



Air Quality Study for a new Thermal Treatment Facility (TTF)

PA/O6O96/23

Report



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1 INTRODUCTION

This report outlines the results from an air dispersion model carried out for the proposed new Thermal Treatment Facility (TTF). The assessment has been requested by the ERA to evaluate various operational scenarios and thus obtain a good understanding of the impacts from the proposed facility. The assessment has been based on the Terms of Reference (ToRs) issued by ERA for a new Thermal Treatment Facility (PA/6096/23).

The modelling suite used throughout this exercise has been capable of incorporating all the substances included in the terms of reference. Specifically, the same suite of dispersion modelling was used, in order to assess for the likelihood of significant effect on ambient air quality (including exceedances of the ambient limit values in SL.549.59) as well as on the deposition levels of particular components, due to the operation of the new plant TTF.

Under normal operations, the project designers have stated that the TTF will operate a thermal load ranging between 60% and 100% (and at 110% for 1 hour every 24hours). The waste type and quantities being incinerated shall influence the thermal load. The facility is not designed to operate outside the aforementioned range and would thus automatically shut down.

Therefore, the analysis was developed with three different scenarios in mind:

- Typical operations (Scenario A): 60% thermal load for 24hours, with a flue gas flow per line of 4116 Nm³/h for 24 hours;
- Maximum operating conditions (Scenario B): 100% thermal load for 23hours (flue gas flow per line of 6860 Nm³/h) and 110% load for 1 hour (a flue gas flow per line of 7814 Nm³/h);
- Abnormal operating conditions 'worst case scenario' (Scenario C): based on the limits defined in Schedule 2 of S.L.549.81, a dust concentration of 150 mg/Nm³ shall be set at the stack at maximum operating conditions

All simulations were conducted by considering the optimal height of the stack at 25 meters defined on the basis of the results of a previous study which compared three chimney stack heights for the TTF, at 25m, 30m and 35m respectively. The study had revealed that there were no significant variations in the impacts on air quality for the three different stack height scenarios, and thus the designers opted for a shorter chimney stack to minimise visual impacts and associated costs.

The model also considered the cumulative air quality impacts from the operation of the adjacent Waste-to-Energy facility.

2 METHODOLOGY

The impact of air quality emissions is determined by applying a mathematical model of dispersion and atmospheric fallout, which calculates the concentration of substances emitted by the incinerator in ambient air at ground level, integrating and processing the emission data, the data meteorological and geomorphological (see figure 1). The following regulatory references have been considered for the preparation of this document:

- a) UNI EN 13725: 2004 "Air quality. Determination of odor concentration by dynamic olfactometry".
- b) UNI 10796: 2000 "Evaluation of the dispersion of aeriform effluents into the atmosphere. Guide to the selection criteria of mathematical models".
- c) UNI 10964: 2001 "Environmental impact studies. Guide to selecting mathematical models for predicting impact on air quality".

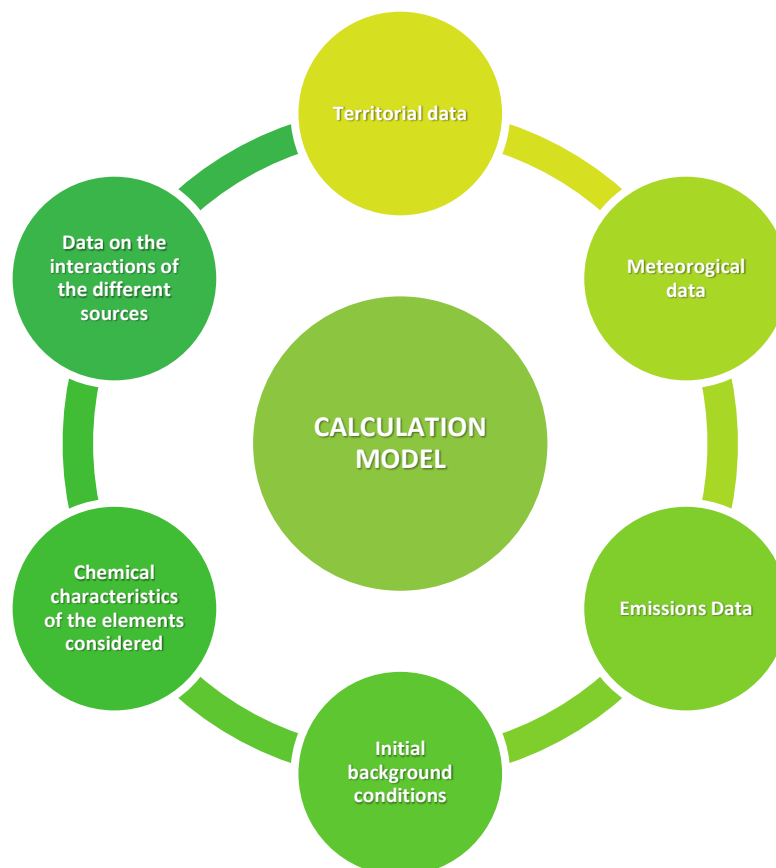


FIGURE 1: SCHEMATIC REPRESENTATION OF THE TYPE OF INFORMATION AND INPUT DATA REQUIRED BY THE MODEL

The emission factors used are the provisional limit values in normal operating conditions based on "Tentative limit values under normal operating conditions based on BAT and IED" shown in Table 3 of the EIA TORs dated 05/08/2024. The model used in this study is capable of predicating the dispersion and deposition of pollutants under variable meteorological conditions ranging from the most favorable to the least favorable. The modelling suite permitted the annual calculation of the required

parameters. The spatial resolution obtained by the model is equal to 5 x 5 m, to enable the identification of impacts at sensitive receptors.

Generally, an air quality model (or "atmospheric dispersion model") is a mathematical algorithm that has as its objective the calculation of the concentrations in the atmosphere of one or more pollutants emitted by a defined set of sources. The two main categories of models are *stochastic* and *deterministic* models.

The *stochastic* do not refer to physical cause-and-effect relationships but only to statistical correlations, for which they are characterized by a series of intrinsic limits and are mainly used to formulate semi-quantitative forecasts on air pollution, which must however be validated by an experienced operator.

The *deterministic* models, on the contrary, are made up of mathematical algorithms which reproduce (more or less according to the typology of the model itself) the diffusion, transport and chemical transformation processes to which the pollutants are subjected once emitted into the atmosphere.

The information presented here refers mainly to this second category of models: it is in fact to the deterministic models that the legislation refers (in particular the DM 261/2002 - *Regulation containing the technical directives for the preliminary assessment of the quality of the ambient air, the criteria for the preparation of the plan and the programs referred to in articles 8 and 9 of the legislative decree 4 August 1999, n.351*), as they potentially allow to face any type of simulation scenario.

Deterministic models, by their own nature, need a series of input data, which can be divided into three general types:

- a) *geographical data*, which describe the geographical characteristics of the territory in which the emissive phenomenon occurs, in particular the topography and roughness. The territorial context in which the model is applied is called the calculation domain;
- b) *emission data*, which describe the characteristics of the sources of atmospheric pollution that are taken into consideration, in particular the quantity and type of pollutants emitted;
- c) *meteorological data*, which describe the ways in which pollutants are dispersed in the atmosphere, in particular anemology and phenomena related to turbulence and atmospheric stability. A typical set of weather data needed for an analysis is made up of an annual data set.

They provide the spatial distribution of one or more pollutants in a given area, the so-called concentration fields which, in the case of the most advanced models, have a three-dimensional character.

The most advanced air quality models require real input data pre-processing modules, in particular as regards meteorological data; in this case we speak more properly of modeling chain since the pre-processing modules of meteorological data are in turn

real models that provide output fields of quantities such as: wind characteristics, temperature, atmospheric turbulence etc.

There are two basic categories of deterministic models, depending on the spatial coordinate system which they refer. The *Eulerian models* refer to a fixed coordinate system, while the *Lagrangian models* use a mobile coordinate system that follows the movements of the air masses. The Eulerian models are divided into *analytical models*, and into *grid models*. In the analytical ones, through the introduction of a series of simplifications, it is possible to analytically solve the general differential equation that describes transport and diffusion.

The so-called "*plume*" *Gaussian models*, which constitute the simplest tool in the field, and the "*puff*" *models*, belong to the analytical Eulerian models. The fundamental difference consists in the fact that the Gaussian models assume that the process is stationary (ie that in every point of the domain the variation in concentration over time is zero), while the "*puff*" models allow a treatment, albeit simplified, also of non-stationary processes. Both solutions assume that the emission originates at a point in space (point source) and also the meteorological geometries considered are very simplified.

In grid models, however, the calculation domain is always three-dimensional, it is divided into a series of cells through a suitable grid and the general transport and diffusion equation is taken in a more complete (non-stationary) form that requires resolution by numerical methods. To this category belong the photochemical models capable of describing, in addition to diffusion and transport, also the phenomena of chemical transformation to which pollutants are subjected once they are released into the atmosphere.

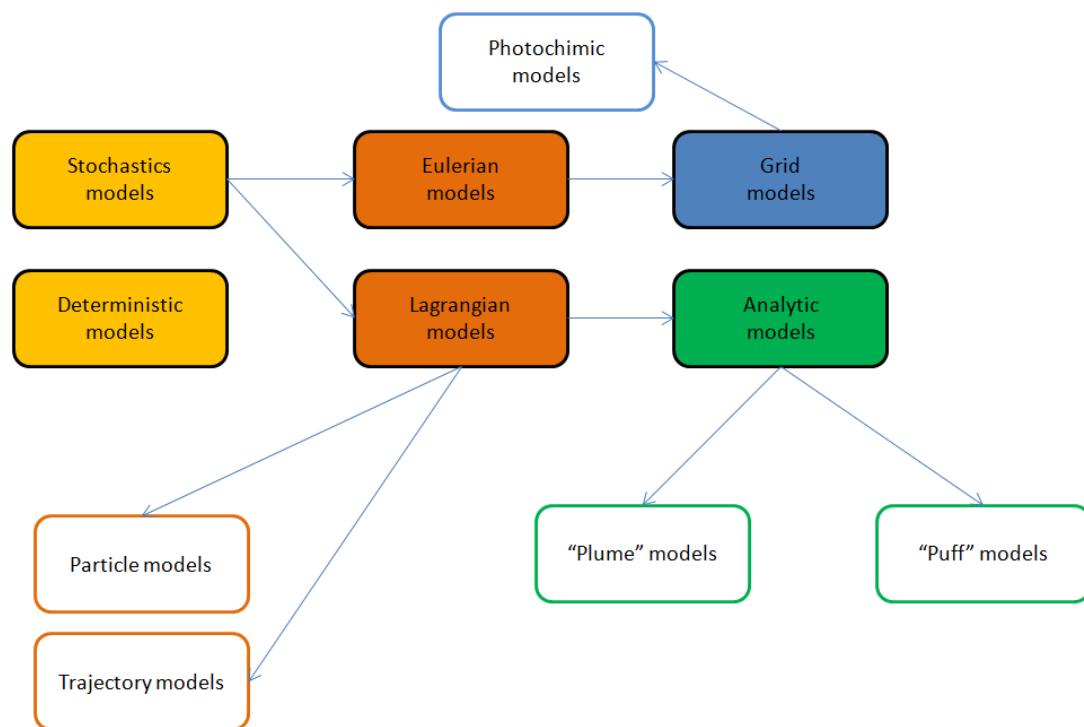


FIGURE 2: MAIN TYPES OF MODELS

Lagrangian models, which are also capable of describing non-stationary processes, are divided into *particle* and *trajectory models*. The emission of each pollutant is represented, in the first case through a series of small units of known mass (called particles), in the second by one-dimensional vertical columns. In both cases, these are models that use a three-dimensional computation domain, but while particle models are also suitable for simulations of high spatial detail, trajectory models are used in the study of phenomena at a very large spatial scale, of the order thousands of kilometers, as in the case of cross-border pollution.

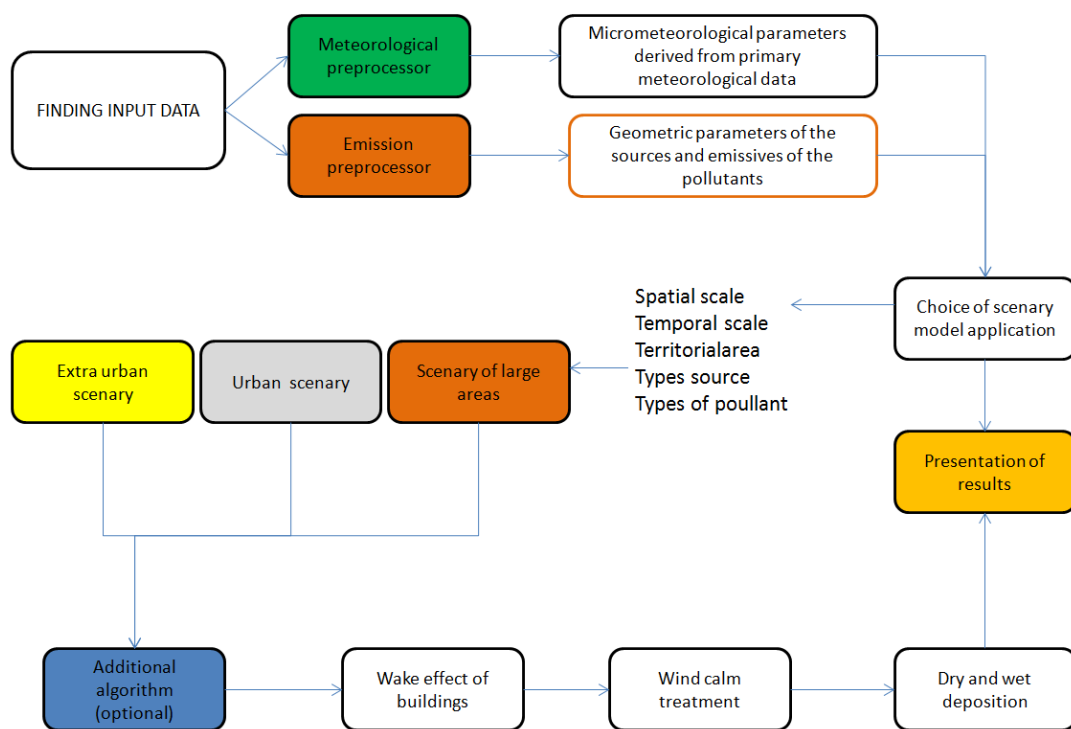


FIGURE 3: REALIZATION PHASES OF A DIFFUSION MODEL IN THE ATMOSPHERE.

2.1 MODEL APPLICATION

When making the choice of an air quality model (or a modeling chain), it is necessary to bear in mind the nature of the problem to be addressed. For this purpose, the notion of scenario is very useful, that is, the set of elements that characterize a specific application. Based on the Guidelines for the selection and application of atmospheric dispersion models for assessing air quality, a scenario is defined by five elements:

- the *spatial scale*, for which micro-scale applications (up to 1 km), local scale (up to 10 ÷ 20 km), mesoscale (up to 100 ÷ 200 km) are distinguished;
- the *time scale*, for which short-term (roughly a few minutes to a few days) and long-term (seasonal and annual periods) applications are distinguished.
- the *territorial context*, for which applications on a simple site (flat terrain, homogeneous territorial and meteorological characteristics) and on a complex site (complex orography, territorial and / or uneven meteorological characteristics) are distinguished.
- the *types of source* present, for which point, linear and areal sources are distinguished.
- the *types of air pollutant* taken into consideration, whereby a distinction is made between non-reactive (or reactive to the first order, that is, decay expressed by means of time constant) and reactive pollutant.

From the choice of the different types of elements, one of the three different types of possible scenarios emerges:

1. Urban areas
 - 500x500 m² spatial staircase (typical size of a block that houses buildings and roads), up to 10x10 km² (surface within which the entire urban area can be included).
 - This scenario is dominated by pollutants emitted above all at ground level by vehicular traffic, and is characterized by a marked spatio-temporal variability of concentrations. It can be described with analytical models that allow the treatment of linear sources in the form of a road graph and of areal sources as a composition of emissions from domestic heating or in cases where it is desired to describe the contribution of a network of roads without distinguishing the individual contributions.
2. Extra urban areas
 - This scenario is dominated by the typical emissions of a given production area (e.g. sulfur dioxide and nitrogen oxides due to the combustion processes of fossil fuels), generally conveyed into chimneys (emissions from point sources) and / or from emissions of extra-urban road arteries (emissions from linear sources).
 - This is the case most frequently treated with models: since the 1960s simulations of the dispersion of radionuclides emitted in the event of accidental release from nuclear plants were carried out and then the study was carried out of the behavior of plumes of pollutants emitted into the atmosphere by large industrial plants through chimneys (point springs) or from the buildings of the plants (area springs)
3. Extended areas
 - This scenario is the most general one and considers the set of polluting sources located on spatial scales ranging from extended urban realities, such as large metropolitan areas to aerological basins affecting multiple regions (as in the case of the Po valley). The treated domains can therefore be of the order from 50x50km² up to 500x500km² and consider both primary and secondary pollutants.

2.2 TYPE OF SOURCES AND ASSIGNMENT CRITERIA

There are three types of sources: *point*, *linear* and *areal*.

Generally, the assignment of a source to one of these classes takes place on the basis of several criteria: the form (typically, for example, the emissions distributed on a line such as road, air transport infrastructures etc.) fall within the line, whether or not to relocate the source in the form of point or linear. In this regard, for example, the position of large industrial plants is usually sufficiently characterized, therefore emissions are generally attributed to a specific source, vice versa, emissions from heating systems for civil use, since they cannot be georeferenced individually due to their number, are usually attributed to the emissions of the polygon corresponding to the census / municipality / province / region to which they belong according to the detail and therefore treated as areal.

A similar example concerns road traffic emissions, in fact usually the main road arches are treated individually while the secondary ones are sometimes considered as a whole, corresponding to the neighborhood or cell to which they belong. A further classification criterion involves the identification of appropriate threshold values, i.e. emission values on the basis of which to differentiate between sources that must be considered stand-alone if the emissions exceed the established threshold or can be grouped with others, similar for type of pollutant and process. On the basis of these considerations, the sources are then divided between punctual, to be considered individually, and areal.

In the impossibility of treating all the sources individually, it is evident that the choice of the threshold values sometimes depends on the resources available and the purposes of the inventory or modeling application.

2.3 EMISSIONS PREPROCESSOR

An emissions preprocessor is a SW tool that processes the information relating to the emissions necessary for the execution of an air quality model using appropriate estimation methods or from existing data (emission inventories, measurements). Usually for modelling purposes, emissions are treated as:

- punctual
- linear
- areal and volumetric

The emissions present in the simulation domain, once assigned with appropriate criteria to one of these types, must be adequately characterized according to the information required by the models. The main sources for obtaining this information are the emission inventories which are prepared both on a national scale by the APAT (Agency for the Protection of the Environment and for Technical Services), and on a local (regional, provincial etc.) scale by the related entities. The input relating to emissions generally represents one of the most complex input data to be obtained both for the small number of local inventories available on the national territory and for the complexity of the processing to be performed on the data coming from the inventories, as it is generally aimed at other purposes and not equipped with sufficient spatial and temporal detail to be directly usable by a model.

It is therefore necessary to use more or less complex emission processors depending on the availability of the initial data and the type of QA model to be applied, on which the complexity of the input to be prepared depends. The case of a three-dimensional model for reactive pollutants undoubtedly represents the most complex one since it requires the emissions specified for each cell of the grid, for each hour of simulation, for each chemical species treated individually or combined.

A processor for the predisposition of the emissions must therefore allow to carry out:

- a) the spatial allocation to allow the passage from the territorial detail (common for example) to the cell;

- b) the temporal breakdown to allow the estimates to be reduced from annual to hourly basis;
- c) speciation to transform the overall information of VOCs and PTSs into group species required by the model;
- d) the particle size distribution to derive PTS estimates in particle size classes according to the requests of the model.

This obviously applies in a completely general way, this does not exclude that, in some cases, the available emissions may already exhaustively cover one or all four of the desired details (spatial and / or temporal and / or chemical-physical of the polluting species) and therefore the use of the processor is limited to the supply of the missing detail or to the reading / writing of the emissions in the requested IT format.

2.4 TYPE OF DATA REQUIRED BY A QA MODEL

Usually, a model requires the following groups of information about the source:

- a) coordinates (coordinates of the extremes of the arc usually described by means of broken lines in the case of linear ones, coordinates of an angle in the case of areas usually treated as a composition of square-shaped area sources, of the center of gravity of the chimney in the case of points);
- b) physical-geometric parameters (height and diameter of the chimney, temperature and speed of the fumes or equivalent parameters such as the flow rate, in the case of the linear ones, for example, the slope may be required, if above / below high etc.);
- c) quantity of polluted emissions per unit of time or emission accruals for each pollutant. The emission accruals are usually deducted either from direct measurements or from estimates according to the reference methodologies.
- d) a time modulation profile referring to the year / month / day.

This applies in the simplest case, for example referred to the Gaussian models. The numerical dispersion models for the study of reactive pollutants, taking instead the more complex but more significant case in order to better highlight all the critical issues, require hourly emission values for the entire simulation period, specified for each cell of the grid, and for about twenty species containing either single chemical species or group species, that is, they treat groups of compounds similar in structure and reactivity as a single chemical species. The discussion is further complicated if you also want to model the particulate matter, in which case it is necessary to know the distribution by particle size classes (knowledge of the finest particles of particular interest) and the chemical composition.

During the development and analysis of the emission pre-processors, the definition of some strictly spatial and geographical parameters, such as the coordinate system, the dimensions and plans of the receptor grid, the orographic data and the any effects of the orography if considered complex.

2.5 METEOROLOGICAL PREPROCESSOR

The most frequently used models for the simulation of point and linear sources from extra-urban traffic (Gaussian or "puff" analytics) generally require primary meteorological data (wind speed and direction, temperature). Stability classes (eg Pasquill-Gilford) and mixing height, micrometeorological parameters derived from primary meteorological data, are generally used to characterize stability.

To derive these quantities, it is possible to use a one-dimensional meteorological preprocessor applied to the data collected as close as possible to the release point. It is very useful to have vertical wind and temperature profiles. Since there are no on-site stations, it is possible to use meteorological information suitably processed using a three-dimensional meteorological preprocessor applied using all the meteorological information available on a given area (ground stations and radio soundings).

EXAMPLE 1 - Point source simulation

In these cases the source term is generally known or easily estimated (from the fuel used or the number of vehicles present), as well as the characteristics of the emission (emitting surface, height of release, temperature of fumes, etc.); the size of the domain of interest for assessing the impact of these sources varies from a few hundred meters for releases of cold fumes near the ground or for the estimation of concentrations near road viaducts, to a few tens of kilometers for releases from chimneys high (> 200m) of hot fumes or for the emissions of a motorway section.

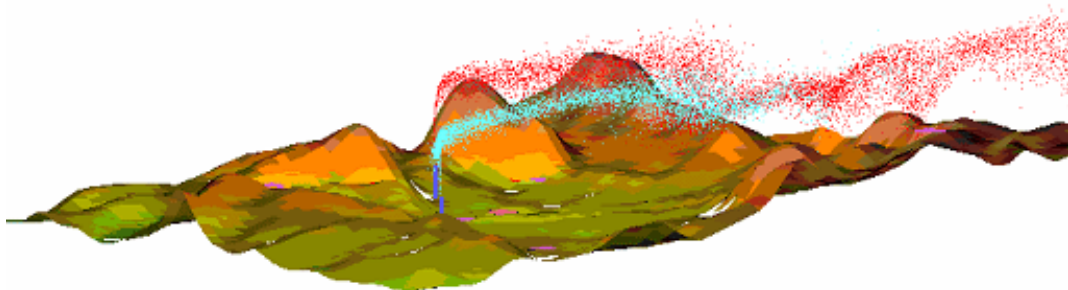


FIGURE 4: POINT SOURCE SIMULATION

The models historically developed and used for these cases are the "Gaussians"; however, it is necessary to take into account the limitations to their use: in fact the application of these models in incorrect conditions has often led to very disappointing results in the comparison between simulated and measured concentrations. Its use can be recommended for sites that are not orographically complex, with very low percentages of calm and weak winds and for emissions close to the ground; in these cases, even with few meteorological data (the historical series of the data of an anemometer placed at altitude release is sufficient) it is possible to obtain useful indications on the concentrations on the ground; it is necessary to pay attention to the choice of the dispersion parameters and to be guided in the choice between the different families of curves (Pasquill, Briggs, etc.) by comparing them with measured data.

To simulate emissions in all other conditions (releases above 100m of hot fumes, complex sites) it is necessary to collect an adequate data-set of meteorological measurements at ground level and at altitude which describe in detail the weather-diffusive phenomena acting on the site, so to be able to activate the simulation models for the dispersion of pollutants as closely as possible to the actual conditions of the atmosphere. In these cases, puff and particle models can be used, supported by appropriate meteorological models for the reconstruction of wind fields on sites with complex orography.

