Nr. 4.3 - 4.5 of the TA Luft

Substance	Ambient air quality value	Averaging period	Irrelevant additional load
Protection against considerable nuisance or major drawbacks due to dust precipitation - Ambient air quality values according to number 4.3 TA Luft			
Dust precipitation (non-hazardous dust)	0.35 g / (m² · d)	year	0.0105 g / (m² d)
Protection against nuisances, in particular protection of vegetation and ecosystems - Ambient air quality values according to 4.4 TA Luft			
Ammonia	Whether the protection against nuisances and drawbacks by damage of sensitive plants (eg nurseries, crop plants) and ecosystems by the effect of ammonia is guaranteed, is to be examined according to number 4.8 TA Luft.		
Protection against harmful environmental effects through pollutant deposition - Ambient air quality values according to number 4.5 TA Luft or protection against considerable disadvantages according to number 4.4 TA Luft			
Mercury and its inorganic compounds, expressed as mercury	1 µg / (m² · d)	year	0.05 µg / (m² · d)
Hydrogen fluoride and gaseous inorganic fluorine compounds, indicated as fluorine	0.4 µg / m³	year	0.04 µg / m³
Arsenic and its inorganic compounds, expressed as arsenic	4 µg / (m² · d)	year	0.2 µg / (m² · d)

Substance	Ambient air quality value	Averaging period	Irrelevant additional load
Lead and its inorganic compounds, indicated as lead	100 µg / (m² · d)	year	5 µg / (m² · d)
Cadmium and its inorganic compounds, expressed as cadmium	2 µg / (m² · d)	year	0.1 µg / (m² · d)
Nickel and its inorganic compounds, expressed as nickel	15 µg / (m² · d)	year	0.75 µg / (m² · d)
Thallium and its inorganic compounds, reported as thallium	2 µg / (m² · d)	year	0.1 µg / (m² · d)

6 Determination of significance of effects

According to the TA Luft calculated emission loads were assessed against the relevant critical loads fixed in the regulation. Only for the loads which are over the critical load (minimum mass flow) an detailed air dispersion model is required. For the purpose of the determination of the signfificance of effects and the need of a detailed ADM the following parameters have been considered:

- Total suspended material/dust expressed as PM10
- Sulphur oxide and dioxide expressed as Sulphur dioxide (SO_2)
- Nitrogen oxide (NO_x)
- Ammonia (NH_3)
- And mercury (Hg).

In the present case, the emissions are calculated with the calculation program for all relevant pollutants, insofar as emission values are specified for these substances in the TA Luft

For the other relevant pollutants: total C, carbon monoxide (CO), hydrogen chloride, dioxins and furans, no emission values are specified in the TA Luft.

7 Baseline conditions

7.1 Project location (Macrolocation)

The development of the proposed project takes place at Thilafushi. Thilafushi is located in North Male' atoll, 9.5km from Male'. 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. The reef system is approximately 4.65 km long, 0.94 km wide (width of ring reef, including the lagoon area). A newly reclaimed Industrial Island (Gulhi Fahlu) is approximatevly at 650 m from the eastern tip of the Thilafushi and the nearest resort (Centar Ras Fushi) at more than 3,2 km on the North-West of the Island.

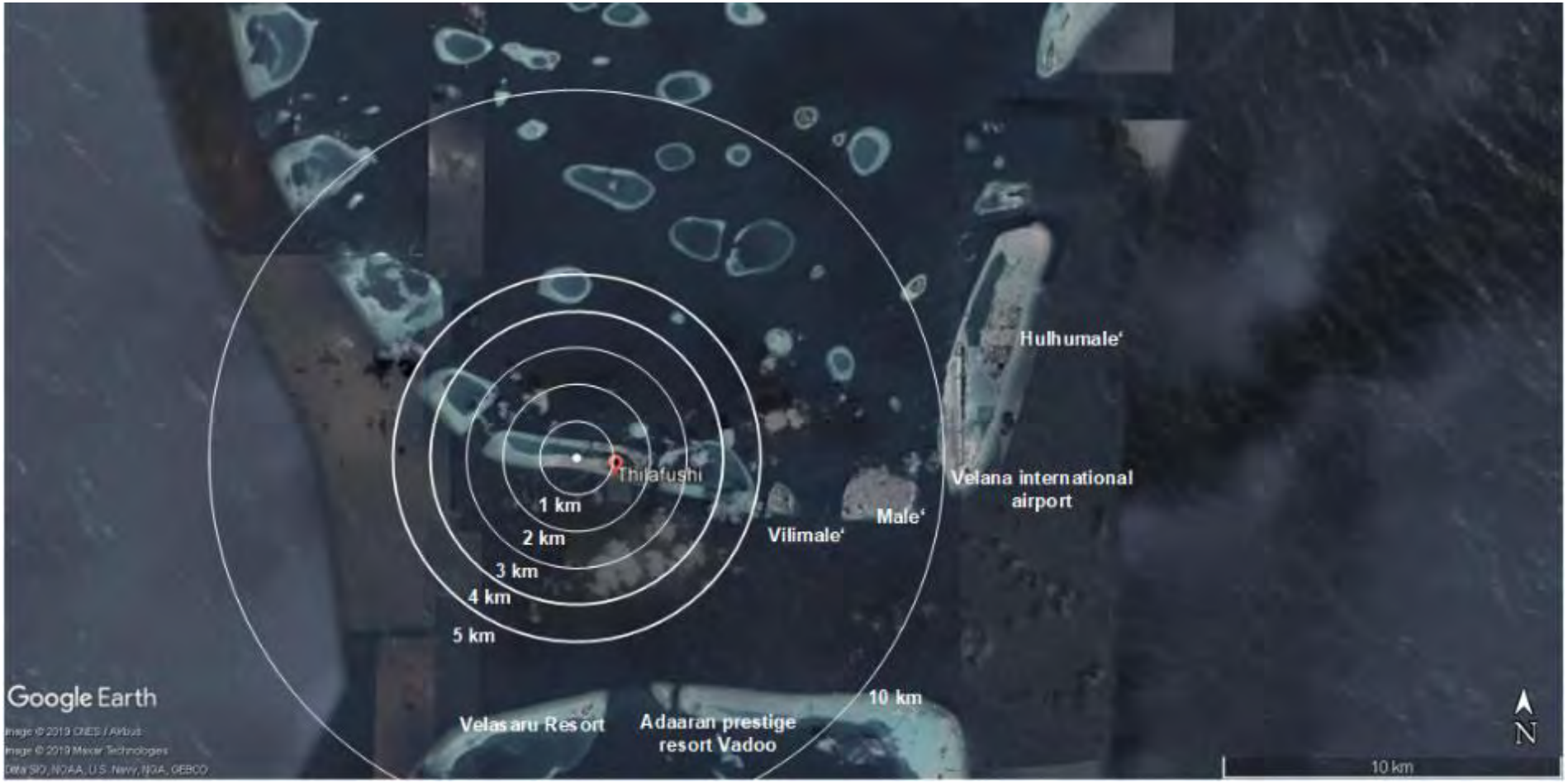


Figure 9: Project location (macro-location) [Source Google Earth]

Figure 10: Project location (Meso-location, distances from tentative stack location of the WtE) [Source google Earth]

Thilafushi Island has been developed as a solid waste land fill since December 1992. The island was initially developed as a sand bank using dredged material from the Thilafushi Reef. Since then, land has been reclaimed by placing solid waste in dredged holes on the reef flat and later topping it up with fresh lagoon sand. The island referred to as Thilafushi-1 was and is being reclaimed using this method.

A second island, zoned as Thilafushi-2, was reclaimed from lagoon sand to meet the demand. Subsequently a third island, Thilafushi-3, was initiated to reclaim 167 Ha of land from the remaining reef areas of Thilafushi.

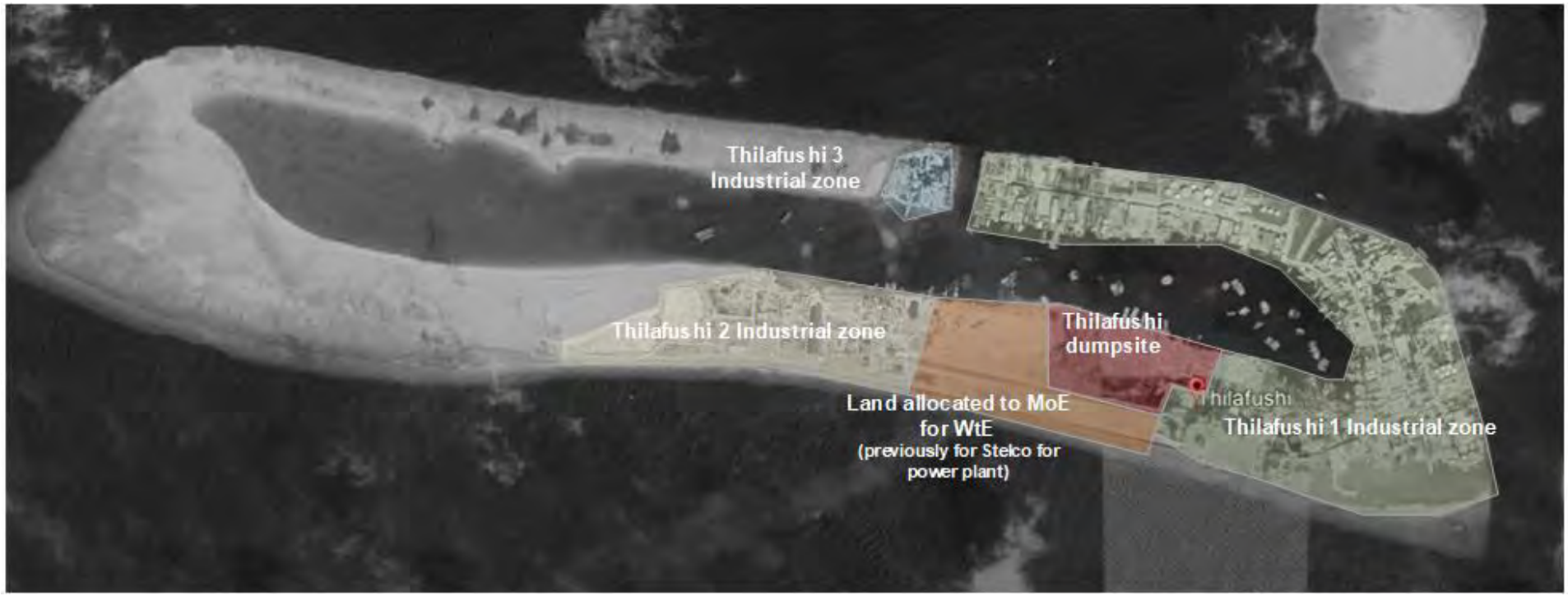


Figure 11: land use plan [developed by given land use plan and Google Earth Image]

Name	Thilafushi Island
History	1992 lagoon became dumpsite by filling with waste and sand. Development of the site by land reclamation through waste and sand dumping
Coordinates	4°11′N 73°26′E
Dimensions	Length : approx. 3.50 km Width: approx. 0.20 km
Vocation	Industrial Island
Population	Registred people (workers) Approx. 2,052 workers 2,048 male, 04 female, no children, 69 % Foreigners (international migrants) Approx. 1,500 residents (one base camp) Others relocated in Guli Fahlu
Borders/Boundaries	Island surrounded by seawater
Nearest Island	Guli Fahlu at 2,081 km from WtE stack (650 m from edge of Thilafushi), Industrial Island and workers camp
Nearest Resort or inhabited Island	Centar Ras fushi resort at 3,20 km (from WtE stack)
Vegetation	Basic vegetation, after landscaping measure, no rare or endangered species, no high vegetation
Tourism	None
Industry	Boat building Cement conditioning Construction companies' base/storage sites Methane gas bottling Storage of goods Water bottling Small industry (RO plants, etc.)
Facilities	Customs Small police and fire station Ferry station

Table 4: Summary of Thilafushi project location (macro-location

7.2 Project location (Microlocation)

The coordinates of the project location are 4°10'54.49"N 73°26'24.38"E. The establishment of RWMF for Zone 3 at Thilafushi requires 15 hectares which have been reclaimed from the adjacent shallow lagoon. Figure 12 illustrates the location of the project.

Figure 12: Project location (micro-location)

Name	Waste to Energy facility Thilafushi
Description of the components	Waste acceptance area with weighbridge Waste bunker with crane Waste incineration (grate technology) with 3 combustion chambers Boiler Flue gas cleaning and stack Residual waste treatment : bottom ash treatment plant Residual waste disposal: residual waste (fly ash conditioned in big bags) state of the art landfill Buildings and facilities (admin, storage, maintenance, water supply, sewerage, electricity, firewater, stormwater, etc..)
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
Borders/boundaries	North: Lagoon East: Old dumpsite West: New reclaimed industrial area South: Open sea
Contract	Design-Build Operate Contract for 20 years
Actual stage	Preliminary design and Tender documents for DBO contractor
Project site	Newly reclaimed area (no waste) with compacted coarse sand North side (lagoon) closed by a concrete quay wall with a height of 1,5 m over MSL South side is closed by a coastal shore protection of rock boulders and a separation liner of a geotextile with an average height of 2,0 over MSL
Vegetation	No vegetation actually, landscaping measures foresee in the DBO
Activity	None (WtE later stage)
Ambient air quality	No activities/negligible
Surface water	Lagoon seawater on the north of the site Open seawater at the Southside
Groundwater	Brackish seawater (after land reclamation)

Table 5: Summary of project location (Micro-location WtE plant)

7.3 Component of the WtE facility

The WtE facility 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 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; waste water 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 the 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.

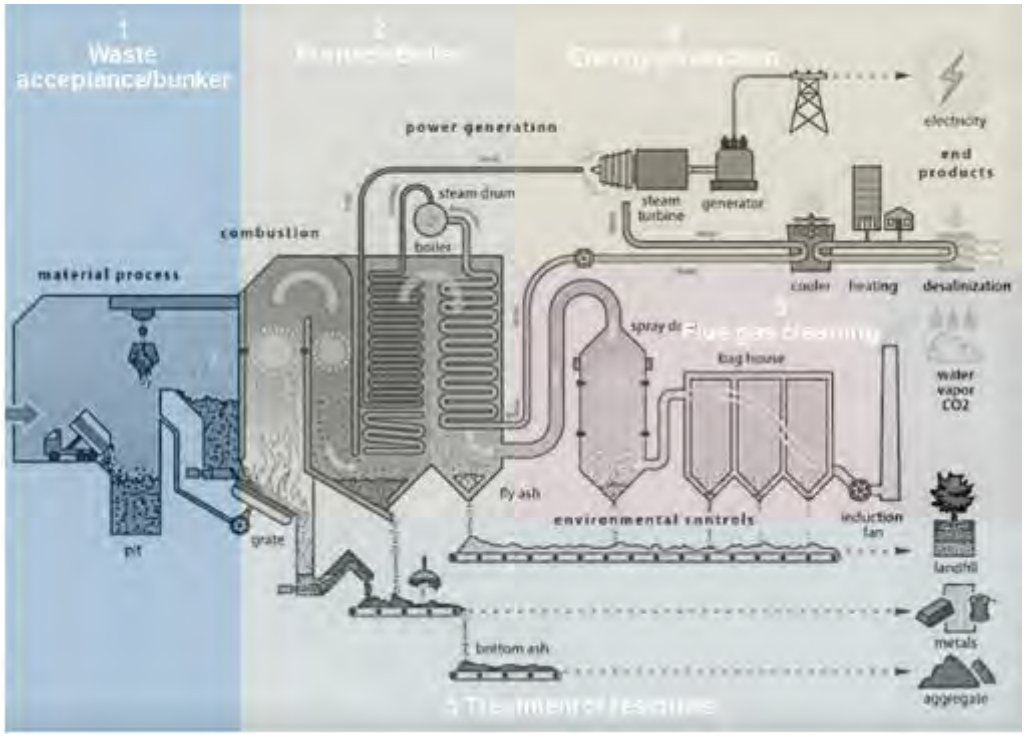


Figure 13: schematic layout of the WtE Facility

These process units are accomodated by the following buildings, housings and civil constructions:

a) Waste reception/guard house
b) Tipping hall
c) Waste bunker
d) Machinery hall and steam turbine housing
e) Housing for the bottom ash processing plant
f) Administration block incl. control room and visitors' center
g) Workshop

h) Housing of the leachate treatment plant

The WtE facility shall be designed and built to allow the extension of the plant by a third line of 250 Mg/d (to reach a total of 750 Mg/d)

To operate the facility the following infrastructure needs also to be realised:

- Water supply, electricity supply (emergency Genset), sewerage system
- Roads, carriageways and sidewalks
- Cooling water inlet and outlet structure
- Storm water drainage system
- Landscaping
- Fencing

All infrastructural elements shall be incorporated into the buildings and process units to allow an easy operation and maintenance of all facilities.

The residual waste from the waste incineration is bottom ash, slag and the residues from flue ash. Bottom ash and slag is a valuable fraction which may potentially be used for many purposes: as covering material for landfill, as a ballast layer or reinforcement layer in road construction or as a filler/aggregate for construction blocks. A bottom ash processing plant is also part of the facility

The residues from the flue gas cleaning (fly ash) are hazardous and need to be dumped in a controlled way on a sanitary landfill after being conditioned safely in sealed big bag.

7.3.1 Stack height

The stack height has been established through the use of modelling services engaged for the EIA. The assessment was done with reference to standards applied for air quality control in Germany, as set out in an instruction document with legal standing in Germany,TA Luft. The stack height required to comply with the technical instruction was determined, following which predictions of concentrations of pollutants in the emissions from the WtE were predicted, and dispersion modelling undertaken for those exceeding a designated minimum level.

Determination of the requisite stack height was undertaken using a nomogram and calculation steps provided in the German TA Luft. The input values for this process are the inside diameter of the stack, the temperature of the waste gas at the mouth of the stack, the volume of flow of the waste gas in standard conditions after subtraction of the water vapour content, and the rate of emission mass flow of the air pollutants from the plant. In determining these parameters, a feed of 500 tons of household waste per day was assumed. The final stack height is determined based on the dimensions of adjoining buildings.

A stack height of minimum 45.7m would have sufficient dilution of the exhaust gases and an undisturbed transport with the free air flow is ensured.

With a view to alleviate the potential air quality impacts at critical air sensitive receivers (ASRs) but at the same time to minimize potential visual impact associated with a tall stack, 50m is selected as the stack height for the RWMF at Thilafushi. It has considered the air quality benefit and visual impact due to a relatively tall stack in a small island geographic setting. The cleaned and cooled gases from the gas cleaning system are discharged into a stack. The gases are discharged by means of an induced drafted fan.

7.3.2 Coolling system

The heat energy of the exhaust air from the furnace is transmitted to water, converting the water to high pressure steam. The high pressure steam is used to rotate a steam turbine and generate electricity. After the electricity generation process, steam pressure is reduced and the steam is further cooled down by a cooling system. The proposed cooling system uses a seawater cooled condenser and involves exchange of the heat of the low pressure steam to sea water, which is then discharged to the sea from south side of Thilafushi.

7.3.3 Bottom ash treatment

The DBO-Contractor shall be responsible for designing and building the bottom ash processing plant including bottom ash storage to satisfy the requirements of the envisaged bottom ash reuse. Subject to the design considerations of the DBO Contractor an intermediate bottom ash storage shall be provided. The floor of the bottom ash storage hall shall allow run-off from the wet bottom ash via a drainage system. The drained run-off from the bottom ash storage area shall be forwarded after either mechanical or gravity cleaning to buffer tanks prior to the leachate treatment system. The intermediate bottom ash storage area shall be sized to accommodate short term stoppages in the conveying system (e.g. the overhead cranes and belt conveyors.

Table 6: Design parameters for Bottom ash treatment plant

Bottom ash Handling System (design parameter)	
Ash content in SW (dry ash/wet)	Max. 35%
Water content in bottom ash downstream extractor	Max. 15%
Capacity	Min. 160% of the maximum bottom ash flow
Boiler & Fly ash transport system	
Boiler hopper ash and air pollution control system fly ash shall be collected from each boiler, economizer, and air pollution control system hopper with drag conveyors, screw conveyors, or a pneumatic conveying system to conditioning the fly ash into big bags. After conditioning the fly ash shall be deposed into the landfill cell. Provisions will be made to prevent dusting during transfer to a disposal truck. The big bags shall be fully enclosed and dustproof and located in the residue building before transport Boiler ash and fly ash drag conveyors, screw conveyors, or pneumatic system shall be completely dust-tight to prevent leakage of fly ash.	

7.3.4 Residual waste landfill

The DBO Contractor's shall design the residual waste landfill complying with the following criteria:

- The landfill arrangement shall be designed to maximise the useable landfill volume of the Site;
- The landfill cell arrangements shall be designed to allow for the progressive closure of individual landfill cells on completion and thereby to minimise the amount of leachate requiring treatment over the lifetime of the landfill;

- The design shall allow for the development of individual cells in a coherent and logical sequence and in a manner which ensures the stability of all working faces and of the waste mound as a whole.
- The design shall incorporate appropriate back-up systems in the event of failure of any component of the environmental control and management systems;
- The landfill concept shall be designed to minimise the lateral and vertical extent of the working face and thereby the amount of deposited waste that is exposed to the environment;
- The design shall ensure that waste can be deposited in a manner that prevents damage to the engineered barrier or liner, the leachate control system, and the collection and transfer system.
- The landfill design shall incorporate an internal access corridor to allow for safe traffic movement and to accommodate site services and monitoring devices;
- Measures shall be provided for controlling unauthorised access to the landfill including, as appropriate, the provision of ditches, berms, planting and fencing;
- Slopes shall be graded to ensure long term slope stability. Graded slopes shall be a maximum of 25%;
- Soil erosion and dust generation shall be minimised;
- All landfill construction materials shall be free of organic matter and debris;
- Measures shall be provided to monitor and manage groundwater beneath and adjacent to the landfill area;

The Contractor's design shall include surface water and storm water collection and diversion systems in order to protect the landfill area and minimise the generation of leachate. Sedimentation ponds shall be established to contain polluted drainage and runoff containing soil and sediment.

The Contractor's design shall include an engineered barrier to prevent leachate contamination of surface water and groundwater. The barrier shall comply with the following:

- The hydraulic conductivity of the barrier shall be no greater than the equivalent of 1 x 10^{-9} metres per second.
- The level of the engineered barrier shall be no deeper than 1.5 metres above mean sea level and in accordance with the applicable environmental standards;

All components of the leachate collection, extraction, transfer and treatment system shall be capable of being maintained in a clean condition to ensure effective operation. Concentrate shall be re-injected in the flue gas treatment process of the WtE. The Contractor shall design and build or organise a system for the safe collection, transport and re-injection of the LTP concentrate.

7.3.5 Electricity generation

The heat produced during the incineration process will be recovered and used for electricity generation. The electricity generated from the incineration process will be used to support the normal operation of the facilities within the RWMF. Surplus energy will be exported to other users via the existing electricity grids maintained by the State Electric Company (STELCO). The supply of process steam and electrical energy for the side shall take place via combined heat and power.

7.3.6 Layout arrangement

The RWMF has been designed to provide long term environmentally sustainable solution for waste management in Zone 3 of the Maldives. Limitations and scarcity of land and the requirement to protect the fragile eco-system have also been considered during the design of RWMF. With a view to minimize the land use and the associated environmental impacts, the preferred location for the RWMF was the area around the old dumpsite of Thilafushi. This has the advantage to reduce environmental risks on another location and islands, and to conduct the dumpsite rehabilitation in parallel. The vocation of Thilafushi as an industrial island plays also in favour of a site location of the facility on this island.

The layout for the RWMF is considered appropriate, taking into consideration the functional need for operation of the RWMF, reasonable flexibility in design for the DBO contractor and allowance of suitable size of land for provision for the future. The design of the RWMF has been done considering factors such as waste composition, quantity reaching RWMF, applicability in the local condition and regulatory compliance.

