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)

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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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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

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				• 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.

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	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/m^3 [24 hr average]	20 mg/dscm	5 mg/m^3 [24 hr average] 20 mg/m^3 [0,5 hr average]
Total Carbon (C)			10 mg/m^3 [24 hr average] 20 mg/m^3 [0,5 hr average]
Sulfur Dioxide (SO_2)	50 mg/m^3 [24 hr average]	30 ppmv (or 80% reduction)	50 mg/m^3 [24 hr average] 200 mg/m^3 [0,5 hr average]
Oxides of Nitrogen (NO_x)	200-400 mg/m^3 [24 hr average]	150 ppmv [24 hr average]	150 mg/m^3 [24 hr average] 400 mg/m^3 [0,5 hr average]
Opacity	n/a	10%	n/a
Hydrochlorid Acid (HCl)	10 mg/m^3	25 ppmv (or 95% reduction)	10 mg/m^3 [24 hr average] 60 mg/m^3 [0,5 hr average]
Dioxins and furans	0,1 ng TEQ/m^3 [6-8 hr average]	13 ng/dscm (total mass)	n/a
Cadmium*	0,05-0,1 mg/m^3 [0,5-8 hr average]	0,010 mg/dscm	n/a
Carbon Monoxide (CO)	50-150 mg/m^3	50-150 ppmv[c]	50 mg/m^3 [24 hr average] 100 mg/m^3 [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).

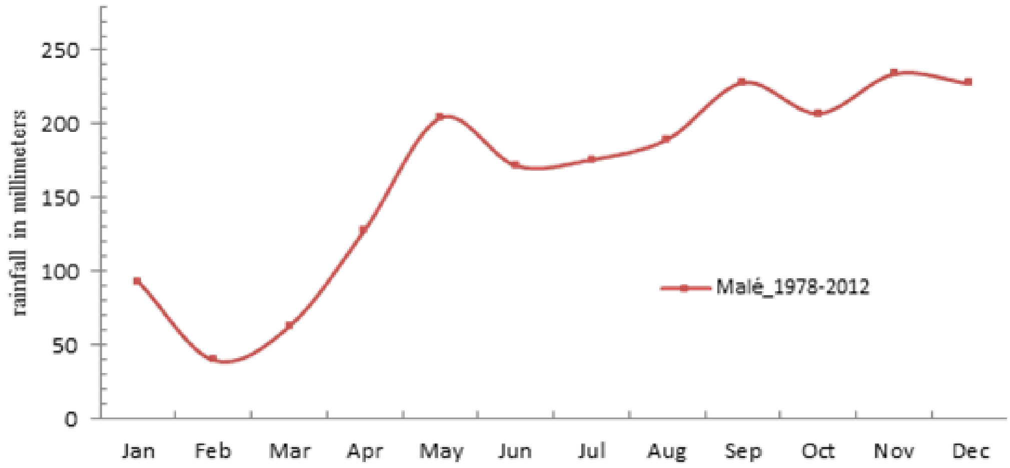


Figure 3: Long term average rainfall for the central atolls (Source: Maldives Meteorological Service, 2016)

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

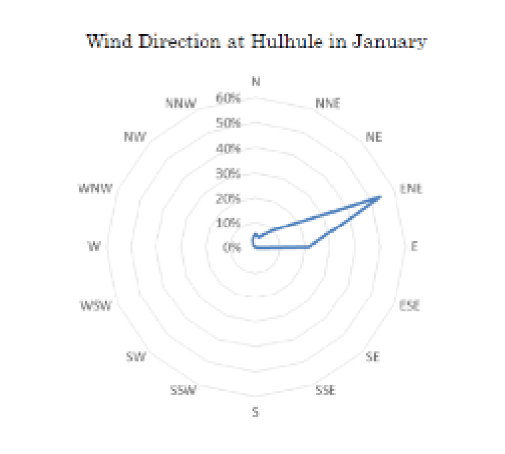
Rainfall data set (daily)	Source : Maldives Meteorological service Location : Weather station Hulhule' (Airport) at 10 km East of Thilafushi Data set: from 08.1974-12.2017
Temperature data set (daily)	Source : Maldives Meteorological service Location : Weather station Hulhule' (Airport) at 10 km East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

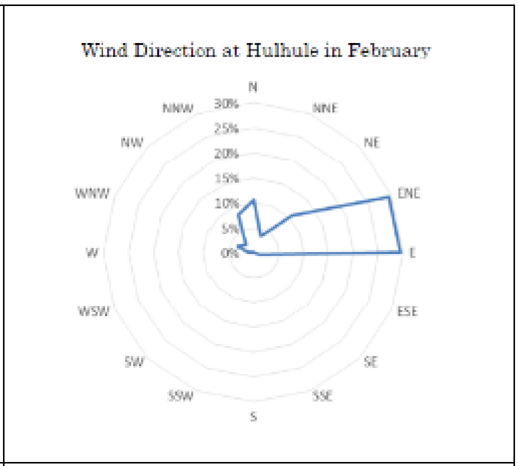
The data set have bee provided in Excel format and have been computed for the purpose of the model in AKterm format.

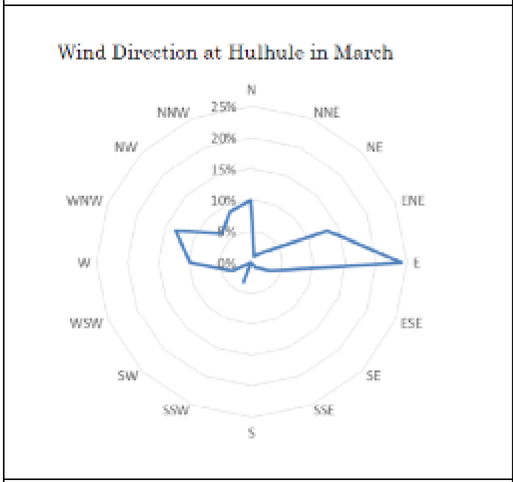
4.2.8.2 *Wind*

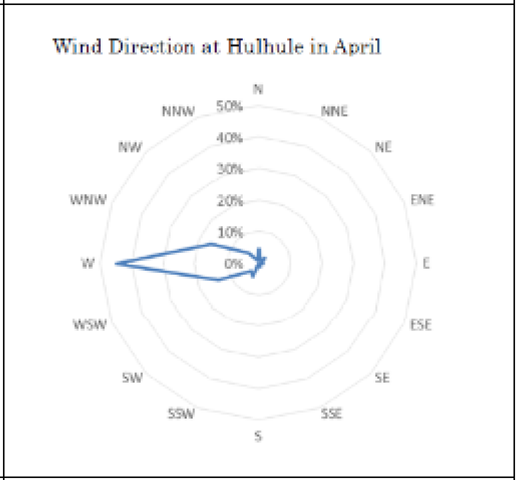
The prevailing wind over the Maldives represents typical Asian monsoonal characteristics. It follows the traditional definition of monsoon as seasonal reversal of wind direction by more than 120° between the months January and July. Looking at annual variations, westerly winds are predominant throughout the country, varying between west-southwest and west-northwest *Figure 4*.

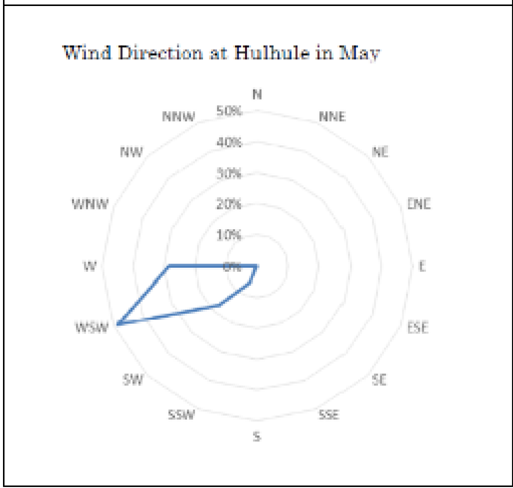
The southwest monsoon, with winds predominantly between SW and NW, lasts from May to October. In May and June, winds are mainly from WSW to WNW, and in July to October, winds between W and NW predominate. The northeast monsoon, with winds predominantly from NE to E, lasts from December to February. During 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.

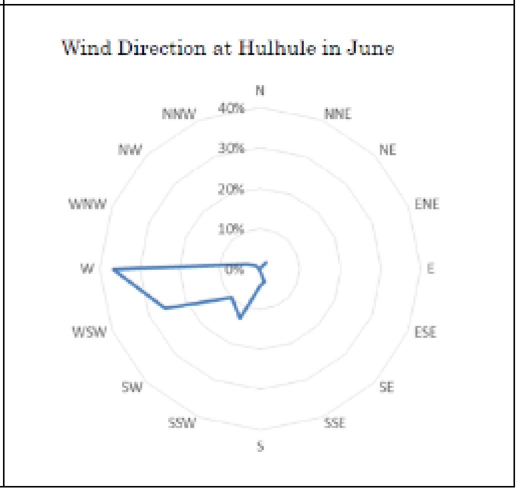

Wind Direction at Hulhule in January
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
60%
50%
40%
30%
20%
10%
0%

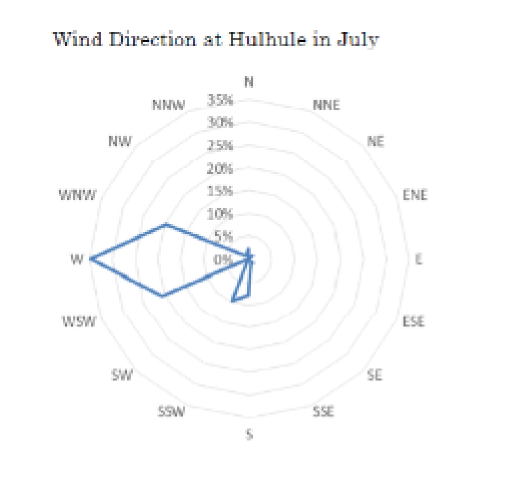

Wind Direction at Hulhule in February
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
30%
25%
20%
15%
10%
5%
0%