Depending on the resources available, two different simulation models can be used.

- Short Term Calculation (punctual)
- Long Term calculation (climatological)

In the first, a sort of snapshot of the diffusion of a certain pollutant is represented on the basis of precise data such as direction and wind speed, and this makes it possible to calculate and evaluate any legal limits on the pollutants emitted in each receptor of the grid.

The second, on the other hand, allows to simulate a significant number of days representative of the different types of weather and therefore, based on their frequency of occurrence, to reconstruct the climatological indicators. Generally, a temporally broad set of starting data is needed in order to characterize the "diffusion trends" in the area of pollutants according to the climatology typical of the study area.

Based on the scenario in question and the characteristics of the area, it may be necessary to calculate some downwash effects (deflection) of the flow, such as the wake effect of the chimney itself and / or the wake effect of the buildings when they are upwind at the point emission (building downwash). The effects of these phenomena therefore entail a lowering of the effective height of the plume and this can increase the spread of pollutants at lower altitudes. In defining the emissions dispersion model and in the study report, the geographical coordinates of each of the buildings and the height of the building relative to the ground must be reported for each of the buildings that generate wake effect.

2.6 WIND CALM TREATMENT

Often the more precise dispersion models have a special method for treating calm winds. Many of the available software have a significantly different algorithm from the regular one for calm winds for all those hours of the simulation time domain in which the wind speed is lower than a certain defined threshold value.

It is also necessary that the percentage of hours for which the model uses the special method is minimal, and possibly less than 2% since:

- a) the olfactory impact parameter to be expressed as the final result of the simulations is in the form of the 98th percentile;

- b) in calm wind conditions the maximum olfactory impact is often obtained, since the pollutants are less effectively mixed in the atmosphere.

Some dispersion models that operate with very rich or very poor weather data on rainy days often need to activate the calculation algorithms relating to the deposition processes that take place within the air mass. These processes are:

- a) Dry Deposition: Mechanism always present in the PBL (Planet boundary layer) which eliminates a part of the pollutant present in the plume and transfers it to the ground without intervention of the water present in the atmosphere.
- b) Wet deposition: Elimination mechanism caused by the action of rainwater on the plume.

In many cases studied however, these algorithms are not often necessary and are cautiously deactivated in the modeling phase.

2.7 DESCRIPTION OF THE SITE AND ITS SURROUNDINGS

The proposed site for the TTF forms part of the ECOHIVE complex, located in Maghtab, a village within the locality of Naxxar. This area forms part of the North-east coastal zone of Malta, as shown in Figure 5, and in greater detail in Figure 6. It is mainly characterised by rural and agricultural land. The satellite map of the scheme size and location, and its 100 m boundary are shown in Figure 7.



FIGURE 5: THE GEOGRAPHICAL LOCATION WITHIN THE MALTESE ISLANDS (SOURCE: GOOGLE EARTH)

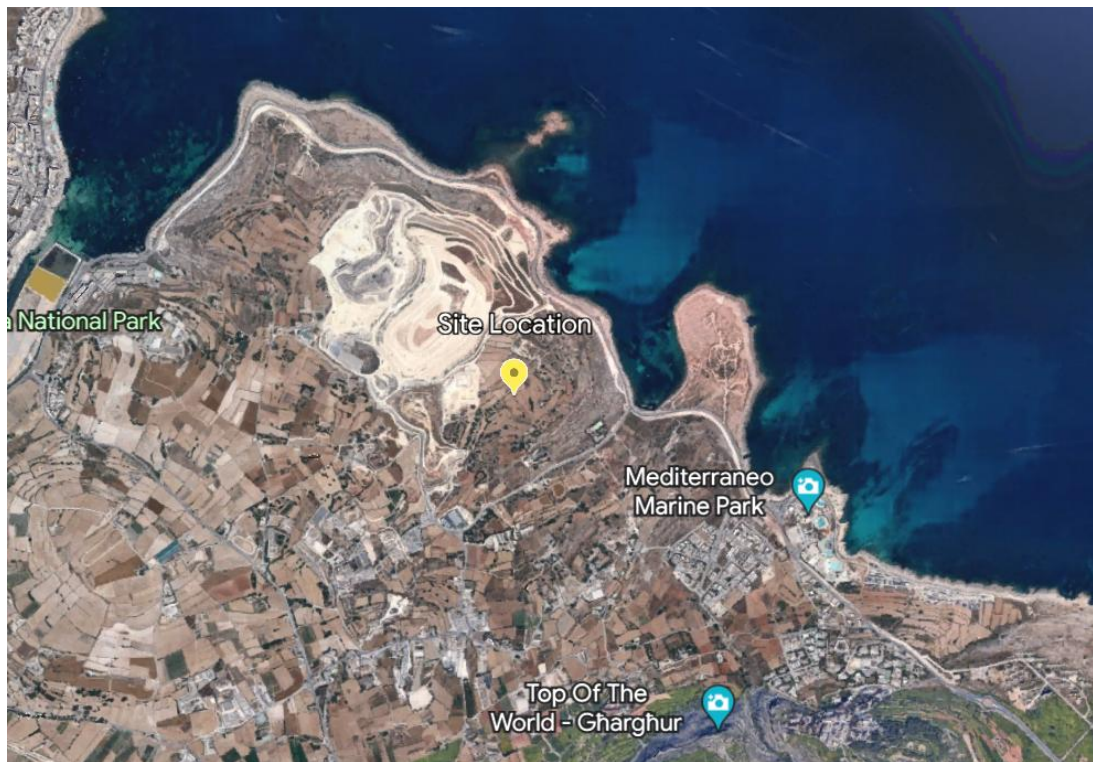


FIGURE 6: SCHEME LOCATION IN MALTA (Source: Google Earth)

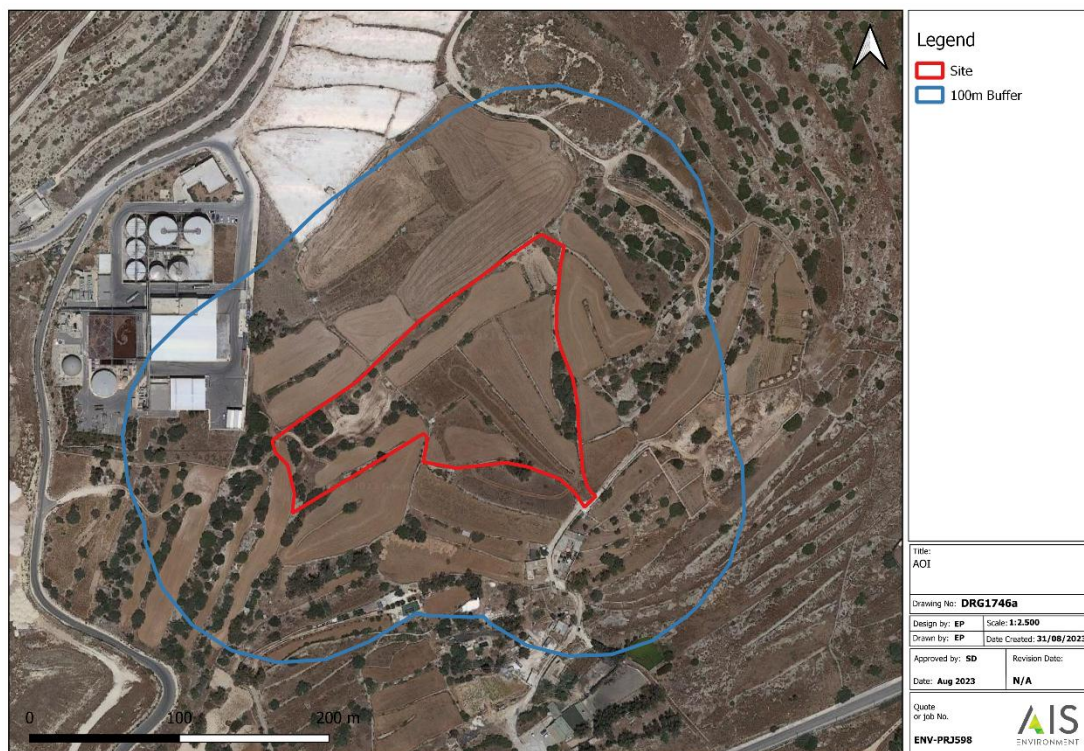


FIGURE 7: PROPOSED SCHEME SITE FOOTPRINT AND IMMEDIATE SURROUNDINGS

2.8 DESCRIPTION OF THE PRODUCTION PLANT (TTF)

The ECOHIVE complex in which the TTF is proposed consists of several other waste management facilities, which to date include the ground work for the Waste to Energy facility, a proposed Material Recovery Facility, an Organic Processing Plant, Biowaste Treatment Plant. The TTF site is an irregular shape, with the longest part measuring 220m. The total site footprint is 18,185m² of land which will undergo a change in use from non-intensive agriculture to accommodate the Thermal Treatment Facility as shown in Figure 8.

This scheme is being proposed to establish a new hazardous waste incineration plant and centralise all the major waste operations carried out by Wasteserv Malta. The project entails the preparation of a new hazardous waste incineration plant with two independent lines, and space for a potential third independent line in the future. The proposed development will form part of the ECOHIVE Complex and will operate in conjunction with the other waste management facilities at Magħtab.



FIGURE 8: RENDER OF THE PROPOSED THERMAL TREATMENT FACILITY

The plant shall comprise of two independent lines, with space for an additional third line. Each line will have an incineration/boiler and Flue Gas Treatment (FGT) that can operate independently of each other.

Each line consists of a rotary kiln, a waste heat boiler with combustion air fans, economiser, FGT reactor and bag house filter.

2.9 FALLOUT MODEL ELABORATION

2.9.1 Model - Windimula

WinDimula is a plume Gaussian model that allows performing diffusion calculations in the atmosphere of non-reactive pollutants emitted from multiple point and area sources, scattered over an area that represents the domain of calculation of the model, in the presence of complex orography. The model allows to perform both "Short Term" and "Climatological" simulations. WinDimula also allows to evaluate the effective heights of pollutants emitted by chimneys for each class of atmospheric stability. The model allows the calculation of the concentrations of pollutants in all the receptors defined within the calculation domain (both Cartesian and discrete) and of both dry and wet deposition.

A "Short Term" or punctual calculation represents a sort of "snapshot" of the diffusion of a certain pollutant based on "punctual" meteorological data (ex: hourly wind direction and speed).

The WD calculation code allows the user to perform multiple point simulations in sequence; in this way it is possible to evaluate any legal limits on the pollutants emitted. In particular, if an annual sequence of hourly meteorological data is available, it is possible to perform WD on the entire sequence of data, evaluating for example in each receptor of the calculation grid the maximum hourly concentration value detected during the whole considered sequence.

With the WDPRO postprocessor it is possible to evaluate other legal limits both in terms of values and percentiles for the pollutants considered. A climatological simulation, on the other hand, does not allow to make assessments on the limits of the law but allows to evaluate the "diffusion trends" in the area of interest (calculation domain), that is those areas of the calculation domain mainly affected by the atmospheric diffusion of pollutants.

A climatological calculation is basically a set of point calculations (by sectors) weighted however with respect to their statistical occurrence frequency. Having therefore available suitable series of meteorological data it is possible to climatologically characterize a certain area through the definition of a suitable JFF (Joint Frequency Function).

The calculation model also allows to evaluate the diffusion of the pollutant into the atmosphere even in situations of "calm wind". In these cases WD integrates a suitable model (Cirillo Poli model) for calm winds. The model has no limitations. The execution times of a simulation depend on the type of calculation required, the size of the grid (number of grid nodes), the number of sources considered, the type of meteorological data used. The presence of calm wind situations always leads to an increase in the temporal performance of the execution, as this is not a directional calculation but carried out on a 360 ° angle around each source.

APAT (Italian agency for environmental protection and technical services) has included WinDimula in the models to be applied for the evaluation of air quality.

2.9.2 Size and unit of measure

- Height (m)
- Internal diameter of the chimney (m)
- Flue gas temperature ($^{\circ}$ K)
- Total emission rates relating to the pollutants considered (m(mass)/s)
- Flow rate (m(mass)/s)
- Sedimentation speed (m/s)
- Wind direction (degrees) in the case of the short-term model
- Wind direction (degrees / sector) in the case of the climatological model
- Wind speed (m / s)
- Temperature ($^{\circ}$ K)
- Height of inversion (m)
- for all that information that needed georeferencing, the UTM Coordinates fused 33N Datum WGS 84 were used

For the mixing heights, rural Briggs, urban Briggs and possible roughness-dependent Briggs were taken into account.

2.9.3 Calculation domain

The calculation grid represents the geographical space within which the diffusion simulation is processed, has been defined geographically according to the following parameters:

- Abscissa and ordinate of the origin of the calculation grid: 446844 AND 3974993 N
- Number of links in x direction and y direction: 120 x, 120 y
- Reticle pitch right and right: 50 m x 50 m
- Height of ground receptors: 2 meters, indicative value obtained from the average height at which the concentration is perceived;
- Absence of discrete receptors;
- Standard control parameters, with the use of the non-conservative approach for the term of reflections in the presence of gravitational sedimentation;
- The resolution of the calculation of the concentrations/deposition is equal to 5x5m.

The figure below shows the extension of the calculation domain used for this study. The subsequent spatial elaborations were produced on a "mask" of territory adapted to the extension of the results obtained in order to emphasize the areas most affected.

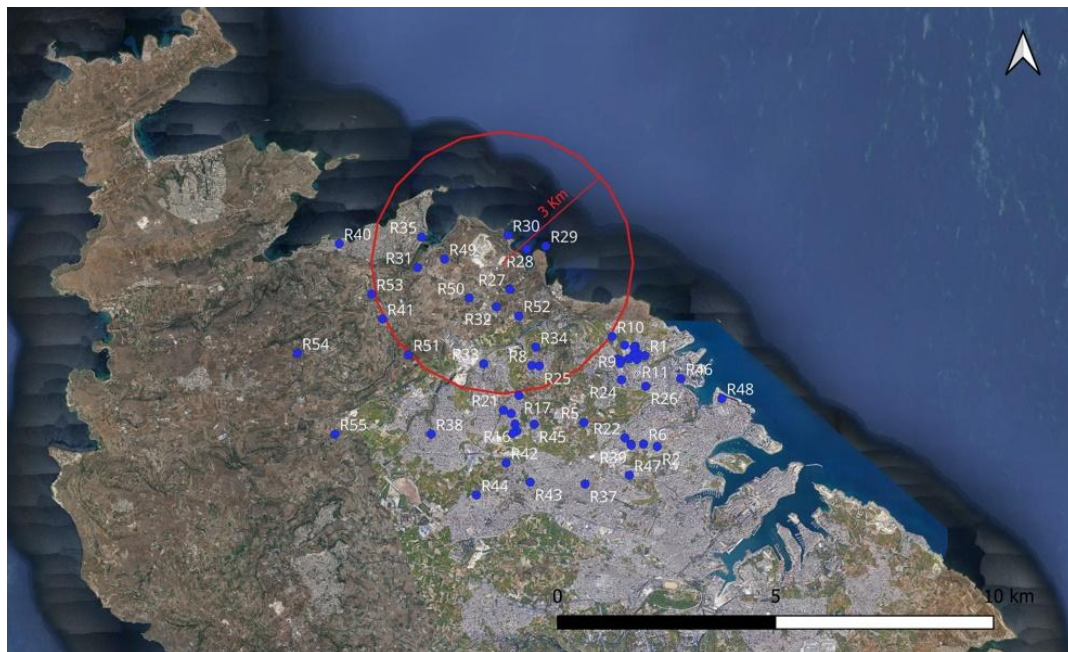


FIGURE 9: CALCULATION DOMAIN BASED ON 3 KM RADIUS

2.9.4 Meteorological Dataset

The meteorological dataset required for the development of the dispersion model have been collected from the weather station of Luqa Hourly-Malta Airport.

Initial modelling efforts were carried out in previous years to determine the optimal stack height for the Thermal Treatment Facility (TTF), using meteorological data from 2021. In the 2024 modelling exercise, the same 2021 dataset was employed. This decision was based on the continuity and integration with earlier modelling frameworks, as well as the fact that annual variations in local meteorological conditions are typically minimal. Consequently, the modelling team determined that the 2021 dataset remained representative and scientifically valid for the current analysis.

2.9.5 Pluvio-thermometric regime

The raw meteorological dataset acquired from weather station of Luqa Hourly, related to temperature and precipitation values for the entire year 2021, has been checked for excluding the presence of no-data values (errors and/or 0-data values), and the hourly values has been merged together using a spreadsheet management SW, to obtain the daily mean values for Temperature and Precipitation.

The time lapses taken into account are 24-hours intervals, (for example from 01/01-00:00 to 01/01-24:00), that were plotted on monthly graphs, shown below.

Final dataset was therefore plotted and represented on various histogram-type and rose diagram-type charts.

These histograms show the total annual precipitation and annual temperature, with daily frequency for both. Have been produced 13 final combined graphs (Histogram + Lines) which shows the trend monthly, as well a final summary all year long.

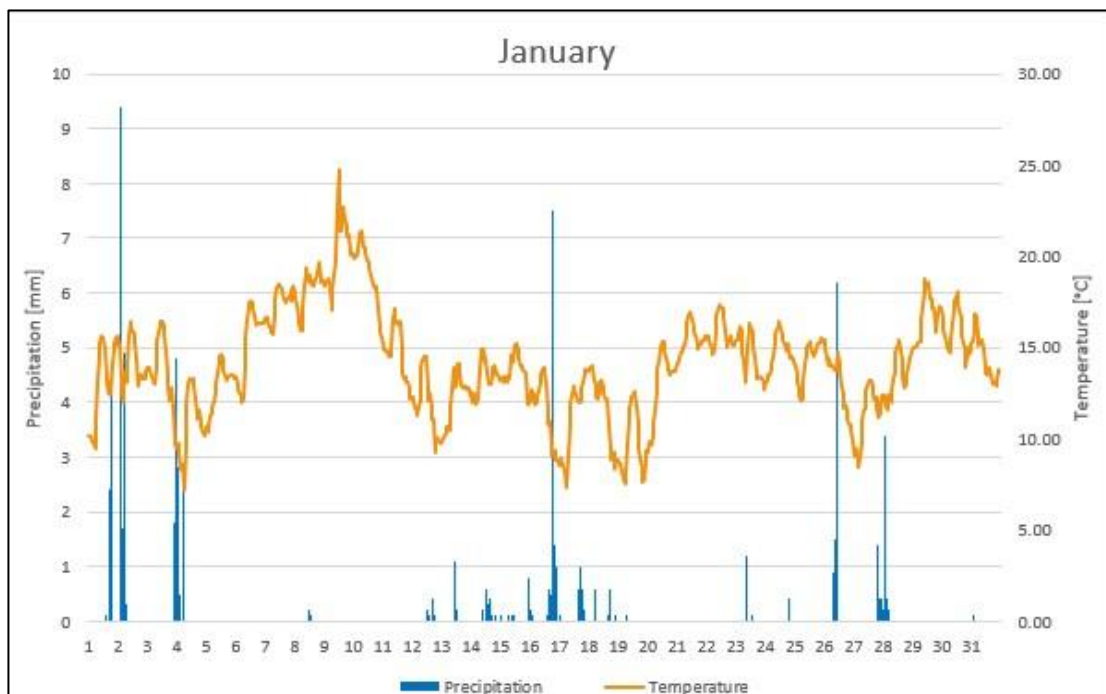
In these graphs, the two vertical axis allows to read at the same time the daily precipitation values expressed in millimeters (left axis) and the mean daily temperature expressed in Celsius degrees (right axis). The horizontal axis on the bottom shows instead the days of the corresponding month.

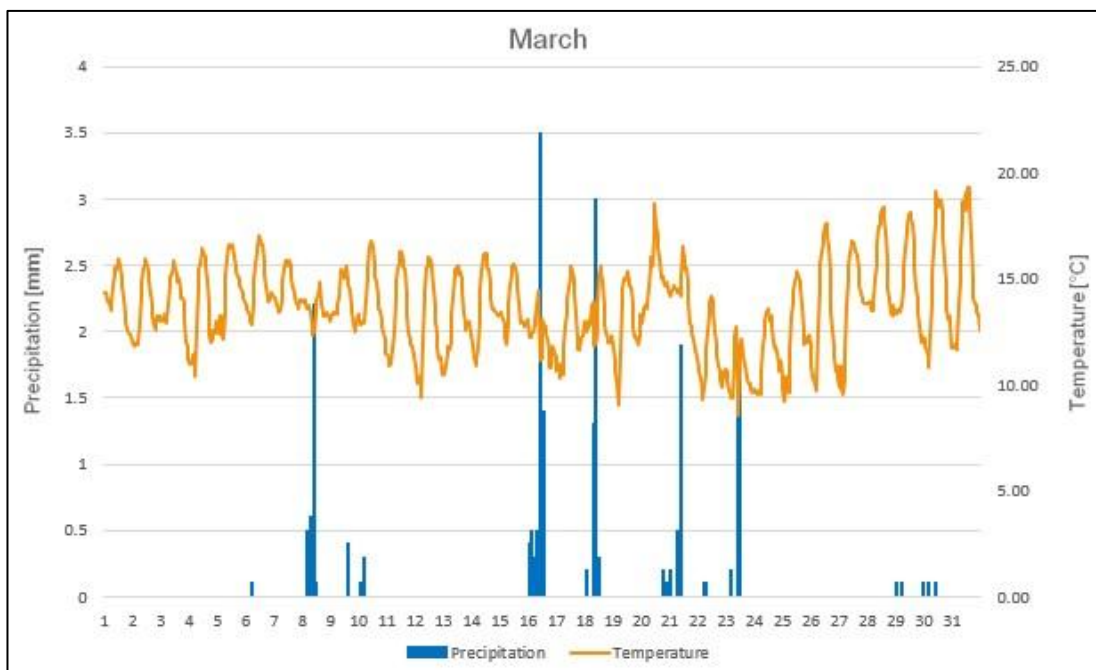
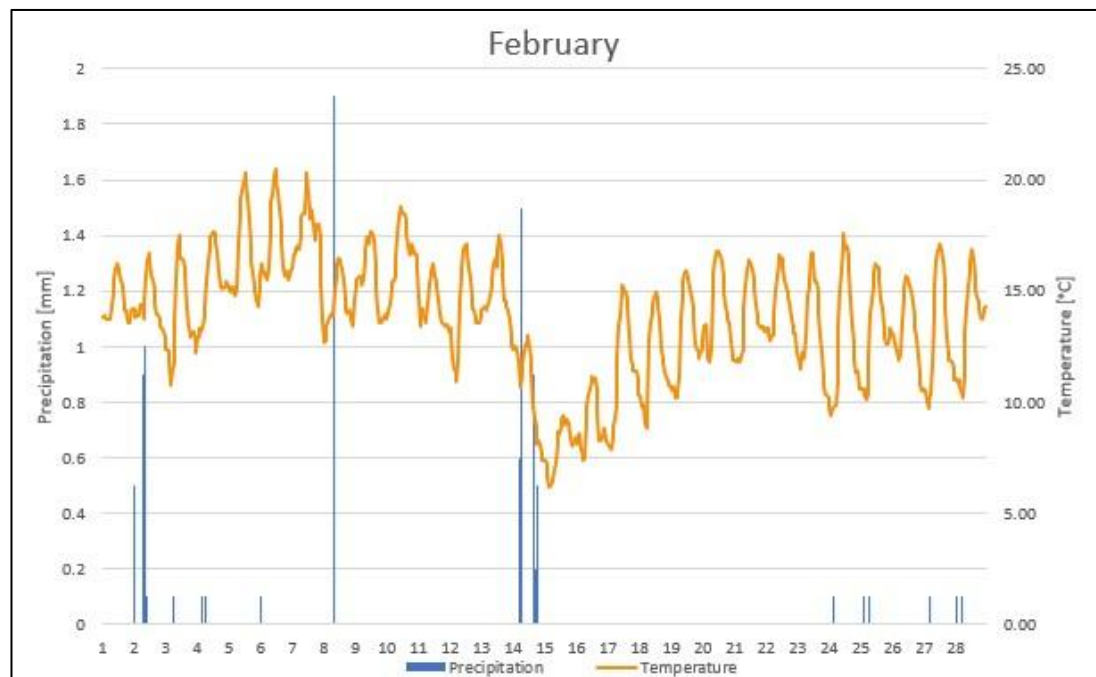
Analysis of temperature trends for example shows:

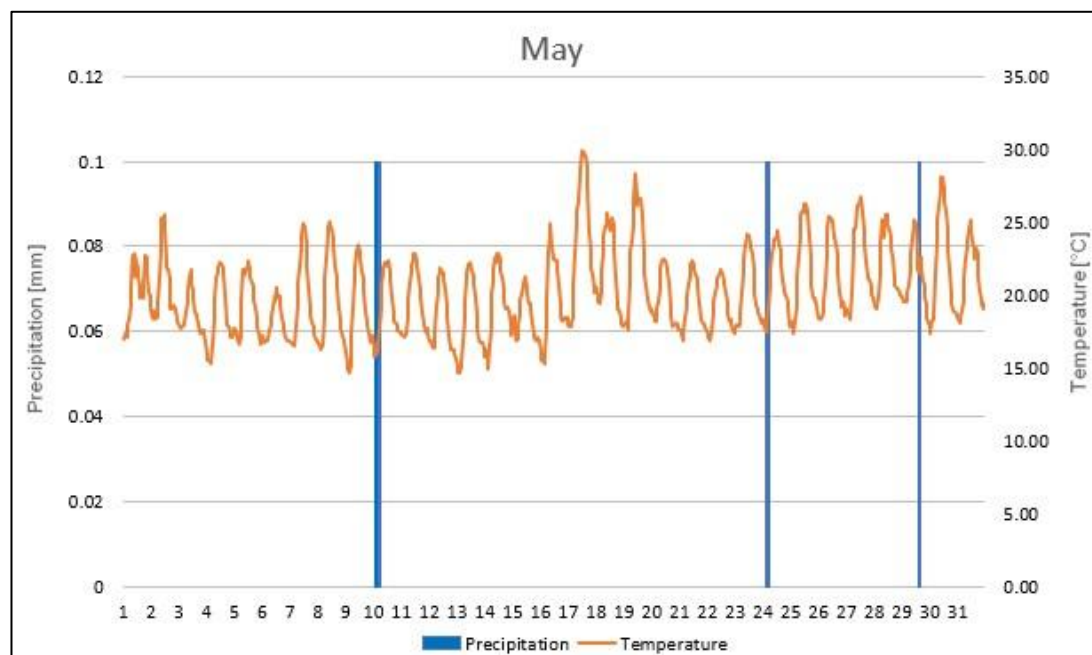
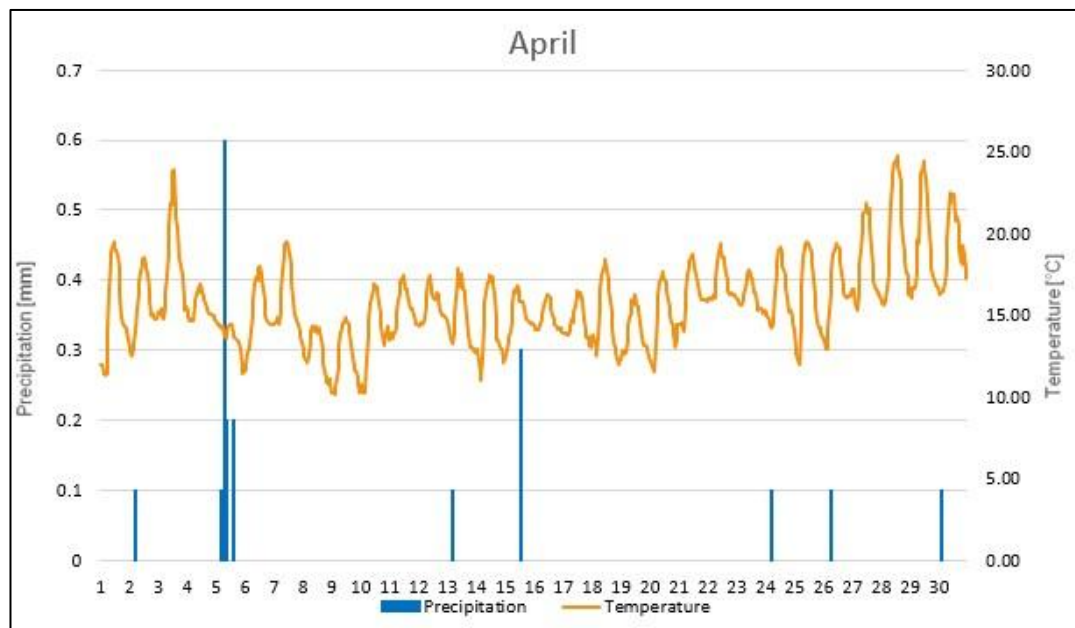
- A very regular and typical trend of mean daily temperature, which during the year follows a normal or “Gaussian” distribution. The temperature range varies from 39.60C° to + 6.20C° and indicates a strong thermal mitigating effect due to the sea proximity.

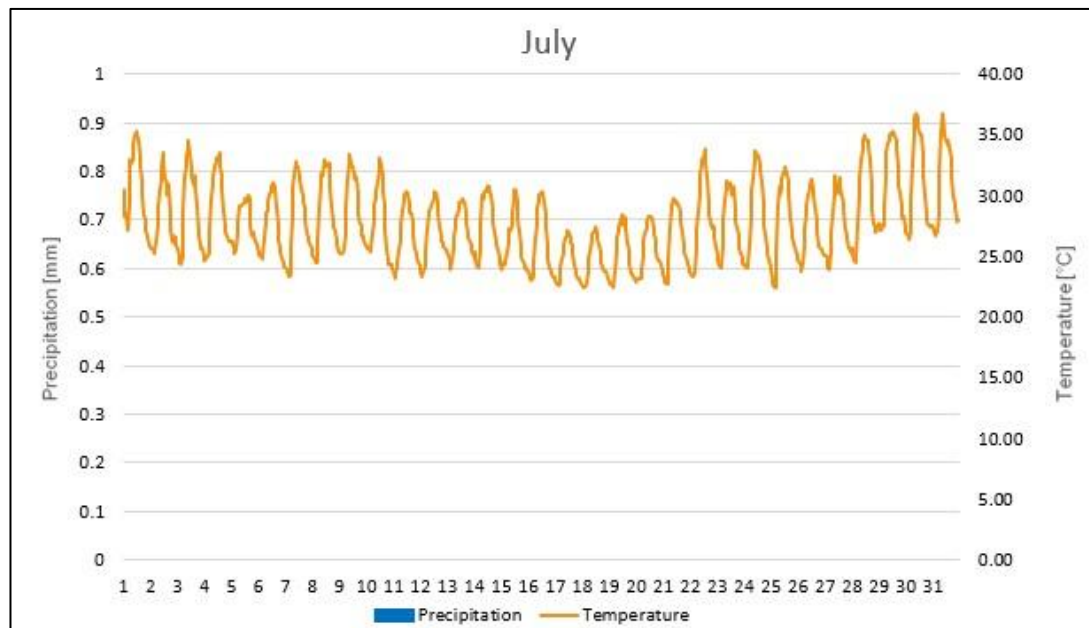
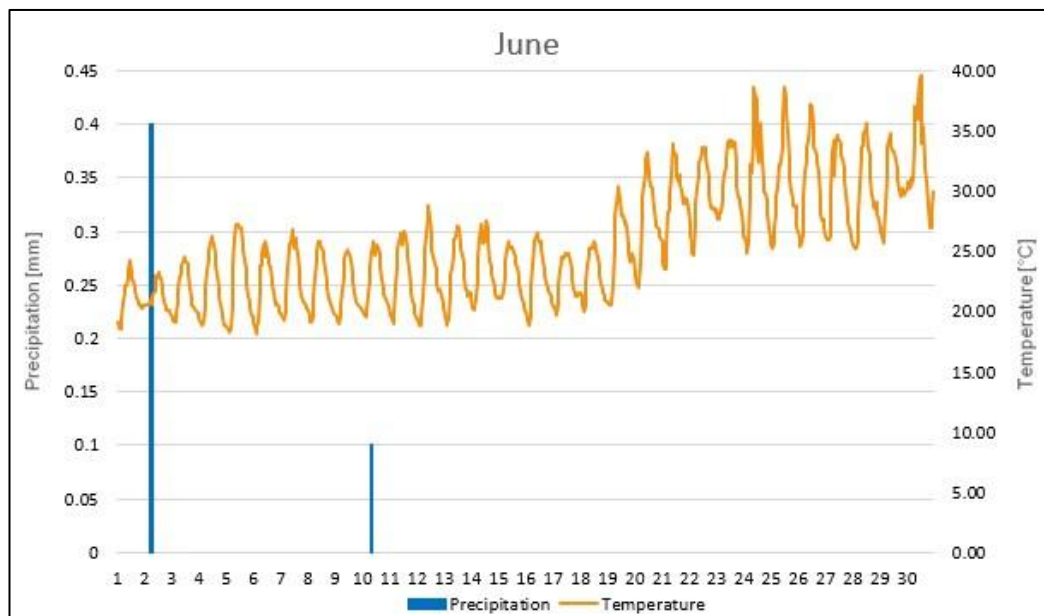
This underlined trend is typical of Mediterranean near-sea and insular areas, with poor rainfall in summer seasons and high peaks of precipitations in winter and spring seasons. The total annual rainfall in this type of climatic area are however low and above average.

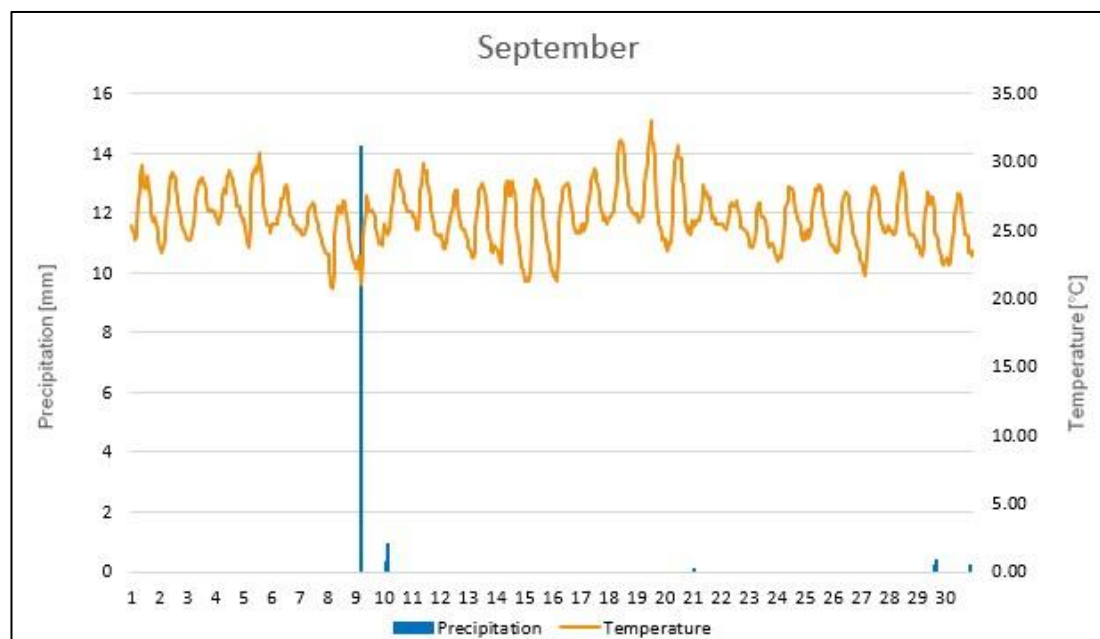
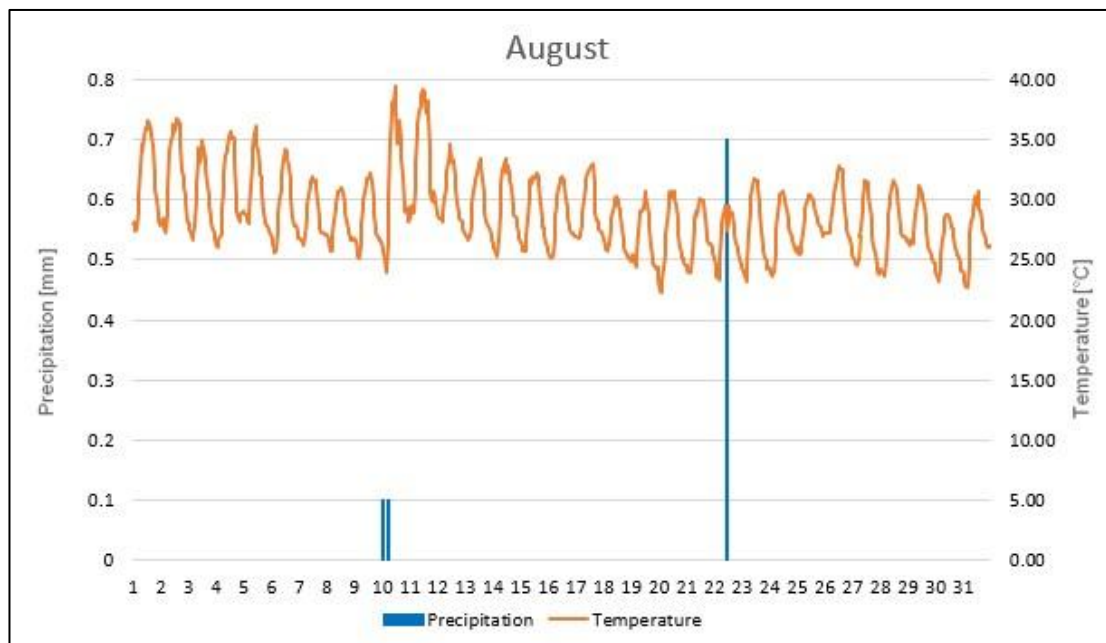
The analysis of annual precipitation or rainfall trend, shows instead the existence of one main peak of rainfall occurring in the October- November period (34-38 mm).

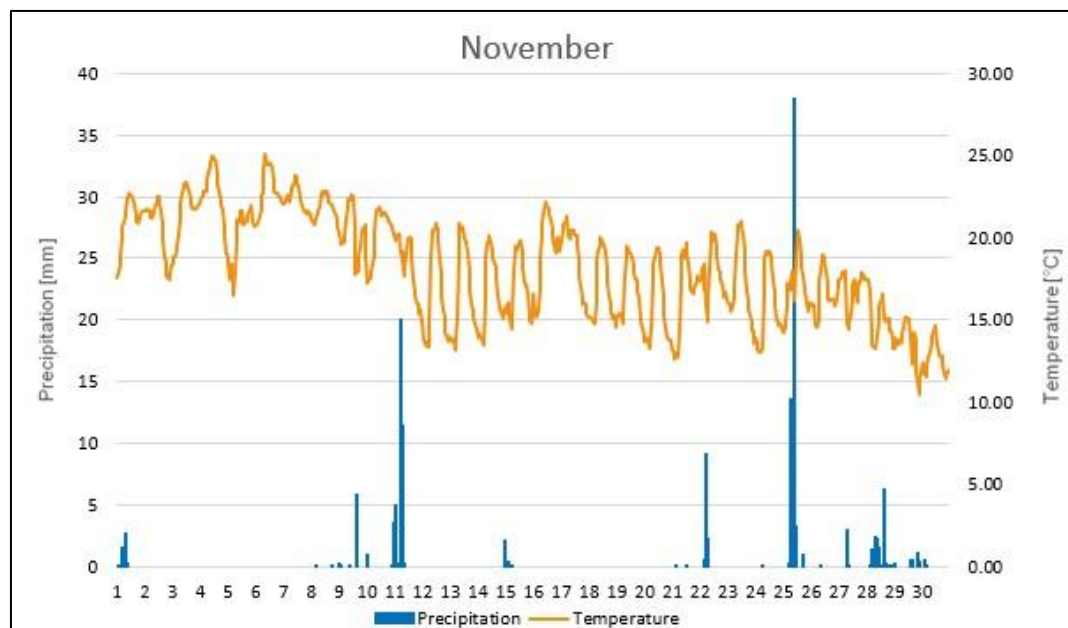
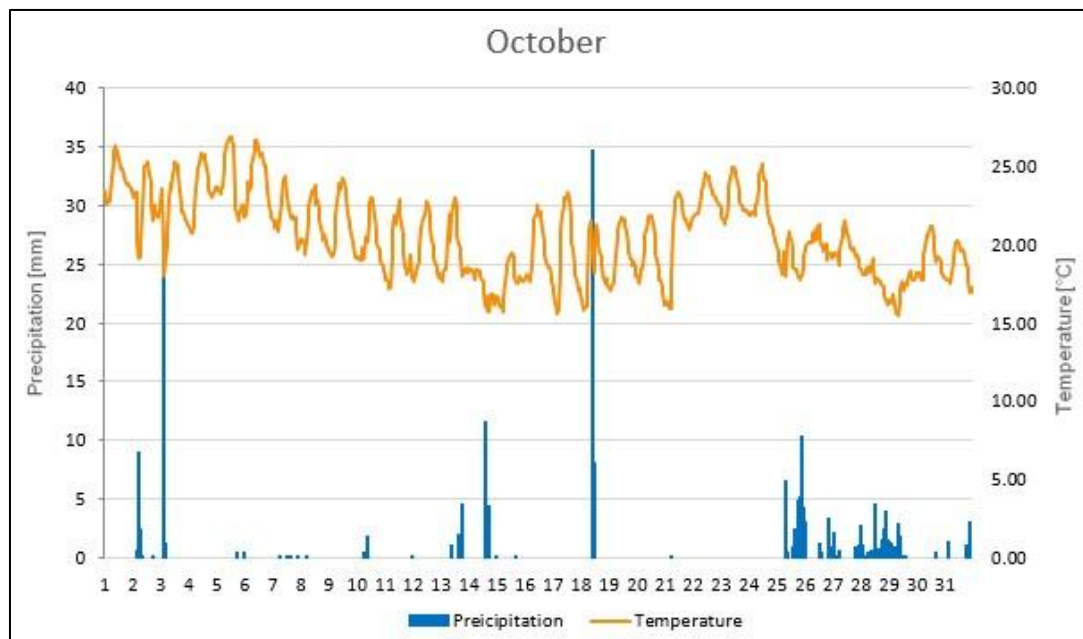


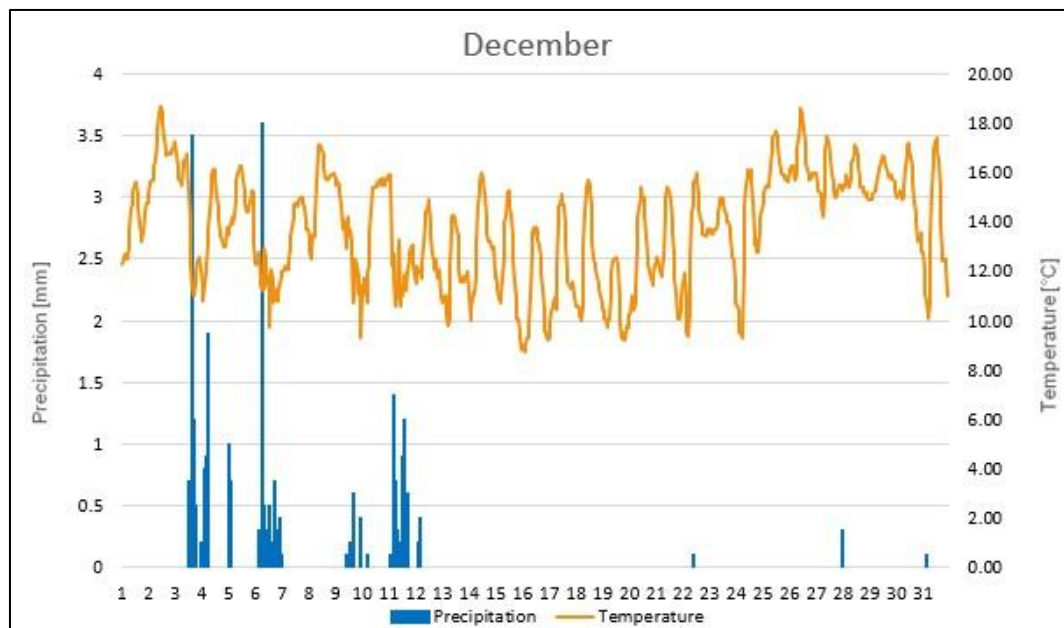












2.9.6 Anemometric regimes

As usual in meteorology studies, in the presented wind rose diagrams, has been indicated the angle or the direction of the wind (the direction in which the wind is coming), clockwise relative to the North.

For example, when indicated that the wind has angle of 90° (East), it is meant that it blows from East to West. Instead, into simulation scenarios and taking into account pollutant dispersion it's more effective to represent the wind vector (the direction in which the wind heads) rather than the direction of coming.

The general wind rose diagram, derived from the data of the whole year 2021, shows two predominant directions of the wind:

- The first, from Northwest to Southeast.
- The second one, almost in perpendicular direction than the first, from West-Southwest to East-Northeast.

The winds are oriented mainly into preferential directions that reflects the geographical and orographic settings of the area, as well the positioning of the major airport structures like the two main landing strips. The distance from the sea (6km in almost all directions) does not allow the development of any significant phenomena of sea breeze or land breeze.

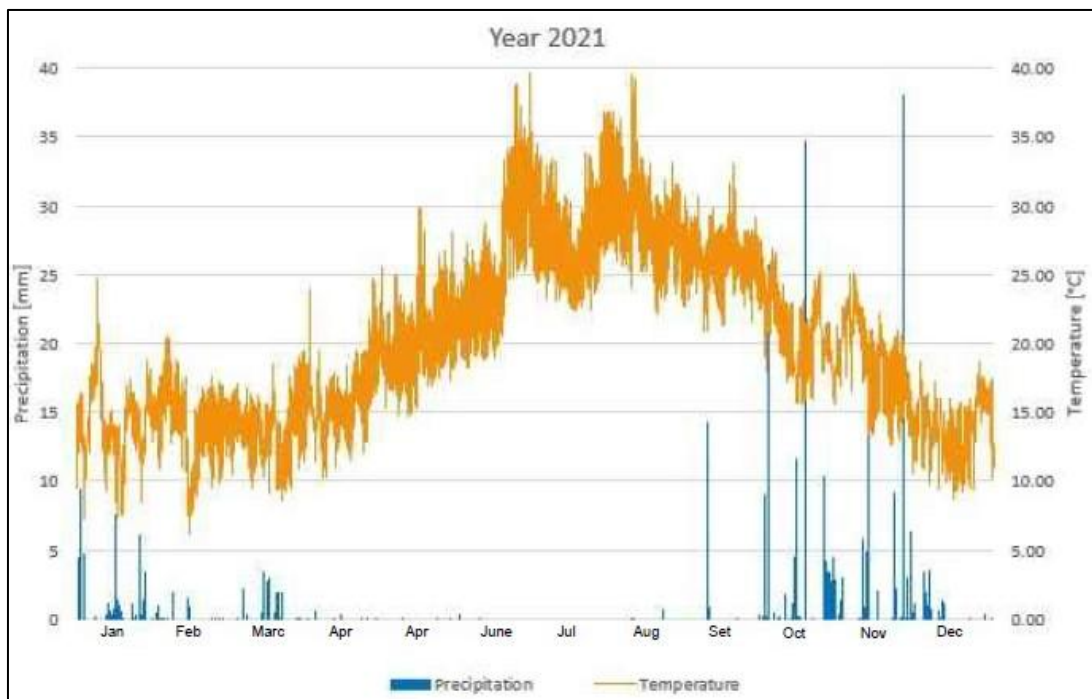


FIGURE 10: WIND YEAR 2021 (8760 OBSERVATIONS)

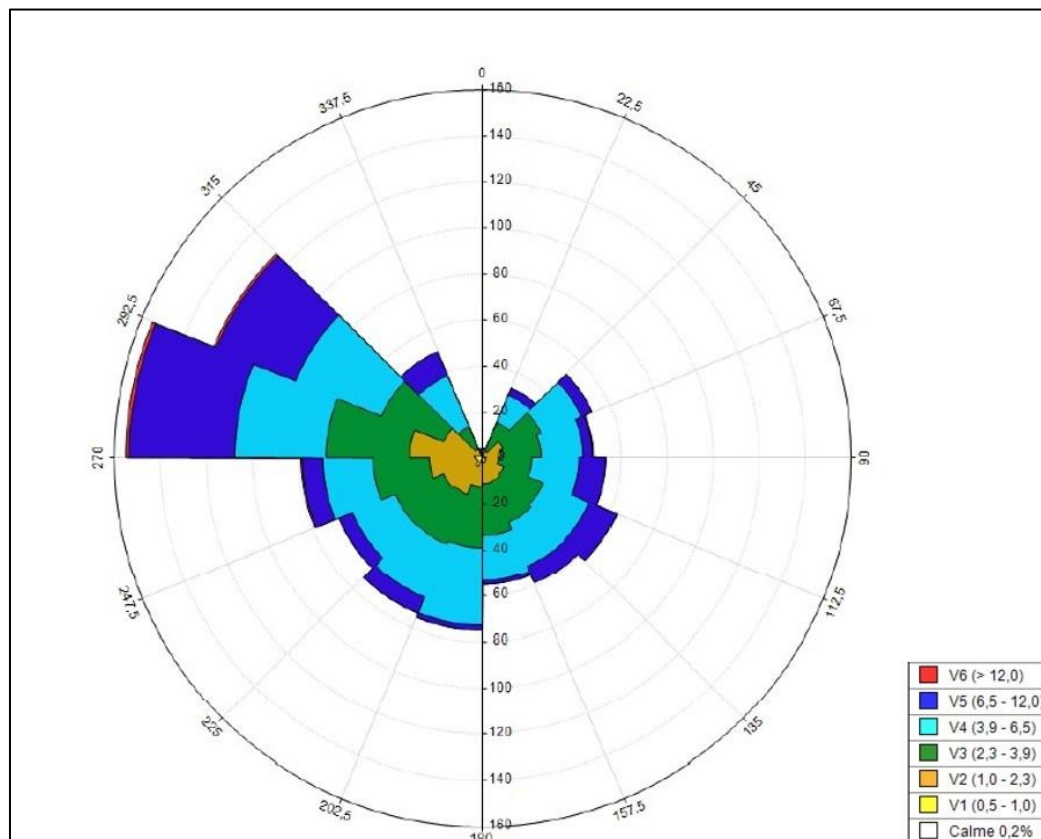


FIGURE 11: WIND-ROSE FOR YEAR 2021

- The almost total absence of winds blowing from Northwest to Southeast and from Southwest to Northeast, can be caused by the presence of low hills that

surround the west side of the area, leading to a poor air circulation in those directions.