7.4 Ambiant Air quality/Baseline survey

Air quality monitoring for baseline was conducted by Water Solutions at Thilafushi (and Villingili). Three locations were selected at Thilafushi and one location at Villingili for baseline Air quality monitoring in 2018 and 2019 (see chapter methodology). The Principal objective of the ambient air quality monitoring is to access background environment status and to check the conformity to the applicable standards of ambient air quality. Despite rapid increase in sources of air pollutants and associated diseases there is no national standard for air quality or regulations to control air emission in the Maldives (MEE, 2017). In the absence of any National Ambient Air Quality Standards, the WHO guidelines were considered to assess the air quality.

Figure 14: View around AQ4 (Villingil) on 3rd March 2019

On each sampling day, 1 set of 24-hour average samples were collected continuously. PM_{10}, $PM_{2.5}$, Sulphur dioxide (SO_2) and Oxides of nitrogen (NO2) were measured by sampling continuously during the sampling period.

Figure 15: Air quality monitoring at location AQ1 on 19rd March 2019

As per ToR additional survey for the parameter CH_4, VOC, CO_2, CO, H_2S has been undertaken at selected locations (see Methodology).

Figure 16: Air quality monitoring at location AQ3 on 20th August 2019

Figure 17: View around AQ2 (Thilhafushi) on 25th August 2019

7.4.1 Air Quality baseline survey AQ 1 (Thilafushi workers camp)

Weather/climate	Clouds	Wind direction	Wind speed	Dumpsite
Sunny 33°C	No	North-East	Low-moderate	Open burning

Parameter	Date	µg/m³	WHO ambient air quality guideline (as per Table 1.1.1 of IFC EHS guidelines) in µg/m³
PM_{10}	19.03.-20.03.2019	26,5 [24 hr]	50 [24 hr]
$PM_{2,5}$	19.03.-20.03.2019	**26,9 [24 hr]**	25 [24 hr]
SO_2	22.03.-23.03.2019	**214 [24 hr]**	20 [24 hr]
		866 [10 min max]	500 [10 min]

NO_2	19.03.-20.03.2019	67,5 [1 hr max.]	200 [hr]

Additional parameters according ToR

Parameter	Date	µg/m³	WHO ambient air quality guideline (as per Table 1.1.1 of IFC EHS guidelines) in µg/m³
CH_4	19.03.-20.03.2019	11.745 [24 hr]	N/a
CO	19.03.-20.03.2019	126 [24 hr]	N/a
VOC	21.03.2019	4.889 [24 hr]	N/a

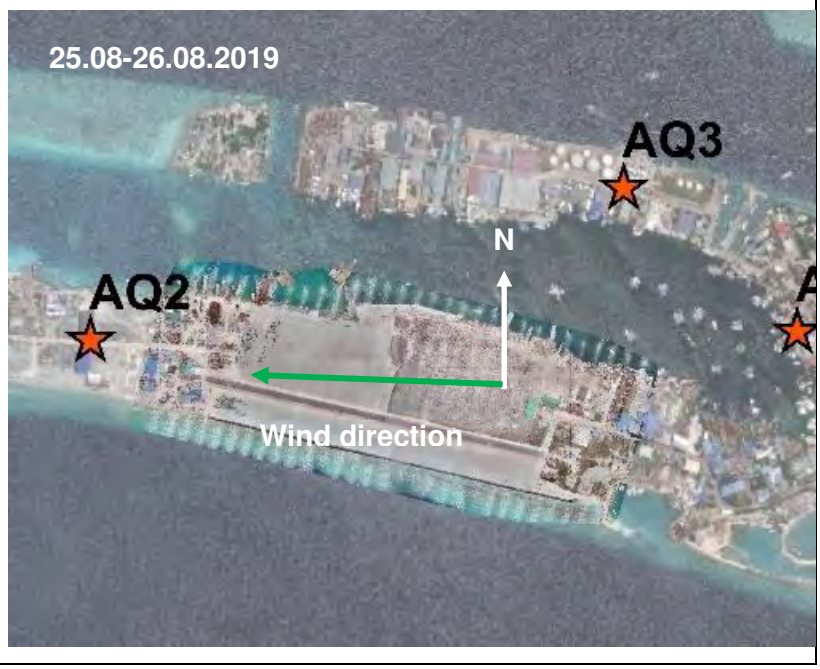
7.4.2 Air Quality baseline survey AQ 2 (Thilafushi 2, new reclaimed area)

Weather/climate	Clouds	Wind direction	Wind speed	Dumpsite
Sunny 32°C	yes	North-East	moderate	Open burning

Parameter	Date	µg/m³	WHO ambient air quality guideline (as per Table 1.1.1 of IFC EHS guidelines) in µg/m³
PM_{10}	25.08.-26.08.2019	**538,93 [24 hr]**	50 [24 hr]
$PM_{2,5}$	25.08.-26.08.2019	**387,45 [24 hr]**	25 [24 hr]
SO_2	-	N/a	20 [24 hr]
		N/a	500 [10 min]
NO_2	28.08.-29.08.2019	72,8 [1 hr max]	200 [hr]

7.4.3 Air Quality baseline survey AQ 3 (Thilafushi 3, Opposite of dumpsite)

Weather/climate	Clouds	Wind direction	Wind speed	Dumpsite
Sunny 31°C	yes	North-East	Moderate-high	Open burning
				

Weather/climate	Clouds	Wind direction	Wind speed	Dumpsite
Sunny 33°C	yes	West	moderate	Open burning
				

Parameter	Date	µg/m³	WHO ambient air quality guideline (as per Table 1.1.1 of IFC EHS guidelines) in µg/m³
PM_{10}	20.06.-21.06.2018	**359,7 [24 hr]**	50 [24 hr]
	21.06-22.06.2018	**96,50 [24 hr]**	
	22.06-23.06.2018	**86,29 [24 hr]**	
	23.06-24.06.2018	**291,47 [24 hr]**	
	25.08.-26.08.2019	**88,46 [24 hr]**	
$PM_{2,5}$	20.06.-21.06.2018	**233,33 [24 hr]**	25 [24 hr]
	21.06-22.06.2018	**61,38 [24 hr]**	
	22.06-23.06.2018	**51,38 [24 hr]**	
	23.06-24.06.2018	**184,70 [24 hr]**	
	25.08.-26.08.2019	**42,81 [24 hr]**	
SO_2	22.06-24.06.2018	**291 24 [hr]**	20 [24 hr]
		970 [10 min max]	500 [10 min]
NO_2	28.08.-29.08.2019	72,8 [1 hr max]	200 [hr]

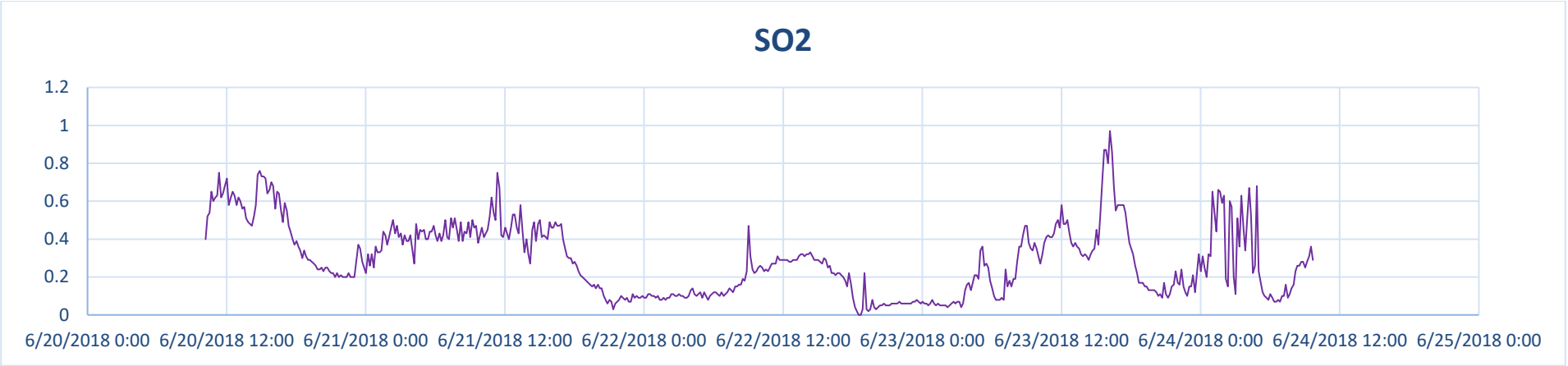


Figure 18: graphical presentation of survey results for SO_2 at AQ3 (PPT)

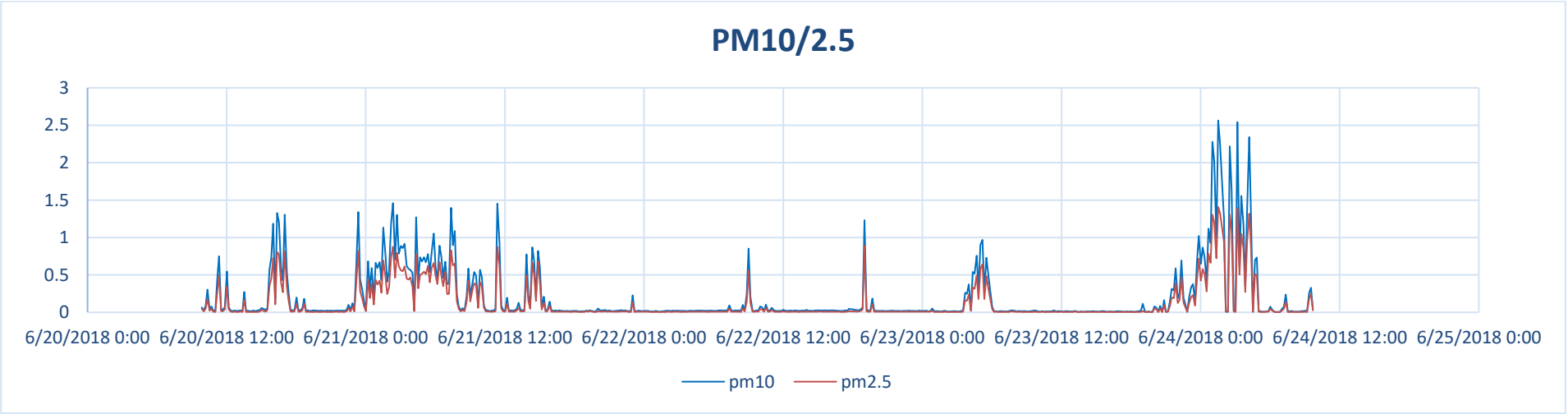


Figure 19: graphical presentation of survey results for $PM_{2,5}$ and PM_{10} at AQ3 (PPT)

7.4.4 Air Quality baseline survey AQ 4 (Vilingili)

Parameter	Date	µg/m³	WHO ambient air quality guideline (as per Table 1.1.1 of IFC EHS guidelines) in µg/m³
PM_{10}	06.03.-08.03.2019	22,7 [24 hr]	50 [24 hr]
$PM_{2,5}$	06.03.-08.03.2019	22,7 [24 hr]	25 [24 hr]
SO_2	06.03.-08.03.2019	7,6 [24 hr]	20 [24 hr]
		190 [10 min max]	500 [10 min]
NO_2	06.03.-08.03.2019	87 [1 hr]	200 [hr]

Additional parameters according ToR

Parameter	Date	µg/m³	WHO ambient air quality guideline (as per Table 1.1.1 of IFC EHS guidelines) in µg/m³
CH_4	06.03.-08.03.2019	0,175 [24 hr]	N/a
CO	06.03.-08.03.2019	124 [24 hr]	N/a

7.4.5 Interpretations of the results

The ambient air quality results obtained from the monitoring undertaken at Thilafushi indicate that only some parameters were within the WHO guidelines for ambient air quality.

As it could be seen one main influencing factor is the dumpsite at Thilafushi and its illegal burning

Particular manners usually varies between 27-540 µg/m³ (daily average) with a min around 4 µg/m³ and a maximum peak reaching more than 2.000 µg/m³.

NO_2 (hourly maximum) are below WHO guidelines at all places

SO_2 is in the rage of 214-290 µg/m³ (24 hr average) and 800-866 µg/m³ and over the WHO values.

It must be noted that at each period of surveying the dumpsite was burning and that unfortunetaly the wind direction and the wind speed (velocity) were during the survey period exactly in the direction of the survey points. It can be seen that when the velocity is low (AQ 1 end of March 2019) or the wind direction is not in the direction of the survey point (AQ3 August 2019) the parameters are closer to the WHO guidelines.

For Vilingili as the main inhabitated islands close to Thilafushi all the parameters are below the WHO guidelines.

8 Identification and assessment on potential effects

8.1 General emission

The following maximum mass concentrations should be achieved by the flue gas cleaning.

Table 7: Maximum mass concentration

Substance	Mass concentration [1]
Total dust, including particulate matter (No 5.2.1 TA Luft)	5 mg /m³
Fluorine and its compounds, indicated as hydrogen fluoride (5.2.4 Class II TA Luft)	1 mg /m³
gaseous inorganic chlorine compounds, indicated as hydrogen chloride (5.2.4 class III TA Luft)	10 mg/m³
Ammonia (5.2.4 class III TA Luft)	10 mg/m³
Sulphur oxides (sulphur dioxide and sulphur trioxide), expressed as sulphur dioxide (5.2.4 Class IV TA Luft)	50 mg/m³
Nitrogen oxides (nitrogen monoxide and nitrogen dioxide), expressed as nitrogen dioxide (5.2.4 (2), 2nd sentence TA Luft)	150 mg/m³
Carbon monoxide (5.2.4 para. 2 sentence 1 TA Luft)	50 mg/m³
organic substances (expressed as total C) (TA Luft 5.4.10.20)	10 mg/m³
Mercury and its compounds, reported as Hg (No 5.2.2 Class I TA Luft)	0.03 mg/m³
Dioxins and furans	0.1 ng/m³
Sum of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel (5.2.2 TA Luft class II and III)	as total 0.5 mg/m³
Thallium and its compounds (5.2.2 TA Luft class I) cadmium	as total of 0.05 mg/m³
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) (5.2.7.1.1 TA Luft Class I)	as total 0.05 mg / m³

8.1.1 Emission mass flow

Table 8: Emission mass flow (for R = 115 713 m³/h, T = 180 °C, Ø = 2.12 m)

Substance	Masses concentration	Mass flow Q in kg/h	Factor S	Q/S in kg/h **
Total dust, including particulate matter (No 5.2.1 TA Luft)	5 mg/m³	0.579	0.08	7.2
Fluorine and its compounds, indicated as hydrogen fluoride (5.2.4 Class II TA Luft)	1 mg/m³	0.116	0.0018	64.3

Substance	Masses concentration	Mass flow Q in kg/h	Factor S	Q/S in kg/h **
Gaseous inorganic chlorine compounds, indicated as hydrogen chloride (5.2.4 class III TA Luft)	10 mg/m³	1,157	0.1	11.6
Ammonia (5.2.4 class III TA Luft)	10 mg/m³	1,157	-	-
Sulphur oxides (sulphur dioxide and sulphur trioxide), expressed as sulphur dioxide (5.2.4 Class IV TA Luft)	50 mg/m³	5,786	0.1 4	41.3
Nitrogen oxides (nitrogen monoxide and nitrogen dioxide), expressed as nitrogen dioxide (5.2.4 (2), 2nd sentence TA Luft)	150 mg/m³	11,108 *	0.1	111.08 *
Carbon monoxide (5.2.4 para. 2 sentence 1 TA Luft)	50 mg/m³	5,786	7.5	0.77
Organic substances (expressed as total C) (TA Luft 5.4.10.20)	10 mg/m³	1,157	0.1	11.6
Mercury and its compounds, reported as Hg (No 5.2.2 Class I TA Luft)	0.03 mg/m³	0.003 47	0.00 013	26.7
Dioxins and furans	0.1 ng/m³	1.16 x 10^{-8}	-	-
Sum of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel (5.2.2 TA Luft class II and III)	0.5 mg / m³	0.057 86	0.05 0.1	1.157 0.579
Thallium and its compounds (5.2.2 TA Luft class I) cadmium	0.05 mg / m³	0.005 79	0.005	1.16
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) (5.2.7.1.1 TA Luft Class I)	0.05 mg / m³	0.00579	0.00005	**115.7**

* According to point 5.5.3 TA Luft, the emission of nitrogen monoxide is based on a conversion rate of 60% to nitrogen dioxide, and is based on a ratio of NO/NO_2 = 90%/10%, cf. Annex 1.1

8.1.2 Control of the necessity of the dispersion calculation

The determination of the ambient air quality characteristics is not required if the emissions of the air pollutants do not exceed the following minor mass flows:

Table 9: Minor mass flow according 4.6.1.1 TA Luft and WtE mass flow

Pollutants	Minor mass flow	Plant mass flow (Annex 2)
	in kg / h	
Emissions derived from stacks		
Dust (without consideration of dust contents)	1	0.579
Fluorine and its compounds, indicated as hydrogen fluoride (5.2.4 Class II TA Luft)	0.15	0.116
Gaseous inorganic chlorine compounds, indicated as hydrogen chloride (5.2.4 class III TA Luft)	-	1,157
Ammonia (5.2.4 class III TA Luft)	-	1,157
Sulphur oxides (sulphur dioxide and sulphur trioxide), expressed as sulphur dioxide (5.2.4 Class IV TA Luft)	20	5,786
Nitrogen oxides (nitrogen monoxide and nitrogen dioxide), expressed as nitrogen dioxide (5.2.4 (2), 2nd sentence TA Luft)	20	11.108
Carbon monoxide (5.2.4 para. 2 sentence 1 TA Luft)	-	5,786
Organic substances (expressed as total C) (TA Luft 5.4.10.20)	-	1,157
Mercury and its compounds, reported as Hg (No 5.2.2 Class I TA Luft)	0.0025	0.00347
Dioxins and furans	-	$1{,}16 \times 10^{-8}$
Sum of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel (5.2.2 TA Luft class II and III)	0.025 lead, nickel (class II)	0.05786
Thallium and its compounds (5.2.2 TA Luft Class I)	0.0025	0.00579
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) (5.2.7.1.1 TA Luft Class I)	0.0025	0.00579

For most of substances the values are below the minor mass flows. For mercury as well as heavy metals and their components (referred to thallium and arsenic/cadmium and lead/nickel) the values are over the minor flows, therefore there is a need to perform the **dispersion modelling** for these substances.

For ammonia and hydrogen chloride (5.2.4 Class III TA Luft), for carbon monoxide, for organic substances (expressed as total C) as well as dioxins and furans no minor mass flow are set in the regulations therefore there is no need to undertake a detailed dispersion modelling for these parameters either.

Emergency Gen-set

For the emissions mass flow calculation of the air pollutants of the emergency Gen-set, data of the client have been made available [1].

The following pollutants have to be considered. The exhaust gas volume flow was given as V_n = 12 470 mN^3/h and the exhaust gas temperature to T=180° C.

Table 10: Minor mass flow according to Section 4.6.1.1 TA Luft - system mass flow

Substance	Minor mass flow	Plant mass flow in kg/h
	in kg / h	
Dust (without consideration of dust contents)	1	0.9976
Nitrogen oxides (nitrogen monoxide and nitrogen dioxide), expressed as nitrogen dioxide (5.2.4 (2), 2nd sentence TA Luft)	20	3.99
Carbon monoxide (5.2.4 (2) sentence 1 TA Luft)	-	3,741
Formaldehyde - HCHO	-	0,748

The minor mass flows have also been not exceeded by the Gen-set emission values, so that no dispersion calculation has to be carried out for these substances.

For carbon monoxide and formaldehyde no minor mass flow has been set in the regulation. For these substances, so that for this substance group also no dispersion calculation is to be carried out.

No indications were found which requires a special case test according to section 4.8 TA Luft.

8.2 Air dispersion modelling for relevant parameter

In order to estimate exposures to airborne pollutants from the incineration and emergency electricity generation, dispersion modelling was carried out. Modelling was done for the pollutants: dust, nitrogen monoxide and nitrogen dioxide), carbon monoxide and formaldehyde from the emergency electricity generation sets. 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 study zone was defined as a 5000 m radius of influence from incinerator stack at Thilafushi. The figure below shows the area around the proposed waste to energy plant at Thilafushi Island.

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

The program system AUSTAL2000 calculates the spread of pollutants and odours in the atmosphere. It is an extended implementation of Annex 3 of the German regulation TA Luft (Technical Instruction on Air Quality Control) demands for dispersion calculations a Lagrangian particle model in compliance with the German guideline VDI 3945 Part 3. The modelling work was carried out by Ulbricht Consulting (Germany). The dispersion modelling report is attached as an Annex 1 to this report.

Steady-state Gaussian plume models assess pollutant concentrations and/or deposition fluxes from a variety of sources associated with an industrial source complex. Unlike the Gaussian models commonly used, this flexible modelling procedure used in AUSTAL2000 provides realistic results even when buildings and uneven terrain influence flue gas dispersion. The model calculates the contribution of specified air pollutants from a given point source to the background concentrations present in the ambient air at ground level in the area surrounding the source.

Parameter for additional load, the parameter for the emission year-additional load (IJZ) is the average of all calculated individual contributions at each reference point.

8.2.1.1 *Emission from installations*

The following emission sources have been considered:

Exhaust stack: WtE

The following operation time has been considered: 8,000 h/a

8.2.1.2 *Emissions from guided sources*

For the emissions of the air pollutants of the incinerator WtE data are available from the client [1]. For the incineration plant, the following pollutants have been taken into account in the dispersion calculation. The exhaust gas volume flow was given as Vn = 115713 mN^3/h and the exhaust gas temperature as T = 180° C.

The air dispersion calculation was made with a stack height of 46,0 m.

In chapter 6 (Employer's requirement) of the DBO a minmum height of 50,0 m has been fixed.

Therefore the calculated emsissions are presenting the worst case. With the extension of the stack, the ambient air concentration value will be reduced at the reception point.