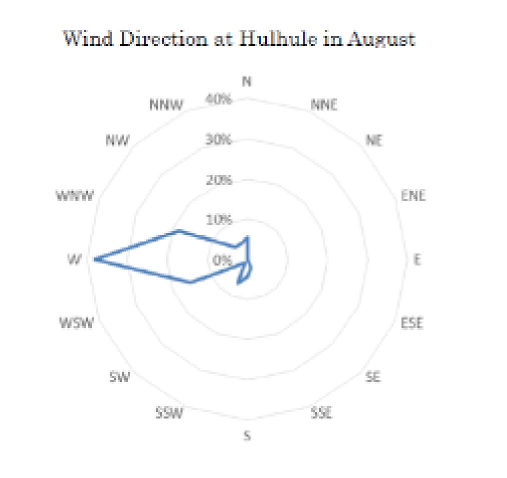

Wind Direction at Hulhule in March
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
25%
20%
15%
10%
5%
0%

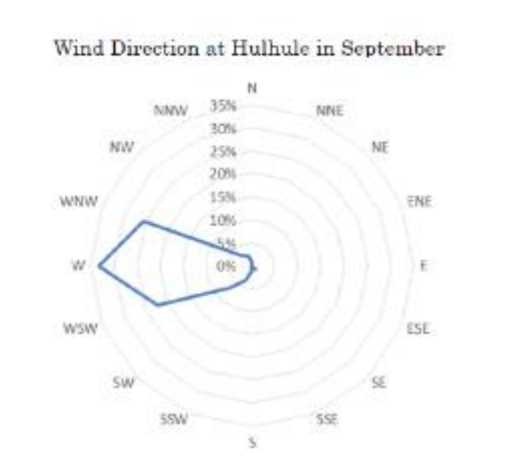

Wind Direction at Hulhule in April
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
50%
40%
30%
20%
10%
0%

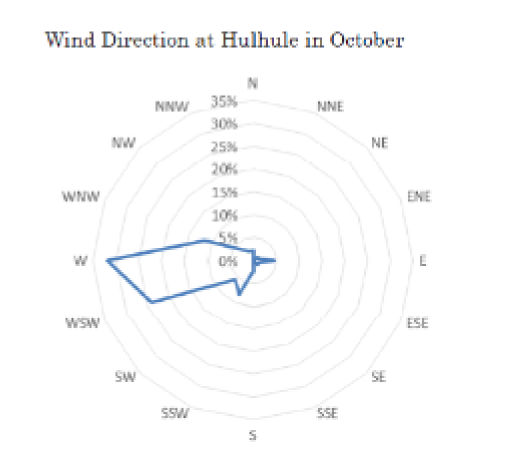

Wind Direction at Hulhule in May
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
50%
40%
30%
20%
10%
0%

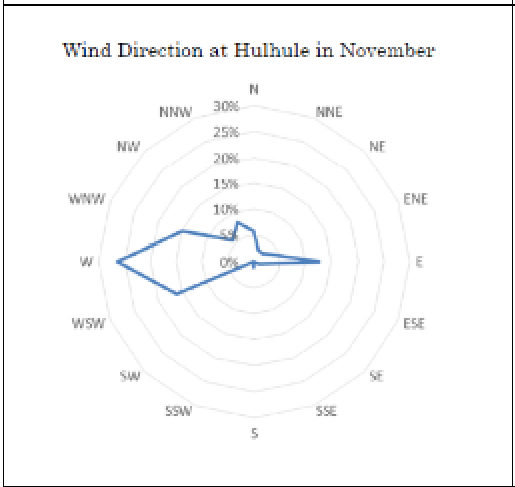

Wind Direction at Hulhule in June
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
40%
30%
20%
10%
0%

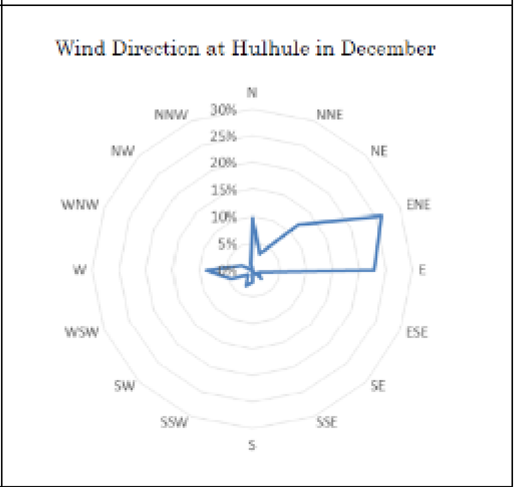

Wind Direction at Hulhule in July
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
35%
30%
25%
20%
15%
10%
5%
0%


Wind Direction at Hulhule in August
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
40%
30%
20%
10%
0%


Wind Direction at Hulhule in September
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
35%
30%
25%
20%
15%
10%
5%
0%


Wind Direction at Hulhule in October
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
35%
30%
25%
20%
15%
10%
5%
0%


Wind Direction at Hulhule in November
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
30%
25%
20%
15%
10%
5%
0%


Wind Direction at Hulhule in December
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
30%
25%
20%
15%
10%
5%
0%

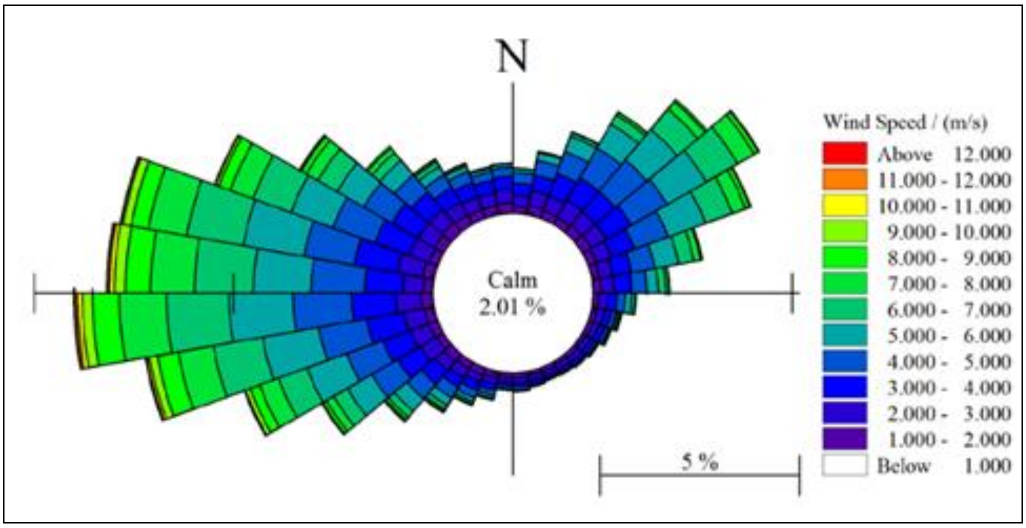


Figure 4: Spatial distribution of wind speed and directions from 1986-2016 (Source: LHI, 2018)

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.

Speed (m/s) \ Dir (Deg N)	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
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
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
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
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
4 – 5	0.26	0.38	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
5 – 6	0.10	0.19	0.42	0.68	0.89	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
6 – 7	0.02	0.04	0.09	0.28	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
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
8 – 9		0.00	0.03	0.02	0.05	0.12	0.11	0.04	0.01	0.01	0.02	0.00						
9 – 10				0.02	0.04	0.05	0.03	0.00	0.00	0.00	0.00							
10 – 11						0.00	0.01											
11 – 12																		
12 – 13																		
13 – 14																		
14 – 15																		
15 – 16																		
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

Speed (m/s) \ Dir (Deg N)	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	0.07	0.06	0.06	0.06	0.07	0.08	0.11	0.03	0.08	0.07	0.08	0.06	0.07	0.06	0.06	0.03	2.07
1 – 2	0.11	0.16	0.19	0.18	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	0.18	7.07
2 – 3	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	0.08	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	0.08	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	0.04	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	0.03	0.04	0.06	0.11	0.20	0.40	0.78	1.24	1.58	1.49	1.43	0.98	0.57	0.25	0.12	0.07	0.03	0.02	12.89
7 – 8	0.02	0.02	0.02	0.06	0.09	0.21	0.50	0.90	1.16	1.07	0.98	0.62	0.33	0.15	0.05	0.03	0.00	0.01	7.78
8 – 9	0.01	0.00	0.01	0.02	0.04	0.09	0.25	0.52	0.65	0.62	0.43	0.30	0.14	0.04	0.03	0.02			3.60
9 – 10			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				0.01	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	0.08	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	0.51	0.81	1.06	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)

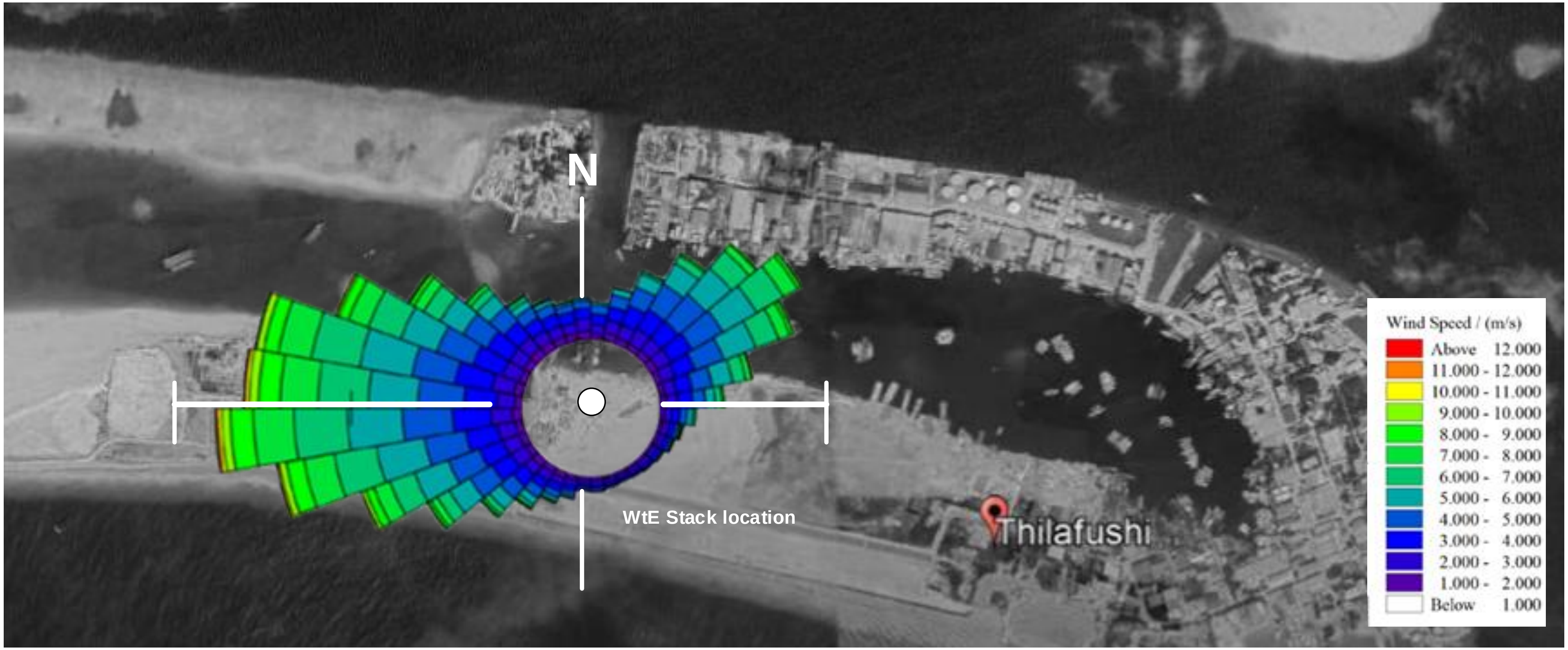


Figure 6: average Wind rose over project location

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.