The seasonal wind rose-diagrams instead, highlights the following:

- Autumn and Winter wind directions resemble each other and are similar to the main trend for the entire year. The predominant direction is from Northwest to Southeast.
- Spring and Summer wind directions resemble each other too but are more often contributing the winds blowing from the other main direction (West-Southwest to East-Northeast).

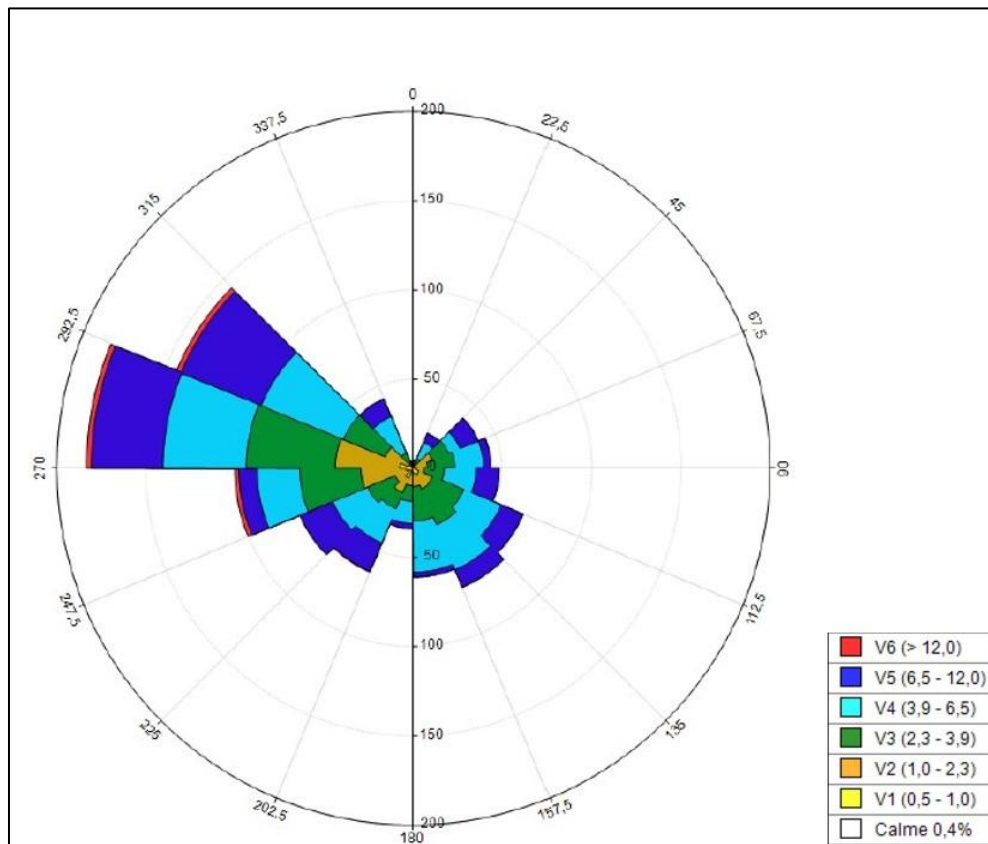


FIGURE 12: SEASONAL WIND ROSE-DIAGRAMS –AUTUMN

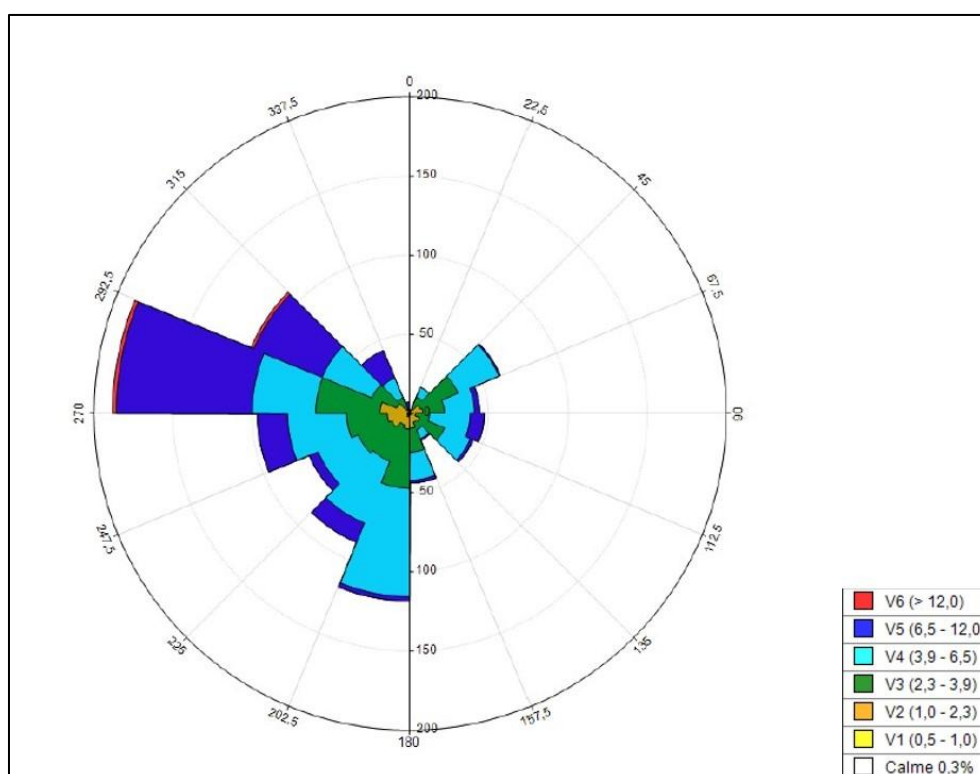


FIGURE 13: SEASONAL WIND ROSE-DIAGRAMS WINTER

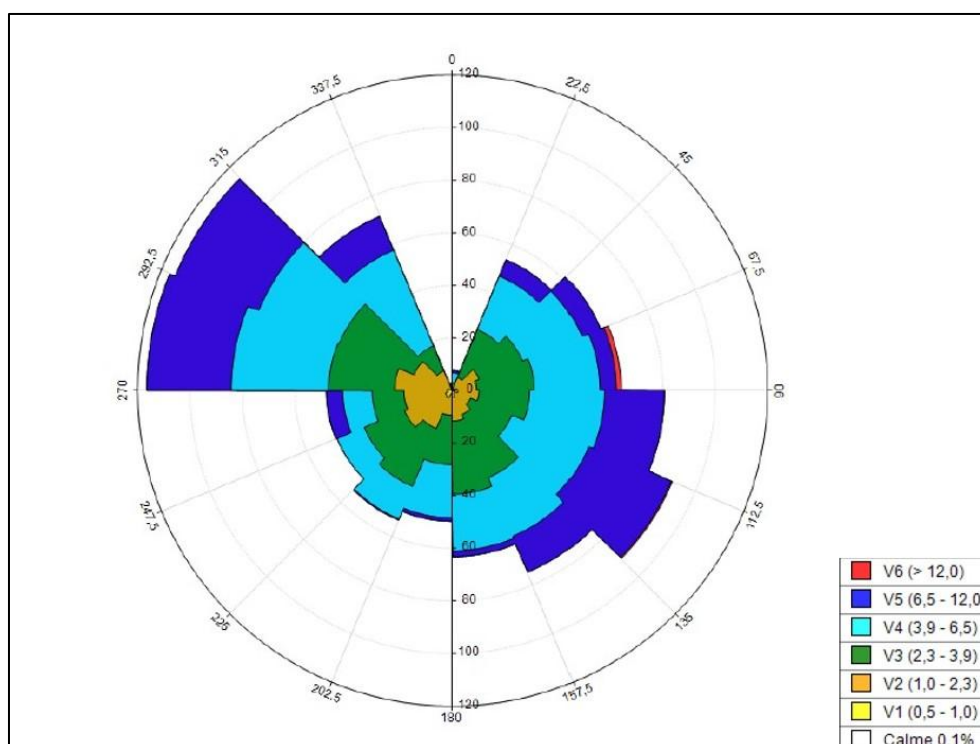


FIGURE 14: SEASONAL WIND ROSE-DIAGRAMS SPRING

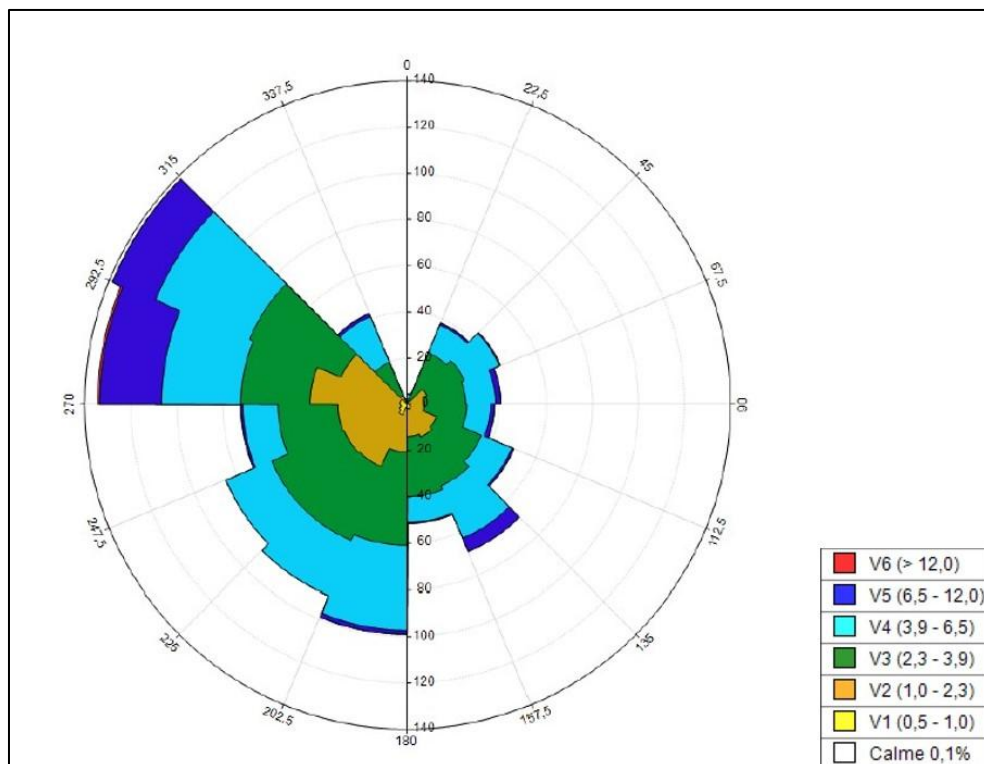


FIGURE 15: SEASONAL WIND ROSE-DIAGRAMS SUMMER

The anemometric data files were created according to the format used by Aeronautica Militare (Joint Frequency Function) and compatible with the calculus module DIMULA.

The climatological model use as raw data the so-called *Joint Frequency Function*. These “functions” are statistical aggregation of meteorological observation derived from historical data series.

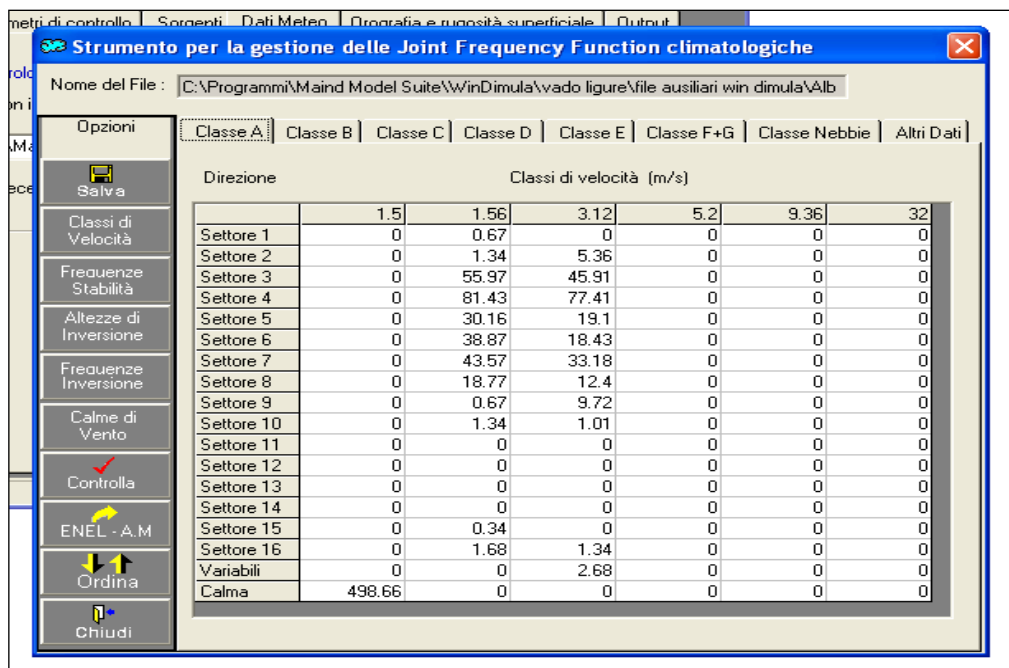
Data are aggregated into seven tables that represents six classes of atmospheric stability A, B, C, D, E, F + G (Fog Class). Each table contain 18 rows and 6 columns of 1000-normalized data.

Columns represent the aggregation based on the wind intensity and velocity; rows represent the aggregation based on the direction in which the wind is coming.

Especially:

- the first 16 rows represent the 16 sectors of direction of the wind, starting from North and going clockwise (each sector has width of 22,5°);
- row 17 contains variable data, for which was possible to establish the intensity but not the direction of the wind;
- row 18 contains wind calm data, not measurable from the instruments.
- the first column contains just data from wind calm, every other wind episode has value set to 0.
- the velocity value written on every column represent the reference value of the velocity class used for the aggregation.

- In addition to the data on the wind condition, the “Joint Frequency Function” contains the following data too:
- A table of occurrence frequencies of single classes normalized to 1000
- Mean temperature of air and altitude of the meteorological station above the ground
- The altitudes of thermal inversion typical for each stability class
- A table normalized to 1000 with the occurrence frequency of the 14 classes of thermal inversion utilized only for Fog Class.
- The wind velocity and the standard deviation, for use in calculations within the wind model.



Nome del File : C:\Programmi\Maind Model Suite\WinDimula\vado figure\file ausiliari win dimula\Alb

Opzioni: ☒ Classe A ☐ Classe B ☐ Classe C ☐ Classe D ☐ Classe E ☐ Classe F+G ☐ Classe Nebbie ☐ Altri Dati

Direzione	Classi di velocità (m/s)					
	1.5	1.56	3.12	5.2	9.36	32
Settore 1	0	0.67	0	0	0	0
Settore 2	0	1.34	5.36	0	0	0
Settore 3	0	55.97	45.91	0	0	0
Settore 4	0	81.43	77.41	0	0	0
Settore 5	0	30.16	19.1	0	0	0
Settore 6	0	38.87	18.43	0	0	0
Settore 7	0	43.57	33.18	0	0	0
Settore 8	0	18.77	12.4	0	0	0
Settore 9	0	0.67	9.72	0	0	0
Settore 10	0	1.34	1.01	0	0	0
Settore 11	0	0	0	0	0	0
Settore 12	0	0	0	0	0	0
Settore 13	0	0	0	0	0	0
Settore 14	0	0	0	0	0	0
Settore 15	0	0.34	0	0	0	0
Settore 16	0	1.68	1.34	0	0	0
Variabili	0	0	2.68	0	0	0
Calma	498.66	0	0	0	0	0

FIGURE 16: EXAMPLE OF A JFF FILE TABLE

2.9.7 Definition of the emission sources

The main problem to estimate the emissions into the atmosphere is linked to the definition of emission source and to the chemical-physical characterization of the fumes. In the following, both geometrical characteristics of the chimney and chemical-physical characteristics of the fumes for the new Thermal Treatment Facility (TTF) for the three scenarios have been defined.

2.9.8 Geometric characteristics of the emission chimney

- Geographical coordinates of the chimney: 449834 mE; 3977782 mN
- Altitude of the base: 33.20m from MSL
- Diameter: 2.50 m
- Height: 25m (58.20m from MSL)

The emission factors used are the provisional limit values in normal operating conditions are based on “Tentative limit values under normal operating conditions based on BAT and IED” as shown in Table 3 of the EIA TORs dated 05/08/2024.

For the following parameters:

- Total dust, total volatile organic carbon (TVOC), hydrochloric acid, hydrofluoric acid, sulfur dioxide, carbon monoxide, nitrogen oxide and ammonia, the Daily Average Value was used;
- Cadmium and Thallium and Total Metals and their compounds (As, Cr, Co, Cu, Mn, Pb, Sb, V and Ni) and Mercury, the Average value over 30 min to 8 hours was used;
- Polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDD/F) + dioxin-like polychlorinated biphenyls (PCBs), the Average value over 6 to 8 hours was adopted.

TABLE 1: CHARACTERISTICS OF THE EMISSIONS FOR EACH POLLUTANT EXPRESSED AS DAILY AVERAGES (TTF)

POLLUTANT	EMISSION LEVEL ASSOCIATED BAT-AEL (NEW PLANT)	UNIT
Dust	5	mg/Nm ³
NO _x	120	mg/Nm ³
NH ₃	10	mg/Nm ³
CO	50	mg/Nm ³
SO ₂	30	mg/Nm ³
HCl	6	mg/Nm ³
HF	1	mg/Nm ³
TVOC	10	mg/Nm ³
Hg	0.02	mg/Nm ³
PCDD/F+PCB dioxine	0.08	ng WHO-TEQ/Nm ³
Cd+Tl	0.02	mg/Nm ³

Group III Sb+As+Pb+Cr+Co+Cu+Mn+Ni+V	0.03	mg/Nm ³

Table Notes:

- a) Concentrations referenced to temperature 273 K, pressure 101.3 kPa, 11% oxygen, dry gas.
- b) Metal groups are as follows:
 Group 1: Cadmium (Cd) and thallium (Tl)
 Group 2: Mercury (Hg)
 Group 3: Antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and vanadium (V).
- c) The emission limit value refers to the total concentration of dioxins and furans calculated using the concept of toxic equivalence (TEQ).

The gas conditions at the chimney top are estimated at:

	Unit	Line 1	Line 2
Normalised flue gas flow, wet at full load	Nm ³ /h @ 11%O ₂ dry gas	6860	6860
Anticipated temperature	°C	120-180	120-180
Anticipated O ₂ content	% dry gas	5 - 9	5-9
Actual flue gas flow, wet (@ 7% O ₂ dg and 150°C). Note 1	m ³ /h	7594	7594
Velocity at stack top, full load. Note 2	m/s	20	20
Velocity at stack top, minimum load (60%) Note 2	m/s	12	12

Notes:

1. The actual flue gas is re-calculated from the normalised using the actual temperature and oxygen content. Accordingly, the actual flue gas will vary depending on the actual data of the gasses. Note that on overload the flue gas flow will be 7,814Nm³/h.
2. The full load velocity at stack top is set in order to avoid stack noise. The EPC will adjust the flue dimensions to achieve correct velocity at the actual gas data of their specific design during the engineering phase. The full load velocity may be increased up to approximately 23 m/s if the part load velocity is too low to achieve sufficient dispersion.

Below are the model simulation scenarios:

- Typical operations (Scenario A): 60% thermal load for 24 hours, also meaning a flue gas flow per line of 4116 Nm³/h for 24 hours;
- Maximum operating conditions (Scenario B): 100% thermal load for 23 hours (flue gas flow per line of 6860 Nm³/h) and 110% load for 1 hour (a flue gas flow per line of 7814 Nm³/h);

- Abnormal operating conditions (Scenario C): based on the limits defined in Schedule 2 of S.L.549.81, a dust concentration of 150 mg/Nm³ shall be set at the stack at maximum operating conditions.

The following abatement technologies were also considered:

POLLUTANT	ABATEMENT TECHNOLOGIES
Particulate matter (dust)	Bag house filters
Oxides of nitrogen (NO _x)	Injection of NH ₃ or Urea in the flue gas at the right temperature
Acid Gases (Sulphur dioxide & Halides (HCl & HF)	Dry sorbents (hydrated lime or possibly sodium bicarbonate) + Bag filter + Wet scrubber (quench & acid scrubber, alkaline scrubber, neutralising). The wastewater from the wet scrubber is expected to be neutralized by the acidic water from the quench and when the salt content is high (measured by the conductivity of the water) the wastewater is discharged into a holding tank and then injected into the incinerator line or reactor for disposal.
Heavy Metals	Activated Carbon Injection & Bag filters
Dioxins & furans	Activated Carbon Injection & Bag filters + Combustion control

2.9.9 Orographic data and surface roughness

The WinDimula calculation module provides for the insertion of the orographic data within the model for the study of the interference of the conformation of the territory with atmospheric diffusion.

The implementation of the orographic data in the model was made by producing an auxiliary calculation file (*.oro) which was produced on a rectangular mesh of the 50 * 50m pitch for a number of points equal to 36,000,000.

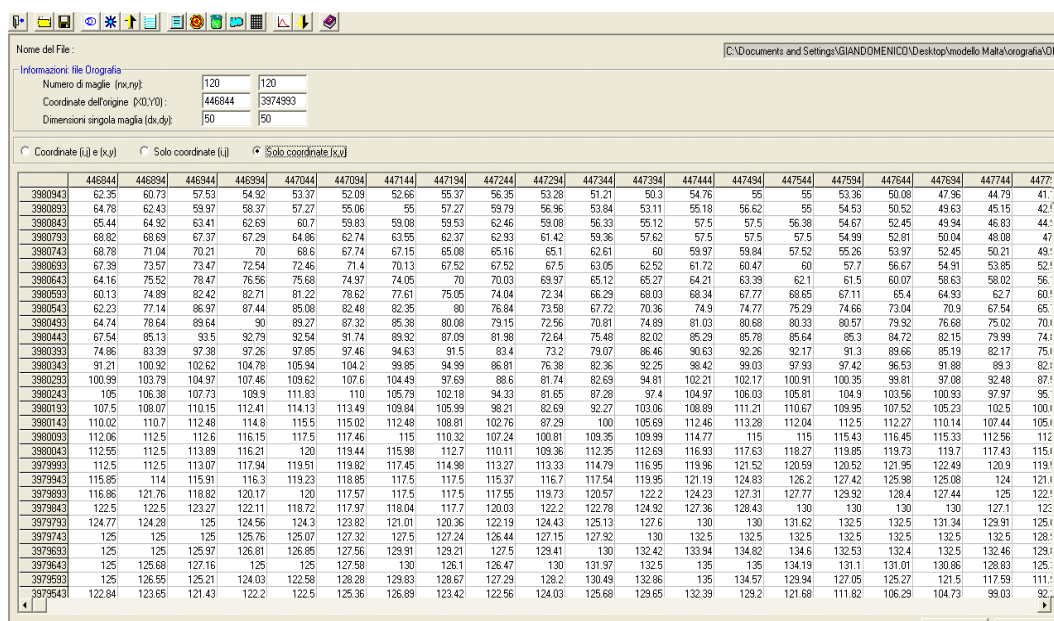
The file with the orographic data is a square matrix that contains the extrapolated altitude value on the intersection of all coordinates. To know the altitude values to be included in the file, a DTM (Digital Terrain Model) was produced starting from georeferenced topographic cartography.

The digital terrain model was produced by triangulating the inserted points, it is based on square areas with regular mesh integrated with a series of points quoted for the areas with more complex orography.

The DTM has the important characteristic of describing an irregular surface by means of a finite set of points with coordinates (X, Y, Z) in space. The original dimensioned points are generally spaced irregularly and according to the technique used for the measurements.

To obtain the model of soil for the present study, an exact interpolator IDW (Inverse Distance Weighting) was used as an interpolation algorithm, i.e. an interpolator capable of returning the exact value at each measuring instrumental point.