Table 11: Emissions Stack WtE

Substance	mg / m³	Total flow V_N m³/h	Emission mass flow in kg/h
Total dust, including particulate matter	5	115713	0.579
Fluorine and its compounds, indicated as hydrogen fluoride	1		0.1 16
Ammonia	10		1,157
Sulphur oxides (sulphur dioxide and sulphur trioxide), expressed as sulphur dioxide	50		5,786
Nitrogen oxides (nitric oxide and nitrogen dioxide), expressed as nitrogen dioxide	150		11.108
Mercury and its compounds, indicated as Hg	0.03		0.0035
Sum of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel (5.2.2 TA Luft class II and III)	0.5 mg / m³		0.05786
Thallium and its compounds (5.2.2 TA Luft class I)	0.05 mg / m³		0.00579
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) (5.2.7.1.1 TA Luft Class I)	0.05 mg / m³		0.00579

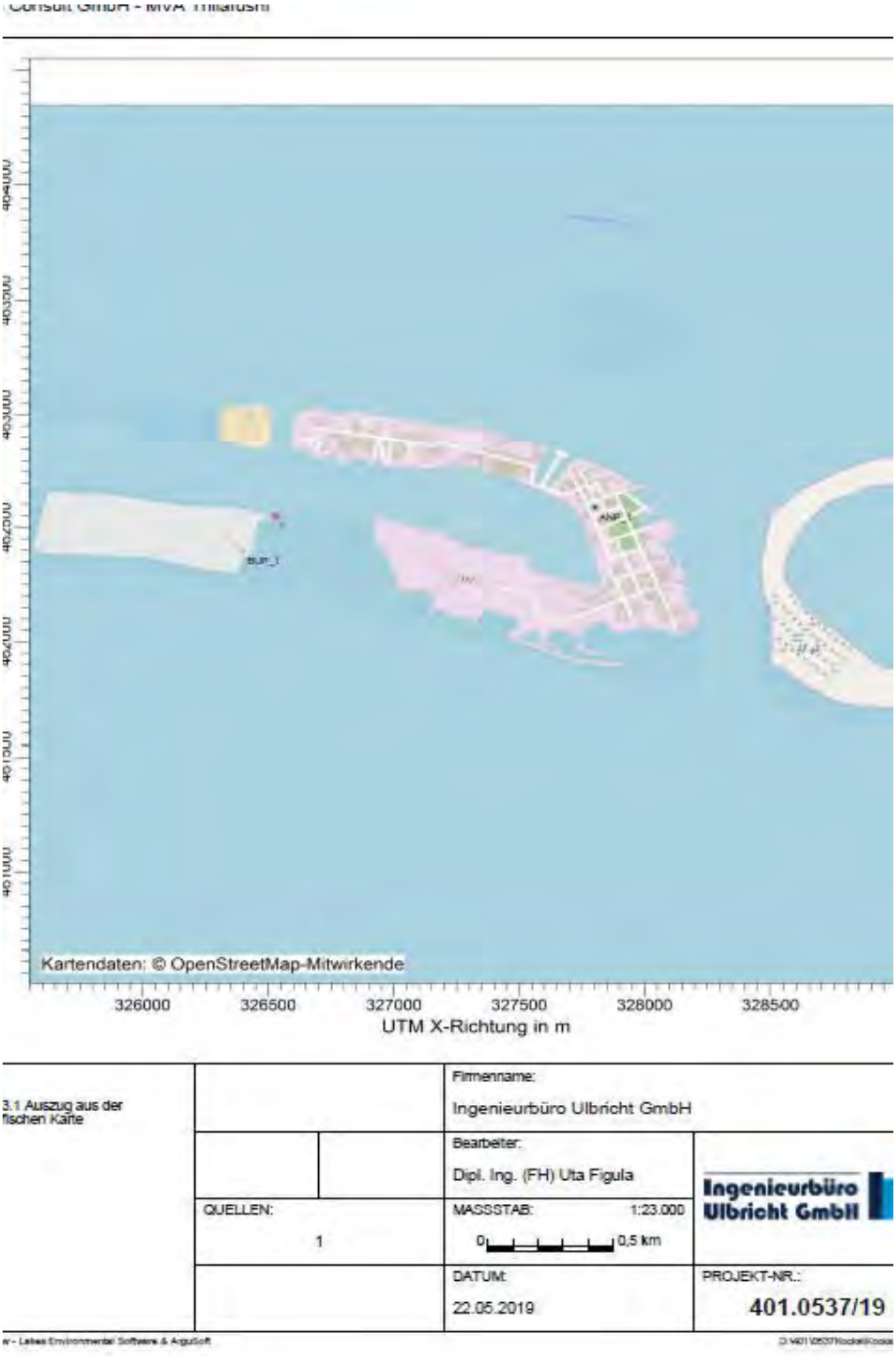


Figure 20: Location of the emission points where maximum load was calculated and examined

Computer model

For the calculation the dispersion model AUSTAL2000, version 2.6.11-WI-x, of the company Janicke Consulting was used, which is implemented in the program AustalView TG of the company Argusoft. The program system AUSTAL2000 calculates the spread of pollutants and odours in the atmosphere. It is an extended implementation of Annex 3 of the TA Luft. The model underlying the program is described in guideline VDI 3945 Part 3.

Computational domain

Due to the stack height of 46 m the calculation area has a radius of at least 2300 m (50 times the height). The grid for the calculation of concentration and deposition shall be selected in accordance with Chapter 7 (2) of Annex 3 of the TA Luft so that the location and contribution of the maximum ambient air quality can be determined with sufficient certainty. This is usually the case when the horizontal mesh size does not exceed the stack height. At source distances greater than 10 times the height of the stack, the horizontal mesh size can be selected proportionally larger. The calculations and assessments were carried out in an area of 3.2 x 2.6 km and a grid with mesh sizes of 5 to 20 m.

Ground roughness

The ground roughness of the terrain is described by an average roughness length z_0 .It is in accordance with the land use classes in the CORINE cadastre. The roughness length was chosen to be $z_0 = 0,2$ in the calculation. This value should be considered representative for the area of calculation

Sources

In the calculation program emission source can be differentiated into different source types. Exhaust stacks are defined as point sources.

The source calculated on the basis of the emission behaviour described in Appendix 3, in accordance with Appendix 3, was entered using the parameters described. The parameters and emission data are given in Appendix 3. An emission source plan is also included in Appendix 3.

Pollutants

As per Table 4 in section 6 the dispersion modelling is required for mercury and heavy metals and their components (represented by lead/nickel, thallium and arsenic/cadmium). For all other pollutants, the minor mass flows according to Table 7 of No. 4.6.1.1 of the TA Luft have not been exceeded. For these substances, it can be assumed that harmful environmental effects from the plant cannot be caused.

The following pollutants relevant to the plant could be calculated according to TA Luft: dusts (dust precipitation, PM10), sulphur dioxide, nitrogen oxide, ammonia, mercury, arsenic, cadmium, nickel, lead, thallium. In the present case, for all relevant pollutants, insofar as emission limits are defined for these substances in TA Luft, the air dispersion modelling has been run.

For the other relevant pollutants: total C, carbon monoxide (CO), hydrogen chloride, dioxins and furans , no emission values are specified in the TA Luft.

Dispersion class time series

The wind direction and wind speeds were modelled with a dispersion class time series for the year 2017 [8].

Terrain and slope

It is a flat terrain. In the computing area, no gradients of more than 1:20 or more than 1:5 occur.

Statistics

The resulting statistical uncertainty (in %) was taken into account in the evaluation. The calculation was performed with the quality level "2". To assess the ambient air quality limits, the calculated value have been increased by the statistical uncertainty.

Receiver points

In the examination area two ambient air quality points have been determined for the calculations. The BUP 1 was chosen as the point of presumed highest load due to the shortest distance to the emission source. The ANP 1 (nearby a food place), due to which in comparison with the BUP 1 gives the higher additional load of pollutant deposition, was to be considered in more detail. The location of the ambient air quality points can be found in Annex 3.

Table 12: Ambient air quality points

Ambient air quality points
BU P 1 West
ANP 1 east

8.3 Maximum ground level/Additional load

The following results apply exclusively taking into account the characteristics of the emission sources mentioned in Chapter 7. The dispersion calculation is required for the substances mentioned in chapter 6.1. All other results in Table 10 are presented for information only. As a guide, a comparison is made with the irrelevance values and the ambient air quality values of TA Luft.

The detailed analysis results are given in Appendix 3 and the grid diagram representation of the substances (except for ammonia and suspended particulate PM_{10}) could be found in Annex 4 .

Table 13: Ambient air quality Maximum ground level/additional load (IZ) (including statistical uncertainty)

Ambient air quality points	Irrel. IZ	IW	BUP 1	ANP 1
Substance				
Mercury g/(m² d)	*0.05*	1	0,007	1.0
PM_{DEP} g/(m² d)	*0.0105*	0.35	0,0001	0,0001
PM10 µg/m³	*1.2*	40	0	0
Hydrofluoric µg/m³	*0.04*	0.4	0	0.005
Sulphur dioxide µg/m³	*1.5*	50	0	0.2
Nitrogen oxides µg/m³	*1.2*	40	0	0.4
Ammonia µg/m³	-		0	0.04
Lead µg/(m² d)	*5*	100	0,2	17,0
Nickel µg/(m² d)	*0.75*	15	0,122	17,1
Thallium µg/(m²d)	*0.1*	2	0,01	1,7
Cadmium µg /(m² d)	*0.1*	2	0.01	1, 7
Arsenic µg/(m² d)	*0.2*	4	0.02	1,7

A pre-pollution with air pollutants at the site is not known (baseline), so it is assumed that the calculated values represent the total load.

Evaluation point BUP 1

At assessment point BUP 1, the values are below the “irrelevance thresholds” of TA Luft for the substances.

Analysis point ANP 1

At the ANP 1 analysis point, the air pollutants PM10, dust precipitation, sulphur dioxide, nitrogen oxides, hydrogen fluoride fall below the irrelevance values according to TA Luft.

If an orienting comparison is made with the air quality values of TA Luft, the following can be stated:

- For lead, thallium, cadmium, arsenic, the ambient air quality value of TA Luft is below. For mercury, the ambient air quality value of TA Luft is reached (not exceeded).
- The specified ambient air quality value in the TA Luft for nickel is exceeded. In the calculation, the heavy metal nickel was considered representative of the group of heavy metals and their components: antimony, chromium, copper, manganese, vanadium, tin, lead, cobalt, nickel (5.2.2 TA Luft class II and III).

Taking into account the volumetric flow and the desired mass concentration (corresponding to the emission limit value (class II according to 5.2.2 TA Luft) for the group of heavy metals, the emission mass flow for the group of heavy metals was assigned to the substance nickel. Fom a technical perspective it is not expected that none of the further elements of the heavy metal group occur in the exhaust gas, so that the exceeding of the ambient air quality value for nickel is likewise not expected.

Ammonia

No ambient air quality value is specified for ammonia. The desired mass concentrations by means of flue gas cleaning are below the values specified in the TA Luft (limit values). A negative impact on the environment is therefore not expected.

Hydrogen chloride, total C, carbon monoxide (CO), dioxins and furans

No ambient air quality values are specified for these substances. The mass concentrations aimed at by means of flue gas cleaning are below the values stated in the TA Luft (limit values). A negative impact is therefore not to be feared.

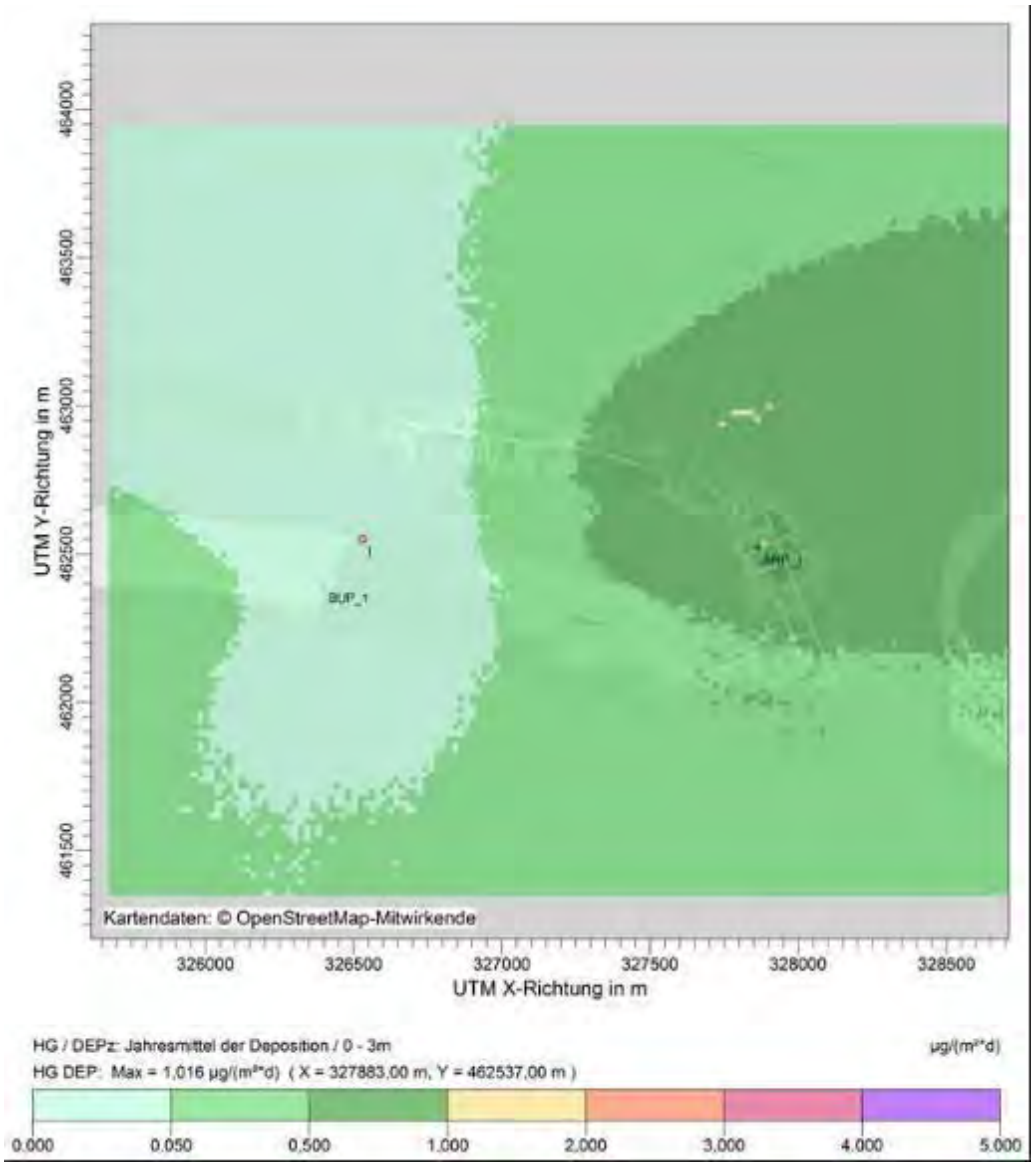


Figure 21: additional load Mercury-Deposit from the dispersion model.

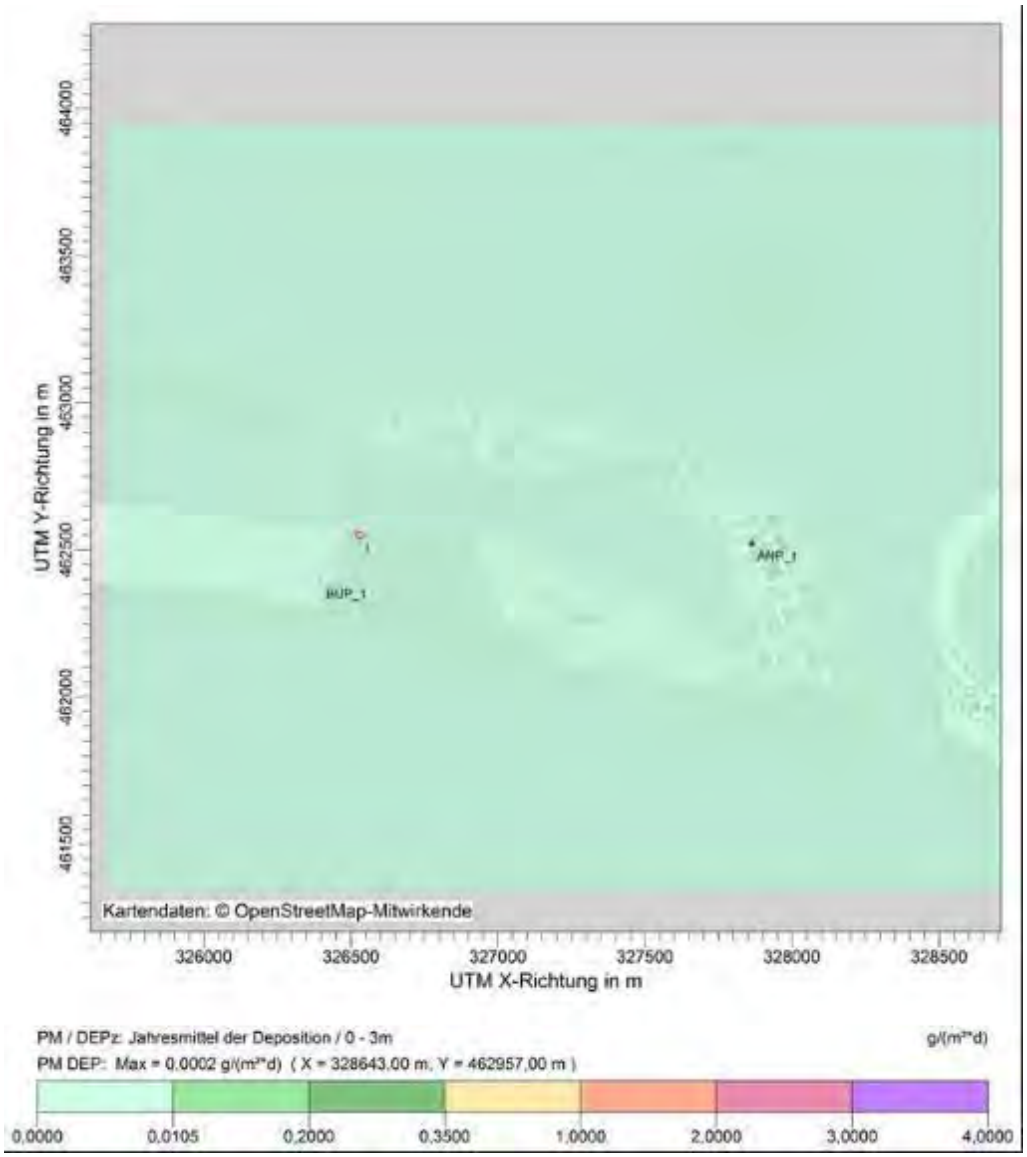


Figure 22: PM-Deposit from the dispersion model.

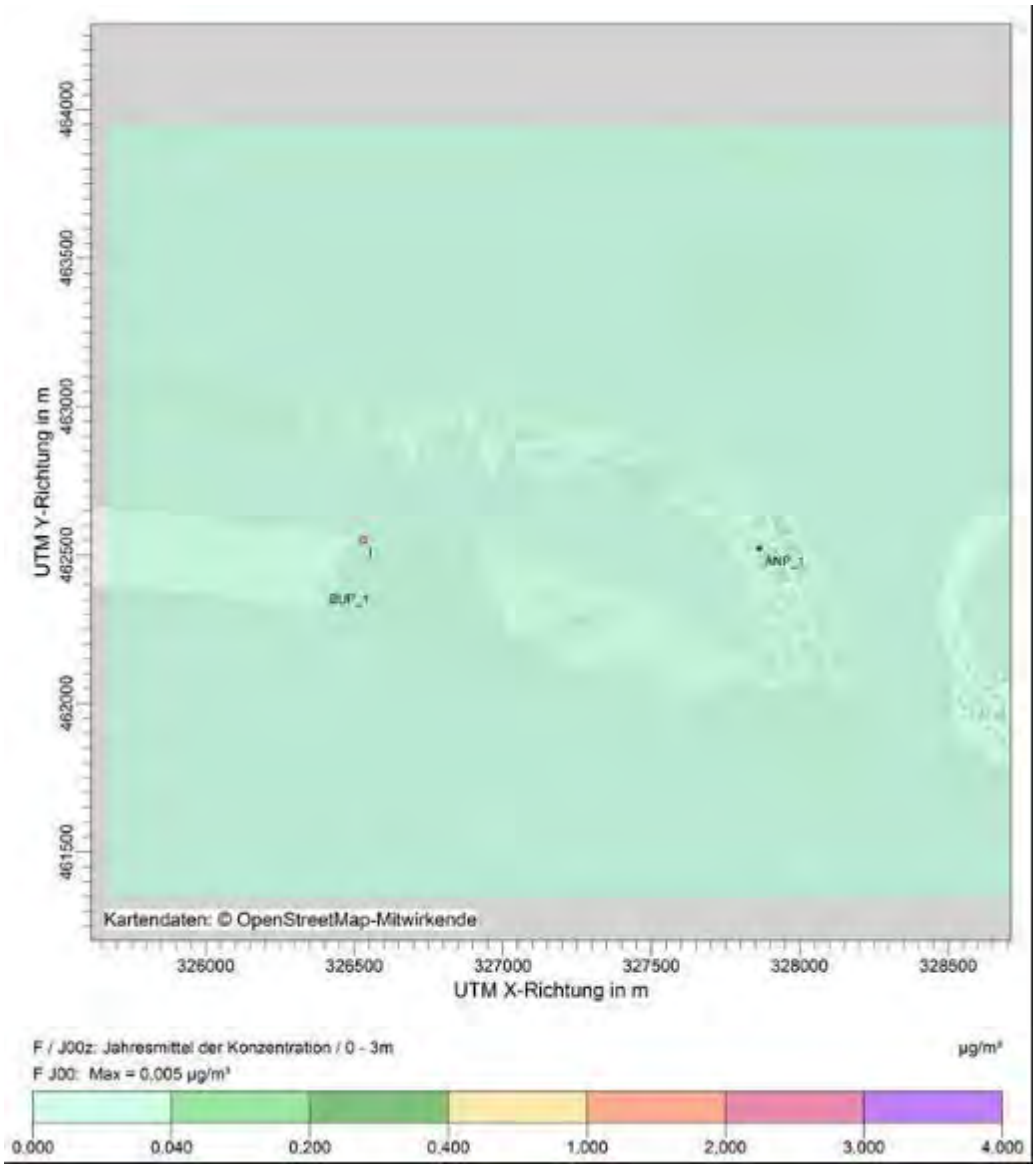


Figure 23: F-Deposit from the dispersion model.

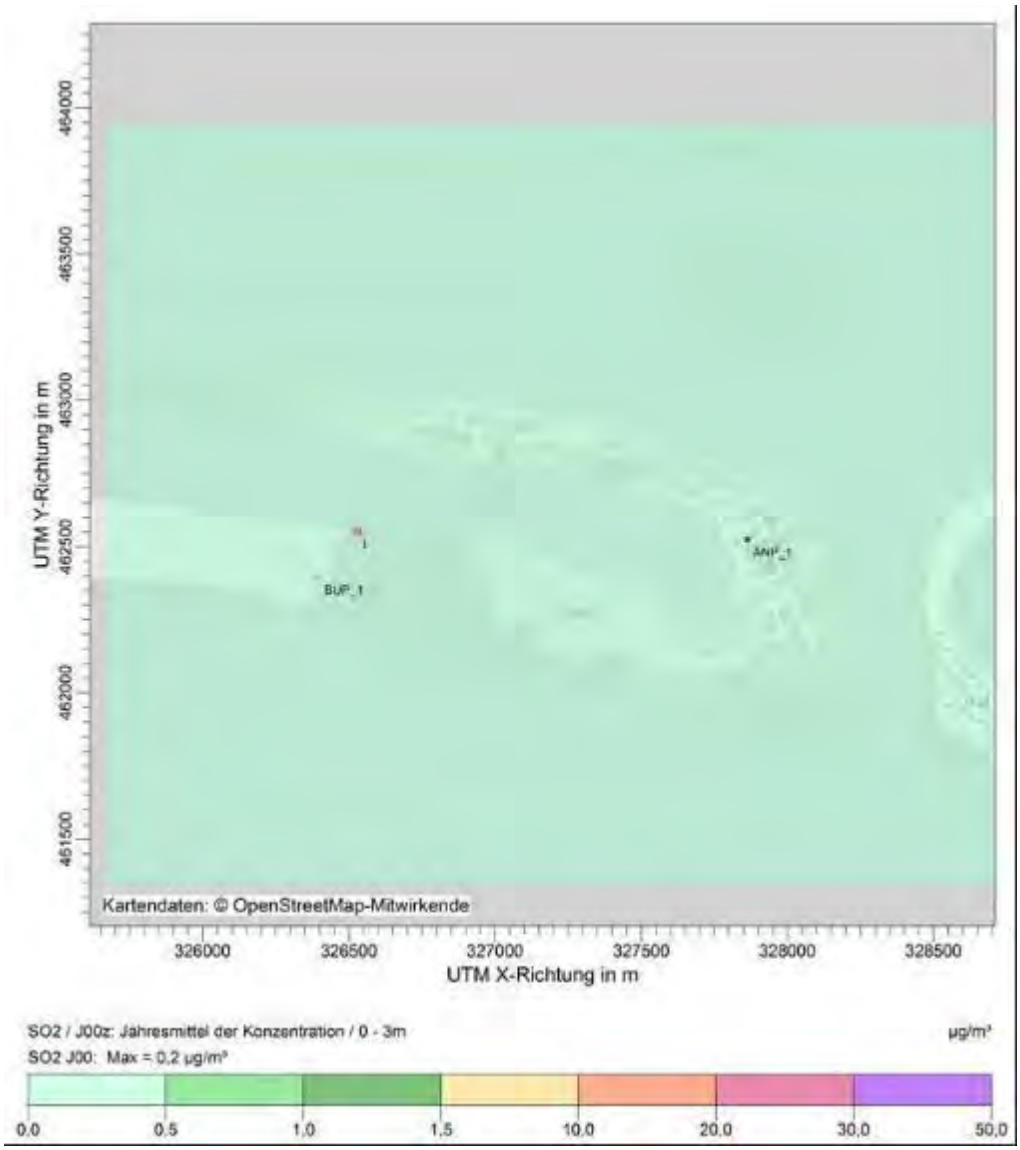


Figure 24: SO_2-Deposit from the dispersion model.