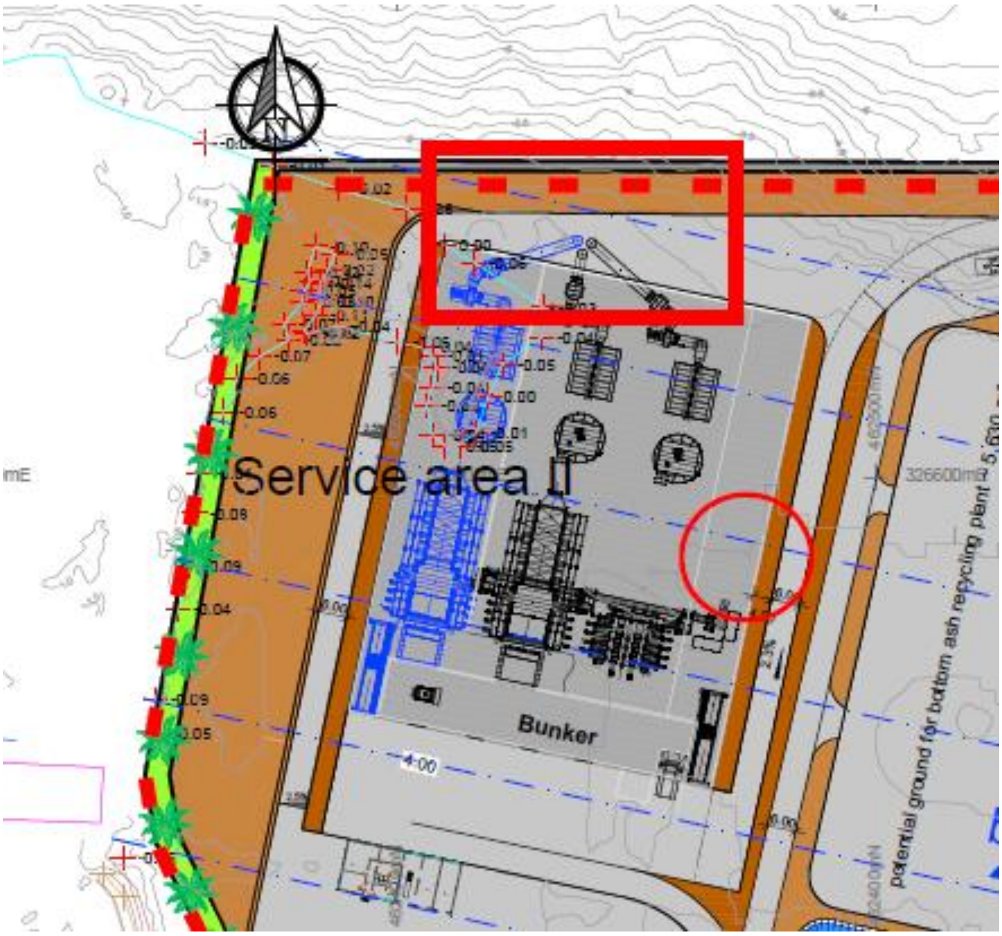


Figure 8: tentative Location of the WtE, the stack (square) and the genset (circle)

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 Nm^3
Emissions (based on 11% O_2 in the flue gas)	
Total dust	5 mg/Nm^3
PM_{10}	0,5 mg/Nm^3
Total carbon	10 mg/Nm^3
HCl	10 mg/Nm^3
Hf	1 mg/Nm^3
SO_2	50 mg/Nm^3
NO_x	150 mg/Nm^3
Hg	0,03 mg/Nm^3
CO	50 mg/Nm^3
NH_3	10 mg/Nm^3
Dioxin/furan	0,1 ng/Nm^3

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 50 µg/m³	year 24 hours	- 35	1.2 µg/m³ -
Sulfur dioxide (SO_2)	50 µg/m³ 125 µg/m³ 350 µg/m³	year 24 hrs 1 hr	- 3 24	1.5 µg/m³ - -
Nitrogen dioxide (NO_X)	40 µg/m³ 200 µg/m³	year 1 hr	- 18	1.2 µg/m³ -

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.

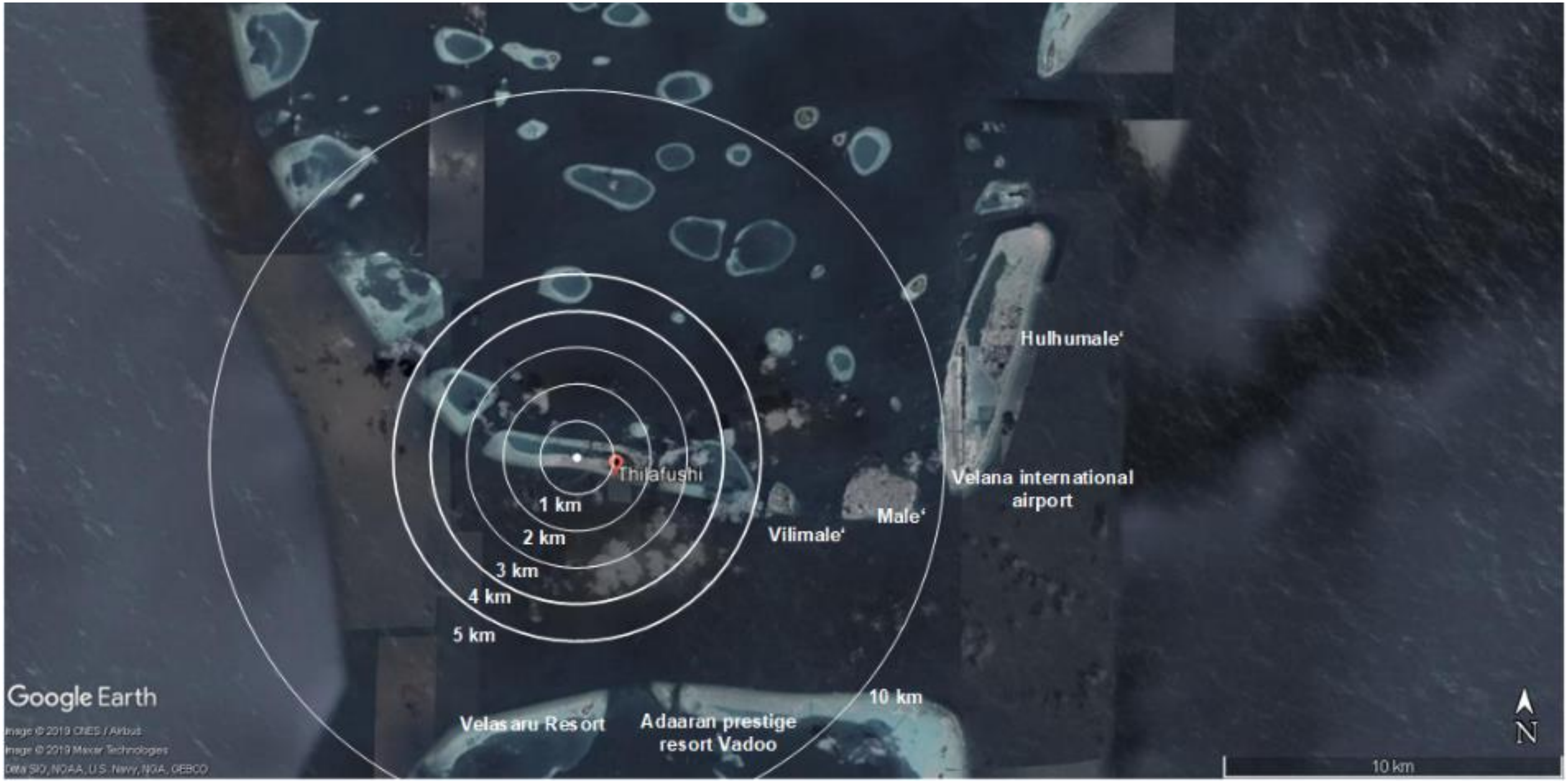


Figure 9: Project location (macro-location) [Source Google Earth]

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.