The three-dimensional model was developed not only for a useful representation of the territory but also for all derivation and analysis operations that can be carried out with it.



	446944	446994	447044	447094	447144	447194	447244	447294	447344	447394	447444	447494	447544	447594	447644	447694	447744	447794
3980943	62.35	60.73	57.53	54.92	53.37	52.09	52.66	55.37	56.35	53.28	51.21	50.3	54.76	55	53.36	50.08	47.96	44.79
3980993	64.78	62.43	59.97	58.37	57.27	56.06	55	57.27	59.79	56.96	53.84	53.11	56.18	56.62	55	54.53	50.52	49.63
3980043	65.44	64.32	63.41	62.69	60.7	59.83	59.08	59.53	62.46	59.08	56.33	55.12	57.5	57.5	56.38	54.67	52.45	49.94
3980793	68.82	68.69	67.37	67.29	64.86	62.74	63.55	62.37	62.93	61.42	59.36	57.62	57.5	57.5	54.99	52.81	50.04	48.08
3980743	68.78	71.04	70.21	70	68.6	67.74	67.15	65.08	65.16	65.1	62.61	60	59.97	59.84	57.52	55.26	53.97	52.45
3980693	67.39	73.57	73.47	72.54	72.46	71.4	70.13	67.52	67.52	67.5	63.05	62.52	61.72	60.47	60	57.7	56.67	54.91
3980643	64.16	75.52	78.47	76.56	75.68	74.97	74.05	70	70.03	69.97	65.12	65.27	64.21	63.39	62.1	61.5	60.07	58.63
3980593	60.13	74.89	82.42	82.71	81.22	78.62	77.61	75.05	74.04	72.34	68.29	68.03	68.34	67.77	68.65	67.11	65.4	64.93
3980543	62.23	77.14	86.97	87.44	85.08	82.48	82.35	80	76.84	73.58	67.72	70.36	74.9	74.77	75.29	74.66	73.04	70.9
3980493	64.74	78.64	89.64	90	89.27	87.32	85.38	80.08	79.15	72.56	70.81	74.89	81.03	80.68	80.33	80.57	79.92	76.68
3980443	67.54	85.13	93.5	92.79	92.54	91.74	89.92	87.09	81.98	72.64	75.48	82.02	85.29	85.78	85.64	85.3	84.72	82.15
3980393	74.86	83.39	97.38	97.26	97.85	97.46	94.63	91.5	83.4	73.2	79.07	86.46	90.63	92.26	92.17	91.3	89.66	85.19
3980343	91.21	100.92	102.62	104.78	105.94	104.2	99.85	94.99	86.81	76.38	82.36	92.25	98.42	99.03	97.93	97.42	96.53	91.88
3980293	100.99	103.79	104.97	107.46	109.62	107.6	104.49	97.69	88.6	81.74	82.69	94.81	102.21	102.17	100.91	100.35	99.81	97.08
3980243	105	106.38	107.73	109.3	111.83	110	105.79	102.18	94.33	81.65	87.28	97.4	104.97	106.03	105.81	104.9	103.96	100.93
3980193	107.5	108.07	110.15	112.41	114.13	113.49	109.84	105.99	98.21	82.69	82.27	103.06	108.89	111.21	110.67	109.95	107.52	105.23
3980143	110.02	110.7	112.48	114.8	115.5	115.02	112.48	108.91	102.76	87.29	100	105.69	112.46	113.28	112.04	112.5	112.27	110.14
3980093	112.06	112.5	112.6	116.15	117.5	117.46	115	110.32	107.24	100.81	109.35	109.99	114.77	115	115	115.43	116.45	115.33
3980043	112.55	112.5	113.89	116.21	120	119.44	115.98	112.7	110.11	109.36	112.35	112.69	116.93	117.63	118.27	119.85	119.73	119.7
3979993	112.5	112.5	113.07	117.94	119.51	119.82	117.45	114.98	113.27	113.33	114.79	116.95	119.96	121.52	120.59	120.52	121.95	122.49
3979943	115.85	114	115.91	116.3	119.23	118.85	117.5	117.5	115.37	116.7	117.54	119.95	121.19	124.83	126.2	127.42	125.98	124
3979893	116.86	121.76	118.82	120.17	120	117.57	117.5	117.5	117.55	119.73	120.57	122.2	124.23	127.31	127.77	129.92	128.4	127.44
3979843	122.5	122.5	123.27	122.11	118.72	117.97	118.04	117.7	120.03	122.2	122.78	124.92	127.36	128.43	130	130	130	127.1
3979793	124.77	124.28	125	124.56	124.3	123.82	121.01	120.36	122.19	124.43	125.13	127.6	130	130	131.62	132.5	132.5	131.34
3979743	125	125	125	125.76	125.07	127.32	127.5	127.24	126.44	127.15	127.92	130	132.5	132.5	132.5	132.5	132.5	132.5
3979693	125	125	125.97	126.81	126.85	127.56	128.91	129.21	127.5	129.41	130	132.42	133.94	134.62	134.6	132.53	132.4	132.5
3979643	125	125.68	127.16	125	125	127.59	130	126.1	126.47	130	131.97	132.5	135	135	134.19	131.1	131.01	130.86
3979593	125	126.55	125.21	124.03	122.58	128.28	129.83	128.67	127.29	128.2	130.49	132.86	135	134.57	129.94	127.05	125.27	121.5
3979543	122.84	123.65	121.43	122.2	122.5	125.36	126.89	123.42	122.56	124.03	125.68	129.85	132.39	129.2	121.68	111.82	106.29	104.73

FIGURE 17: EXAMPLES OF AN OROGRAPHIC MATRIX USED BY THE SOFTWARE

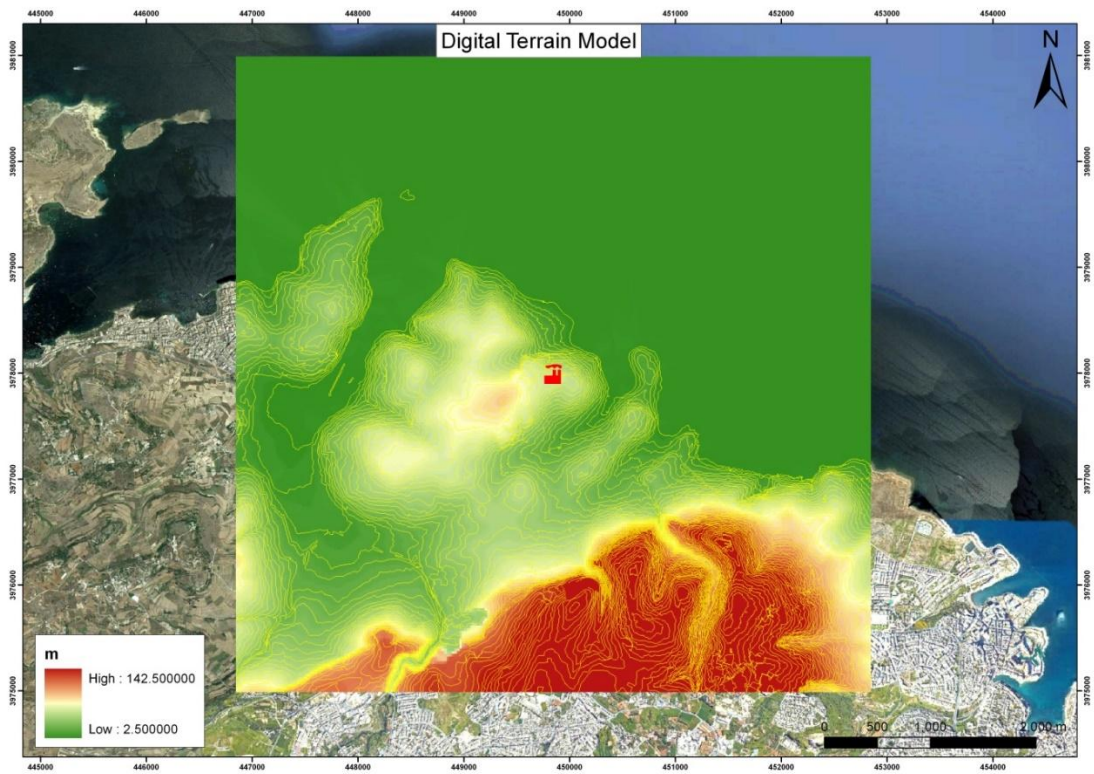


FIGURE 18: EXTRACT OF DTM WITH GIS SOFTWARE

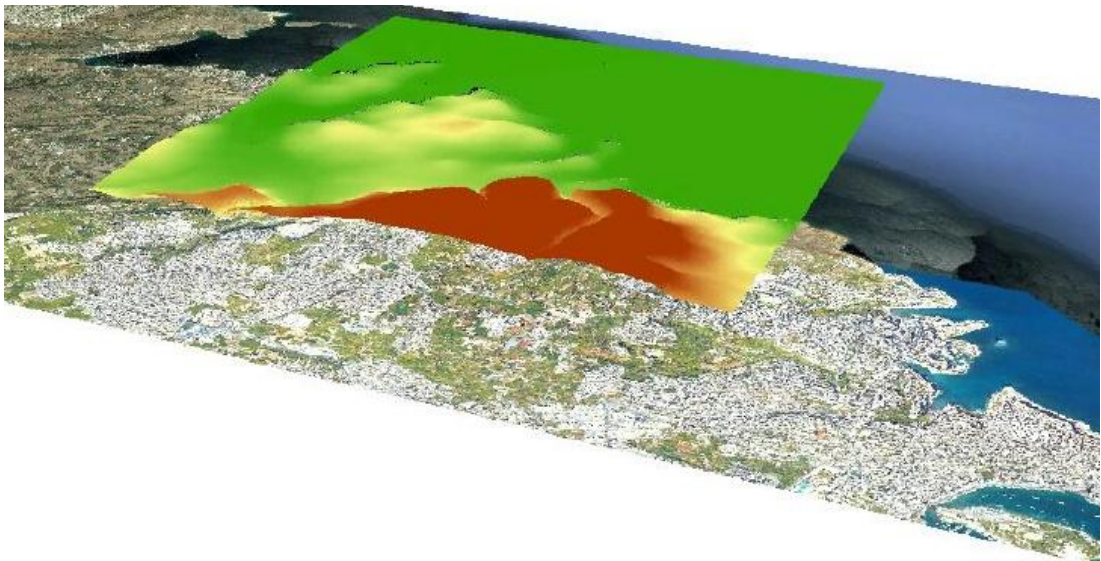
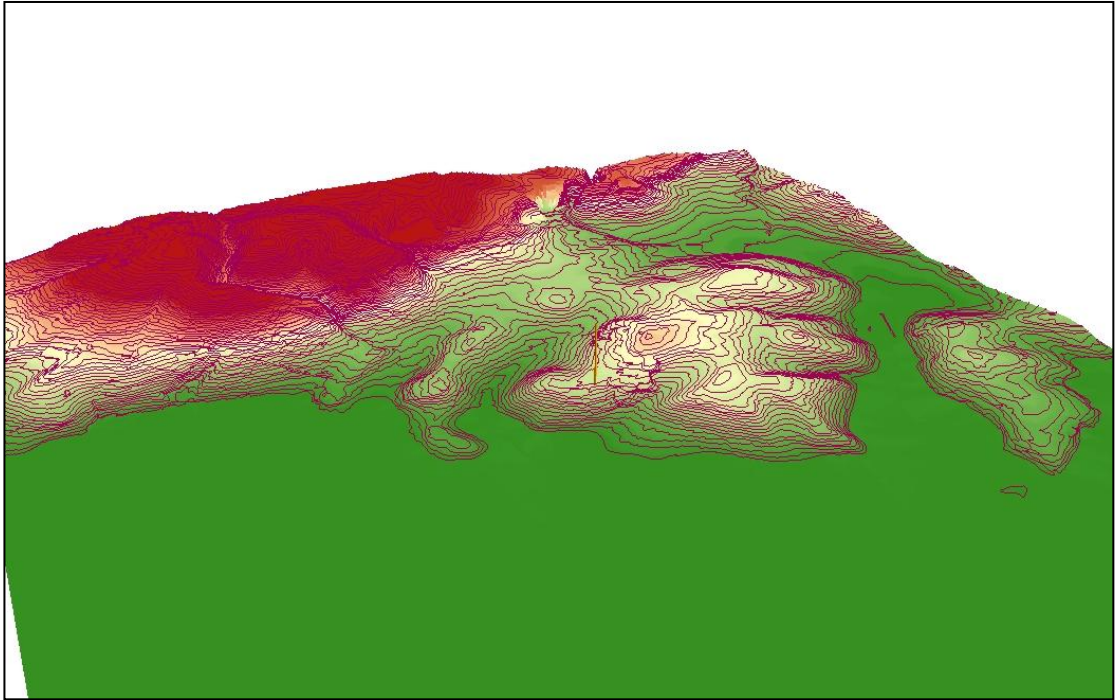


FIGURE 19: EXTRACT OF DTM WITH GIS SOFTWARE

2.9.10 Equations

The Gaussian equation that expresses the concentration for high point sources with continuous emissions takes the following form:

$$C(x, y, z) = \frac{Q}{2\pi\mu\sigma(x)_y\sigma(x)_z} \exp\left[-\frac{y^2}{2\sigma(x)_y^2}\right] \cdot V \cdot D$$

Q: pollutant emission expressed as mass per unit of time

V: vertical term

D: decay term

$\sigma(x)_y, \sigma(x)_z$: lateral and vertical dispersion coefficients (m)

μ : wind speed at the altitude of the release (m / s)

x: leeward distance between the source and the receptor with respect to the wind direction

y: distance perpendicular to the wind direction between the plume axis and the receptor

z: altitude of the receptor relative to the ground

This equation is obtained on the basis of the following hypotheses:

- Stationary process
- Constant weather conditions
- Turbulent transport along the x axis negligible compared to advection transport
- Constant dispersion coefficients in y and z
- Constant emission
- Reflective ground

The climatological calculation uses the Gaussian formulation evaluated on the sectors of origin of the wind. In addition to the basic assumptions already described for the Short-Term model, the following assumptions are made:

- the wind rose is divided into 16 sectors with a width of 22.5 °, the sectors are divided starting from the north in a clockwise direction;
- within each sector the concentration depends only on the radial distance between the source and the receptor (therefore there is no dependence on the distance perpendicular to the wind direction y);

In these hypotheses the equation used for climatological calculation is the following:

$$C(R, \Delta\vartheta, z) = \frac{Q}{\sqrt{2\pi} \cdot u \cdot R \cdot \sigma(R)_z \cdot \Delta\vartheta} \cdot V \cdot D \cdot S$$

Q: pollutant emission expressed as mass per unit of time

V: vertical term

D: decay term

R: source receptor radial distance in the calculation sector

$\Delta\theta$: size of the single sector

u: wind speed at altitude of release (m / s)

z: altitude of the receptor relative to the ground

S: smoothing function

$\sigma(R)_z$: source area

This equation represents the contribution to the concentration at a point R of a single point source. The total concentration value produced by a single source will be given by:

$$C_{tot} = \sum_{istab, idir, ivel} C(R, z) \cdot \frac{f(istab) \cdot f(istab, idir, ivel)}{10^6}$$

istab: sum on the stability classes (A, B, C, D, E, F + G, Mists)

idir: sum on the sectors of origin of the wind

ivel: sum on the speed classes

f(istab): frequency normalized to 1000 of occurrence of the istab-th stability class

f(istab, idir, ivel): normalized frequency at 1000 of the occurrence of the idir-th direction and the ivel-th speed class of the istab-th stability class

2.9.11 Post Processor

The WinDimula calculation model incorporates the WDPstProc program, this is the post-processing module of the results calculated by the model.

The program analyzes the output files (* .mbf -MaindBinaryFile-) produced by WinDimula and evaluates the concentrations relative to:

- average hourly concentrations
- average daily concentration over eight hours
- daily average concentration
- annual concentrations
- winter concentrations
- exceeding of threshold values for consecutive hours.

It is possible to use one of the predefined pollutants using the values provided by the Ministerial Decree or to enter a new type of pollutant specifying the limits and exceedances allowed. In addition to the results of the verification calculation, it is possible to display the time series of each receptor and the results calculated by WinDimula in each meteorological situation analyzed.

2.10 CALIBRATION - SAMPLING CAMPAIGN

2.10.1 PM₁₀

In line with S.L. 549.59, baseline levels of PM₁₀ were measured on site using the reference method (MSA EN 12341:2014), which describes both sampling and measurement methods for PM₁₀. Other specific details regarding the measurement of PM₁₀ can be found in the Terms of Reference provided by ERA.

In line with Annex B and Section IV of Annex IX of the said standard, the monitoring of PM₁₀ was carried out using a Sequential Automatic Sampler (Skypost PMHV, GEMINI or GIANO DADO LAB SEQUENTIAL AUTOMATIC SAMPLER). Since this sampler functions with a constant flow rate of 2.3 m³/h ± 2% (EN 12341), the Sequential Automatic Sampler has a dry gas meter within 2% precision installed. The sampler can also electronically control the flow. The Sequential Automatic Sampler is also equipped with a sensor to measure the atmospheric pressure and temperature and the pressure drop on the filter. This sensor is installed on the suction tube and is protected against adverse meteorological conditions.

The clean filter reservoir can contain up to 18 filter cassettes and can therefore allow a maximum of 18 days of monitoring without the need for a site visit to replace new filters. Unloaded filters were conditioned in the weighing room for a minimum of 48 h before weighing. Filters were weighed twice, with an interval of at least 12 hours, to confirm that the filter weight has stabilized. Loaded filters were placed in the weighing room for a minimum of 48 hours before weighing, and then weighed again after a further 24 to 72 hours, whilst being retained in the appropriate conditions.

The monitoring phase lasted a total of 45 days (6 weeks), but a scale up factor of 0.85 (based on Zejtun 2023 data) provided by ERA was used to scale the values of PM₁₀ to yearly values. Any PM₁₀ readings which were influenced by Saharan dust intrusions were discarded. The specific details on the methodology and instrumentation that were applied for the sampling and analysis of PM₁₀ are listed in the table hereunder. The instrumentation can be seen in Figure 20. The PM10 sampler was positioned at 35°56'24.85"N, 14°26'29.99"E.

TABLE 2 – DETAILS ON THE METHODOLOGY AND INSTRUMENTATION OF THE PM₁₀ ANALYSISPM₁₀

Description of activity:	Sampling was carried out with a sampling constant flow set equal to 38.3 L/min using the appropriate sampling heads: LVS for PM₁₀. The filter sampled was delivered to the laboratory for analysis and then weighed with an analytical balance. The scale was positioned inside a room with controlled temperature and humidity. The flow is programmable under the conditions of temperature and pressure of the sampling point (Qa), or standard (Qs) at 101.3 kPa, 0°C.
Instrument used:	Skypost PM with the following features: » Flow Range: 0.5 to 50 L/min » Autonomy: 16 filters » Electronic measurement of flow » Sensors measure of parameters: - Atmospheric Pressure - Pressure drop filter - Ambient temperature - Temperature volumetric » Volumetric measurement meter with accuracy of $\pm 2\%$ As per specifications of the ISO standard, the room temperature and the relative humidity of the weighing room are continuously monitored and controlled to 20°C ± 1 K and (50 $\pm$ 5) % RH respectively. Unloaded filters were conditioned in the weighing room for a minimum of 48 hours before weighing. Filters were weighed twice, with an interval of at least 12 hours, to confirm weight stabilisation. Loaded filters were placed in the weighing room for at least 48 hours before weighing, and then weighed

PM10

again after a further 24-72 hours, whilst being retained in the appropriate conditions. The balance resolution is of 10 µg.



FIGURE 20: SEQUENTIAL AUTOMATIC SAMPLER INSTALLED ON SITE

2.10.2 NO₂

In line with S.L. 549.59, baseline levels of NO₂ were determined using the reference method, which describes both sampling and measurement methods for NO₂. Other specific details regarding the measurement of NO₂ can be found in the Terms of Reference provided by ERA.

The monitoring of NO₂ was carried out using a type of passive sampler known as Passam Diffusion Tubes. These are cylindrical containers whose mechanism is based on the principle of diffusion through a surface. Pollutants which passively pass through the surface are adsorbed to the filter which should be manually replaced with a clean one every 7 days. The monitoring phase lasted a total 6 weeks, but a scale up factor of 0.96, provided by the ERA, was used to scale the values of NO₂ to yearly values. The sampler was positioned at 35°56'16.83"N 14°26'58.17"E.

The tubes used for the monitoring of NO₂ were then sent to Passam ag, where they were treated to extract the pollutants and analysed. As a result, the analytical technique is divided into two distinct phases: sampling and analysis.

As required by the ToRs, the Consultant should provide at least one article in a peer-reviewed journal which showcases that the equivalence of these tubes has been demonstrated in at least 1 EU Member State. An article by Hafkenscheid et al. (2009) on the application of diffusive samplers in the European Union for the monitoring of nitrogen dioxide in ambient air was chosen, and is enclosed in Appendix 3. This article indicates that in France, Passam samplers were compared to the standard reference method in line with the Guidance to Demonstration of Equivalence (2010). The study found the Passam tubes to be equivalent to the reference method, with an uncertainty

of 6.4% at a 95% confidence level, thus fulfilling the 15% uncertainty level for fixed NO₂ measurements.

The specific details on the methodology and instrumentation that were applied for the sampling and analysis of NO₂ can be seen in Table 3. This methodology was outlined in the Method Statement, which was subsequently approved by the ERA. The instrumentation can be seen in Figure 21.

TABLE 3: DETAILS ON THE METHODOLOGY AND INSTRUMENTATION OF THE NO₂ ANALYSIS

NITROGEN DIOXIDE

Description of activity:	The passive sampler that was used (type Passam) is equipped with an adsorbant (in this case triethanolamine) on which NO₂ adsorbs. The radially symmetrical diffusive body is fixed to a metal plate and is exposed to air between 1.5 and 4 meter above the ground level. The passive sampler is analyzed in the laboratory to determine the amount of NO₂. The uptake rate will be calculated at 298.15K and will then be used to determine the average concentration of the pollutant during the exposure period. Further details on the analyser used are given below:	
Instruments used:	Principle of method	Passive sampler
	Instrumentation	Passam tube
	Lower detectable limit	0.3 µg/Nm ³

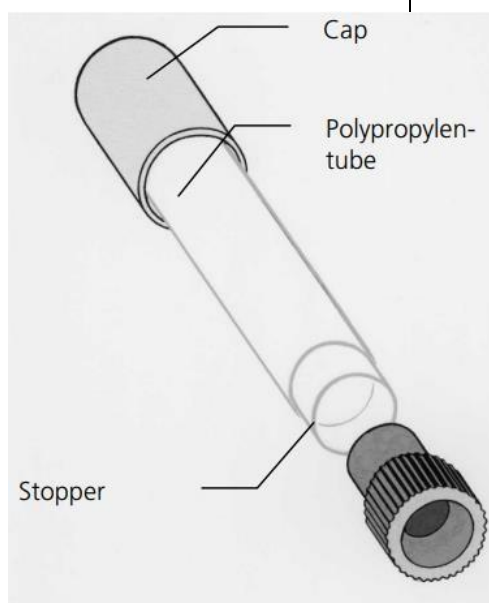


FIGURE 21: PASSAM TUBE

2.11 SIGNIFICANCE CRITERIA

A significance criteria tool provided by the ERA was used to determine the significance of the impact at all sensitive receptors and at any point within the investigated area.

To determine the impact, the tool considers the following inputs:

- The annual limit value ($\mu\text{g}/\text{m}^3$);
- The baseline concentration ($\mu\text{g}/\text{m}^3$) - The baseline concentration value considered was the average daily value;
- The change ($\mu\text{g}/\text{m}^3$) - the worst-case emissions reported from the air dispersion model was considered for the determination of the exchange rate.