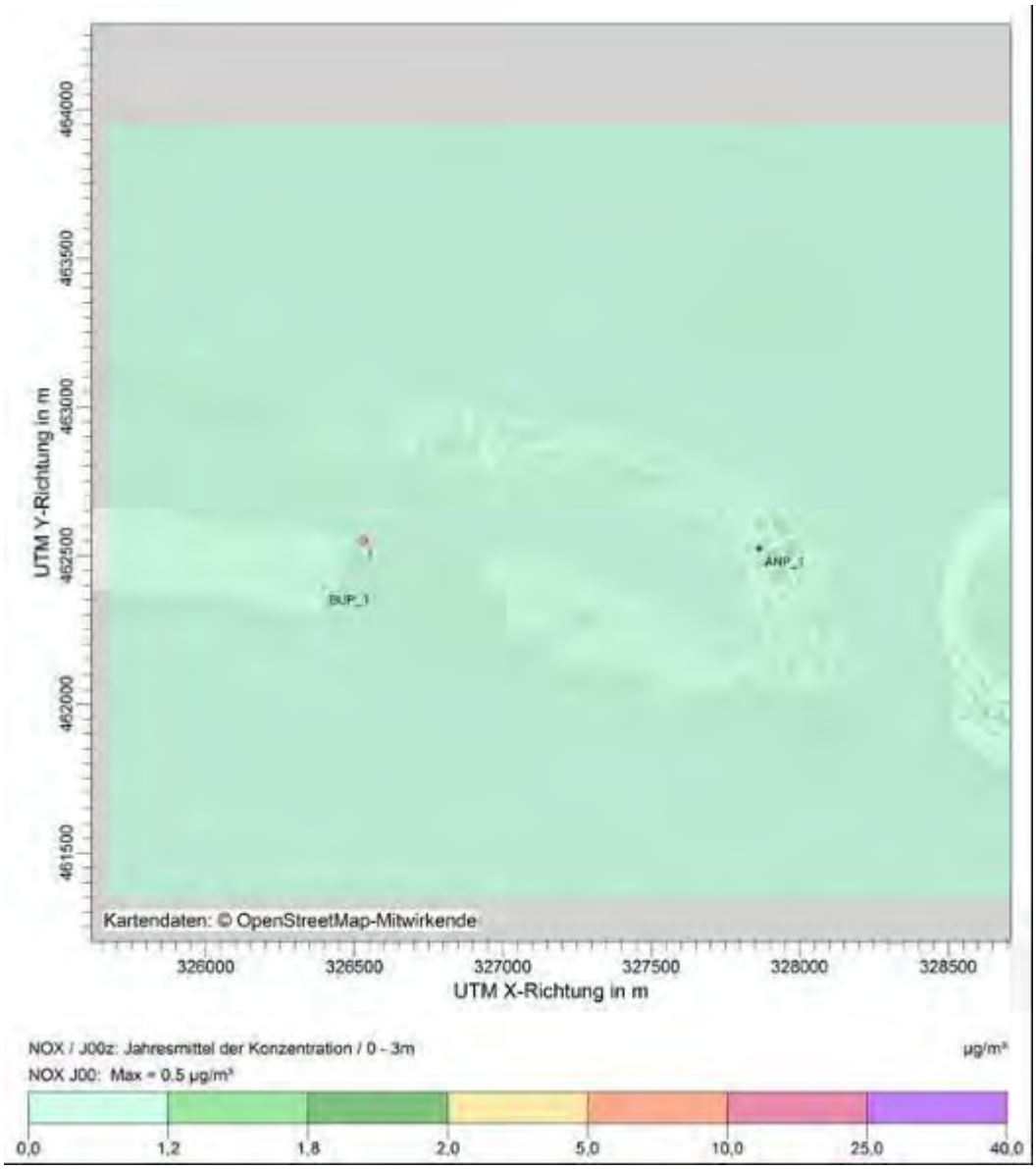


Figure 25: NOx-Deposit from the dispersion model.

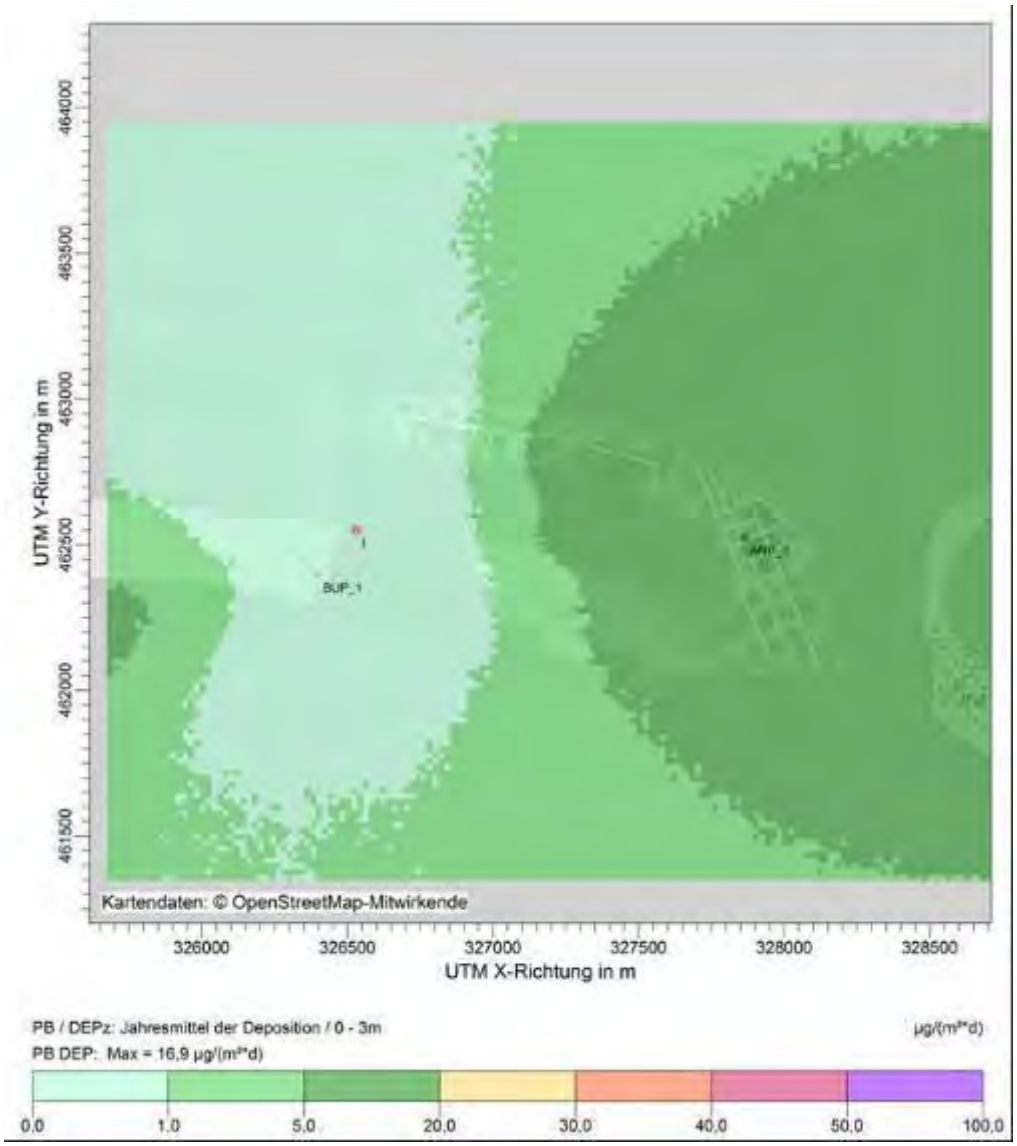


Figure 26: Pb-Deposit from the dispersion model.

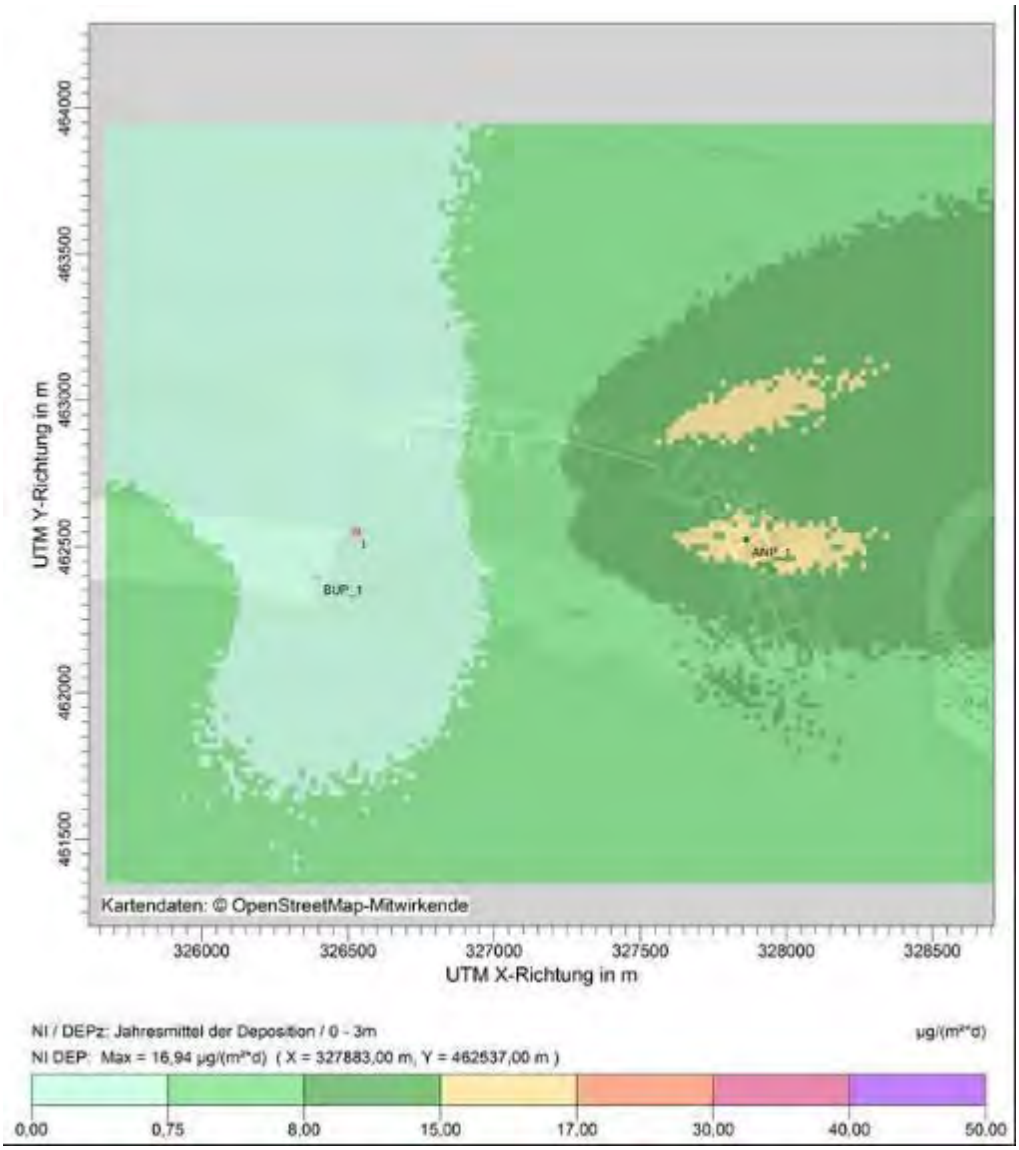


Figure 27: Ni-Deposit from the dispersion model.

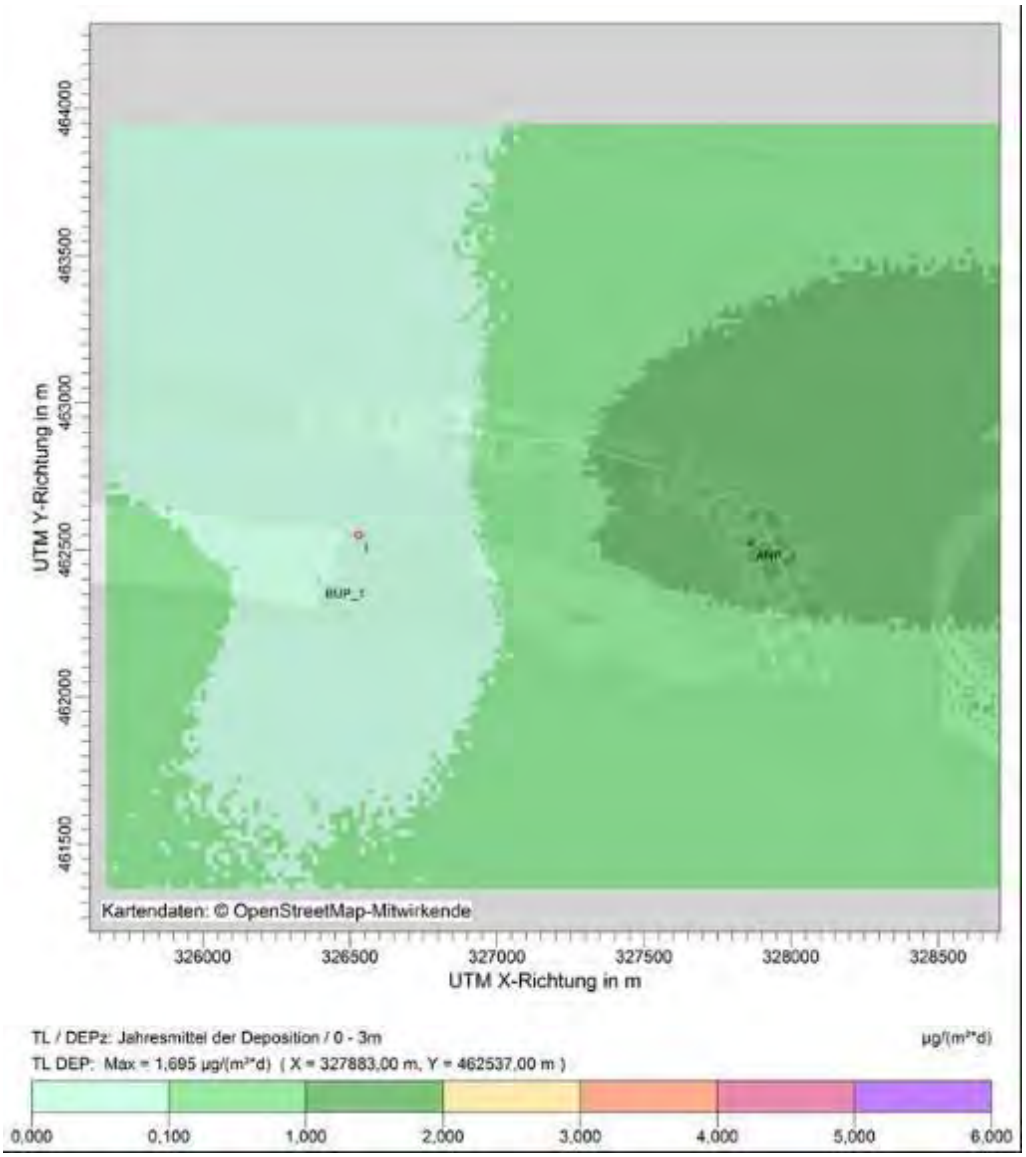


Figure 28: Tl-Deposit from the dispersion model.

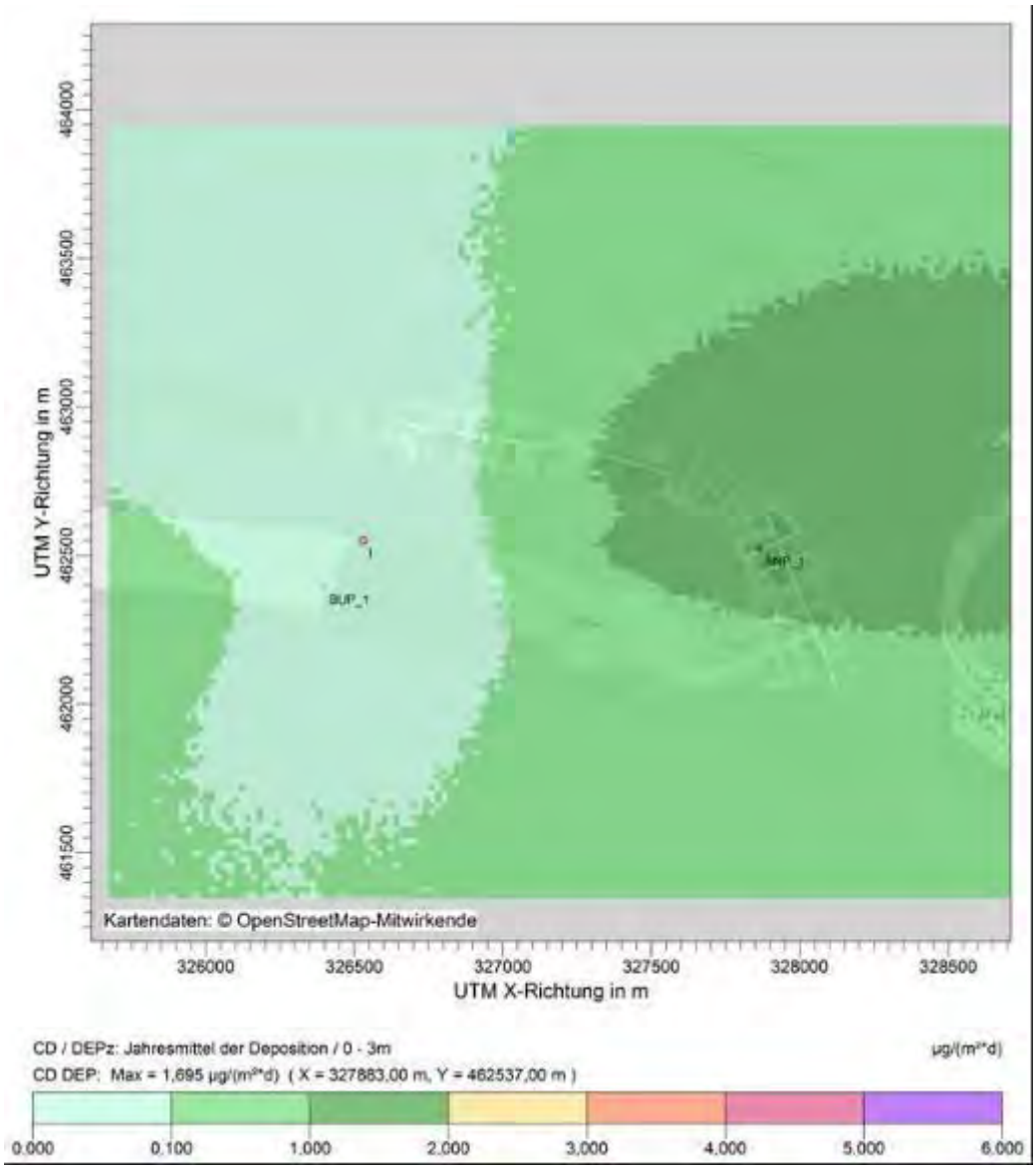


Figure 29: Cd-Deposit from the dispersion model.

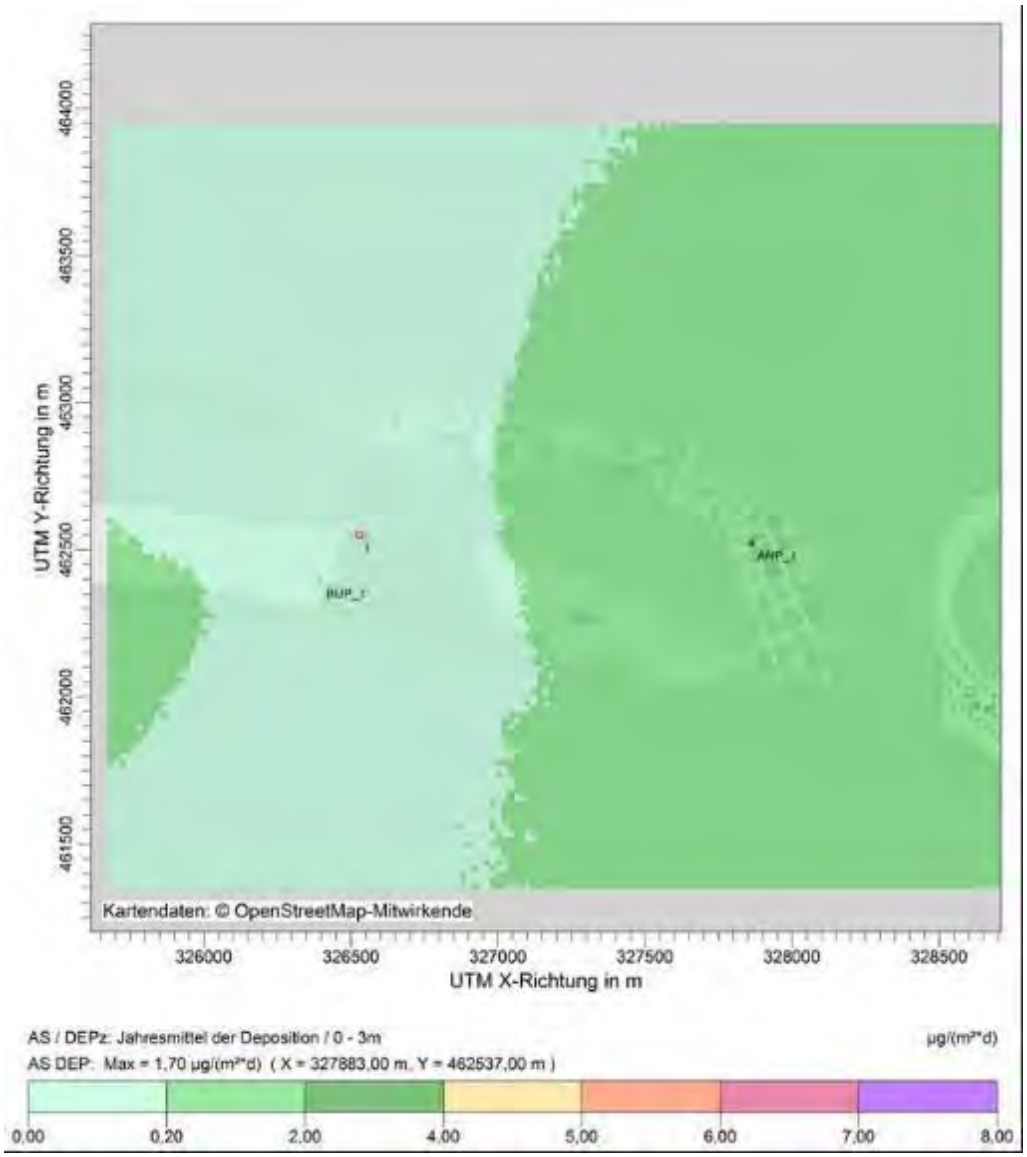


Figure 30: As-Deposit from the dispersion model.