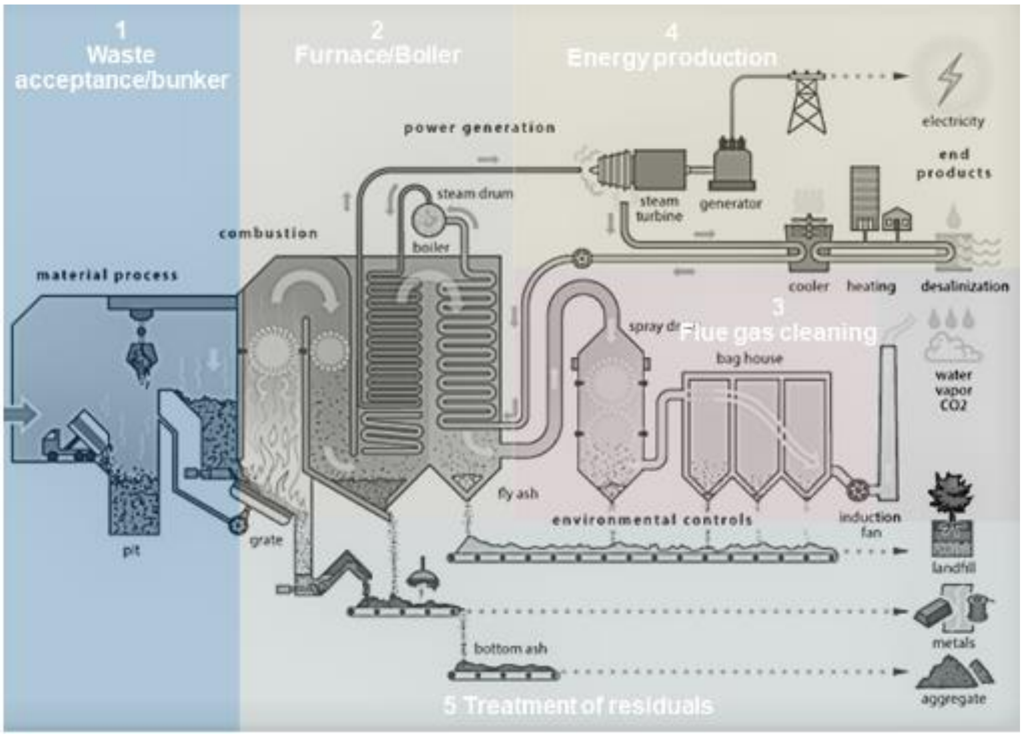


Figure 13: schematic layout of the WtE Facility

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 1×10^{-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]

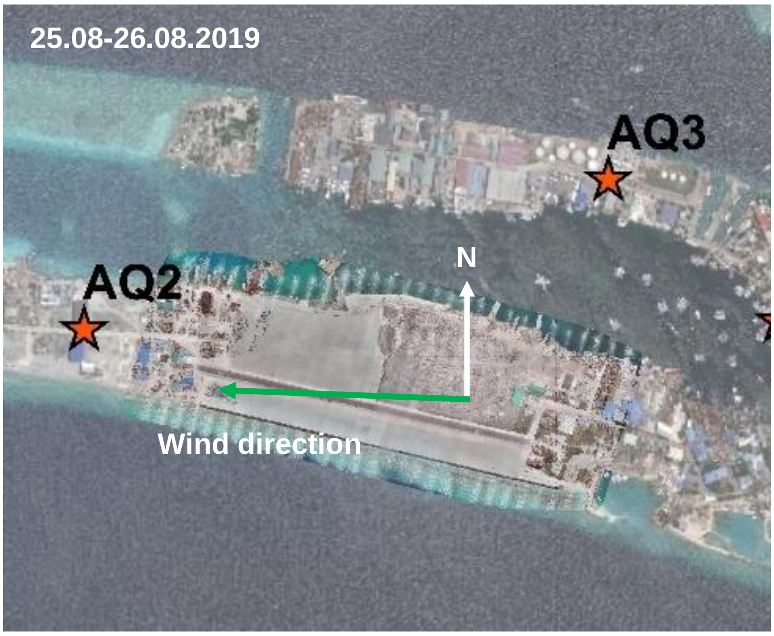
NO_2	19.03.-20.03.2019	67,5 [1 hr max.]	200 [hr]

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

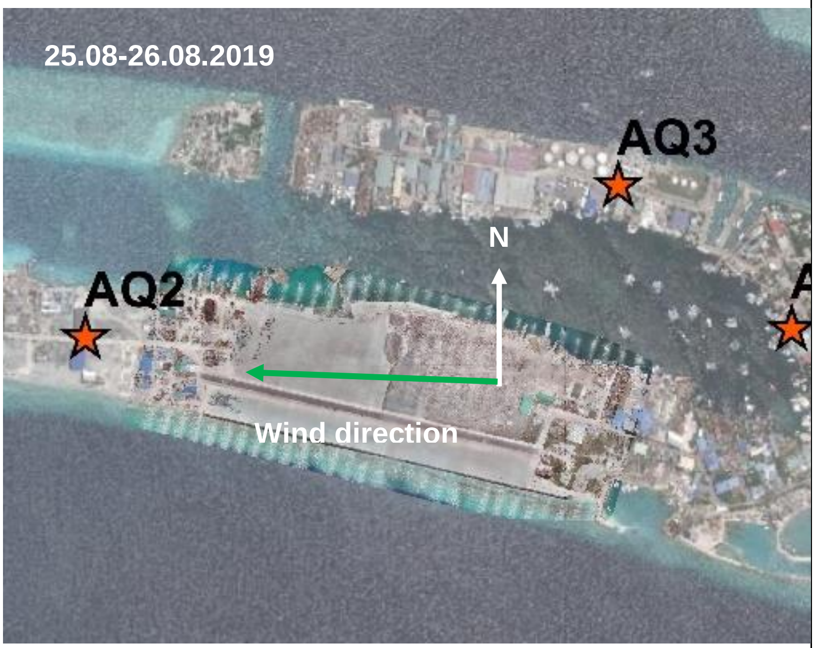
7.4.2 Air Quality baseline survey AQ 2 (Thilafushi 2, new reclaimed area)

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]

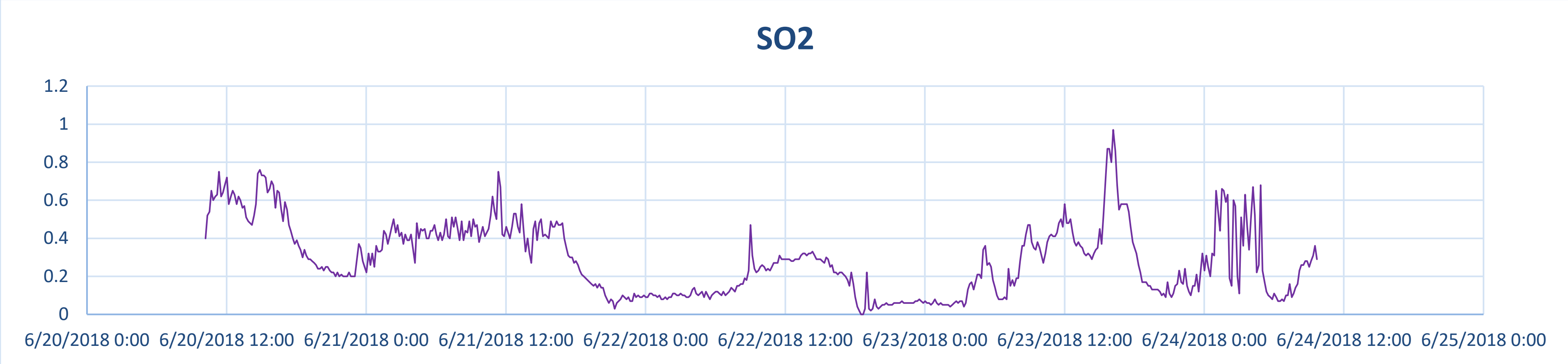


Figure 18: graphical presentation of survey results for SO_2 at AQ3 (PPT)

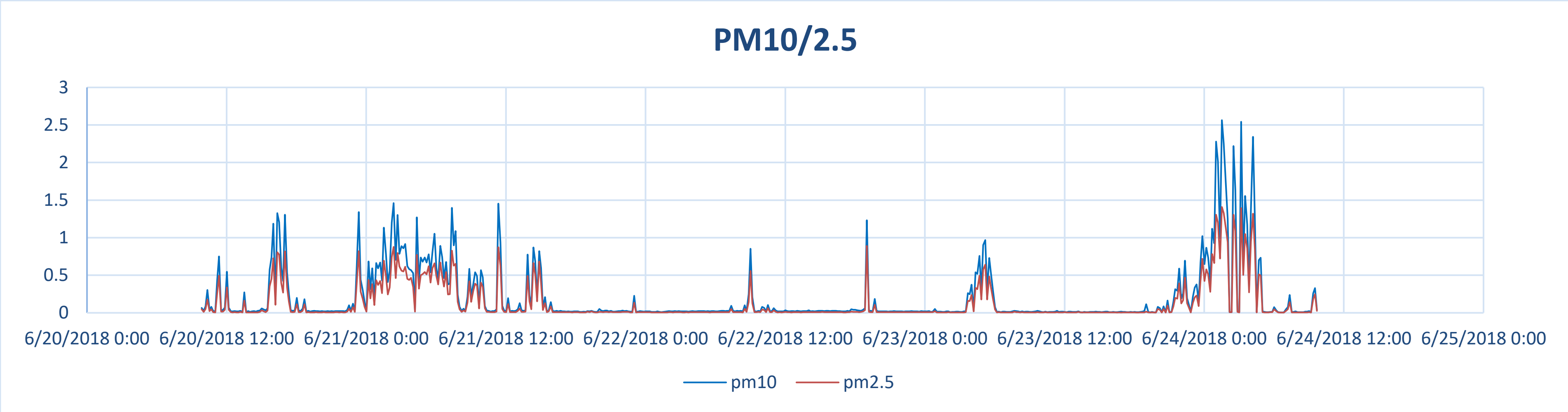


Figure 19: graphical presentation of survey results for $PM_{2,5}$ and PM_{10} at AQ3 (PPT)

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	1.16×10^{-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	-	$1{,}16x\ 10^{-8}$
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