TABLE 4 – IMPACT CRITERIA TOOL FOR PM_{10}

CHANGE IN THE ANNUAL PM_{10} DAA LEVELS DUE TO SCHEME					
CAA FOR PM_{10}	CAA	$\text{DAA} \leq 0,4 \mu\text{G}/\text{M}^3$	$0,8 \mu\text{G}/\text{M}^3 \leq \text{DAA} \leq 2,0 \mu\text{G}/\text{M}^3$	$2,4 \mu\text{G}/\text{M}^3 \leq \text{DAA} \leq 4,0 \mu\text{G}/\text{M}^3$	$\text{DAA} > 4 \mu\text{G}/\text{M}^3$
	$\text{CAA} \geq 44 \mu\text{G}/\text{M}^3$	Moderate	Major	Major	Major
	$43,6 \mu\text{G}/\text{M}^3 \leq \text{CAA} \leq 41,2 \mu\text{G}/\text{M}^3$	Moderate	Moderate	Major	Major
	$40,8 \mu\text{G}/\text{M}^3 \leq \text{CAA} \leq 38 \mu\text{G}/\text{M}^3$	Minor	Moderate	Moderate	Major
	$37,6 \mu\text{G}/\text{M}^3 \leq \text{CAA} \leq 30,4 \mu\text{G}/\text{M}^3$	Not significant	Minor	Moderate	Moderate
	$\text{CAA} \leq 30 \mu\text{G}/\text{M}^3$	Not significant	Not significant	Minor	Moderate

For the calculation of the CAA of PM_{10} , that is the corrected annual average, the following formula has been proposed

$$CAA = \frac{p_{y+1}^{x \text{ weeks}}}{p_y^{x \text{ weeks}}} \times P_y^{52 \text{ weeks}}$$

Where:

- CAA is the corrected annual average;
- $p_{y+1}^{x \text{ weeks}}$ is the concentration of NO₂ or PM₁₀ measured by the consultants throughout the 6 (9) week (baseline) monitoring period;
- $p_y^{x \text{ weeks}}$ is the concentration of NO₂ or PM₁₀ measured throughout the same 6 (9) week monitoring period of the preceding year at a comparable ERA fixed station;
- $p_y^{52 \text{ weeks}}$ is the annual average of NO₂ or PM₁₀ measured at the comparable ERA fixed station.

The annualization factor for PM₁₀ considered is 0,85 (based on the Zejtun 2023 data).

TABLE 5 – IMPACT CRITERIA TOOL NO₂

CHANGE IN THE ANNUAL NO ₂ DAA LEVELS DUE TO SCHEME					
CAA FOR NO ₂	CAA	DAA ≤ 0,4 μG/M ³	0,8 μG/M ³ ≤ DAA ≤ 2,0 μG/M ³	2,4 μG/M ³ ≤ DAA ≤ 4,0 μG/M ³	DAA > 4 μG/M ³
	CAA ≥ 44 μG/M ³	Moderate	Major	Major	Major
	43,6 μG/M ³ ≤ CAA ≤ 41,2 μG/M ³	Moderate	Moderate	Major	Major
	40,8 μG/M ³ ≤ CAA ≤ 38 μG/M ³	Minor	Moderate	Moderate	Major
	37,6 μG/M ³ ≤ CAA ≤ 30,4 μG/M ³	Not significant	Minor	Moderate	Moderate
	CAA ≤ 30 μG/M ³	Not significant	Not significant	Minor	Moderate

The annualization factor for NO₂ considered is 0.96 (based on GHR 2024 data).

3 RESULTS OBTAINED FROM THE MODEL

The data obtained from the model consist of the outputs at average hourly concentrations on an annual basis at each point of the investigated area within a radius of influence equal to 6 km from the chimney.

From the hourly concentrations it was possible to evaluate the concentrations of each pollutant investigated in relation to each month, therefore, the behavior of the fallout for the entire year.

The data obtained were processed with the MMS RunAnalyzed which allows to perform various elaborations such as the calculation of statistical indices (such as averages and percentiles) on the specified time intervals, useful for comparison with the regulatory reference levels for each pollutant or for discriminating analysis in the various receptor points.

The interpolation results were exported in format (.GRD) inserted in a GIS software and reported on cartography using the QGIS program.

This representation is documented by the forecast emission maps shown in the Annexes 1.

By observing the diffusion maps, it was possible to draw further considerations relating to the dispersion of substances from the chimney (for three scenarios) and to deposition on the ground.

3.1 DETERMINATION OF THE AREA OF INFLUENCE

A specific spatial processing of the data obtained from the model was carried out, in order to assess the probability of significant effects on the quality of the ambient air (including exceeding the environmental limit values) as well as on the deposition levels of particular components. The analysis focused on an area of influence estimated within a radius of 6 km from the chimney.

The “Area of Influence – AOI” has been defined as the largest area around the plants obtained considering the areas where the contribution of the plant to the annual environmental levels of NO₂, PM₁₀ or PM_{2,5} is as follows, whichever results in the largest AOI. If the AOI is <11.3km² then the AOI shall be assumed to be a circle of 6km radius centered on the chimney:

- PM₁₀ → 0.3 µg / m³
- NO₂ → 0.3 µg / m³
- PM_{2,5} → 0.19 µg / m³

3.2 IDENTIFICATION AND SELECTION OF SENSITIVE RECEPTORS

The consultants have identified a number of sensitive receptors that could potentially be affected by the proposed development. The list of sensitive receptors has been derived by adopting a risk-based approach based on the pollution contours presented by the ERA's NO₂ passive diffusion tube network in 2023 as depicted below.

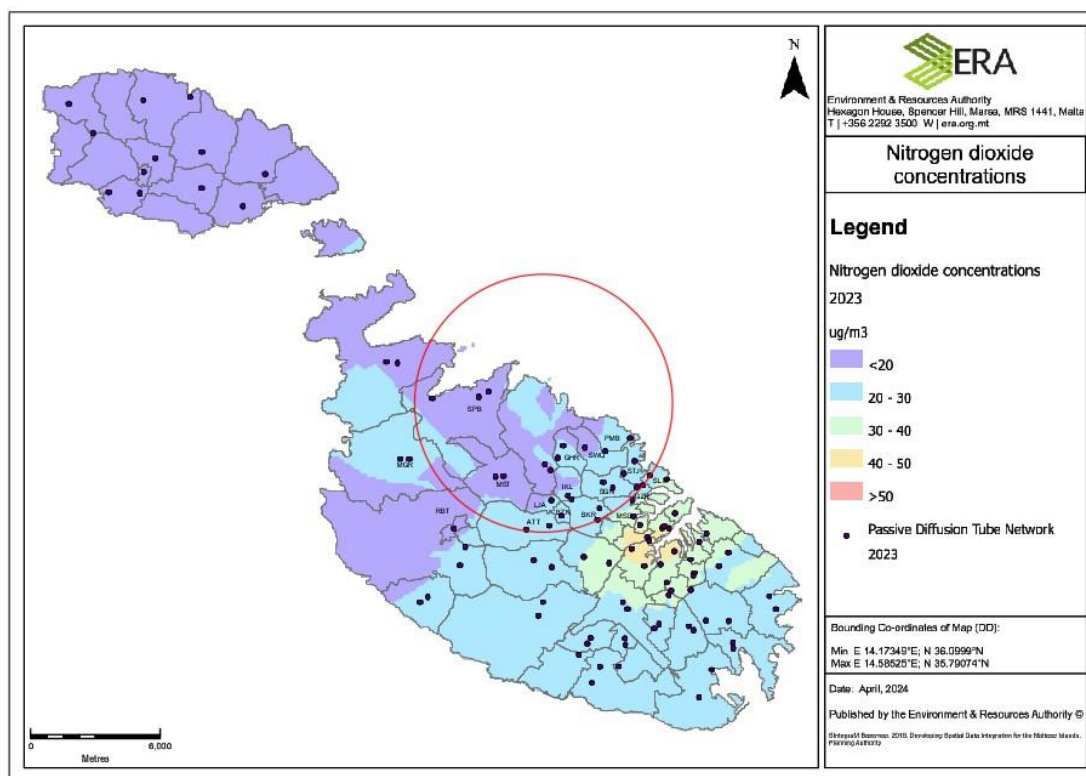


FIGURE 1. NO₂ CONTOUR MAP BASED ON 2023 DATA OBTAINED FROM ERA AND SUPERIMPOSITION OF THE 6KM AOI

The local council boundaries which fall within the 6km radius AoI are: SPB – St’ Paul’s Bay; NXR – Naxxar; MST – Mosta; GHR – Gharghur; LJA – Lija; ATT – Attard; BZN – Balzan; IKL – Iklın; BKR – Birkirkara; SGN – San Gwann; MSD – Msida; SWQ – Swieqi; PMB – Pembroke; STJ – St Julians; SLM – Sliema; GZR – Gzira; RBT – Rabat; MGR – Mgarr.

A risk-based approach has been adopted to select the sensitive receptors considered the distance away from the source and the current pollution levels (as shown in the contour map). Consequently, a hierarchy of risk level has been adopted to establish the location of the sensitive receptors.

TABLE 6 –DEFINITION OF CRITERIA USED FOR THE RISK-BASED APPROACH TO IDENTIFY SENSITIVE RECEPTORS

Criterion	Level	Definition
Closest Distance	Short (3)	Located at <2km away from the scheme site
	Medium (2)	Located at 2-4km away from the scheme site
	Far (1)	Located at >4km away from the scheme site
Current pollution	High (3)	Ambient ²⁰²³ pollution levels are >40 µg/m ³ NO ₂
	Medium (2)	Ambient ²⁰²³ pollution levels are 30-40 µg/m ³ NO ₂
	Low (1)	Ambient ²⁰²³ pollution levels <30 µg/m ³ NO ₂
Risk Level	Major (5-6)	Risk level is considered major when sum of current pollution and closest distance is equal to Level 5-6
	Moderate (3-4)	Risk level is considered moderate when sum of current pollution and closest distance is equal to Level 3-4
	Low (2)	Risk level is considered low when sum of current pollution and closest distance is equal to Level 2

From the risk-assessment carried out above, one can conclude that the following localities pose the highest level of risk (Moderate – Level 4): Naxxar, Gharghur, Pembroke, Swieqi and San Gwann. Therefore, the consultant has identified a number of specific sensitive receptors within the aforementioned localities, that include: residential areas, schools, clinics, old people's home and hospitals. For the lower risk localities, a minimum of one sensitive receptor has also been included.

TABLE 7: RISK ASSESSMENT FOR EACH LOCALITY IN THE AOI

LOCALITY	DISTANCE [KM]	CURRENT POLLUTION	RISK LEVEL
SPB	1.6 – Short (3)	< 20 µg/m ³ – Low (1)	Moderate (4)
NXR	0.0 – Short (3)	20 - 30 µg/m ³ – Low (1)	Moderate (4)
MST	2.6 – Medium (2)	< 20 µg/m ³ – Low (1)	Moderate (3)
LJA	4.2 – Far (1)	< 20 µg/m ³ – Low (1)	Low (2)
BZN	4.6 – Far (1)	20 - 30 µg/m ³ – Low (1)	Low (2)
ATT	5.0 – Far (1)	20 - 30 µg/m ³ – Low (1)	Low (2)
IKL	3.0 – Medium (2)	20 - 30 µg/m ³ – Low (1)	Moderate (3)
BKR	4.6 – Far (1)	20 - 30 µg/m ³ – Low (1)	Low (2)
GHR	1.5 – Short (3)	20 - 30 µg/m ³ – Low (1)	Moderate (4)
PMB	1.9 – Short (3)	< 20 µg/m ³ – Low (1)	Moderate (4)
SWQ	1.5 – Short (3)	< 20 µg/m ³ – Low (1)	Moderate (4)
SGN	3.6 – Medium (2)	20 - 30 µg/m ³ – Low (1)	Moderate (3)
MSD	5.2 – Far (1)	20 - 30 µg/m ³ – Low (1)	Low (2)
STJ	4.7 – Far (1)	20 - 30 µg/m ³ – Low (1)	Low (2)

LOCALITY	DISTANCE [km]	CURRENT POLLUTION	RISK LEVEL
SLM	5.6 – Far (1)	20 - 30 µg/m ³ – Low (1)	Low (2)
GZR	5.6 – Far (1)	20 - 30 µg/m ³ – Low (1)	Low (2)
RBT	5.3 – Far (1)	< 20 µg/m ³ – Low (1)	Low (2)
MGR	5.3 – Far (1)	20 - 30 µg/m ³ – Low (1)	Low (2)

TABLE 8 – SENSITIVE RECEPTORS

RECEPTOR NO.	NAME	COORDINATES	DISTANCE
R1	Verdala International School, Pembroke	35°55'33.67"N 14°28'49.07"E	3.80 km
R2	Chiswick House School, San Gwann	35°54'26.02"N 14°29'0.87"E	5.36 km
R3	St Catherine's High School, Pembroke	35°55'30.98"N 14°28'24.17"E	3.31 km
R4	St Michael's School, Pembroke	35°55'31.24"N 14°28'34.19"E	3.52 km
R5	St Michael's Foundation, San Gwann	35°54'43.73"N 14°27'53.62"E	3.92 km
R6	St Francis School, San Gwann	35°54'27.88"N 14°28'48.44"E	5.10 km
R7	St Clare Primary College, Pembroke	35°55'40.57"N 14°28'40.21"E	3.50 km
R8	Karmnu Sant Primary School, Gharghur	35°55'25.82"N 14°27'5.60"E	2.22 km
R9	Bice Mizzi Vassallo Primary School, Pembroke	35°55'29.92"N 14°28'27.30"E	3.40 km
R10	St Clare Secondary, Pembroke	35°55'47.69"N 14°28'19.09"E	2.93 km
R11	Sprachcaffe Language School, Pembroke	35°55'30.60"N 14°28'41.83"E	3.69 km

RECEPTOR No.	NAME	COORDINATES	DISTANCE
R12	San Miguel Resource Centre, Pembroke	35°55'41.26"N 14°28'30.65"E	3.28 km
R13	M.U.S.E.U.M Pembroke	35°55'35.46"N 14°28'42.10"E	3.62 km
R14	Risen Christ Church, Pembroke	35°55'34.72"N 14°28'39.08"	3.56 km
R15	National Sports School, Pembroke	35°55'27.69"N 14°28'26.35"E	3.42 km
R16	Simblija Care Home, Naxxar	35°54'42.13"N 14°26'50.75"E	3.49 km
R17	Golden Care Retirement Home, Naxxar	35°55'3.49"N 14°26'54.07"E	2.85 km
R18	Primary School, Naxxar	35°54'50.02"N 14°26'47.09"E	3.24 km
R19	MRC Middle School, Naxxar	35°54'37.01"N 14°26'52.35"E	3.65 km
R20	Giovanni Curmi Higher Secondary, Naxxar	35°54'35.28"N 14°26'48.54"E	3.69 km
R21	Naxxar Parish Church, Naxxar	35°54'52.52"N 14°26'39.98"E	3.16 km
R22	St Clare's Primary College, San Gwann	35°54'32.44"N 14°28'31.27"E	4.72 km
R23	San Gwann Parish Chruch, San Gwann	35°54'27.65"N 14°28'36.81"E	4.93 km
R24	Immaculate Mother of the Church, Swieqi	35°55'15.51"N 14°28'27.78"E	3.69 km
R25	St Bartholomew Parish Church, Gharghur	35°55'25.49"N 14°27'12.52"E	2.31 km
R26	Clubclass English School, Swieqi	35°55'10.80"N 14°28'50.10"E	4.20 km

RECEPTOR No.	NAME	COORDINATES	DISTANCE
R27	Agricultural land, Magħtab	35°56'22.21"N 14°26'45.34"E	0.43 km
R28	Żona fil-Baħar madwar Għawdex - MT0000112	35°56'52.41"N 14°27'0.53"E	0.79 km
R29	Żona fil-Baħar bejn Il-Ponta ta' San Dimitri (Għawdex) u Il-Qaliet (MT0000105)	35°56'54.63"N 14°27'17.86"E	1.18 km
R30	L-Għadira s-Safra (MT0000008)	35°57'2.52"N 14°26'43.28"E	0.86 km
R31	Is-Salini (MT0000007)	35°56'38.19"N 14°25'20.58"E	1.94 km
R32	Triq ir-Ramla, Magħtab Residential & Industrial Area	35°56'9.33"N 14°26'32.99"E	0.78 km
R33	Triq Jules Verne, Naxxar Residential Area	35°55'26.90"N 14°26'21.72"E	2.13 km
R34	Triq Fidel Zarb, Għargħur Residential Area	35°55'39.42"N 14°27'9.29"E	1.88 km
R35	Dawret il-Qawra, Qawra Residential Area	35°57'0.72"N 14°25'24.15"E	2.01 km
R36	Triq Napuljun Tagliaferro, Pembroke Residential Area	35°55'39.77"N 14°28'39.18"E	3.48 km
R37	Triq M. Pulis, Birkirkara Residential Area	35°53'57.91"N 14°27'55.10"E	5.21 km
R38	Constitution Road, Mosta Residential Area	35°54'34.35"N 14°25'34.08"E	4.04 km
R39	Triq San Guzepp, San Gwann Residential Area	35°54'26.90"N 14°28'37.06"E	4.95 km
R40	Parish Street, St Paul's Bay Residential Area	35°56'55.42"N 14°24'8.97"E	3.78 km
R41	Triq il-Maghsar, Burmarrad Residential Area	35°55'59.70"N 14°24'49.00"E	2.93 km

RECEPTOR No.	NAME	COORDINATES	DISTANCE
R42	Triq Preziosi, Lija Residential Area	35°54'13.20"N 14°26'42.79"E	4.37 km
R43	Triq Balaguer, Balzan Residential Area	35°53'59.04"N 14°27'4.81"E	4.85 km
R44	Triq Annabelle Preca, Attard Residential Area	35°53'49.31"N 14°26'15.74"E	5.13 km
R45	Triq il-Harruba, Iklin Residential Area	35°54'42.16"N 14°27'8.16"E	3.56 km
R46	Triq L.Apap, St Julian's Residential Area	35°55'16.57"N 14°29'22.03"E	4.78 km
R47	Mater Dei Hospital, Msida	35°54'4.63"N 14°28'35.51"E	5.49 km
R48	Tower Road, Sliema Residential Area	35°55'1.99"N 14°29'59.81"E	5.81 km
R49	Farm at Triq il-Katakombi, Salina	35°56'44.52"N 14°25'45.23"E	1.35 km
R50	Farm at Sqaq Habel Zwejra, Maghtab	35°56'15.73"N 14°26'8.07"E	0.95 km
R51	Farm and fields at Triq Burmarrad, Burmarrad	35°55'33.18"N 14°25'12.83"E	2.86 km
R52	Farms at Bahar ic-Caghaq	35°56'2.57"N 14°26'53.43"E	1.06 km
R53	Agricultural land at Triq il-Wardija, Wardija	35°56'18.06"N 14°24'38.77"E	3.02 km
R54	Agricultural land at Triq is-Sagra Familja, Bidnija	35°55'33.91"N 14°23'31.26"E	5.03 km
R55	Agricultural land, Triq Sir Temi Zammit, Mosta	35°54'33.82"N 14°24'6.01"E	5.32 km



FIGURE 2. MAP OF THE IDENTIFIED SENSITIVE RECEPTORS

3.3 SPATIAL ELABORATIONS

The area of influence - AOI, area around the plant in which the contribution of the plant to the annual ambient levels of NO₂, PM₁₀ or PM_{2.5} is 0.3 µg/m³ for NO₂ or 0.3 µg/m³ for PM₁₀ or 0.19 µg/m³ for PM_{2.5}, whichever results in the largest AOI. If the area of the AOI is < 11.3 km² then the AOI shall be assumed to be a circle of radius 6 km center on the chimney.

Below are the results obtained by the model for the three scenarios considered:

Scenario A

- a. NO₂, the simulated concentrations are lower than 0.3 µg/m³ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.78 km;
- b. PM₁₀, the simulated concentrations are lower than 0.3 µg/m³ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.78 km;
- c. PM_{2.5}, the simulated concentrations are lower than 0.19 µg/m³ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.78 km.

Scenario B

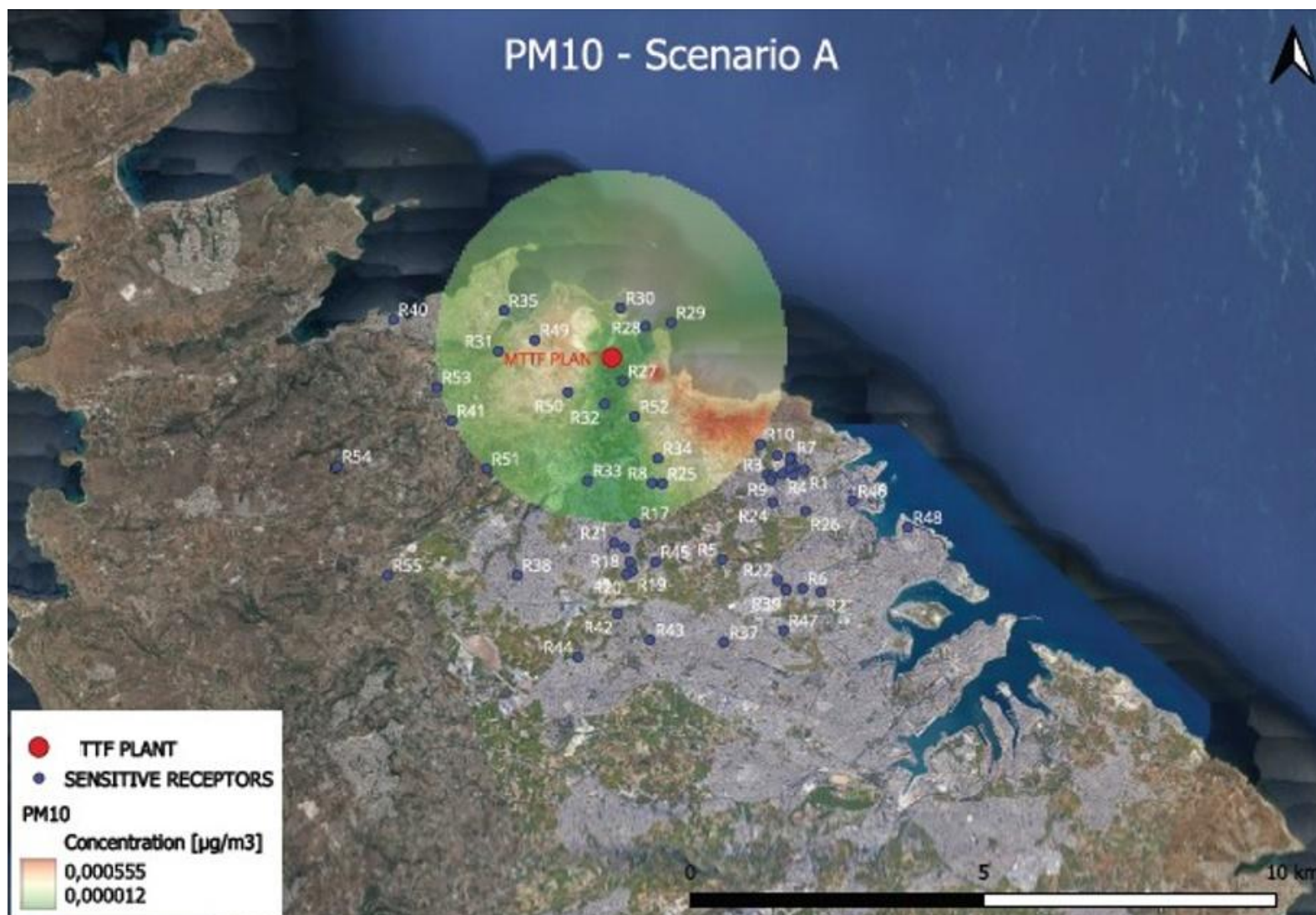
- a. NO₂, the simulated concentrations are lower than 0.3 µg/m³ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.78 km;
- b. PM₁₀, the simulated concentrations are lower than 0.3 µg/m³ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.78 km;
- c. PM_{2.5}, the simulated concentrations are lower than 0.19 µg/m³ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.78 km.