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”

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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.

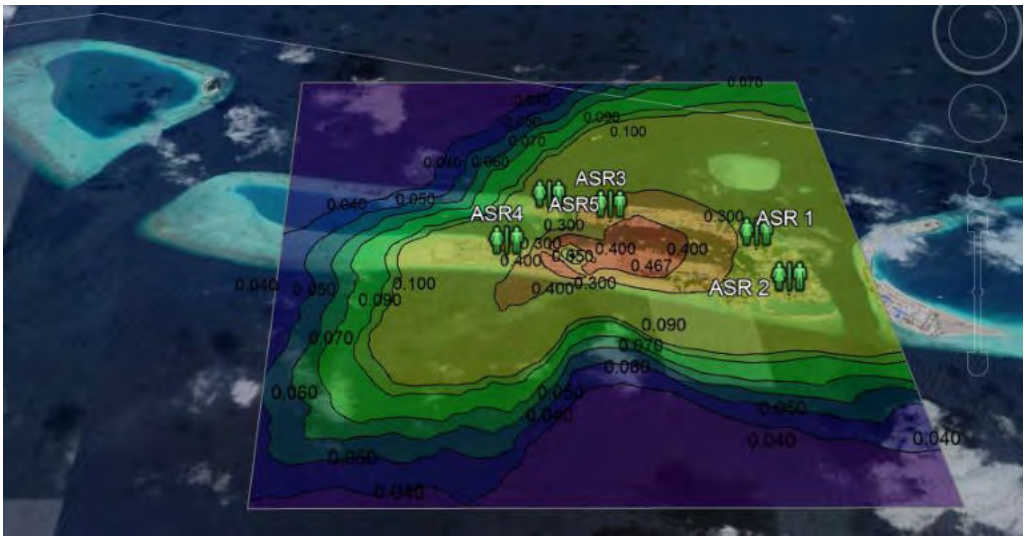
MEE (2017) EIA for the Proposed Reclamation of Thilafalhu for the establishment of the Regional Waste Management Facility for Zone 3, Kaafu Atoll, Ministry of Environment and Energy and Energy, Malé.

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]

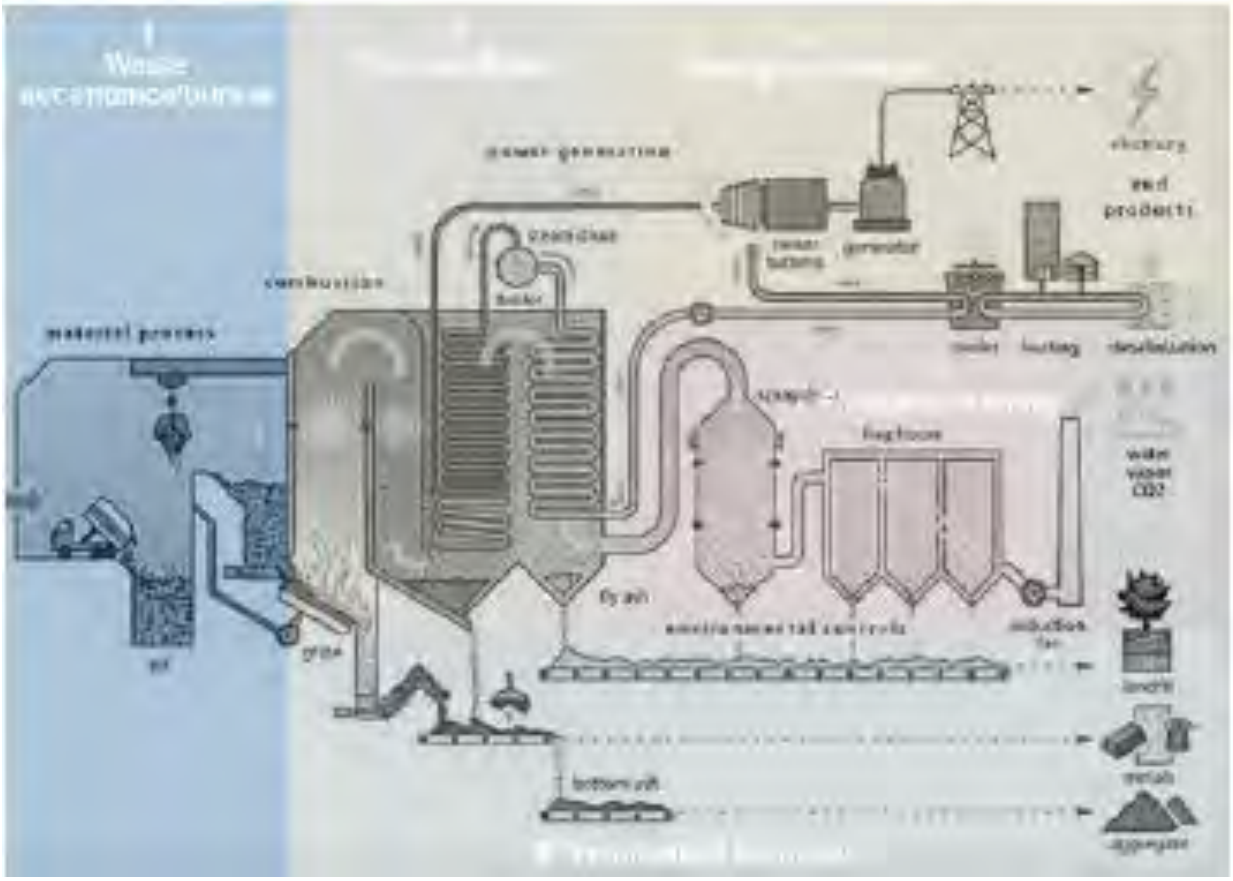
The WTE plant shall be designed and built as a conventional state-of-the-art grate type incinerator of two lines of 250 Mg/d each (total of 500 Mg/d), that shall consist of the following main set of process units and plant components:

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]

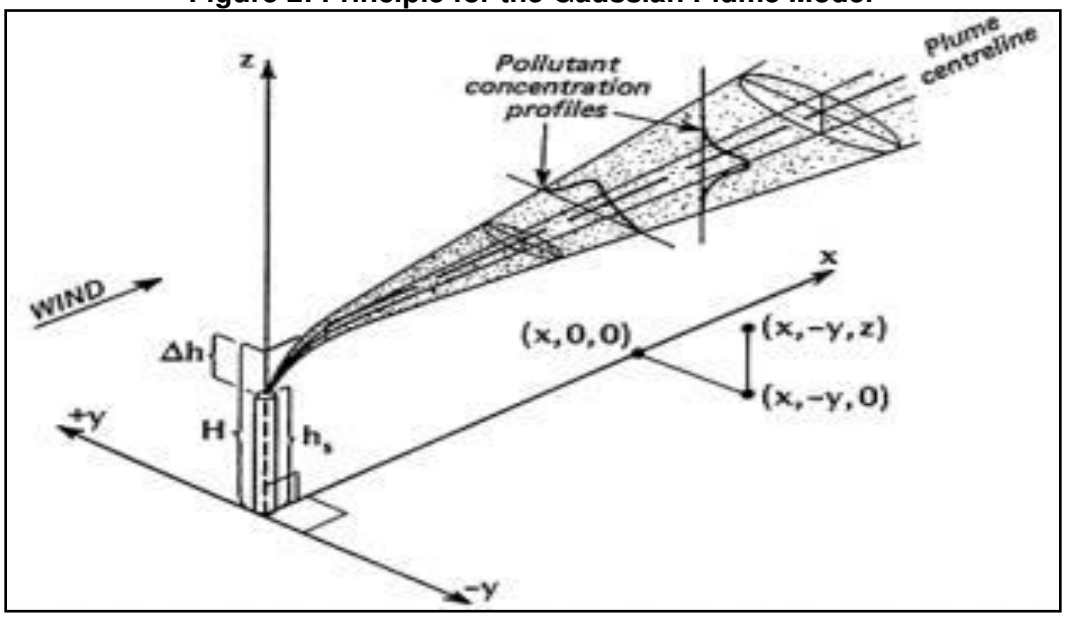
The Air Dispersion Model

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

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

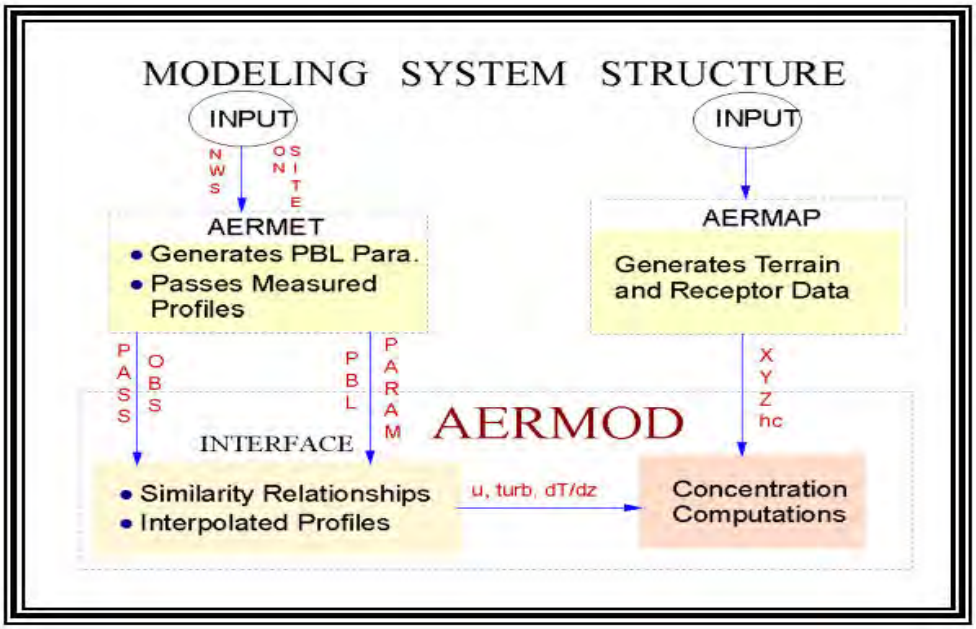
Where	C	=	concentration
	Q	=	emission rate of the pollutant from the source
	u	=	wind speed which defines the direction
	x, y	=	horizontal distance perpendicular to the wind direction
	z	=	vertical direction
	h_s	=	Height of the source
	H	=	effective height of the plume (considering the additional height 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.

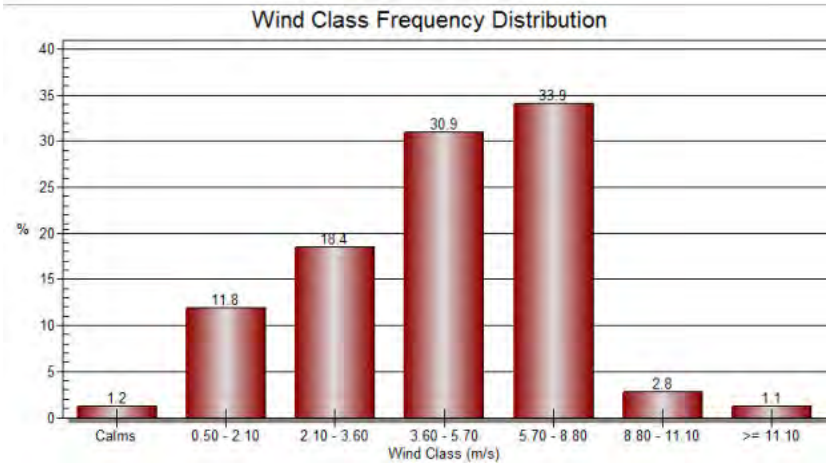
[9] It is a community model maintained by Penn State University and the National Center for Atmospheric Research. The MM5 is a limited-area, terrain-following sigma coordinate model that is used to replicate or forecast mesoscale and regional scale atmospheric circulation.

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

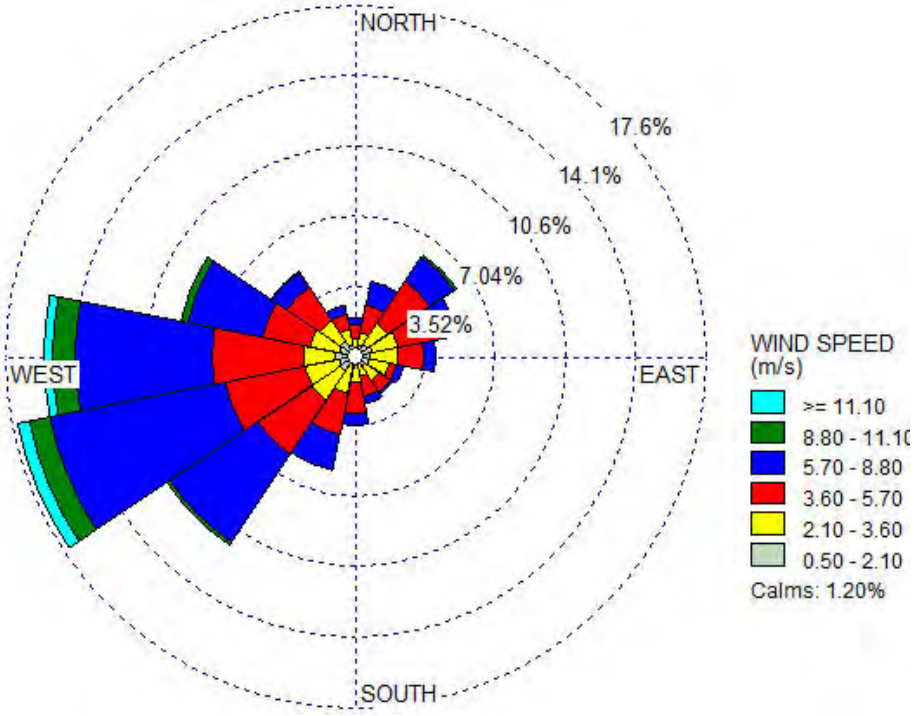
** Reference bearing CW 90⁰*

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
Station Longitude: 0.000W
Upper Air Station ID: 1
Surface Station ID: 1
Onsite Station ID: N/A
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	362.0	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

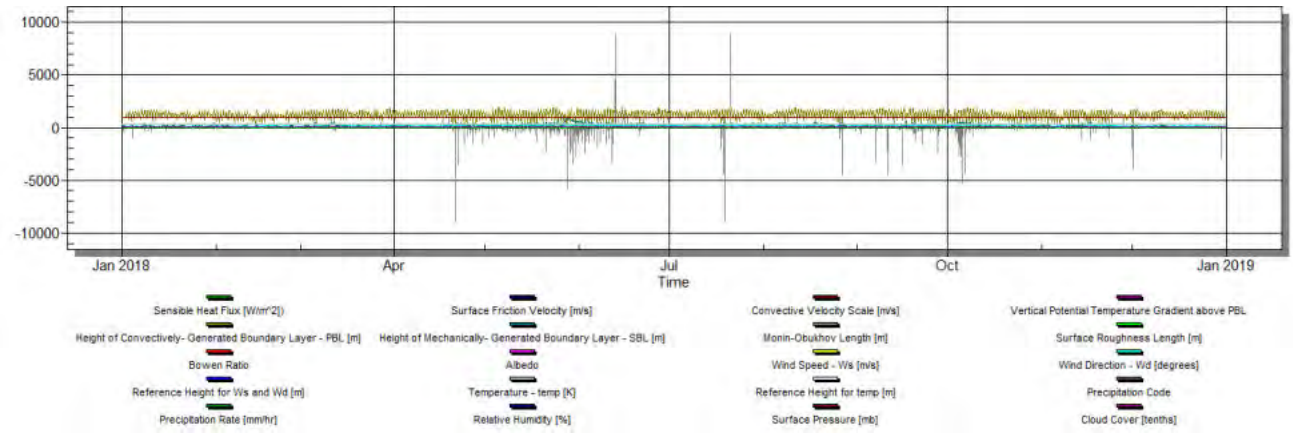


Figure 9: MM5 Profile Meteorology (PFL)

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)

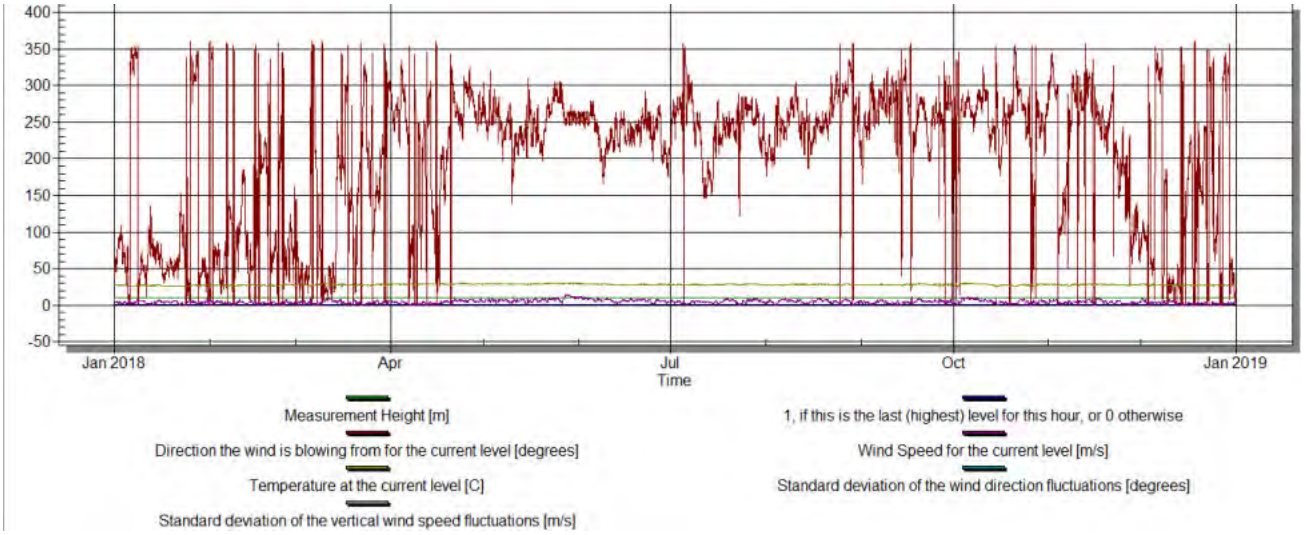
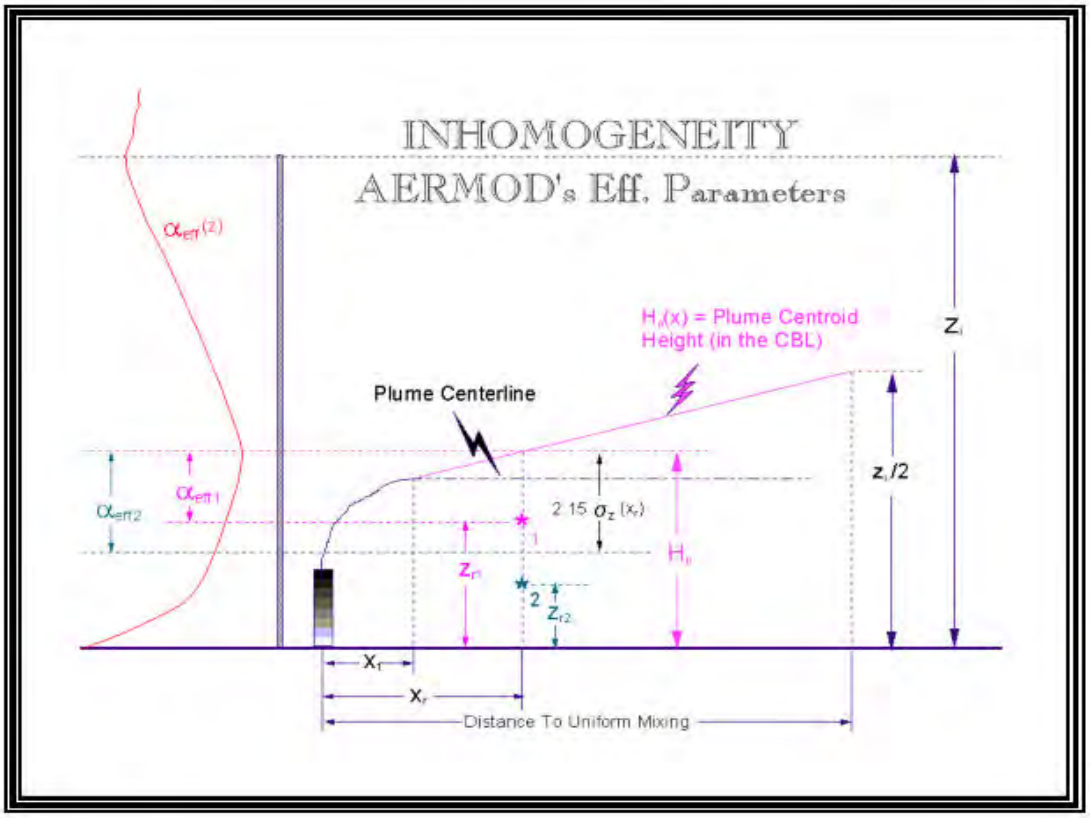


Figure 11: AERMOD Treatment of Boundary Parameters



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)