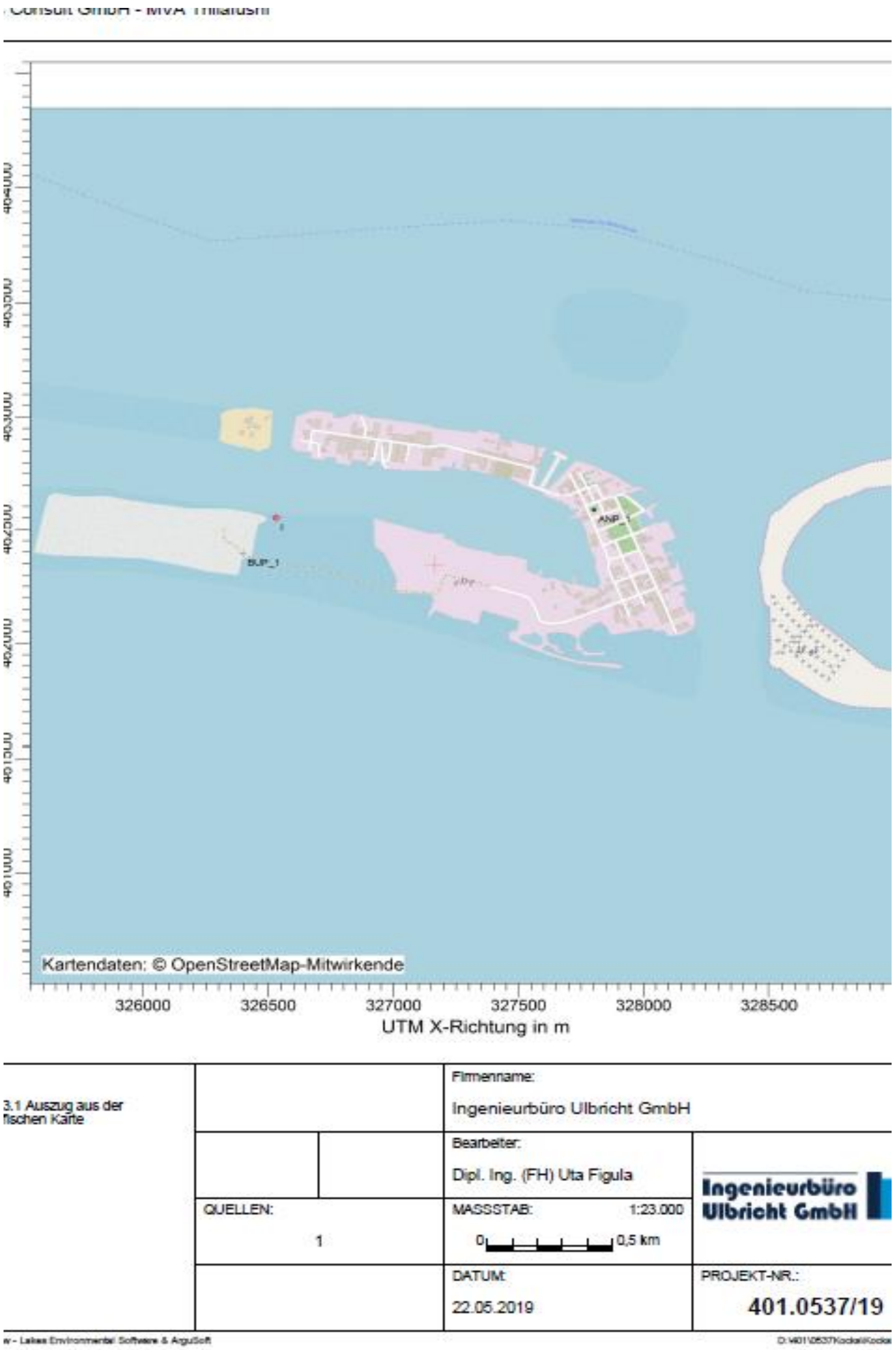


Figure 20: Location of the emission points where maximum load was calculated and examined

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.

<u>Ammonia</u>

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.

<u>Hydrogen chloride, total C, carbon monoxide (CO), dioxins and furans</u>

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.

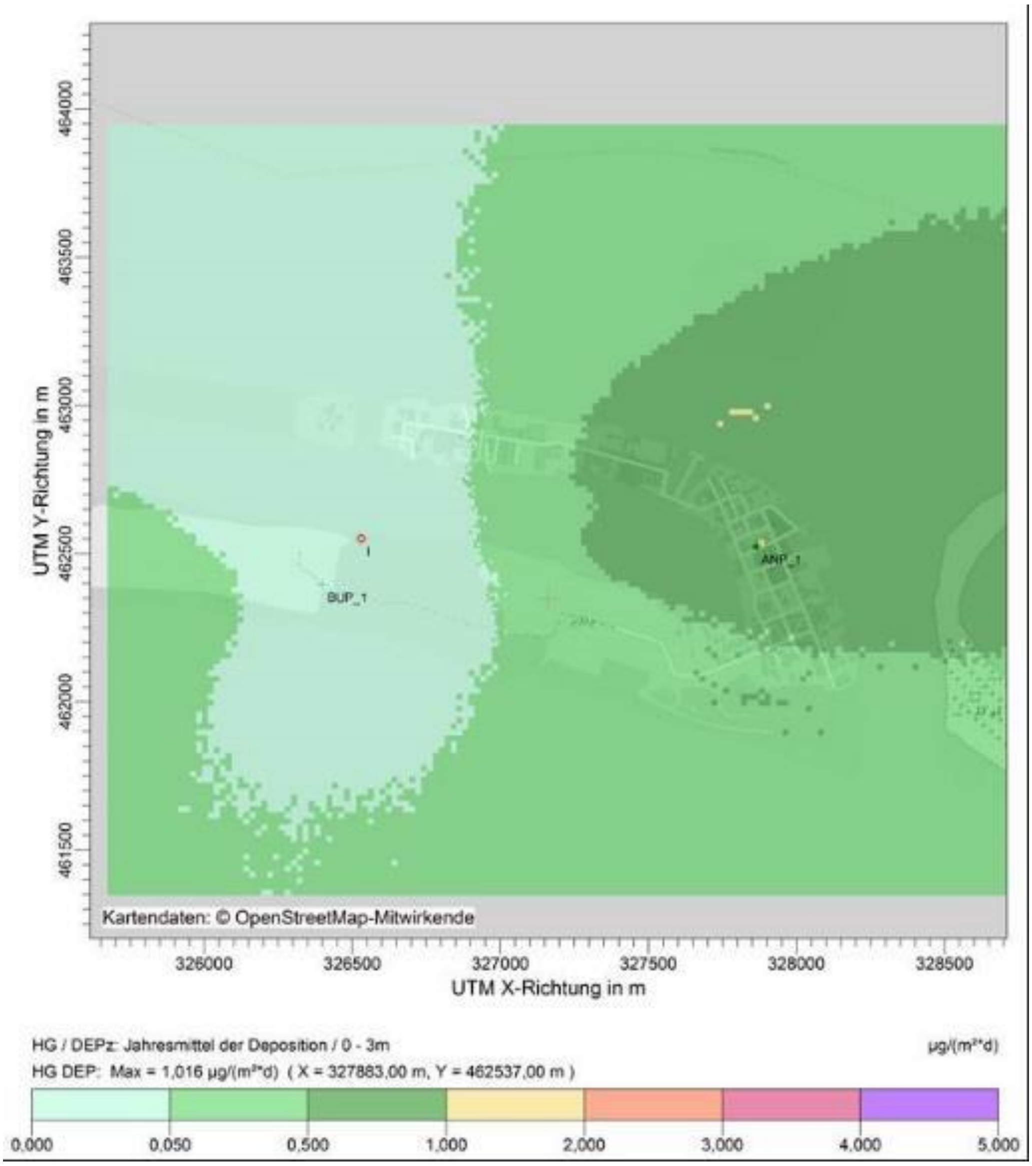


Figure 21: additional load Mercury-Deposit from the dispersion model.

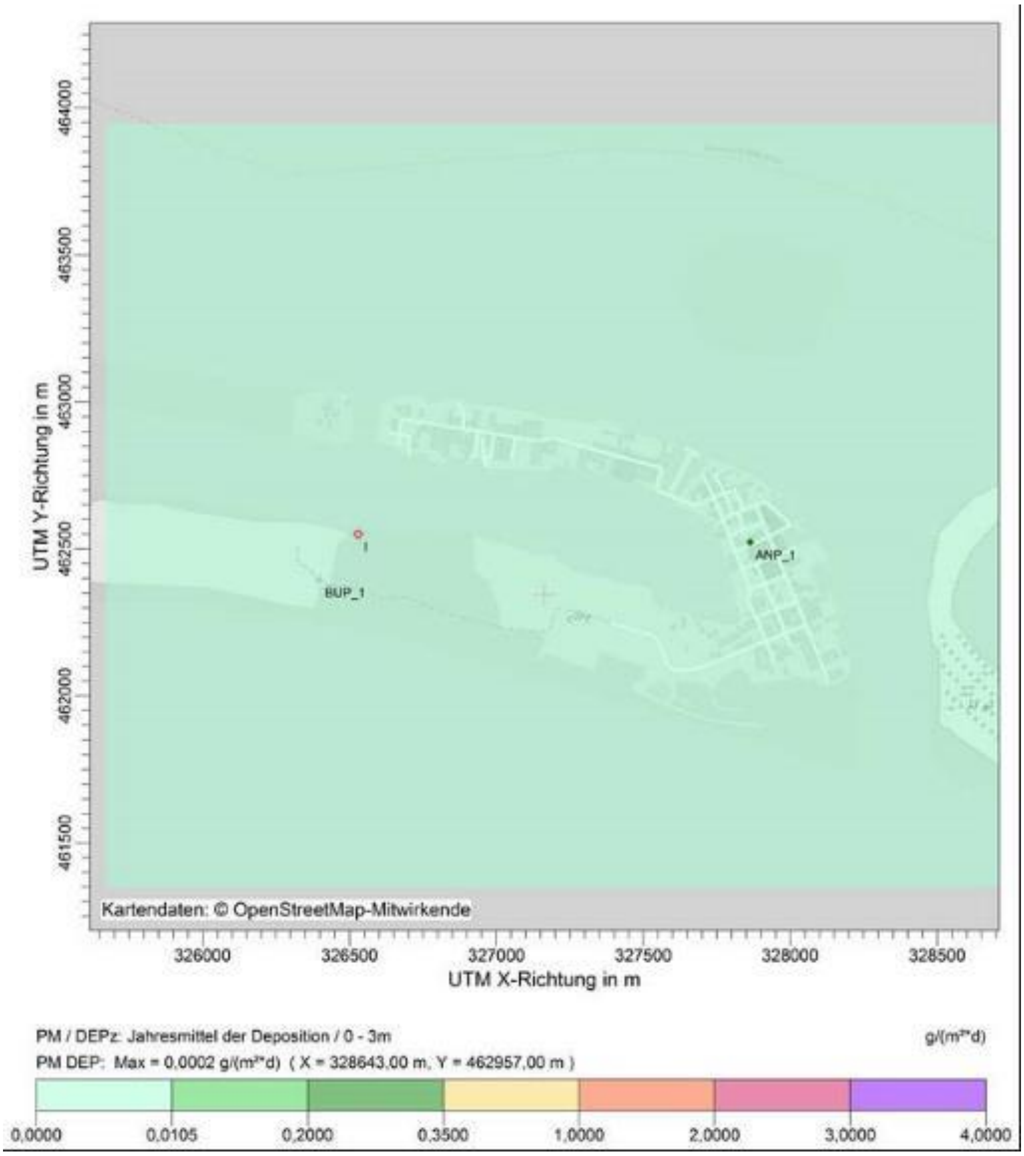


Figure 22: PM-Deposit from the dispersion model.