Scenario C

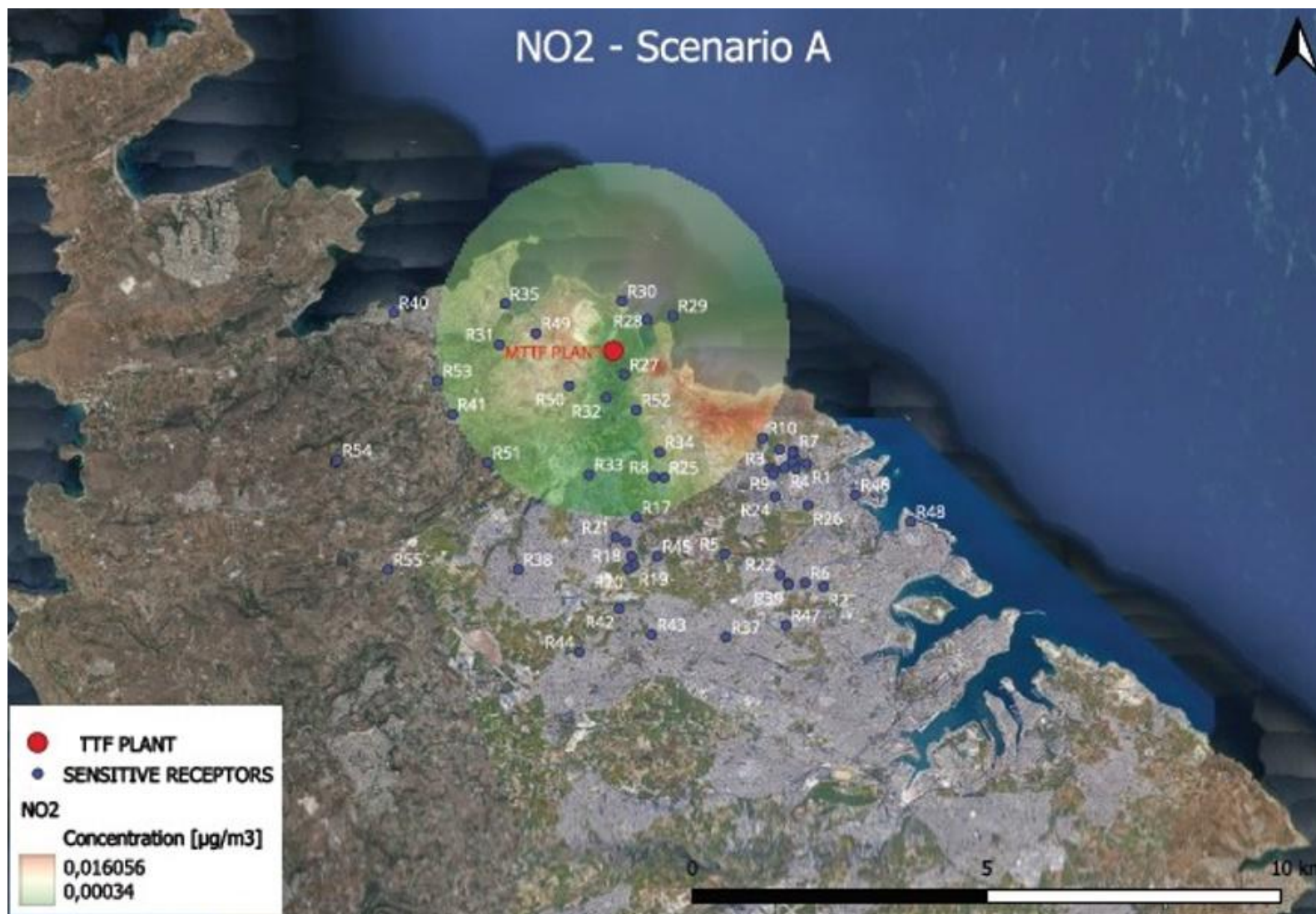
- a. PM₁₀, the simulated concentrations are lower than 0.3 µg/m³ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.78 km;
- b. PM_{2.5}, the simulated concentrations are lower than 0.19 µg/m³ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.78 km.

The isoconcentration maps have been created in order to define in detail the areas in which the calculated concentrations expressed as µg/m³. A color gradient between orange and red was used to highlight areas with higher concentrations. All maps are listed in Annex 1.

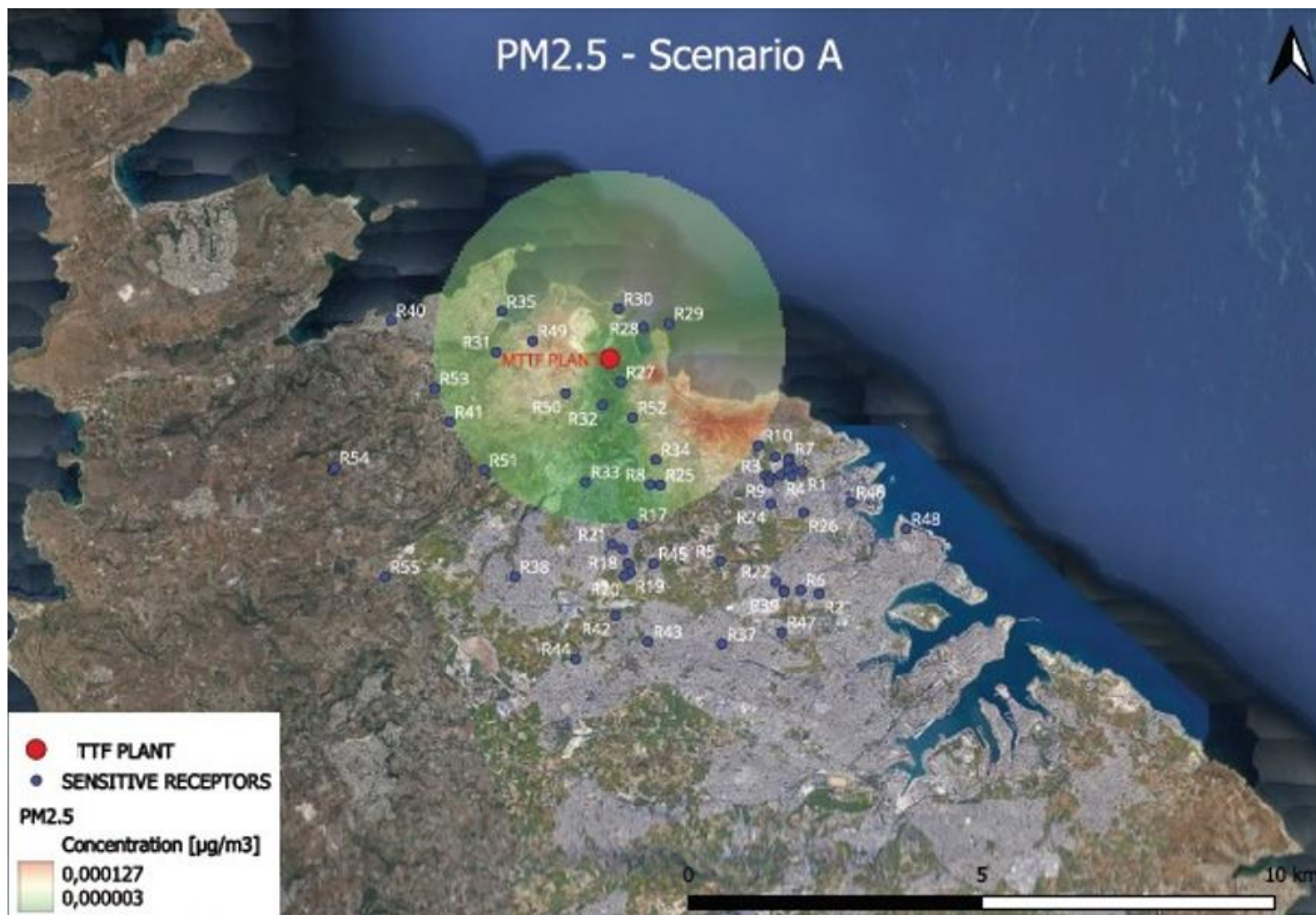
The simulations have revealed that the concentration of NO₂, PM₁₀ and PM_{2.5} are lower than the established thresholds. Consequently, an AoI with a radius of 6km has been established. The models and the spatial analysis was developed with the aim of obtaining a spatial data resolution of 5 × 5 m².

3.3.1 Isoconcentration map of PM₁₀ - Scenario A

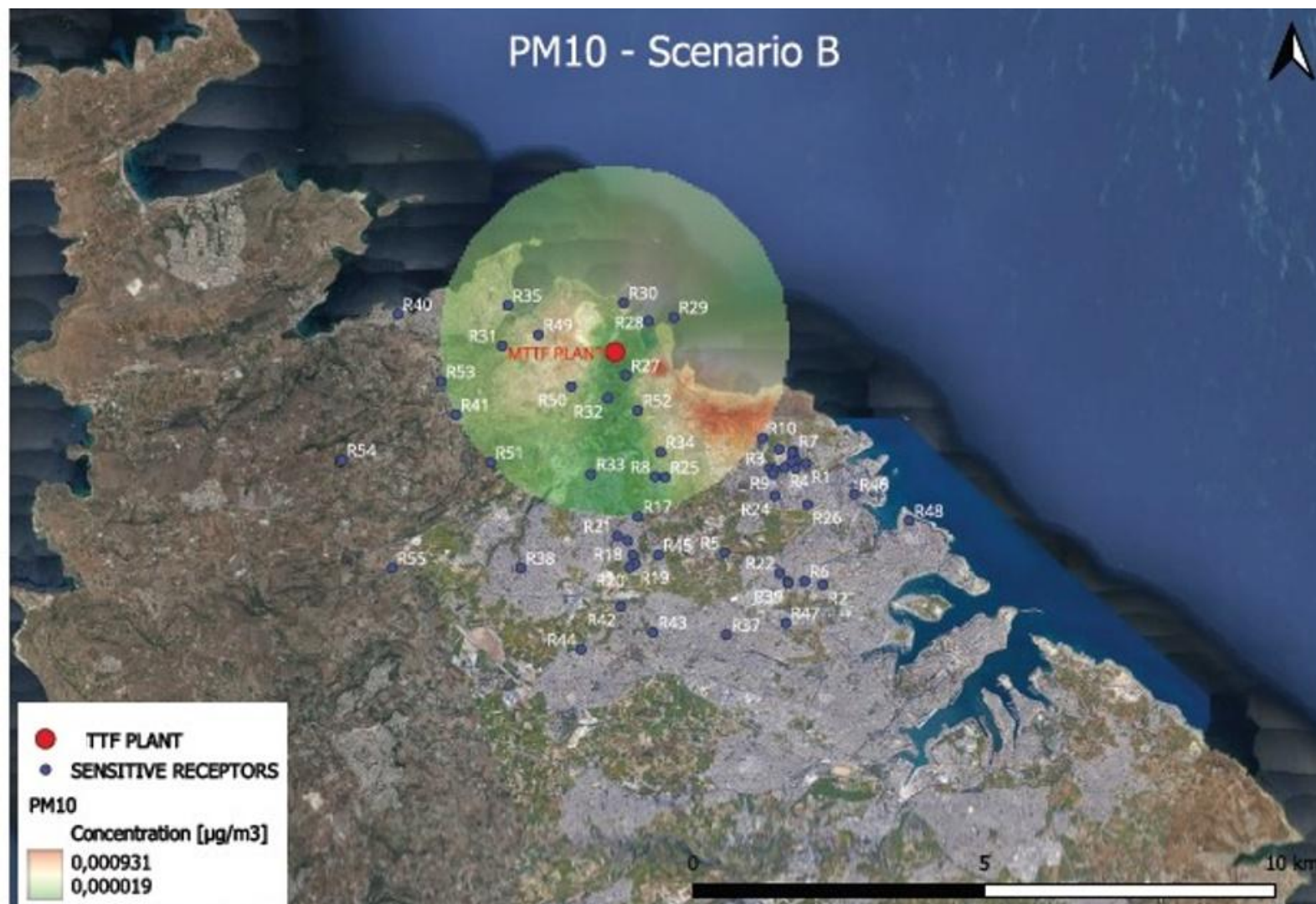
3.3.2 Isoconcentration maps of NO₂ - Scenario A

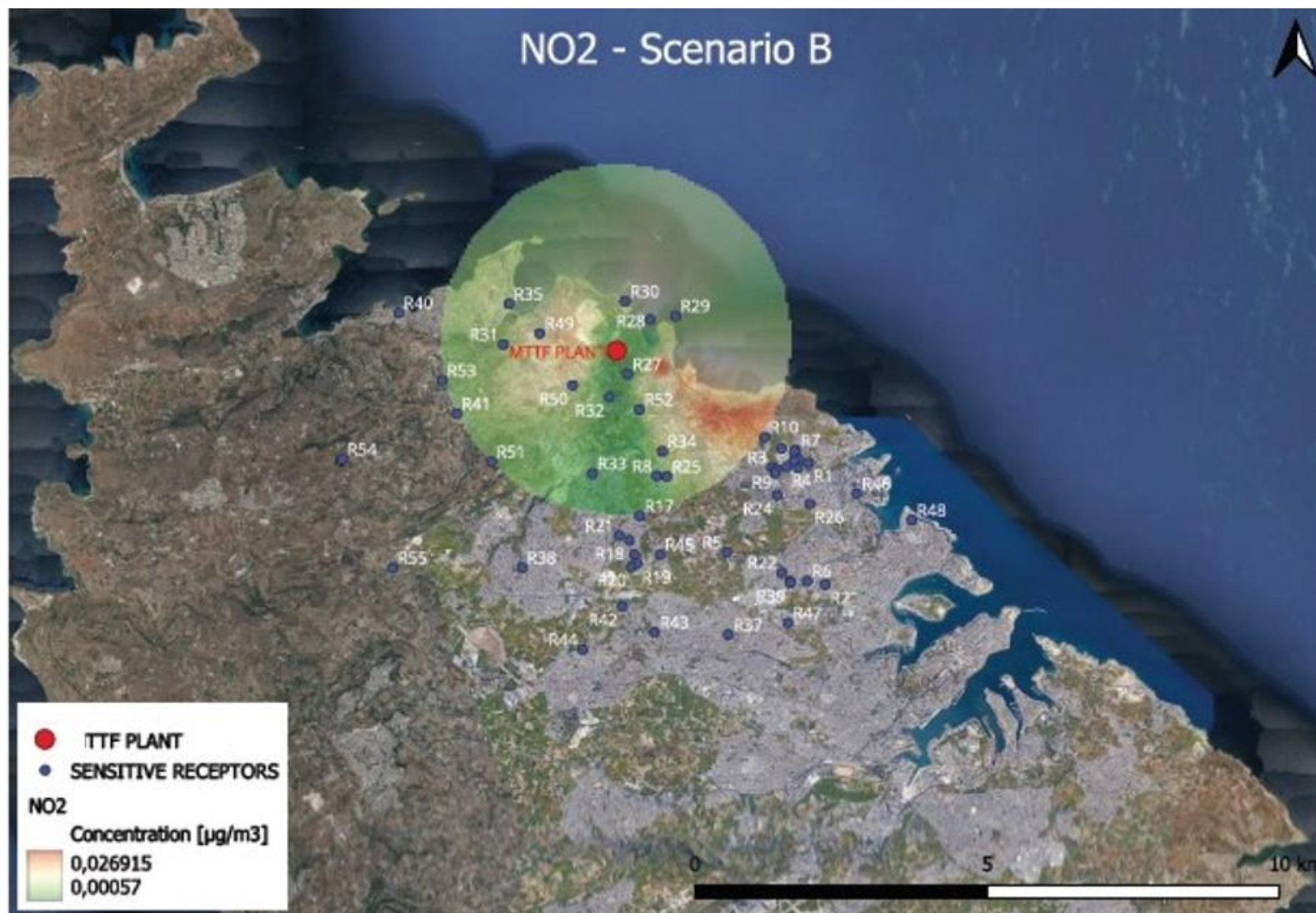


3.3.3 Isoconcentration maps of PM_{2.5}- Scenario A

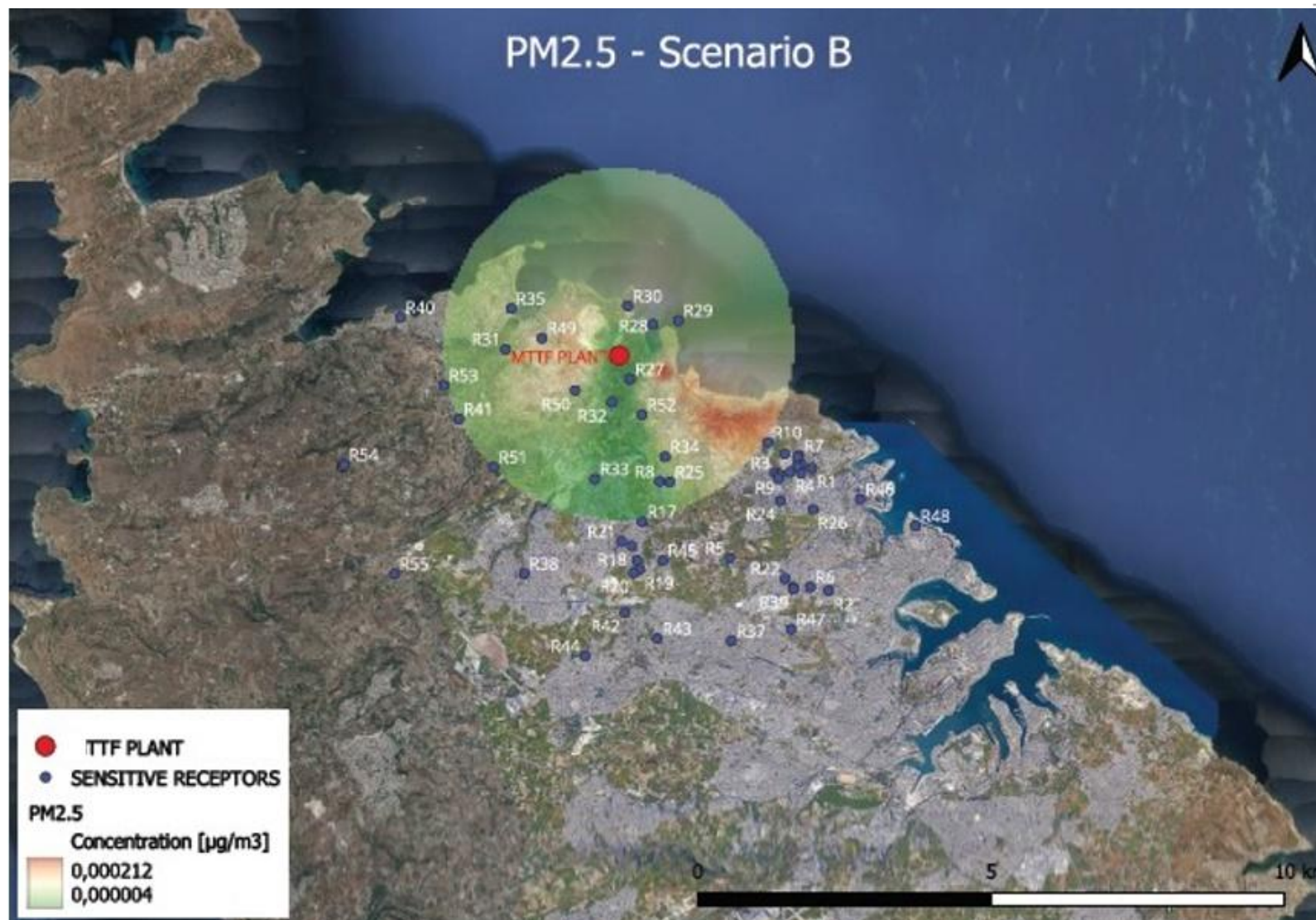


3.3.4 Isoconcentration map of PM10 - Scenario B

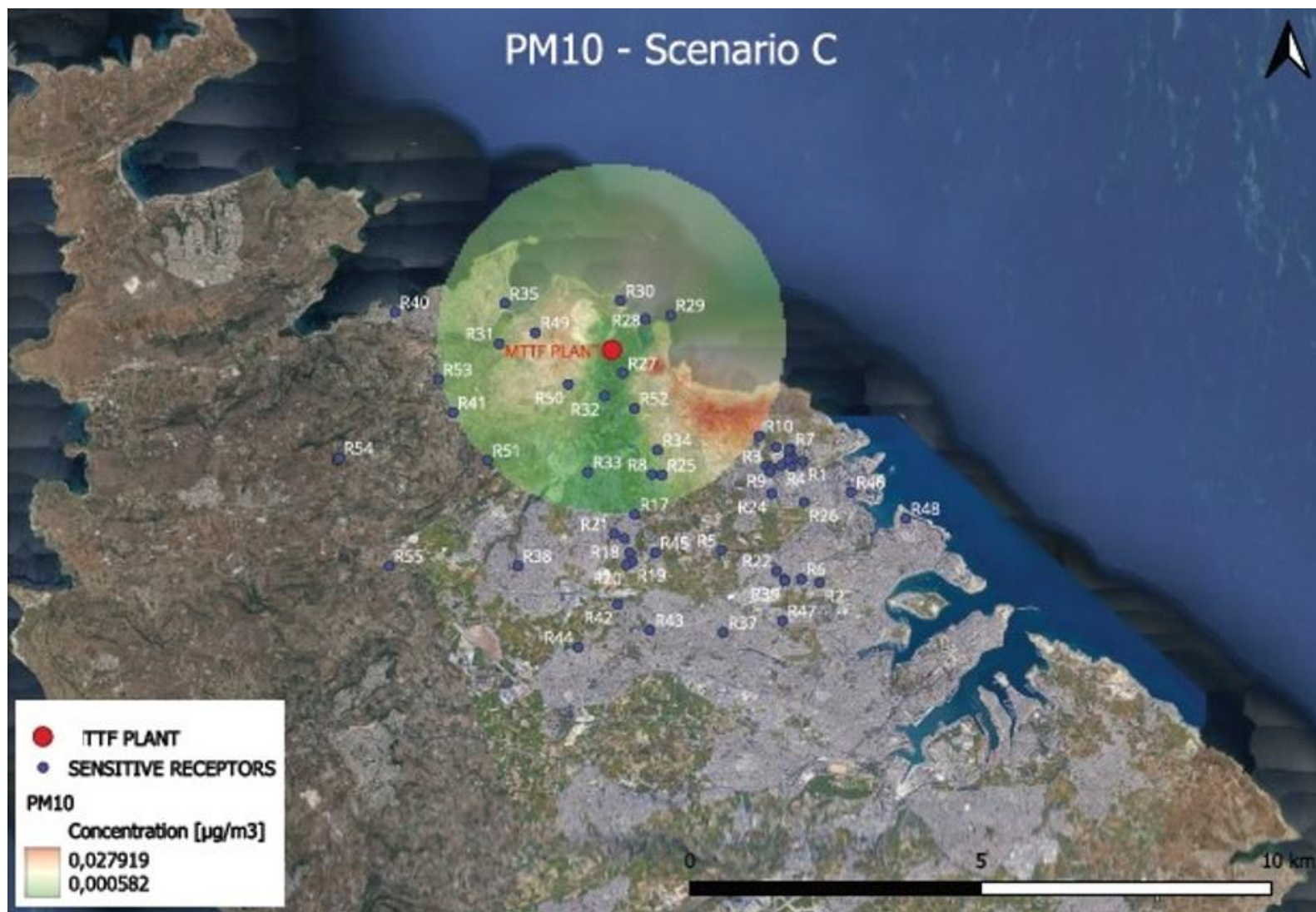


3.3.5 Isoconcentration maps of NO₂ - Scenario B

3.3.6 Isoconcentration maps of PM_{2.5}- Scenario B



3.3.7 Isoconcentration maps of PM₁₀ - Scenario C



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3.4 PERCENTILE EVALUATION

In accordance with the ERA TOR's, the 90.4th percentile of concentrations for PM₁₀ and the 99.8th percentile of concentrations for NO₂ were estimated.

With the aim of obtaining a comparable dataset, these statistical parameters have been calculated at the receptors for each parameter relation to a year (as shown in table 1 and table 2).

Part II of Schedule 7 to Regulation 29 of S.L. 549.59 sets the following (legally binding limit values):

- an annual limit value of 40 µg/m³ for PM₁₀, a daily limit value for PM₁₀ of 50 µg/m³ which cannot be exceeded on more than 35 calendar days (90.4% of the daily readings in a calendar year should be < 50 µg/m³);
- an annual limit value of 40 µg/m³ for NO₂ and an hourly limit value of 200 µg/m³ which cannot be exceeded more than 18 times per calendar year (99.8 % of the hourly readings in a calendar year should be < 200 µg/m³).

From the model results it emerges that:

- in the Scenario A the 90.4th percentile of concentrations for are below the regulatory limits of 50 µg/m³ which cannot be exceeded on more than 35 calendar days and are below an annual limit value of 40 µg/m³; also, the 99.8th percentile of concentrations for NO₂ in the Scenario A are below an hourly limit value of 200 µg/m³ which cannot be exceeded on more than 18 times per calendar year and are below an annual limit value of 40 µg/m³;
- in the Scenario B the 90.4th percentile of concentrations for are below the regulatory limits of 50 µg/m³ which cannot be exceeded on more than 35 calendar days and are below an annual limit value of 40 µg/m³; also, the 99.8th percentile of concentrations for NO₂ in the Scenario A are below an hourly limit value of 200 µg/m³ which cannot be exceeded on more than 18 times per calendar year and are below an annual limit value of 40 µg/m³;
- in the Scenario C the 90.4th percentile of concentrations for are below the regulatory limits of 50 µg/m³ which cannot be exceeded on more than 35 calendar days and are below an annual limit value of 40 µg/m³; Also the 99.8th percentile of concentrations for NO₂ in the Scenario A are below an hourly limit value of 200 µg/m³ which cannot be exceeded on more than 18 times per calendar year and are below an annual limit value of 40 µg/m³ (evaluated in the Scenario B).