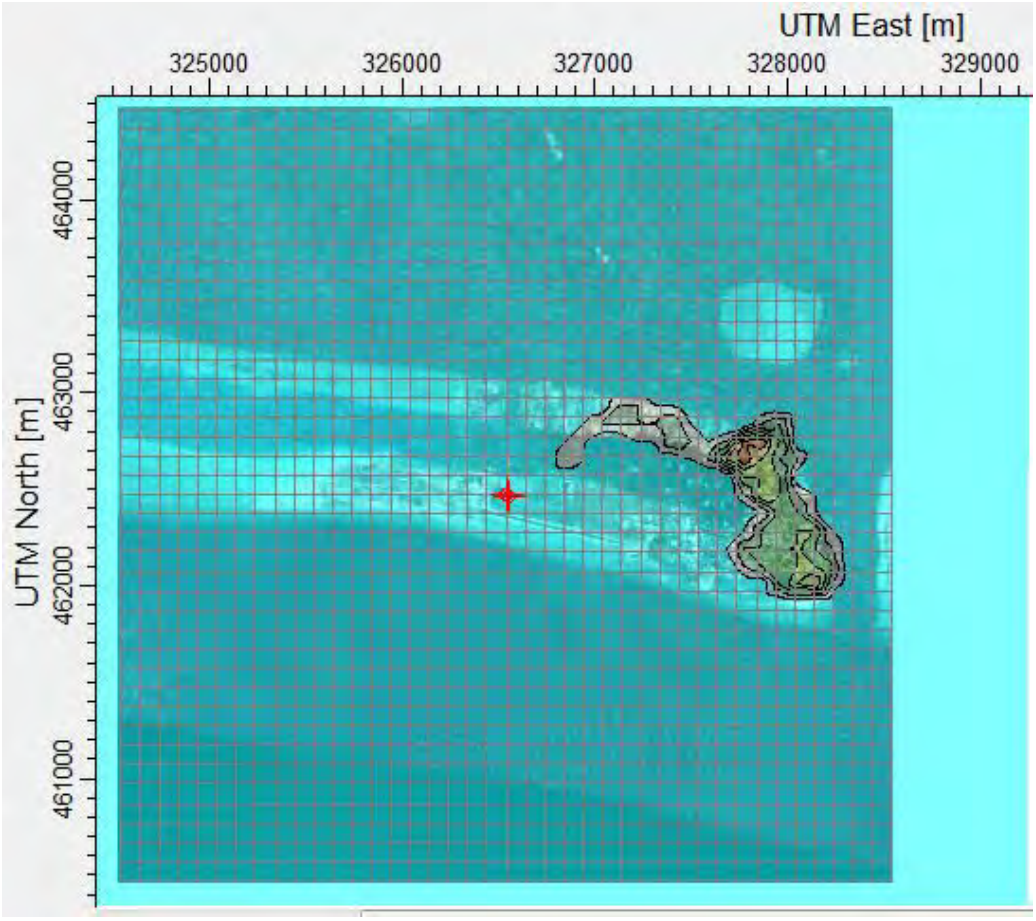
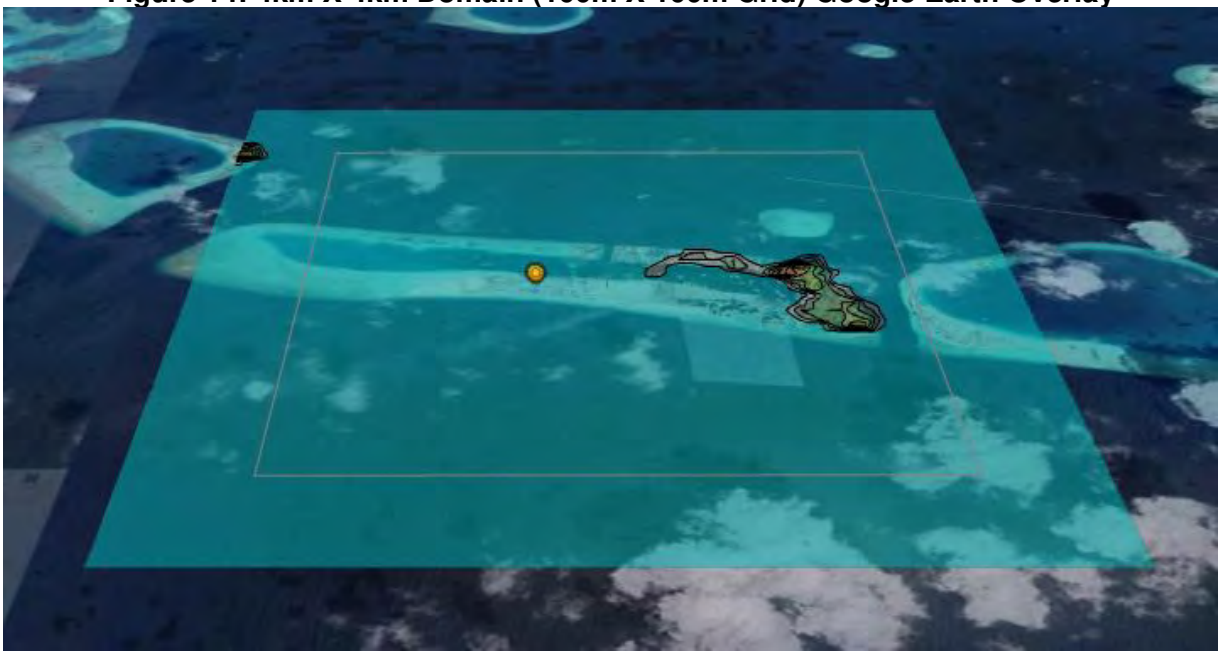


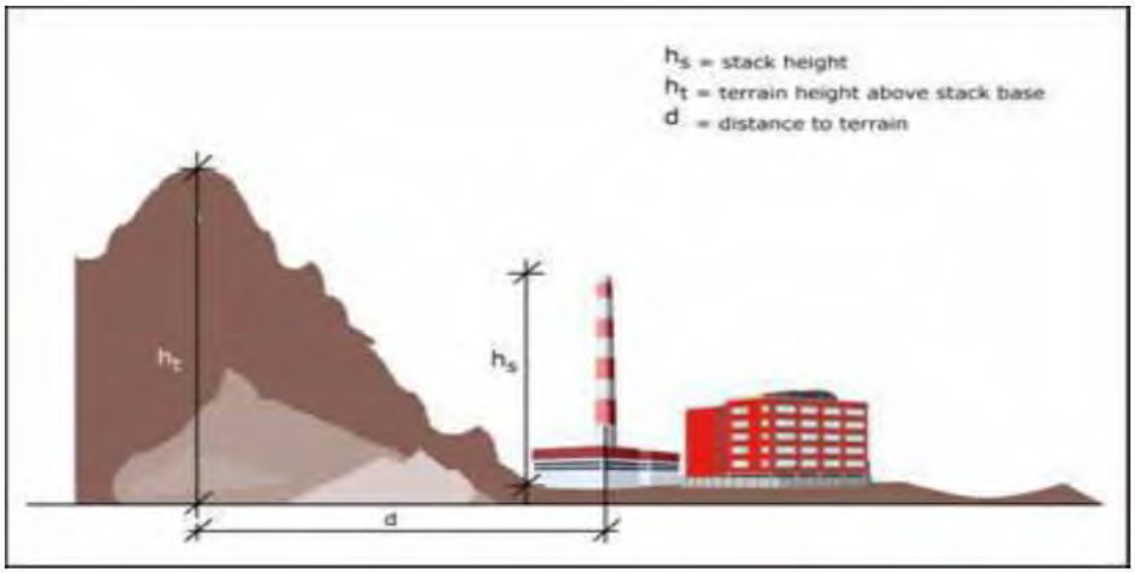
Figure 14: 4km X 4km Domain (100m X 100m Grid) Google Earth Overlay



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

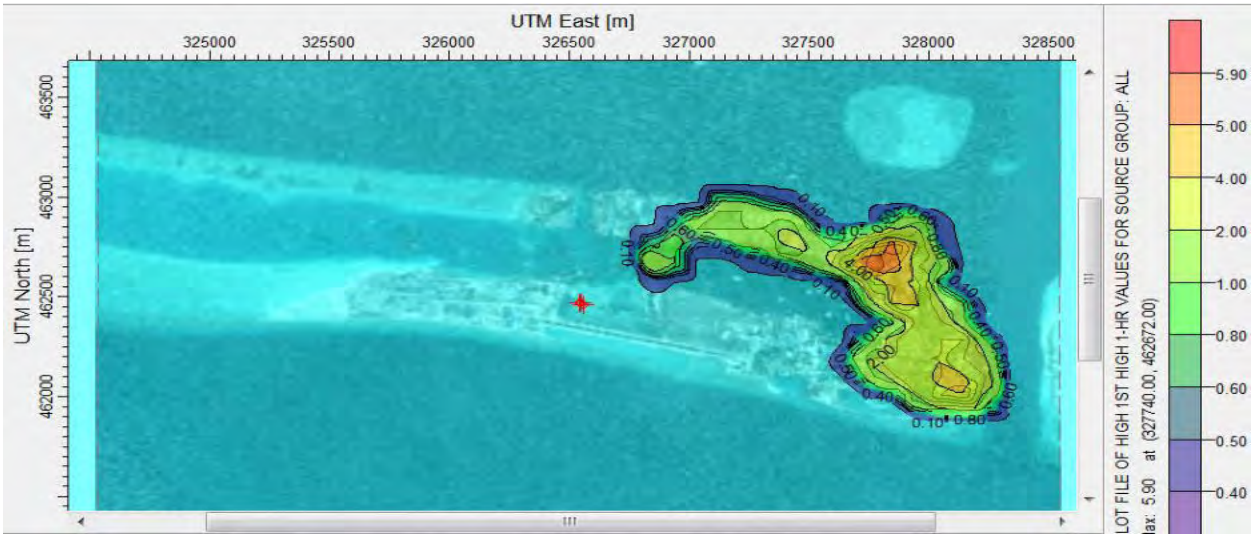


Figure 17: SRMT Terrain Elevation Google Earth Overlay

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

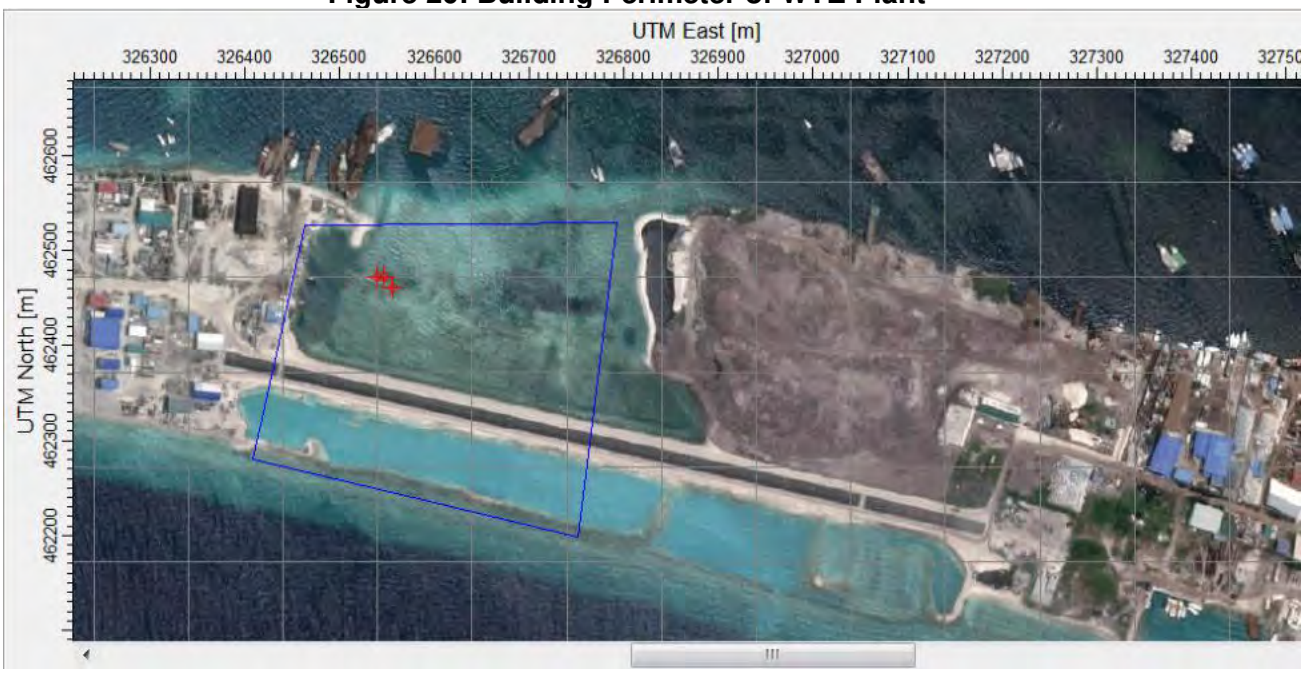


Figure 21: Building Area of WTE Plant

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

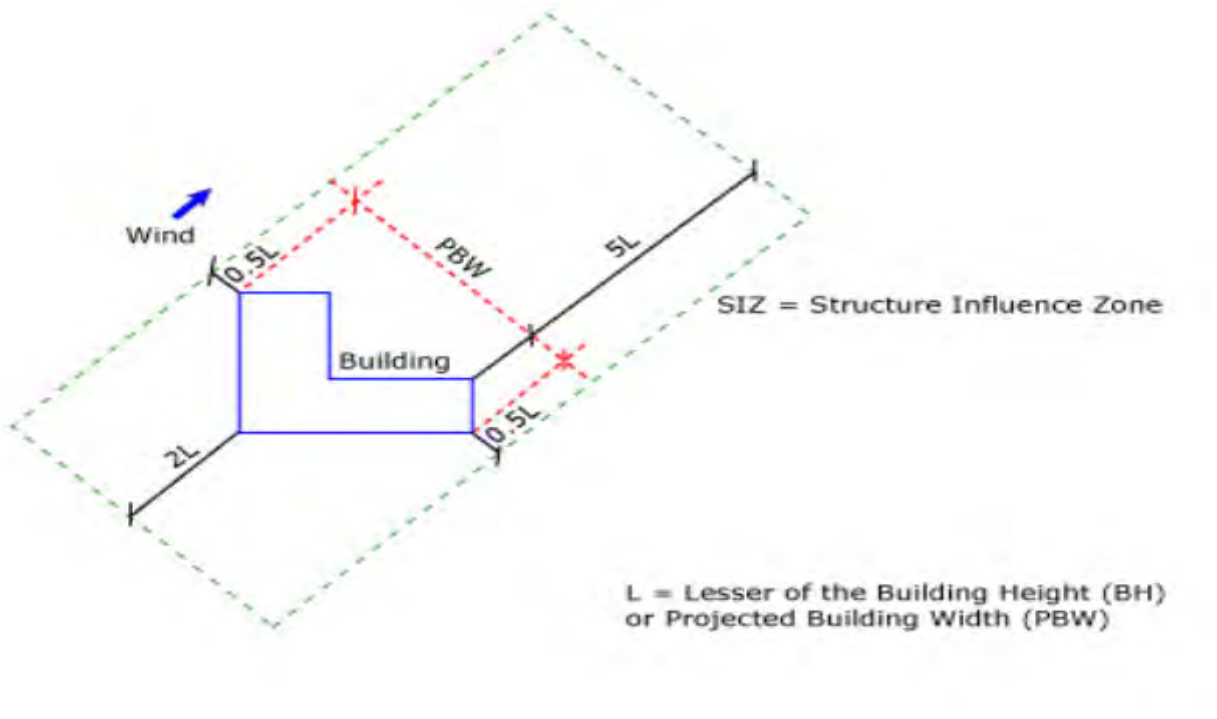


Figure 23: Building Source Influence Zones of buildings to plume dispersion

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

	Capacity	X	Y	Stack	Stack	VFR	Stack	Stack	Stack Ht.
APSE	T/day	Long	Lat	Temp. ^{O}C	Temp. (K)	(Ncm/sec)	Diam (m)	Area (m^2)	(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

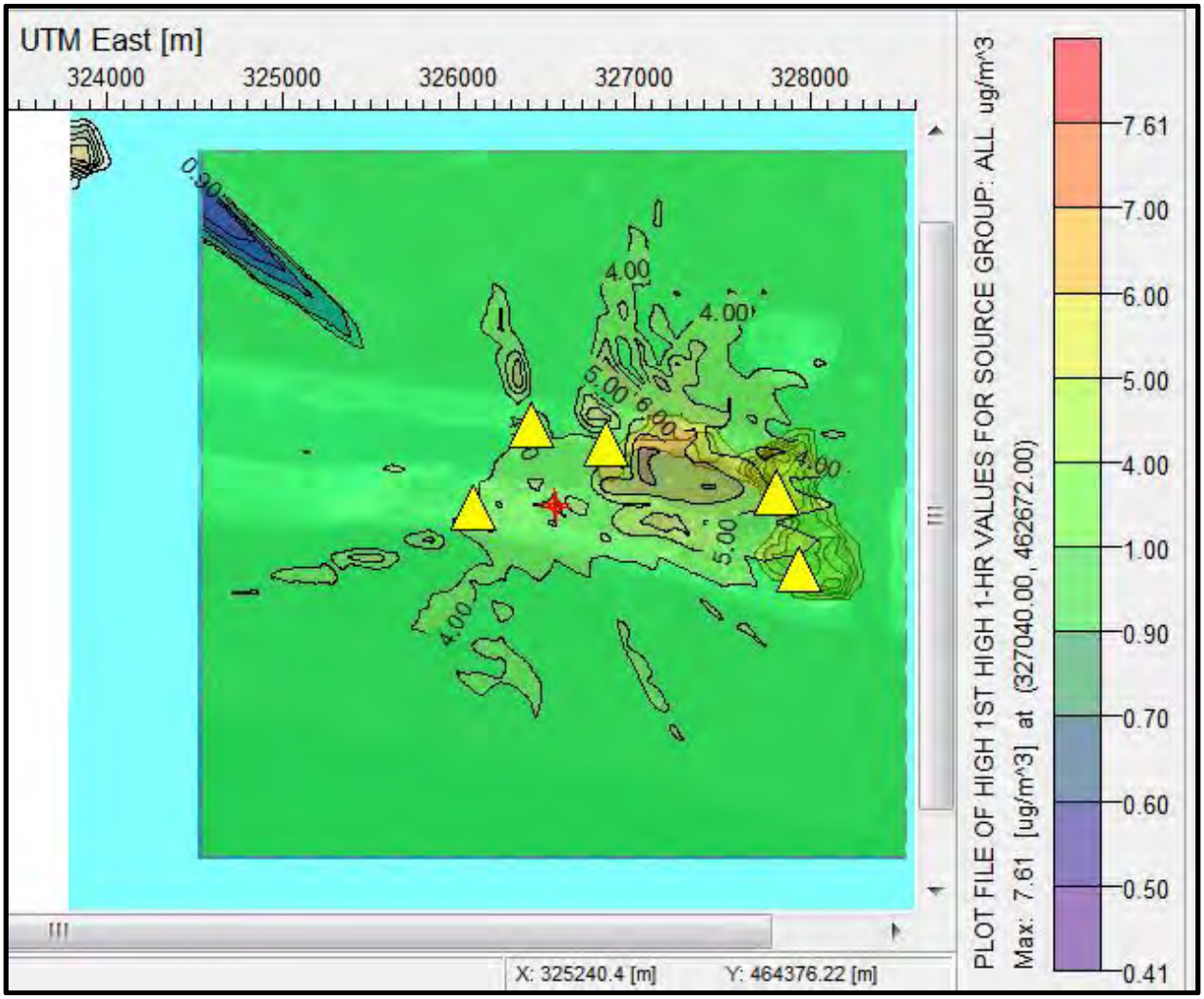


Figure 25: Total Dust (TD) (1 HR) (Isopleth in microgram/m3)

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

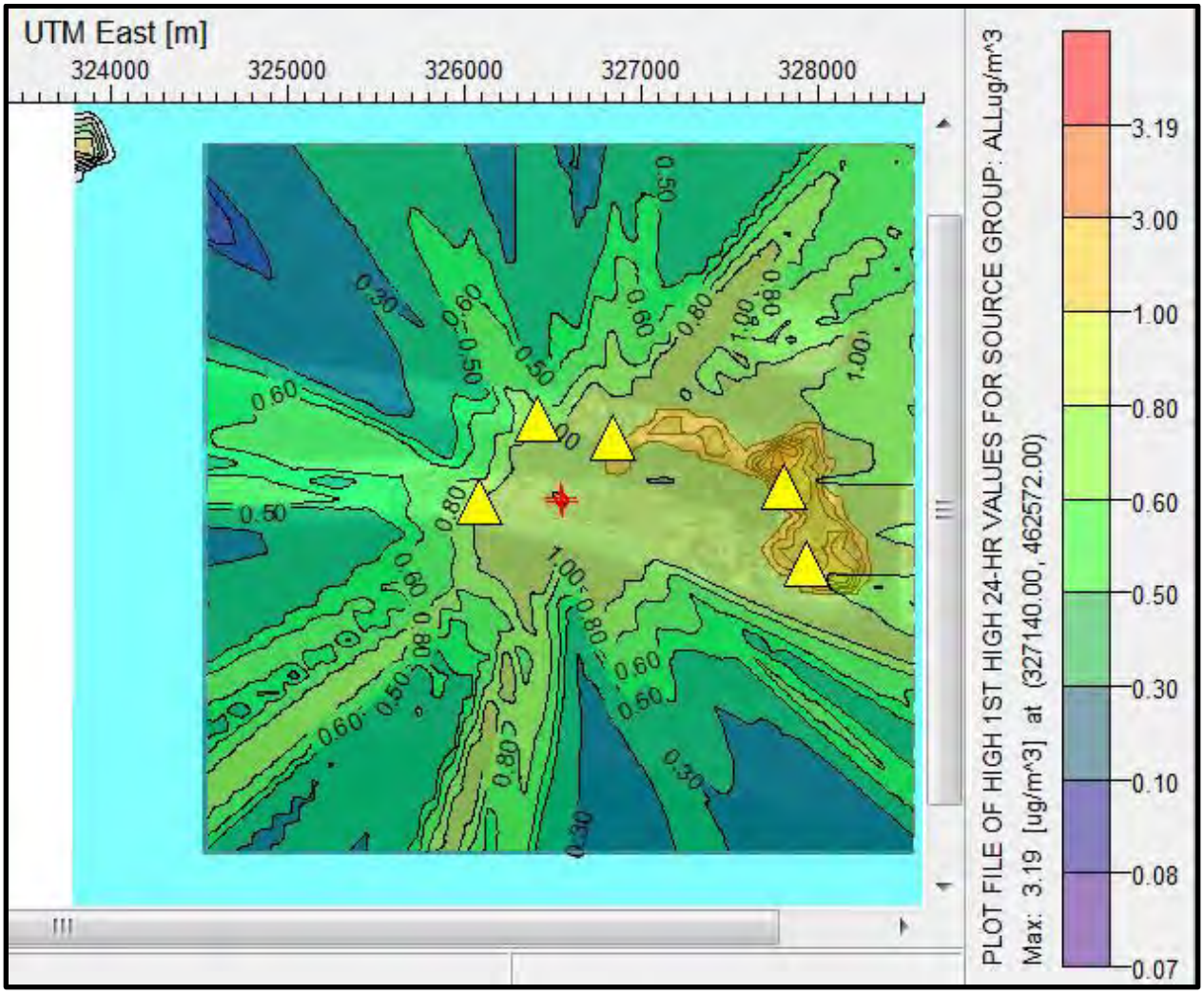


Figure 26: TD (24 HR) (1-HR RUN) (Isopleth in microgram/m3)

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

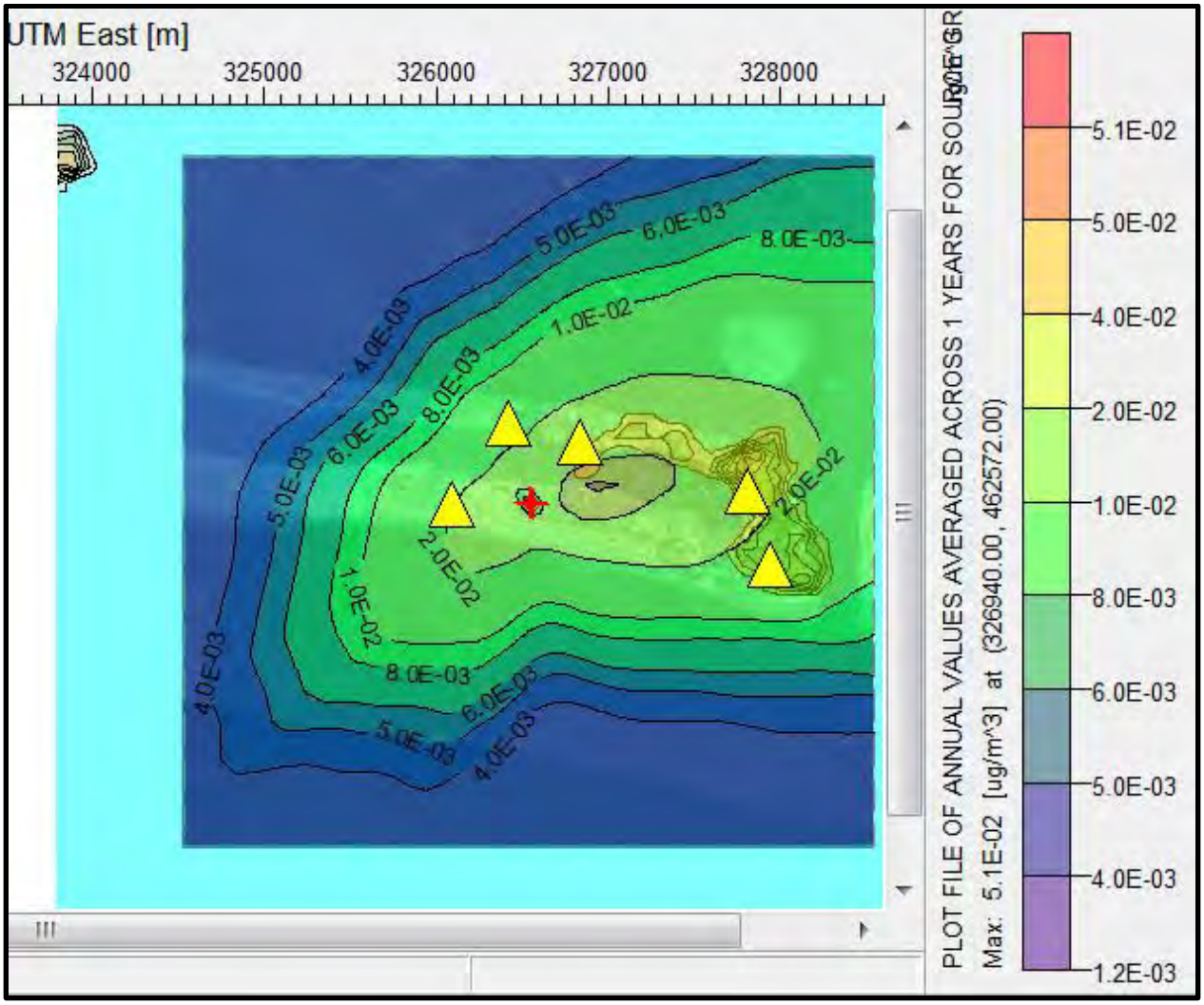


Figure 27: Total Dust 1YR (Isopleth in microgram/m3)