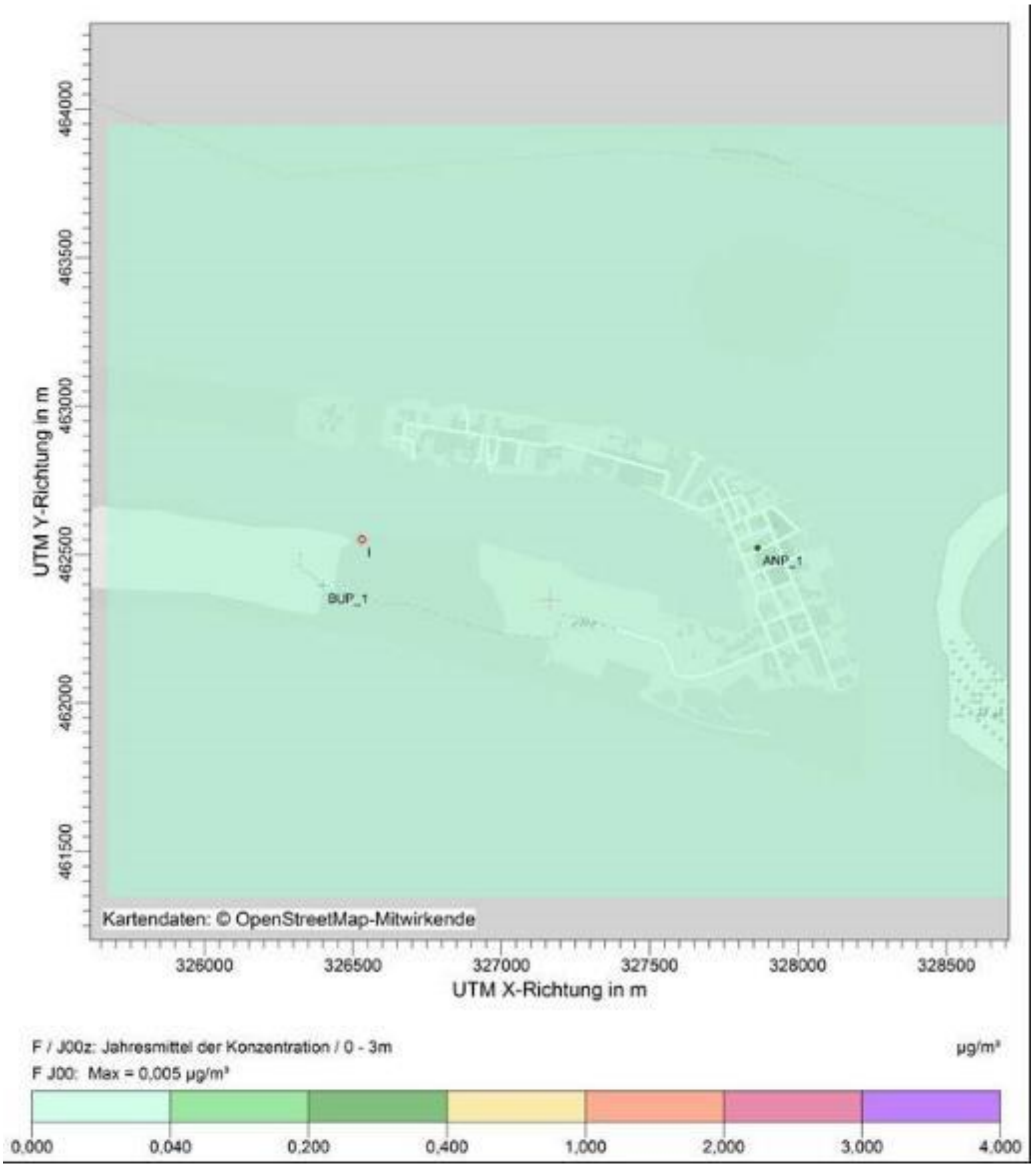


Figure 23: F-Deposit from the dispersion model.

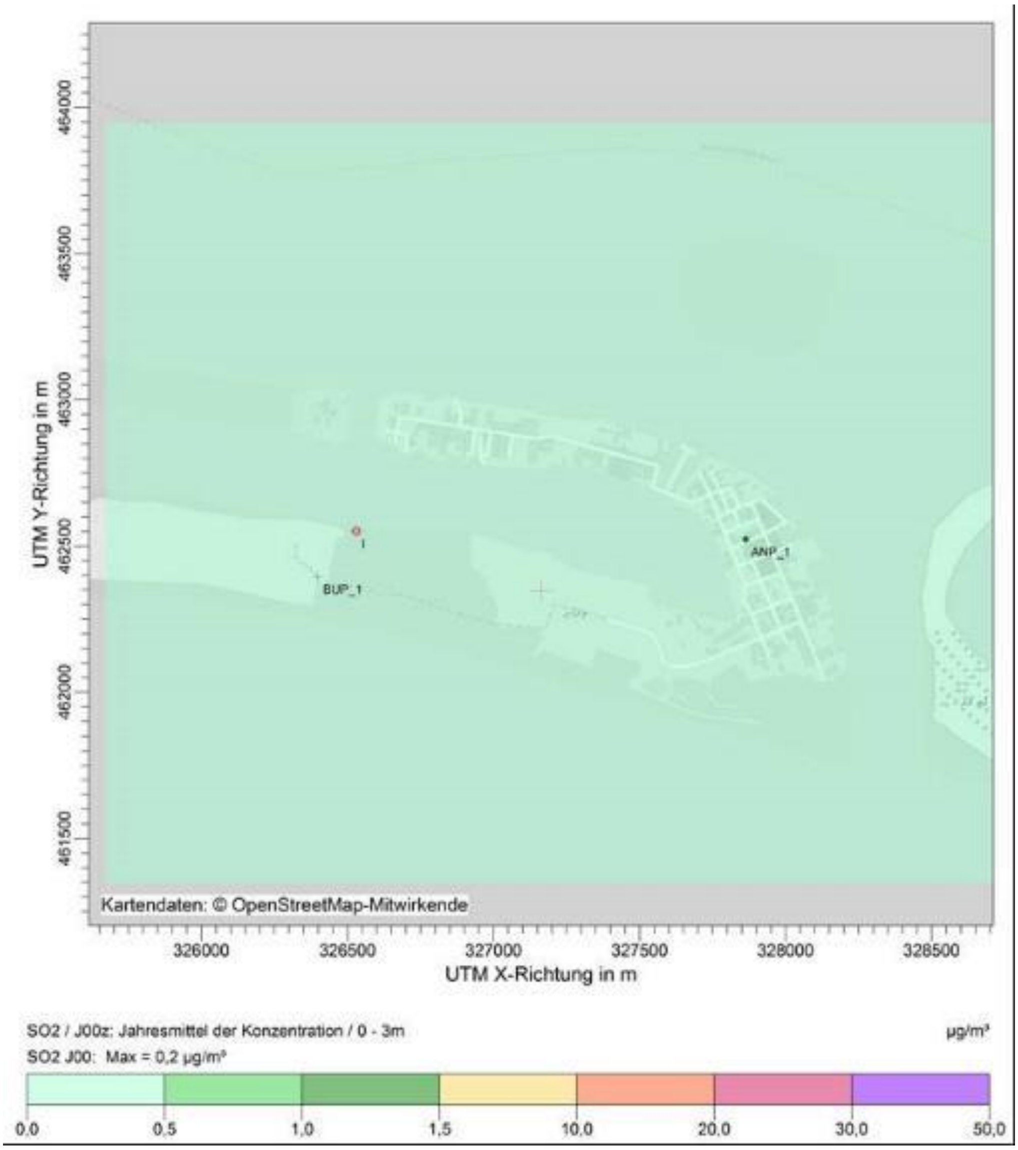


Figure 24: SO_2-Deposit from the dispersion model.

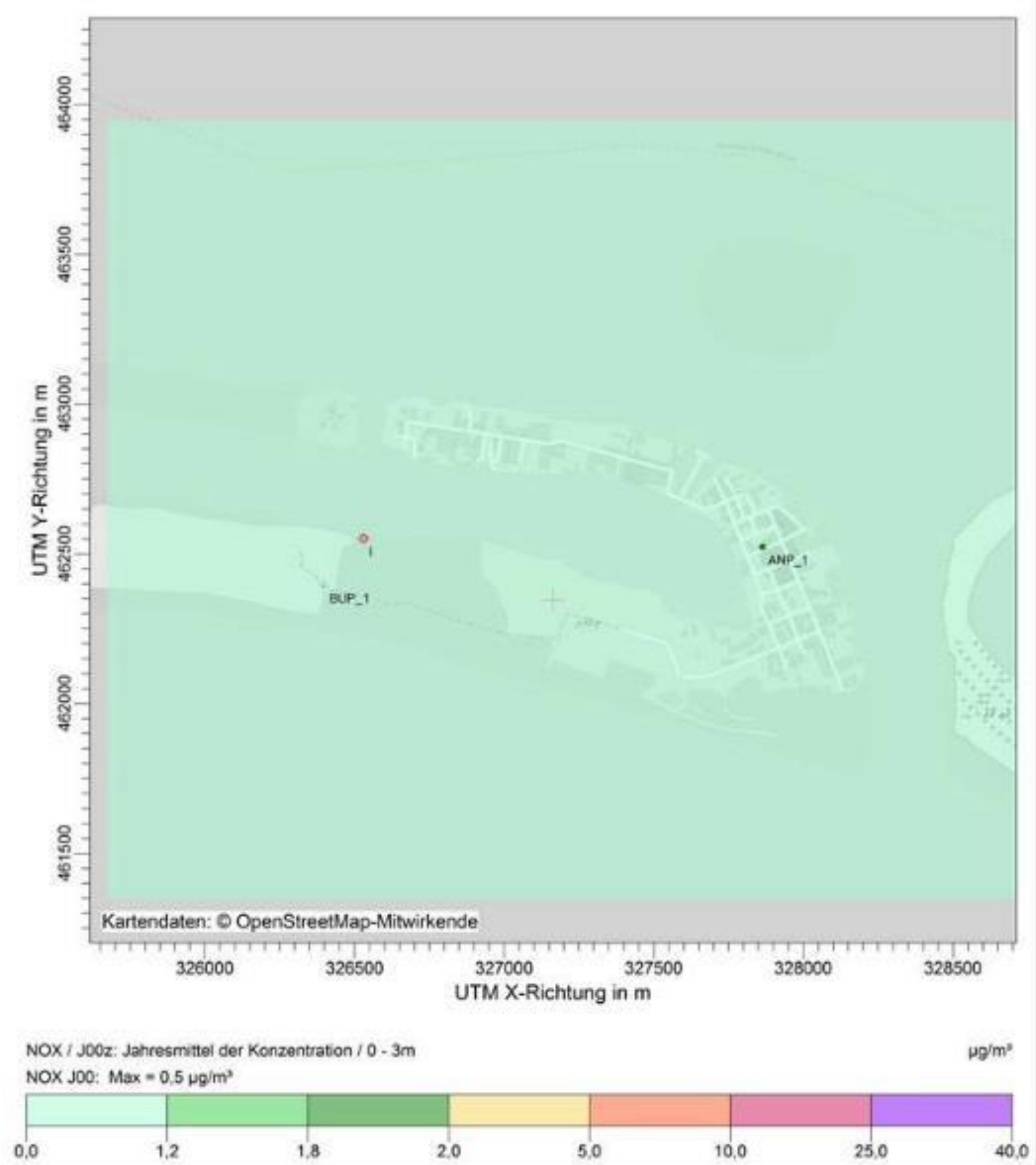


Figure 25: NOx-Deposit from the dispersion model.