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

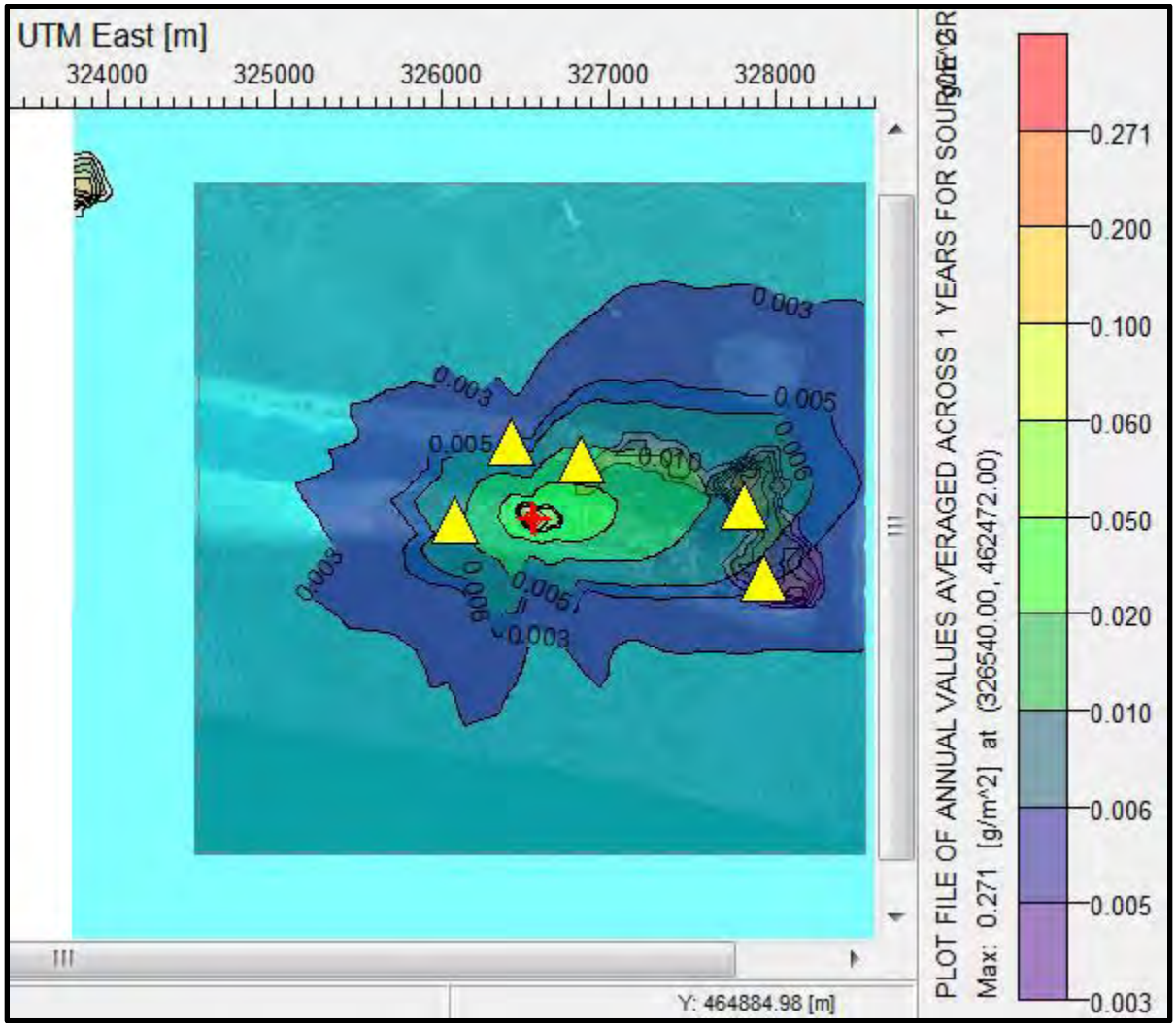


Figure 28: Total Dust 1YR Deposition (Isopleth in microgram/m3)

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

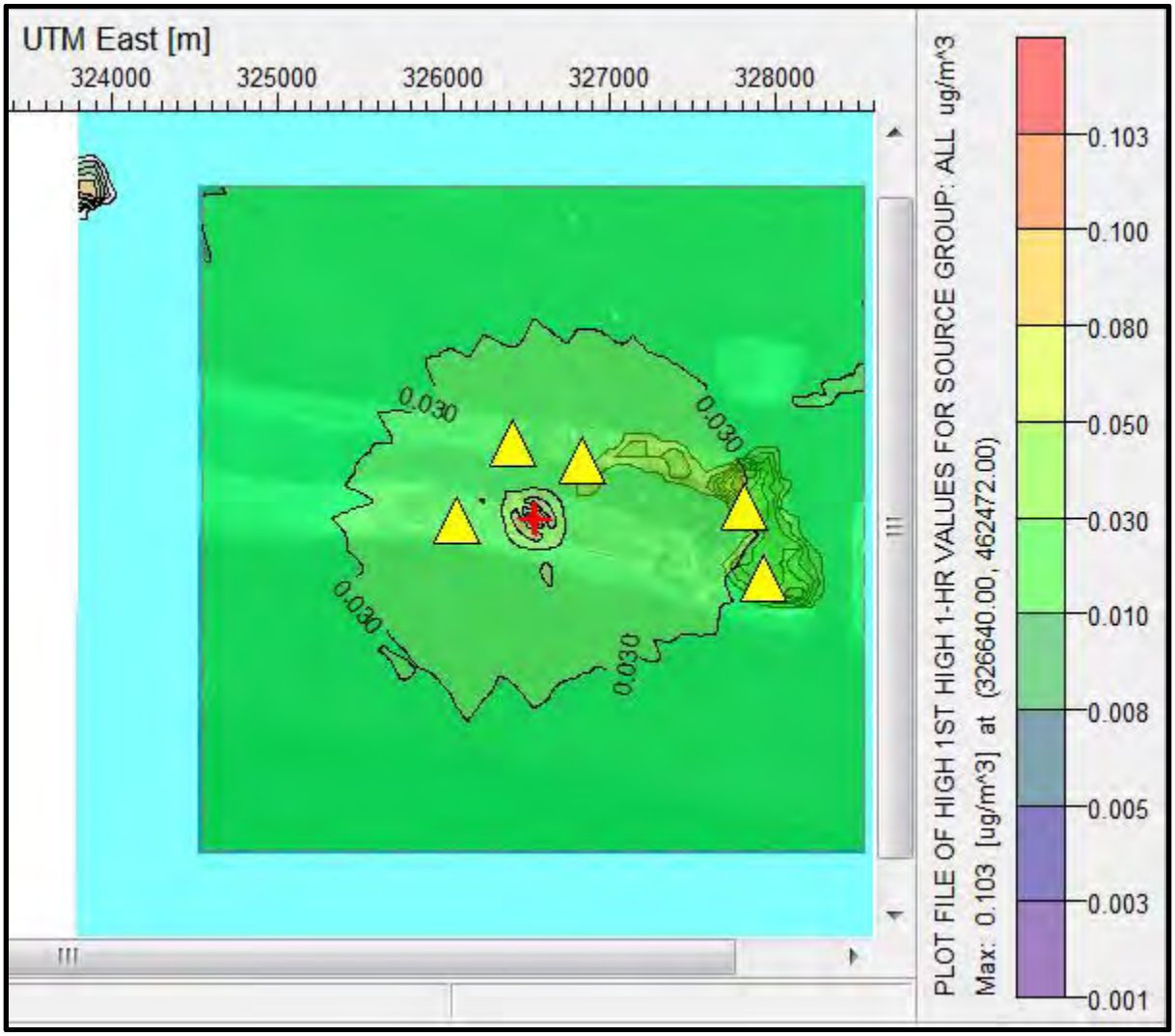


Figure 29: PM10 1 HR (Isopleth in microgram/m3)

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

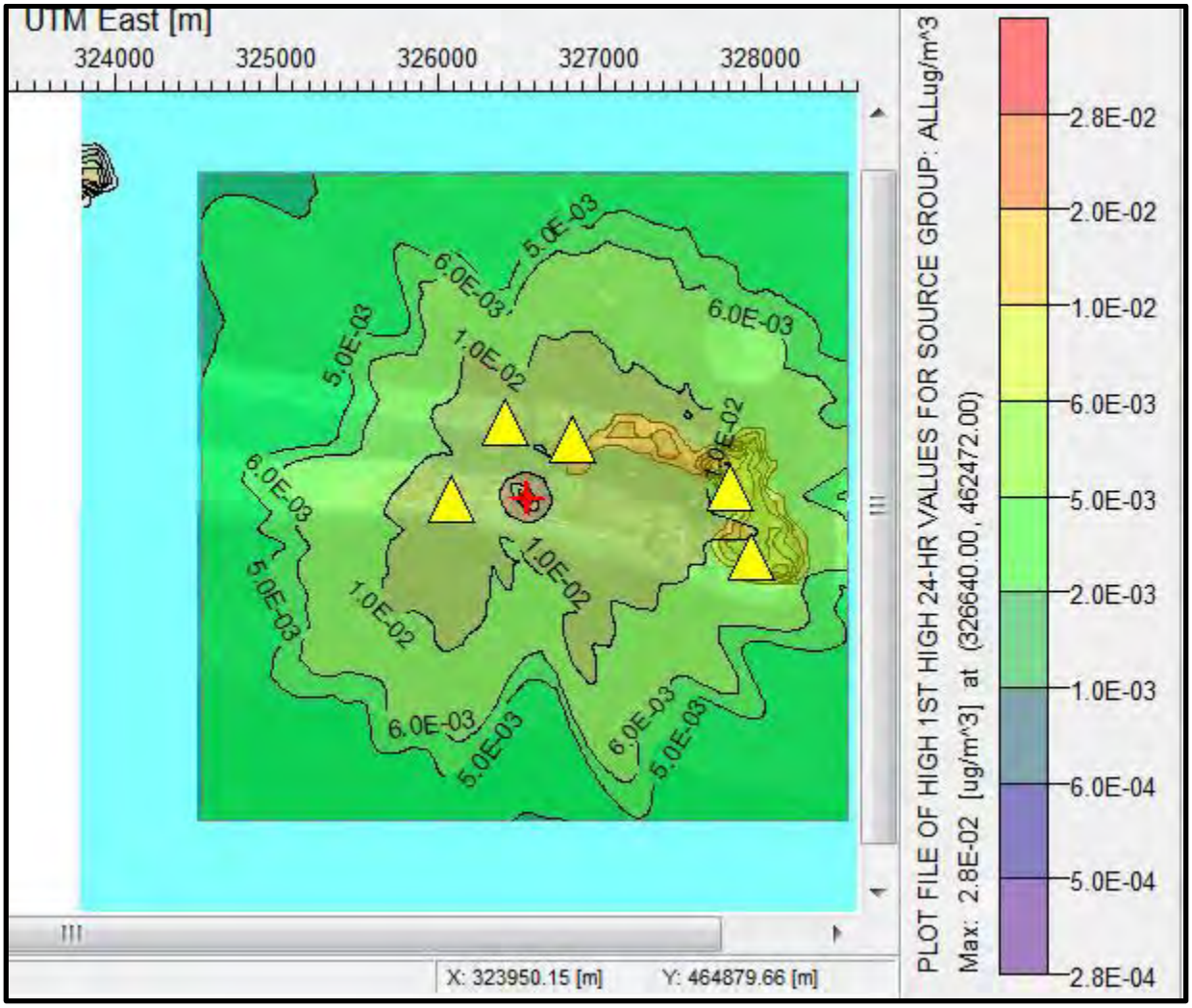


Figure 30: PM10 24 HR (Isopleth in microgram/m3)

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

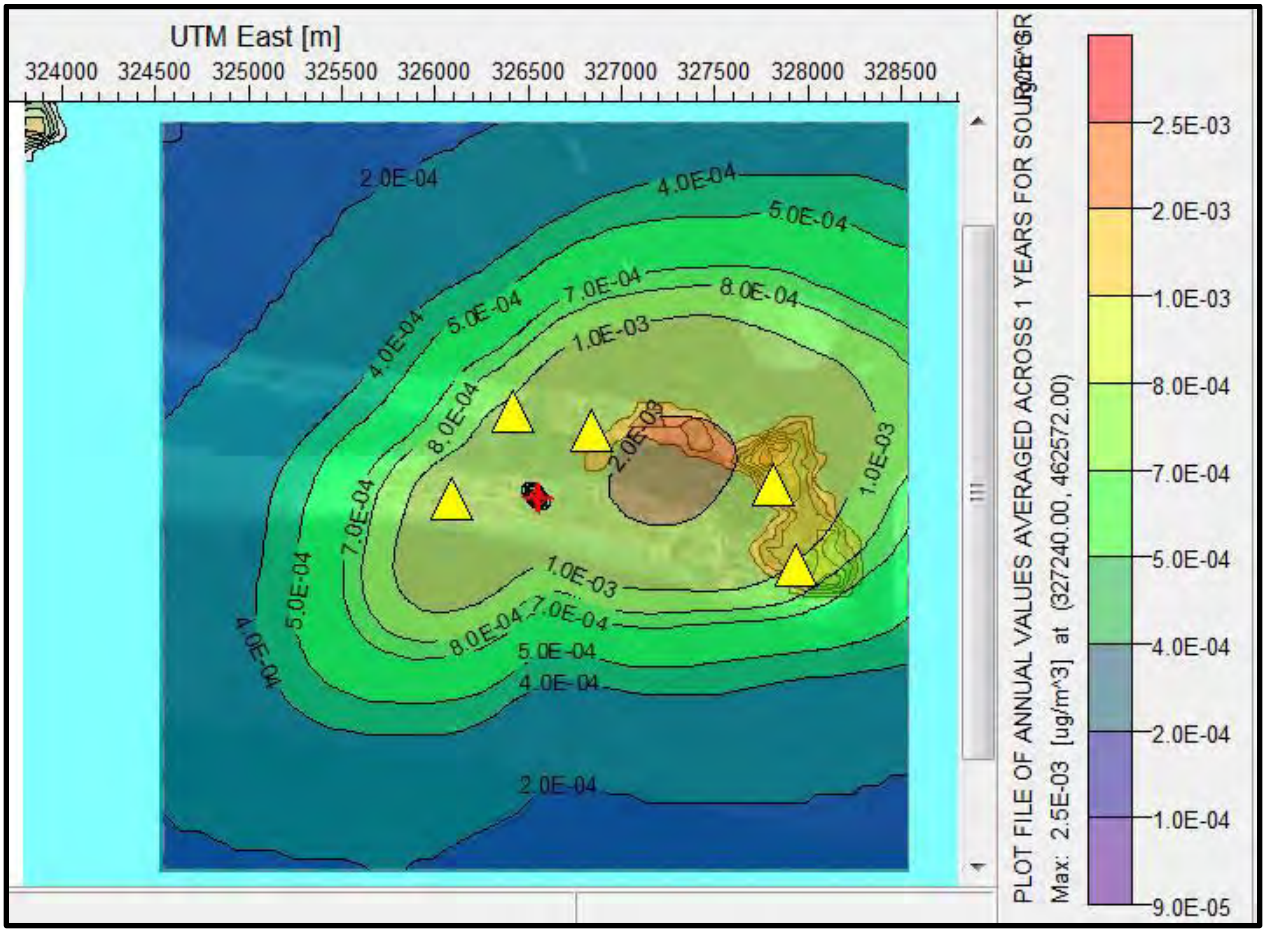


Figure 31: PM10 1 YR DEPOSITION (Isopleth in microgram/m3)

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

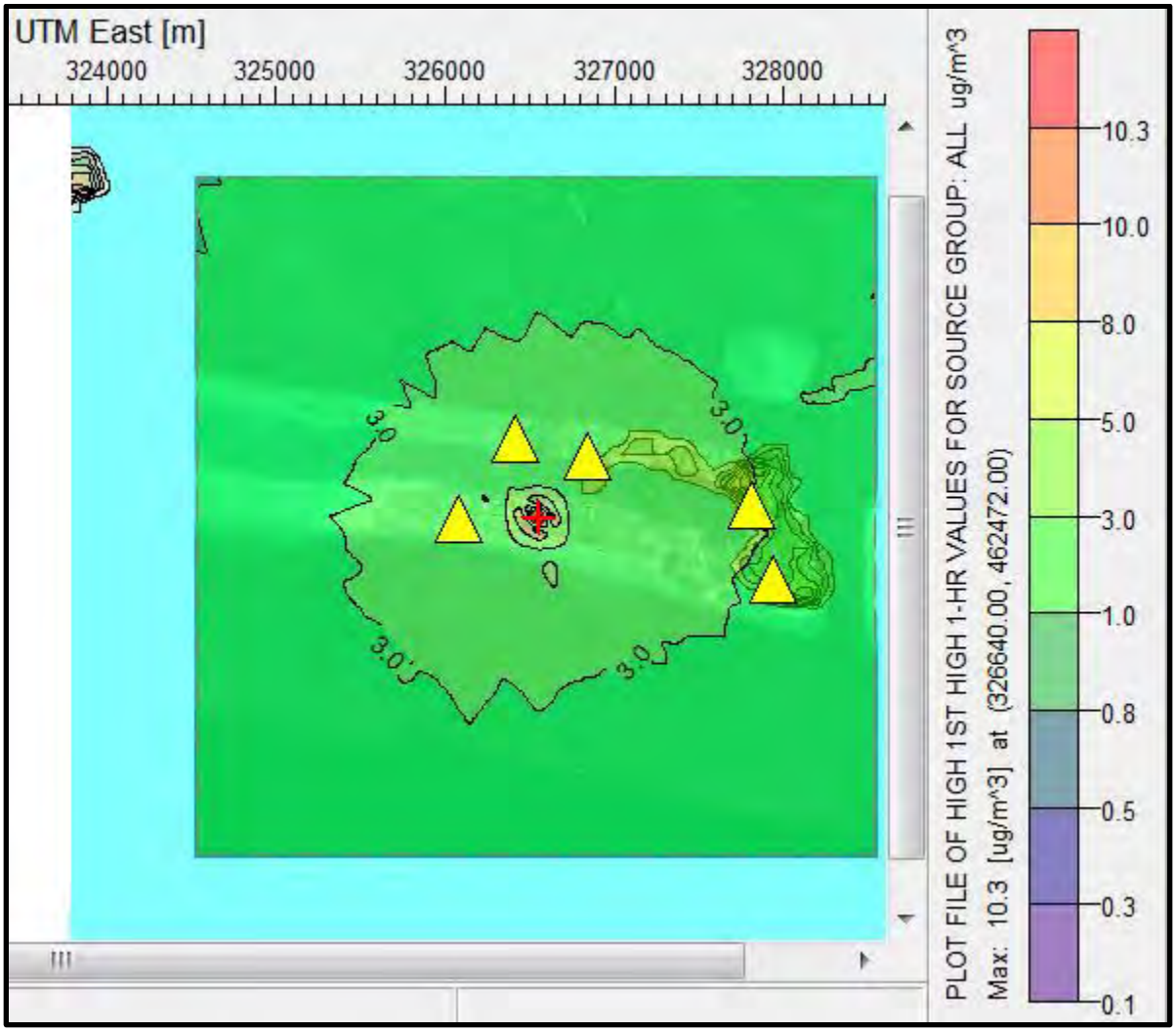


Figure 32: SO2 1 HR (Isopleth in microgram/m3)

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

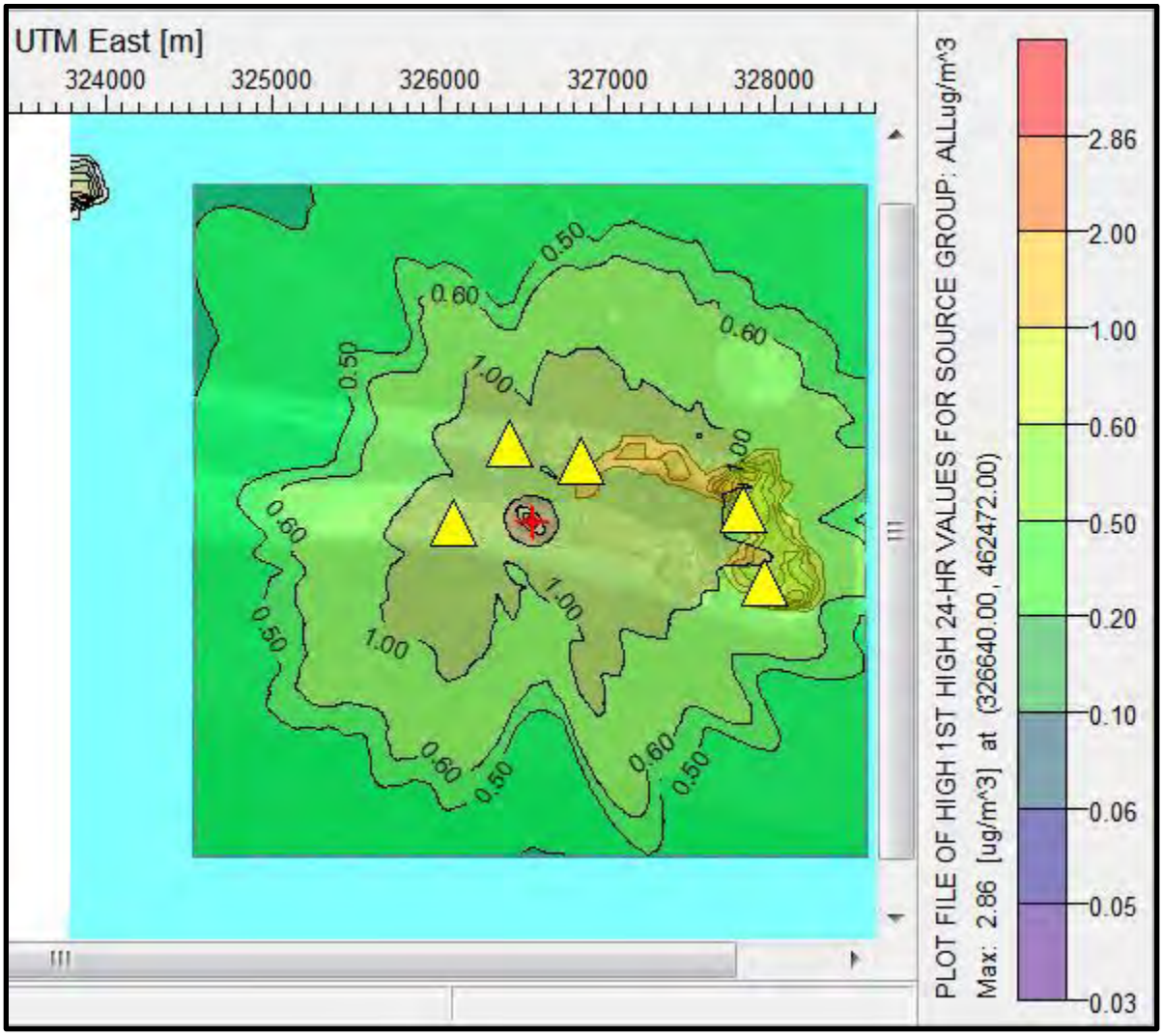


Figure 33: SO2 24 HR (Isopleth in microgram/m3)

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

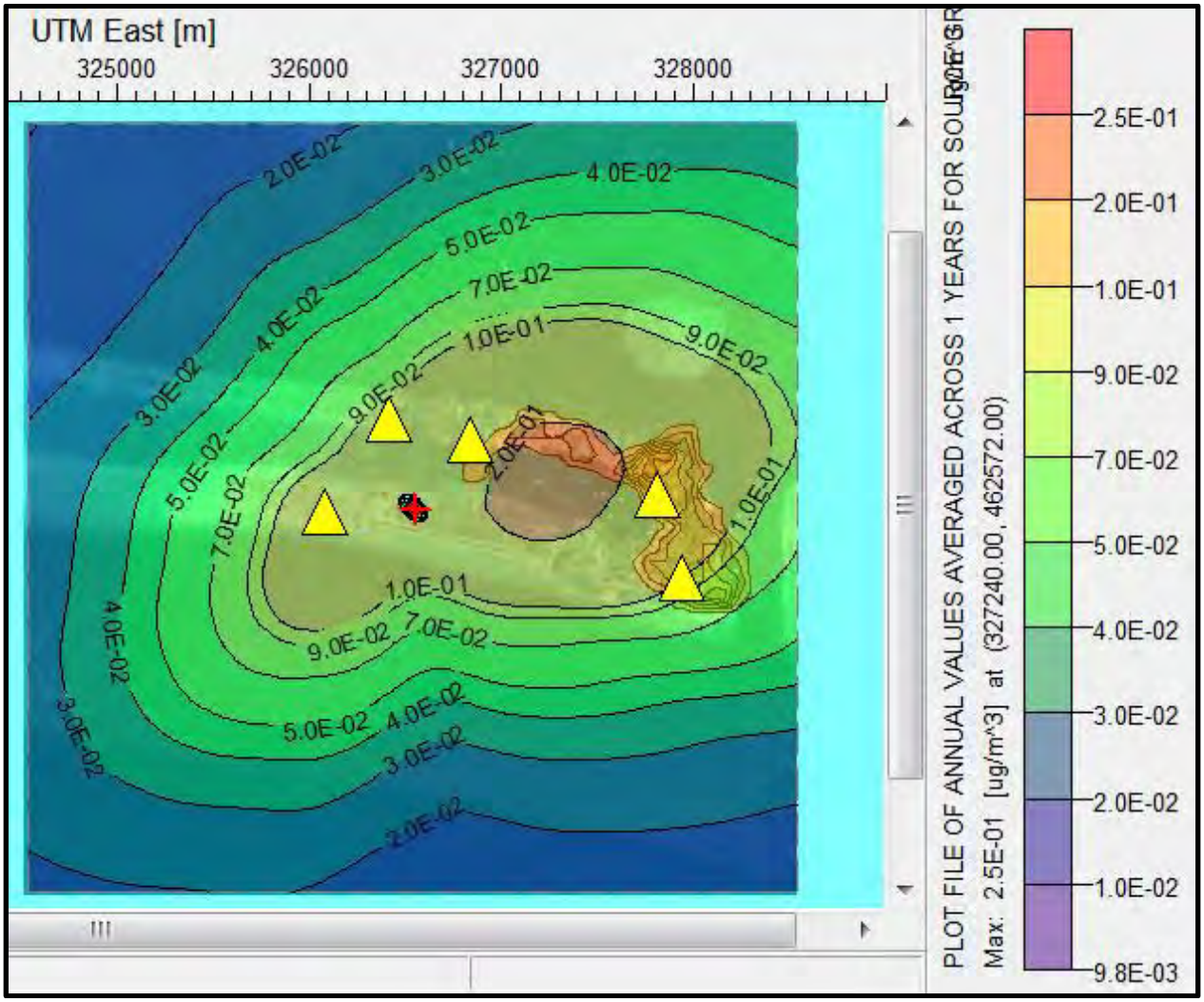


Figure 34: SO2 1 YR (Isopleth in microgram/m3)

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

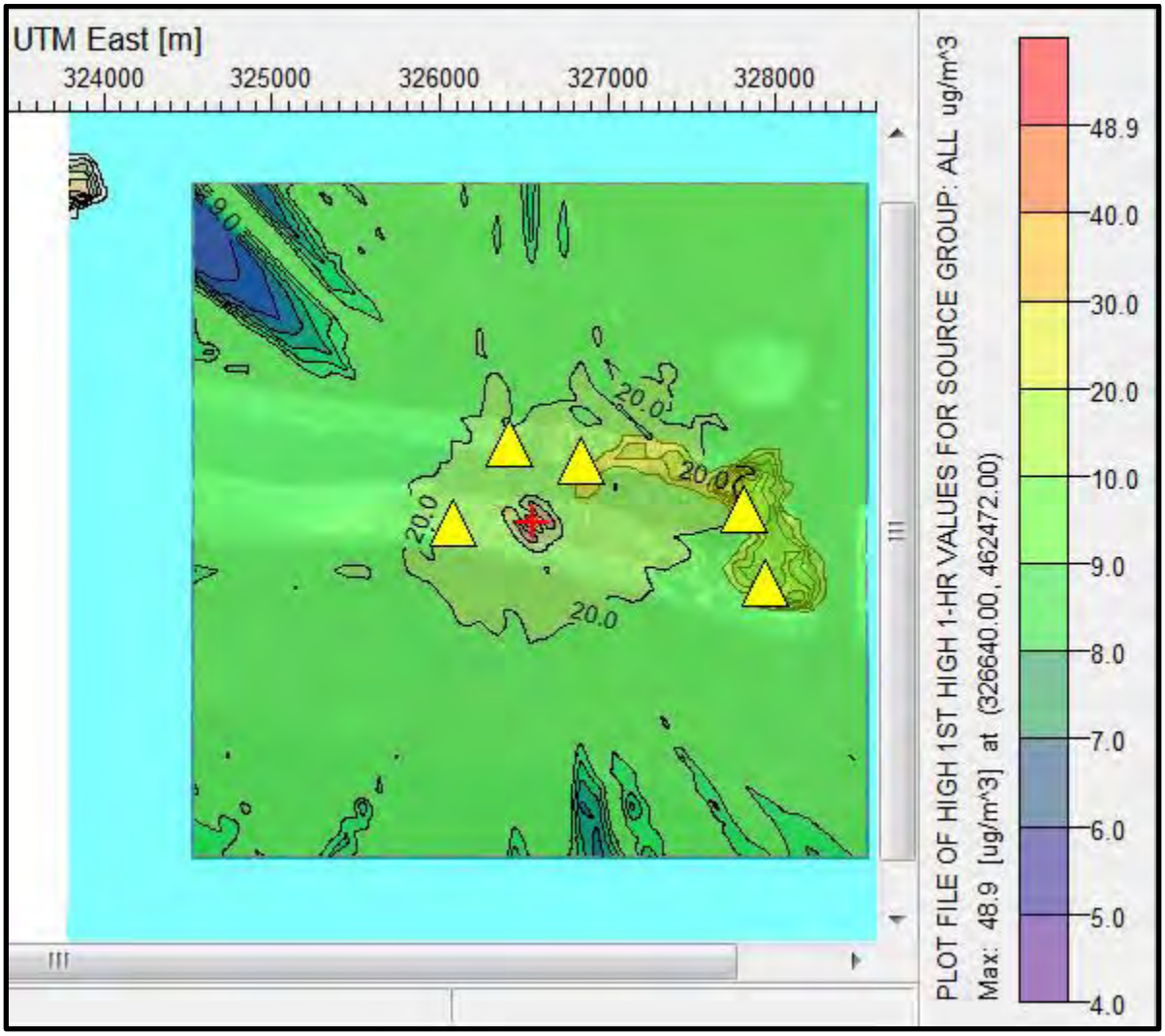


Figure 35: NO2 1 HR (Isopleth in microgram/m3)

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

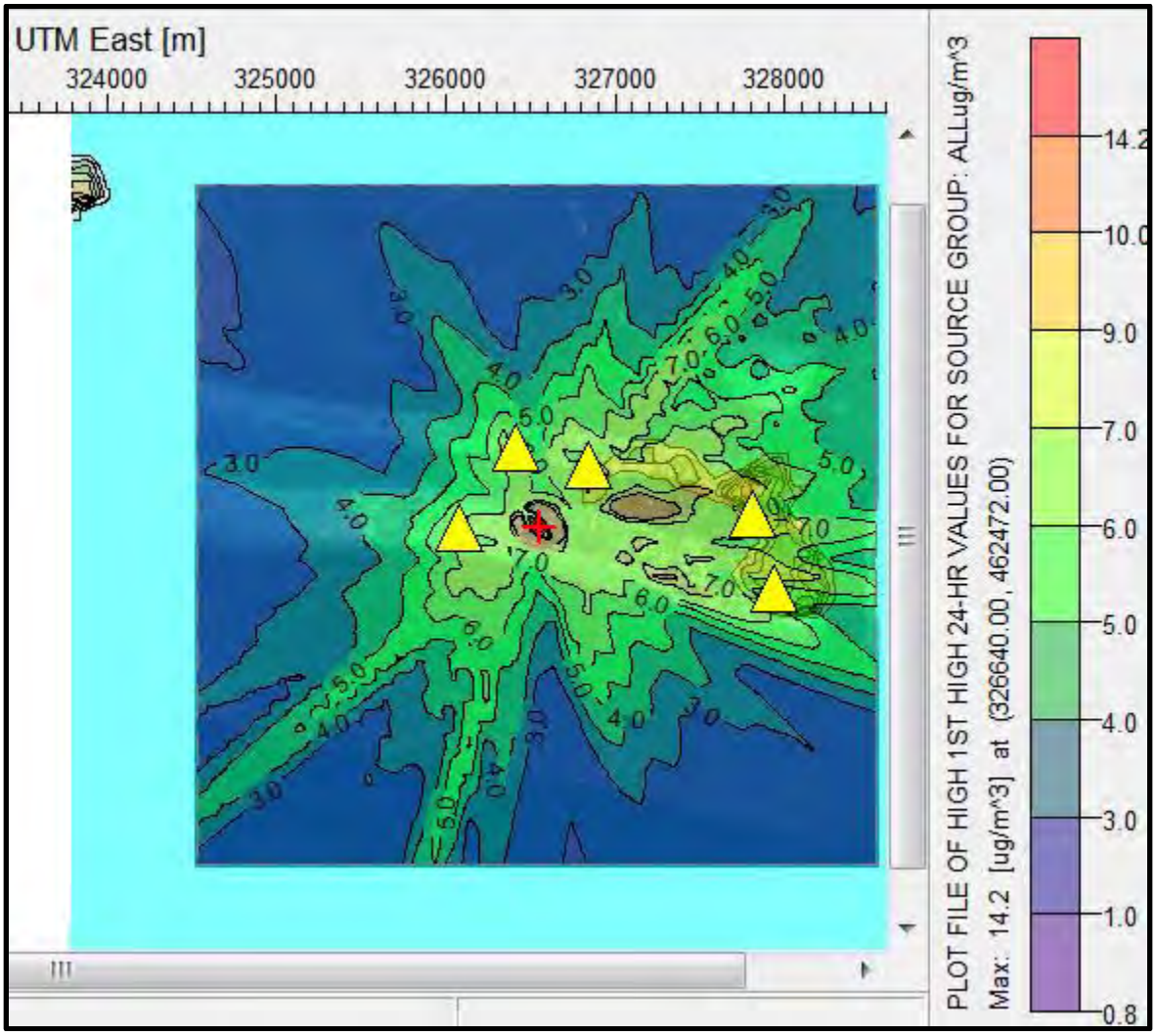


Figure 36: NO2 24 HR (Isopleth in microgram/m3)

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

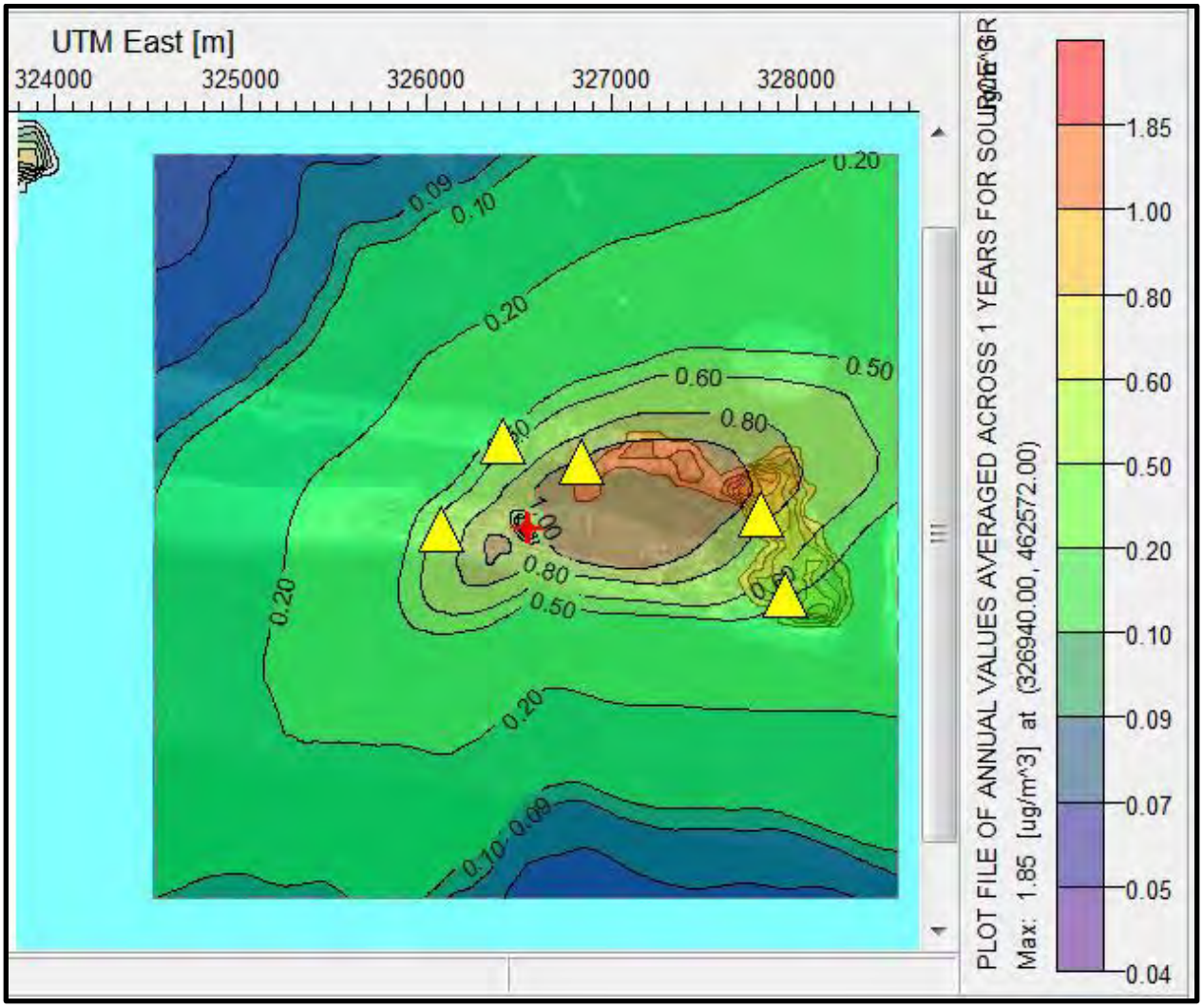


Figure 37: NO2 1 YR HR (Isopleth in microgram/m3)

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

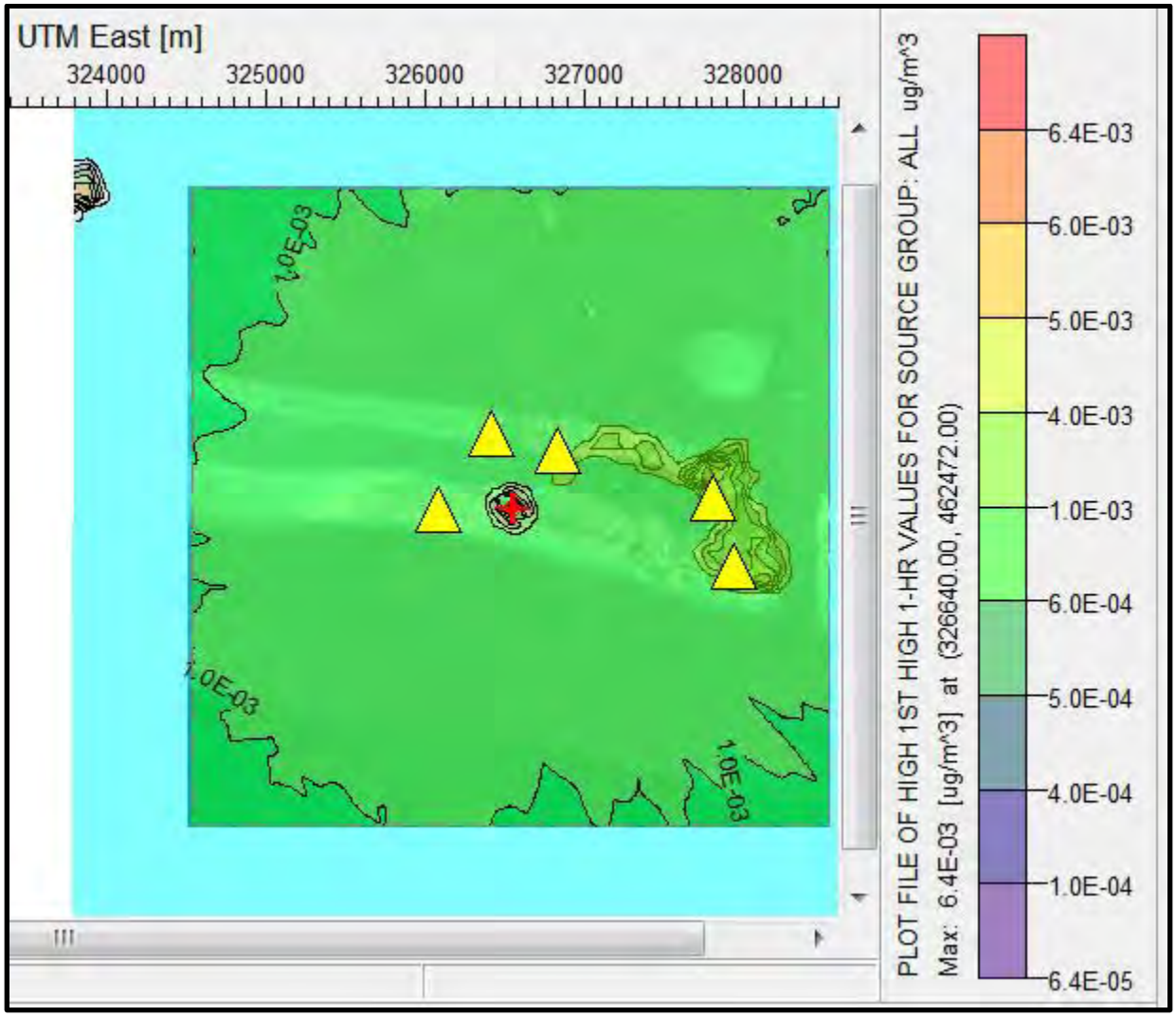


Figure 38: Hg 1 HR (Isopleth in microgram/m3)

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

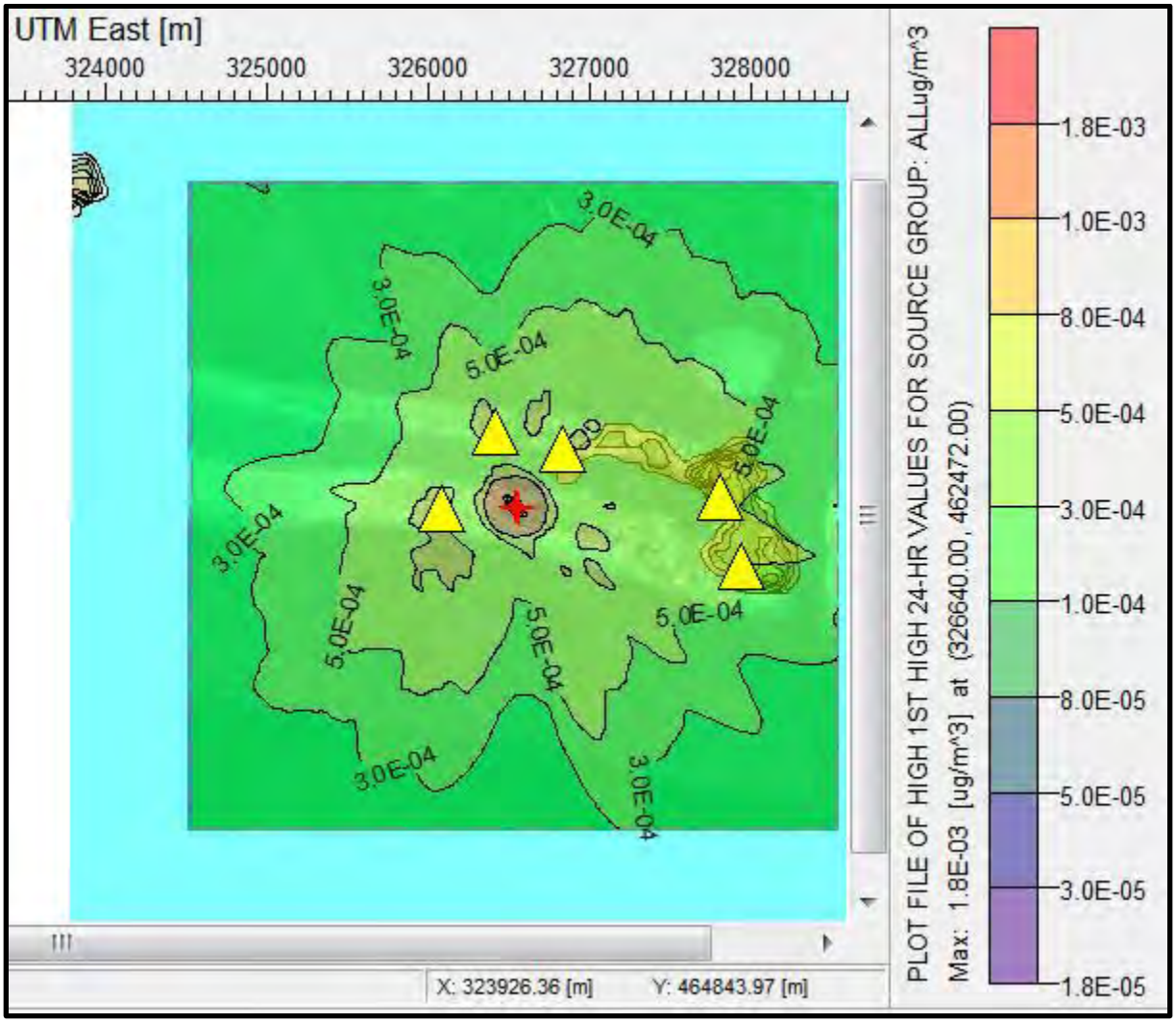


Figure 39: Hg 24 HR (Isopleth in microgram/m3)

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