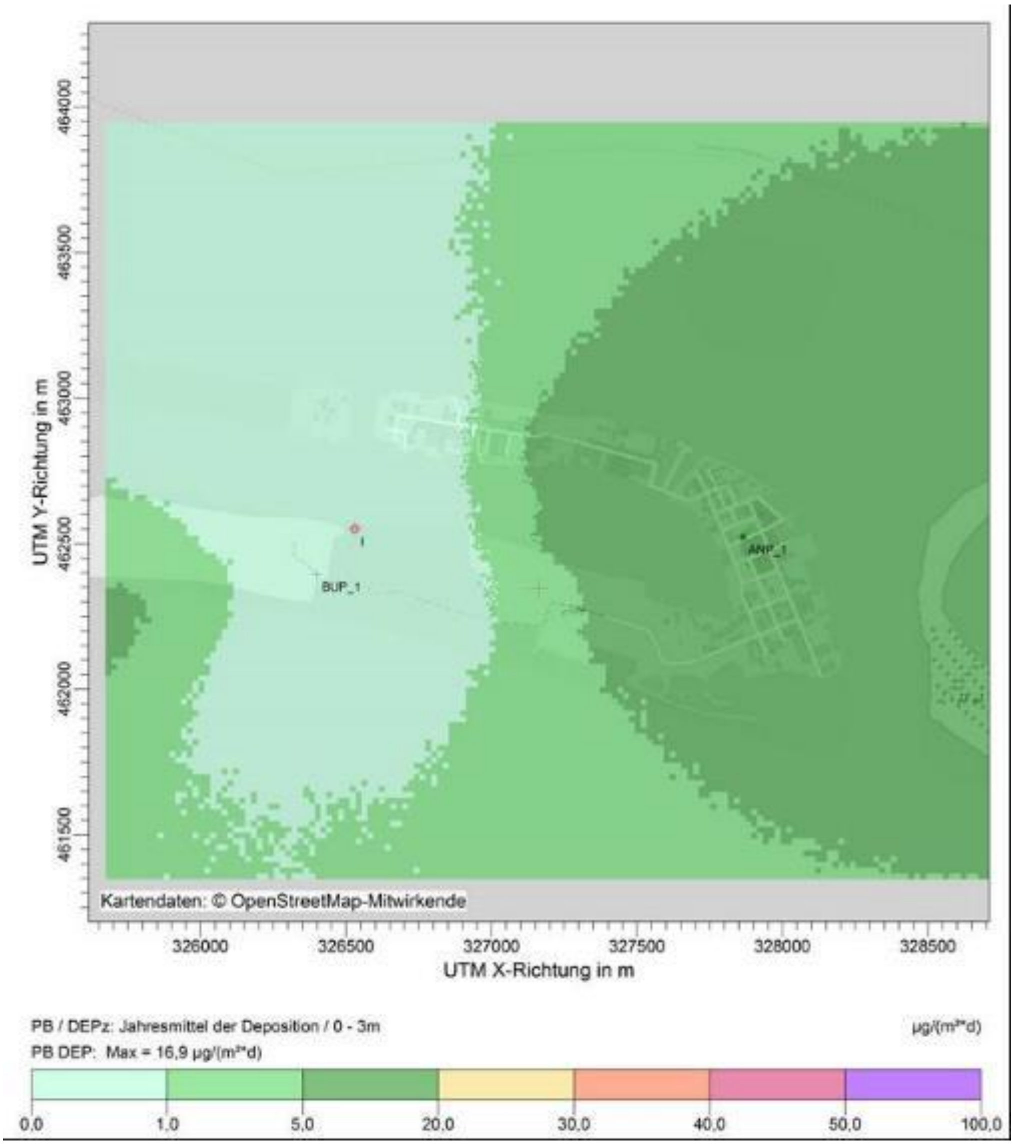


Figure 26: Pb-Deposit from the dispersion model.

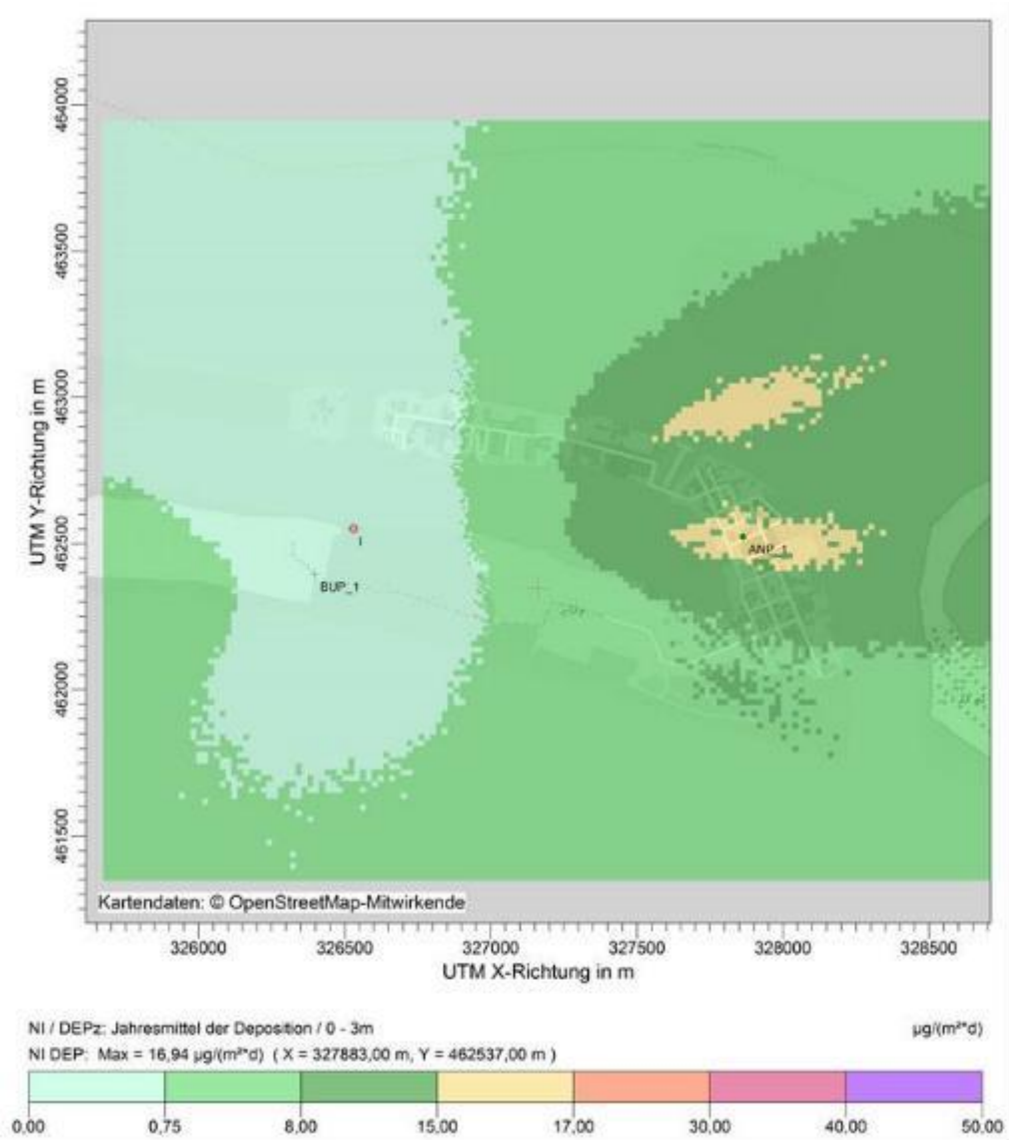


Figure 27: Ni-Deposit from the dispersion model.

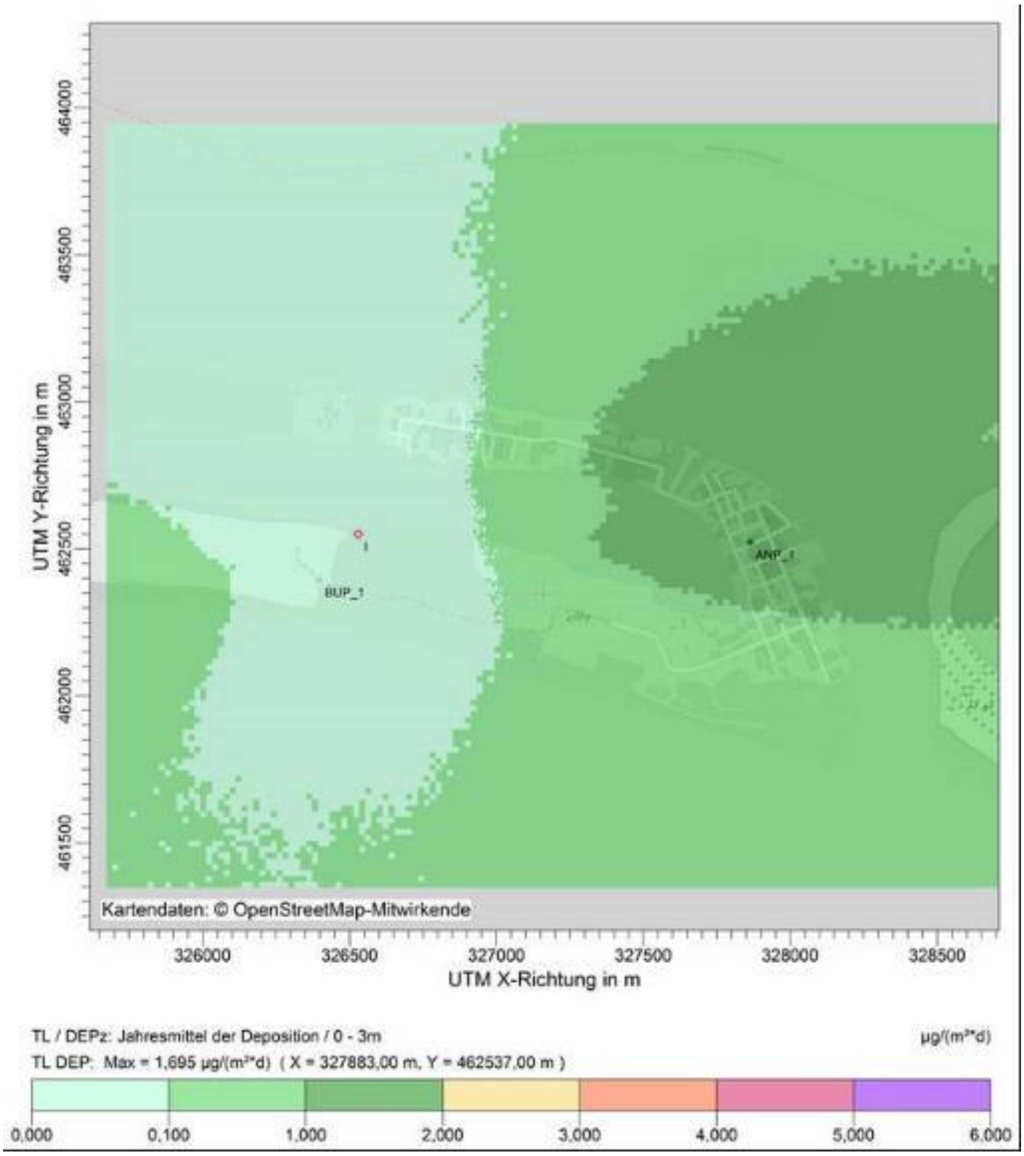


Figure 28: Tl-Deposit from the dispersion model.

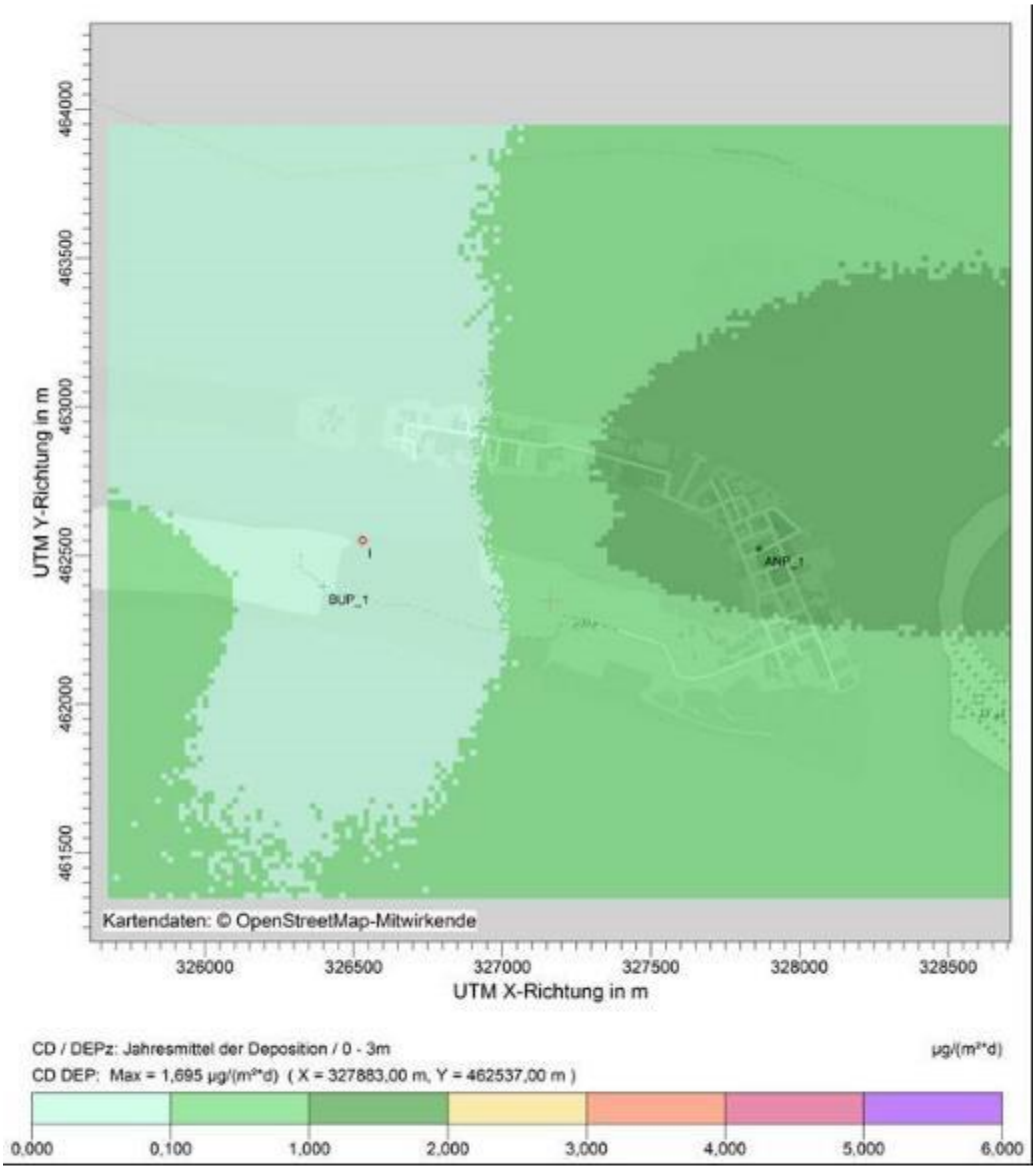


Figure 29: Cd-Deposit from the dispersion model.

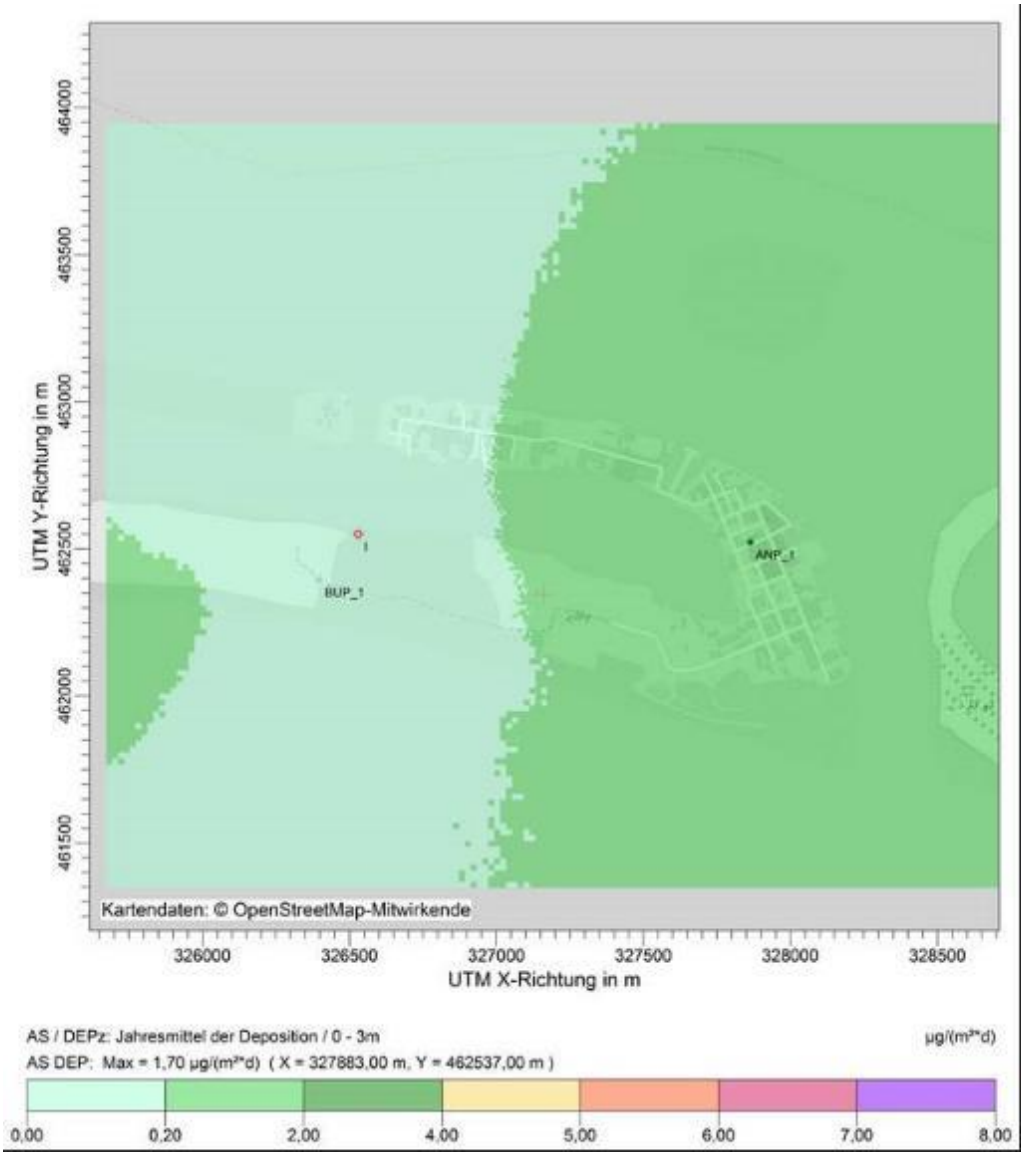


Figure 30: As-Deposit from the dispersion model.

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 ($\mu g/m^3$)	Baseline ($\mu g/m_3$)	Process contribution ($\mu g/m_3$)	PC/ AQSG	Combined process + baseline ($\mu g/m_3$)	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.

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