TABLE 9: MAXIMUM VALUES OF FALLOUT TO THE RECEPTORS (PM₁₀) FOR THREE SCENARIOS

RECEPTORS		Distance from the chimney [km]	SCENARIO A		SCENARIO B		SCENARIO C	
			PM10		PM10		PM10	
			Avarege hourly value	Percentile 90.4 (PM10)	Avarege hourly value	Percentile 90.4 (PM10)	Avarege hourly value	Percentile 90.4 (PM10)
			Annual limit value [40 µg/m3]	Daily Limit Value [50 µg/m3]	Annual limit value [40 µg/m3]	Daily Limit Value [50 µg/m3]	Annual limit value [40 µg/m3]	Daily Limit Value [50 µg/m3]
R1	Verdala International School Pembrok	3,80 km	0.00023	0.00072	0.00039	0.00121	0.01170	0.03620
R2	Chiswick House School San Gwann	5,36 km	0.00009	0.00028	0.00016	0.00047	0.00464	0.01410
R3	St Catherine?s High School Pembroke	3,31 km	0.00032	0.00096	0.00054	0.00161	0.01610	0.04830
R4	St Michael?s School Pembroke	3,52 km	0.00032	0.00096	0.00053	0.00161	0.01590	0.04820
R5	St Michael?s Foundation San Gwann	3,92 km	0.00007	0.00024	0.00012	0.00040	0.00348	0.01190
R6	St Francis School San Gwann	5,10 km	0.00009	0.00028	0.00015	0.00047	0.00444	0.01420
R7	St Clare Primary College Pembroke	3,50 km	0.00025	0.00078	0.00041	0.00130	0.01240	0.03900
R8	Karmnu Sant Primary School Gharghur	2,22 km	0.00008	0.00024	0.00013	0.00039	0.00379	0.01180
R9	Bice Mizzi Vassallo Primary School P	3,40 km	0.00031	0.00093	0.00051	0.00156	0.01540	0.04690
R10	St Clare Secondary Pembroke	2,93 km	0.00043	0.00138	0.00073	0.00231	0.02180	0.06920
R11	Sprachcaffe Language School Pembroke	3,69 km	0.00022	0.00065	0.00037	0.00109	0.01100	0.03280
R12	San Miguel Resource Centre Pembroke	3,28 km	0.00038	0.00117	0.00063	0.00196	0.01880	0.05890
R13	M.U.S.E.U.M Pembroke	3,62 km	0.00023	0.00069	0.00039	0.00115	0.01160	0.03460
R14	Risen Christ Church Pembroke	3,56 km	0.00023	0.00069	0.00038	0.00116	0.01140	0.03480
R15	National Sports School Pembroke	3,42 km	0.00029	0.00090	0.00049	0.00151	0.01470	0.04540
R16	Simblija Care Home Naxxar	3,49 km	0.00001	0.00004	0.00002	0.00006	0.00060	0.00176
R17	Golden Care Retirement Home Naxxar	2,85 km	0.00002	0.00006	0.00003	0.00011	0.00082	0.00323
R18	Primary School Naxxar	3,24 km	0.00001	0.00004	0.00002	0.00006	0.00060	0.00185
R19	MRC Middle School Naxxar	3,65 km	0.00001	0.00003	0.00002	0.00006	0.00058	0.00171
R20	Giovanni Curmi Higher Secondary Naxx	3,69 km	0.00001	0.00003	0.00002	0.00006	0.00056	0.00169
R21	Naxxar Parish Church Naxxar	3,16 km	0.00001	0.00003	0.00002	0.00006	0.00054	0.00171
R22	St Clare?s Primary College San Gwann	4,72 km	0.00009	0.00026	0.00014	0.00043	0.00428	0.01300
R23	San Gwann Parish Chruh San Gwann	4,93 km	0.00009	0.00027	0.00014	0.00046	0.00431	0.01370
R24	Immaculate Mother of the Church Swie	3,69 km	0.00024	0.00074	0.00040	0.00124	0.01190	0.03710
R25	St Bartholomew Parish Church Gharghu	2,31 km	0.00011	0.00042	0.00019	0.00070	0.00564	0.02100
R26	Clubclass English School Swieqi	4,20 km	0.00016	0.00042	0.00026	0.00071	0.00777	0.02120
R27	Agricultural land Mag?tab	0,43 km	0.00003	0.00012	0.00005	0.00020	0.00156	0.00595
R28	?ona fil-Ba?ar madwar G?awdex - MT000	0,79 km	0.00017	0.00062	0.00029	0.00103	0.00875	0.03100
R29	?ona fil-Ba?ar bejn Il-Ponta ta? San	1,18 km	0.00017	0.00057	0.00028	0.00095	0.00833	0.02860
R30	L-G?adira s-Safra (MT0000008)	0,86 km	0.00022	0.00082	0.00037	0.00137	0.01120	0.04110
R31	Is-Salini (MT0000007)	1,94 km	0.00015	0.00057	0.00025	0.00095	0.00744	0.02850
R32	Triq ir-Ramla Mag?tab Residential &	0,78 km	0.00002	0.00007	0.00003	0.00011	0.00100	0.00335
R33	Triq Jules Verne Naxxar Residential	2,13 km	0.00003	0.00009	0.00005	0.00015	0.00148	0.00434
R34	Triq Fidel Zarb G?arg?ur Residential	1,88 km	0.00018	0.00065	0.00030	0.00109	0.00885	0.03280
R35	Dawret il-Qawra Qawra Residential Ar	2,01 km	0.00020	0.00065	0.00033	0.00109	0.00980	0.03270
R36	Triq Napuljun Tagliaferro Pembroke R	3,48 km	0.00024	0.00075	0.00040	0.00125	0.01190	0.03750
R37	Triq M. Pulis Birkirkara Residential	5,21 km	0.00003	0.00012	0.00005	0.00020	0.00161	0.00589
R38	Constitution Road Mosta Residential	4,04 km	0.00004	0.00011	0.00006	0.00018	0.00195	0.00541
R39	Triq San Guzepp San Gwann Residentia	4,95 km	0.00009	0.00027	0.00014	0.00046	0.00429	0.01370
R40	Parish Street St Paul?s Bay Resident	3,78 km	0.00010	0.00033	0.00017	0.00056	0.00500	0.01670
R41	Triq il-Maghsar Burmarrad Residentia	2,93 km	0.00013	0.00040	0.00022	0.00067	0.00671	0.02010
R42	Triq Preziosi Lija Residential Area	4,37 km	0.00001	0.00003	0.00001	0.00005	0.00045	0.00137
R43	Triq Balaguer Balzan Residential Are	4,85 km	0.00001	0.00005	0.00002	0.00008	0.00058	0.00231
R44	Triq Annabelle Preca Attard Resident	5,13 km	0.00001	0.00004	0.00001	0.00006	0.00045	0.00191
R45	Triq il-Harruba Iklin Residential Ar	3,56 km	0.00002	0.00007	0.00003	0.00012	0.00095	0.00350
R46	Triq L.Apap St Julian?s Residential	4,78 km	0.00020	0.00059	0.00034	0.00099	0.01010	0.02960
R47	Mater Dei Hospital Msida	5,49 km	0.00007	0.00023	0.00011	0.00038	0.00337	0.01140
R48	Tower Road Sliema Residential Area	5,81 km	0.00018	0.00054	0.00031	0.00090	0.00926	0.02710
R49	Farm at Triq il-Katakombi Salina	1,35 km	0.00031	0.00117	0.00052	0.00196	0.01570	0.05890
R50	Farm at Sqaq Habel Zwejra Maghtab	0,95 km	0.00021	0.00077	0.00036	0.00130	0.01070	0.03890
R51	Farm and fields at Triq Burmarrad Bu	2,86 km	0.00010	0.00034	0.00016	0.00057	0.00480	0.01700
R52	Farms at Bahar ic-Caghaq	1,06 km	0.00008	0.00028	0.00014	0.00047	0.00422	0.01400
R53	Agricultural land at Triq il-Wardija	3,02 km	0.00011	0.00034	0.00018	0.00057	0.00537	0.01700
R54	Agricultural land at Triq is-Sagra Fa	5,03 km	0.00008	0.00023	0.00013	0.00038	0.00380	0.01130
R55	Agricultural land Triq Sir Temi Zamm	5,32 km	0.00006	0.00019	0.00009	0.00031	0.00280	0.00934

TABLE 1. MAXIMUM VALUES OF FALLOUT TO THE RECEPTORS (NO₂) FOR TWO SCENARIOS

RECEPTORS		Distance from the chimney(km)	SCENARIO A		SCENARIO B	
			NO ₂		NO ₂	
			Avarege hourly value Annual limit value [40 µg/m3]	Percentile 99.8 (NO2) Hourly Limit Value [200 µg/m3]	Avarege hourly value Annual limit value [40 µg/m3]	Percentile 99.8 (NO2) Hourly Limit Value [200 µg/m3]
R1	Verdala International School Pembrok	3,80 km	0.00652	0.07920	0.01090	0.13300
R2	Chiswick House School San Gwann	5,36 km	0.00257	0.04750	0.00431	0.07960
R3	St Catherine's High School Pembroke	3,31 km	0.00898	0.11100	0.01510	0.18600
R4	St Michael's School Pembroke	3,52 km	0.00886	0.10300	0.01480	0.17200
R5	St Michael's Foundation San Gwann	3,92 km	0.00197	0.06370	0.00331	0.10700
R6	St Francis School San Gwann	5,10 km	0.00246	0.04850	0.00413	0.08120
R7	St Clare Primary College Pembroke	3,50 km	0.00691	0.08740	0.01160	0.14700
R8	Karmnu Sant Primary School Gharghur	2,22 km	0.00218	0.18700	0.00365	0.31300
R9	Bice Mizzi Vassallo Primary School P	3,40 km	0.00860	0.10800	0.01440	0.18100
R10	St Clare Secondary Pembroke	2,93 km	0.01220	0.12700	0.02050	0.21300
R11	Sprachcaffe Language School Pembroke	3,69 km	0.00611	0.08170	0.01020	0.13700
R12	San Miguel Resource Centre Pembroke	3,28 km	0.01060	0.10900	0.01770	0.18400
R13	M.U.S.E.U.M Pembroke	3,62 km	0.00647	0.08360	0.01080	0.14000
R14	Risen Christ Church Pembroke	3,56 km	0.00637	0.08490	0.01070	0.14200
R15	National Sports School Pembroke	3,42 km	0.00822	0.10800	0.01380	0.18100
R16	Simblija Care Home Naxxar	3,49 km	0.00035	0.02770	0.00059	0.04640
R17	Golden Care Retirement Home Naxxar	2,85 km	0.00048	0.03880	0.00080	0.06500
R18	Primary School Naxxar	3,24 km	0.00035	0.02900	0.00059	0.04860
R19	MRC Middle School Naxxar	3,65 km	0.00034	0.02680	0.00057	0.04500
R20	Giovanni Curmi Higher Secondary Naxx	3,69 km	0.00033	0.02660	0.00055	0.04460
R21	Naxxar Parish Church Naxxar	3,16 km	0.00032	0.02780	0.00053	0.04650
R22	St Clare's Primary College San Gwann	4,72 km	0.00239	0.05060	0.00401	0.08480
R23	San Gwann Parish Church San Gwann	4,93 km	0.00240	0.04940	0.00402	0.08280
R24	Immaculate Mother of the Church Swie	3,69 km	0.00662	0.10300	0.01110	0.17200
R25	St Bartholomew Parish Church Gharghu	2,31 km	0.00324	0.18500	0.00543	0.31000
R26	Clubclass English School Swieqi	4,20 km	0.00431	0.06420	0.00723	0.10800
R27	Agricultural land Mag'tab	0,43 km	0.00090	0.06640	0.00152	0.11100
R28	?ona fil-Ba?ar madwar G?awdex - MT000	0,79 km	0.00503	0.29900	0.00844	0.50000
R29	?ona fil-Ba?ar bejn il-Ponta ta? San	1,18 km	0.00480	0.28100	0.00805	0.47000
R30	L-G?adira s-Safra (MT0000008)	0,86 km	0.00645	0.35800	0.01080	0.60000
R31	Is-Salini (MT0000007)	1,94 km	0.00428	0.18200	0.00718	0.30500
R32	Triq ir-Ramla Mag'tab Residential &	0,78 km	0.00059	0.03900	0.00098	0.06540
R33	Triq Jules Verne Naxxar Residential	2,13 km	0.00084	0.12300	0.00141	0.20600
R34	Triq Fidel Zarb G?arg?ur Residential	1,88 km	0.00509	0.22800	0.00853	0.38200
R35	Dawret il-Qawra Qawra Residential Ar	2,01 km	0.00562	0.18500	0.00943	0.31000
R36	Triq Napuljun Tagliaferro Pembroke R	3,48 km	0.00664	0.08740	0.01110	0.14600
R37	Triq M. Pulis Birkirkara Residential	5,21 km	0.00091	0.04480	0.00153	0.07510
R38	Constitution Road Mosta Residential	4,04 km	0.00109	0.05700	0.00183	0.09560
R39	Triq San Guzepp San Gwann Residentia	4,95 km	0.00239	0.04930	0.00401	0.08260
R40	Parish Street St Paul's Bay Resident	3,78 km	0.00283	0.07260	0.00475	0.12200
R41	Triq il-Maghsar Burmarrad Residentia	2,93 km	0.00380	0.11000	0.00637	0.18500
R42	Triq Preziosi Lija Residential Area	4,37 km	0.00026	0.02340	0.00044	0.03920
R43	Triq Balaguer Balzan Residential Are	4,85 km	0.00034	0.03250	0.00056	0.05450
R44	Triq Annabelle Preca Attard Resident	5,13 km	0.00026	0.02160	0.00044	0.03630
R45	Triq il-Harruba Iklin Residential Ar	3,56 km	0.00055	0.05420	0.00092	0.09080
R46	Triq L.Apap St Julian's Residential	4,78 km	0.00555	0.05760	0.00931	0.09660
R47	Mater Dei Hospital Msida	5,49 km	0.00188	0.04570	0.00315	0.07660
R48	Tower Road Sliema Residential Area	5,81 km	0.00506	0.04940	0.00849	0.08280
R49	Farm at Triq il-Katakombi Salina	1,35 km	0.00904	0.31300	0.01520	0.52400
R50	Farm at Sqaq Habel Zwejra Maghtab	0,95 km	0.00617	0.40900	0.01030	0.68600
R51	Farm and fields at Triq Burmarrad Bu	2,86 km	0.00271	0.10800	0.00454	0.18100
R52	Farms at Bahar ic-Caghaq	1,06 km	0.00243	0.23200	0.00408	0.39000
R53	Agricultural land at Triq il-Wardija	3,02 km	0.00306	0.10000	0.00513	0.16800
R54	Agricultural land at Triq is-Sagra Fa	5,03 km	0.00210	0.04870	0.00352	0.08160
R55	Agricultural land Triq Sir Temi Zamm	5,32 km	0.00154	0.04580	0.00258	0.07680

3.5 DEPOSITION RATE EVALUATION

The dispersion model was used to define and calculate the areas in which the mass deposition rates on an annual daily basis are higher.

The results obtained were then compared with the limits indicated in the TOR's and shown below in the table.

TABLE 10: LIMIT OF POLLUTANT

POLLUTANT	LIMIT
Dioxin/Furans	4 pg WHO-TE/m ² ·day (bulk deposition)
Cd	2 µg/m ² ·day (bulk deposition)
As	4 µg/m ² ·day (bulk deposition)
Hg	1 µg/m ² ·day (bulk deposition)
Pb	100 µg/m ² ·day (bulk deposition)
Tl	2 µg/m ² ·day (bulk deposition)

Corine land cover was used for the definition of the type of soil cover, this allowed to define the site-specific parameters for the calculation of the depositions.

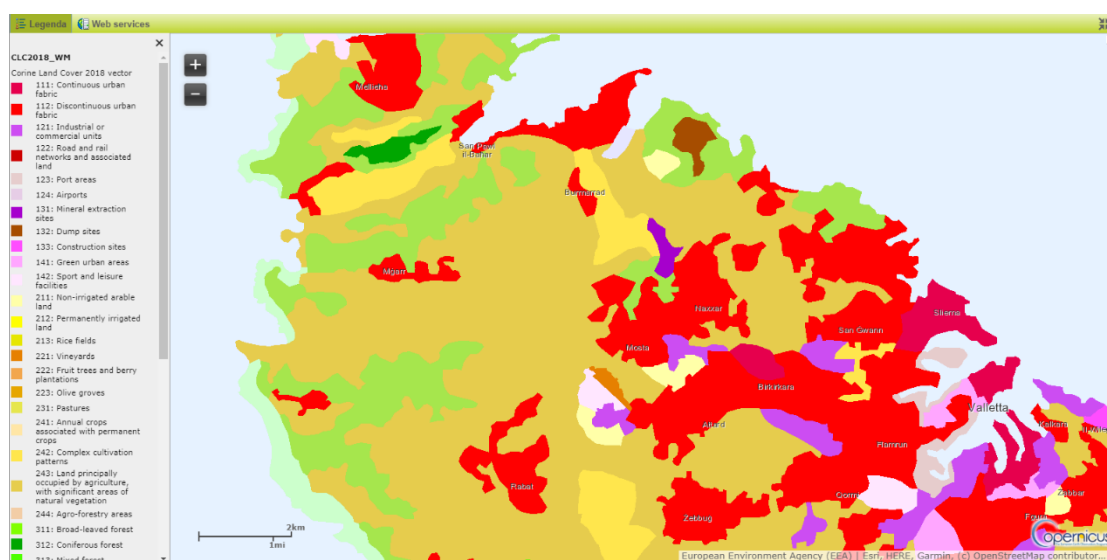


FIGURE 22: EXTRACT OF CORINE LAND COVER UTILIZED IN TO MODELLIZATION

The results obtained are listed below with the individual conservative assessments:

3.5.1 Scenario A

- Metals Group 1

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.0098 $\mu\text{g}/\text{m}^2\cdot\text{day}$, a much lower value than:

- the deposition limit imposed for Cadmium equal to 2 $\mu\text{g}/\text{m}^2\cdot\text{day}$;
- the deposition limit imposed for Thallium equal to 2 $\mu\text{g}/\text{m}^2\cdot\text{day}$;

This result is conservative because it comprises the total of Cd and Tl concentrations – metal of group 1-).

- Metals Group 2

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.0069 $\mu\text{g}/\text{m}^2\cdot\text{day}$, a much lower value than:

- the deposition limit imposed for mercury equal to 1 $\mu\text{g}/\text{m}^2\cdot\text{day}$.

- Metals Group 3

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.00486 $\mu\text{g}/\text{m}^2\cdot\text{day}$, a much lower value than:

- the deposition limit imposed for Arsenic equal to 4 $\mu\text{g}/\text{m}^2\cdot\text{day}$;
- the deposition limit imposed for Nickel equal to 15 $\mu\text{g}/\text{m}^2\cdot\text{day}$;
- the deposition limit imposed for Nickel equal to 100 $\mu\text{g}/\text{m}^2\cdot\text{day}$.

This result is a conservative result because it comprises the total of Sb-As-Pb-Cr-Co-Cu-Mn-Ni-V concentrations –metal of group 3-).

- Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F) + dioxin – like polychlorinated biphenyls (PCBs)

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.0339 pg WHO-TE/ $\text{m}^2\cdot\text{day}$, a much lower value than:

- the deposition limit imposed for Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F) equal to 4 pg WHO-TE/ $\text{m}^2\cdot\text{day}$.

TABLE 11: COMPARISON OF THE TABLE LIMITS IN EIA TORs WITH THE MAXIMUM CONCENTRATIONS – SCENARIO A

POLLUTANT	LIMIT TABLE NO.4 OF TORs 08/05/2024	MASS DEPOSITION RATES ON ANNUAL DAILY BASIS MAX CONC DOMAIN	DISTANCE FROM THE CHIMNEY (KM) MAX CONC DOMAIN	HOURLY AVERAGE VALUE – MAX CONC ON RECEPTORS	DISTANCE FROM THE CHIMNEY (KM) MAX CONC ON RECEPTORS
Cd [µg/m ² ·day]	2	0.0098	2.45	0.0085	2.93
Tl [µg/m ² ·day]	2	0.0098	2.45	0.0085	2.93
Hg [µg/m ² ·day]	1	0.0069	0.21	0.0009	1.18
Ni [µg/m ² ·day]	15	0.0486	2.45	0.0414	2.93
As [µg/m ² ·day]	4	0.0486	2.45	0.0414	2.93
Pb [µg/m ² ·day]	100	0.0486	2.45	0.0414	2.93
PCDD/F + PCB [pgWHO-TE/m ² ·day]	4	0.0339	2.45	0.0286	2.93

3.5.2 Scenario B

- Metals Group 1

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.0164 µg/m²·day, a much lower value than:

- the deposition limit imposed for Cadmium equal to 2 µg/m²·day;
- the deposition limit imposed for Thallium equal to 2 µg/m²·day;

This result is conservative because it comprises the total of Cd and Tl concentrations –metal of group 1-).

- Metals Group 2

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.0115 µg/m²·day, a much lower value than:

- the deposition limit imposed for mercury equal to 1 µg/m²·day.

- Metals Group 3

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.0814 $\mu\text{g}/\text{m}^2\cdot\text{day}$, a much lower value than:

- the deposition limit imposed for Arsenic equal to 4 $\mu\text{g}/\text{m}^2\cdot\text{day}$;
- the deposition limit imposed for Nickel equal to 15 $\mu\text{g}/\text{m}^2\cdot\text{day}$;
- the deposition limit imposed for Nickel equal to 100 $\mu\text{g}/\text{m}^2\cdot\text{day}$.

This result is conservative because it comprises the total of Sb-As-Pb-Cr-Co-Cu-Mn-Ni-V concentrations –metal of group 3-).

- Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F) + dioxin – like polychlorinated biphenyls (PCBs)

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.0568 pg WHO-TE/ $\text{m}^2\cdot\text{day}$ (scenario 1), a much lower value than:

- the deposition limit imposed for Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F) equal to 4 pg WHO-TE/ $\text{m}^2\cdot\text{day}$.

TABLE 12: COMPARISON OF THE TABLE LIMITS IN EIA TORs WITH THE MAXIMUM CONCENTRATIONS – SCENARIO B

POLLUTANT	LIMIT TABLE NO.4 OF TORs 08/05/2024	MASS DEPOSITION RATES ON ANNUAL DAILY BASIS MAX CONC DOMAIN	DISTANCE FROM THE CHIMNEY (KM) MAX CONC DOMAIN	HOURLY AVERAGE VALUE – MAX CONC ON RECEPTORS	DISTANCE FROM THE CHIMNEY (KM) MAX CONC ON RECEPTORS
Cd [$\mu\text{g}/\text{m}^2\cdot\text{day}$]	2	0.0164	2.45	0.0142	2.93
Tl [$\mu\text{g}/\text{m}^2\cdot\text{day}$]	2	0.0164	2.45	0.0142	2.93
Hg [$\mu\text{g}/\text{m}^2\cdot\text{day}$]	1	0.0115	0.21	0.0015	1.18
Ni [$\mu\text{g}/\text{m}^2\cdot\text{day}$]	15	0.0814	2.45	0.0694	2.93
As [$\mu\text{g}/\text{m}^2\cdot\text{day}$]	4	0.0814	2.45	0.0694	2.93
Pb [$\mu\text{g}/\text{m}^2\cdot\text{day}$]	100	0.0814	2.45	0.0694	2.93

POLLUTANT	LIMIT TABLE NO.4 OF TORs 08/05/2024	MASS DEPOSITION RATES ON ANNUAL DAILY BASIS MAX CONC DOMAIN	DISTANCE FROM THE CHIMNEY (KM) MAX CONC DOMAIN	HOURLY AVERAGE VALUE - MAX CONC ON RECEPTORS	DISTANCE FROM THE CHIMNEY (KM) MAX CONC ON RECEPTORS
PCDD/F + PCB [pgWHO-TE/m ² ·day]	4	0.0568	2.45	0.0479	2.93

3.5.3 Scenario C

For Scenario C, the mass deposition rates on an annual daily basis are the same as those shown in Scenario B because in the simulation only modified the dust concentration, as defined by the limits in Schedule 2 of S.L.549.81.

3.6 COMPARISON WITH AIR QUALITY LIMITS

The following table shows the maximum concentration values of the pollutants calculated on the calculation domain and on the receptors when compared with the air quality limits established in DIRECTIVE 2008/50/EC ON QUALITY ENVIRONMENTAL AIR AND CLEANER AIR FOR LIVING IN EUROPE (Table n°2 and Table n°3 of EIA TORs). The results obtained from the air dispersion model show lower values than the limits set in the EIA TORs for each Scenario.

3.6.1 Scenario A

TABLE 13: COMPARISON WITH LIMITS – SCENARIO A

POLLUTANT	TYPE	RESULT - MAX CONC ON DOMAIN	RESULT - MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of Group 1 elements [ng/m ³]	Value	0.002990	0.002291	Cd - 0.15 ng/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of Group 2 elements [ng/m ³]	Value	0.002978	0.002271	Hg - 1.5 ng/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
	Value	0.004563	0.003560	

POLLUTANT	TYPE	RESULT - MAX CONC ON DOMAIN	RESULT - MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of Group 3 elements [ng/m ³]	Receptor/ distance from chimney	0.78km	R10 - 2.93km	Pb - 15 ng/m ³ As - 0.18 ng/m ³ Ni - 0.60 ng/m ³ Cr - 0.50 ng/m ³
Average Hourly value of PCDD/F +PCB [fg WHO-TE/m ³]	Value	0.011893	0.009057	70 fg WHO-TE/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average hourly value of PM ₁₀ [µg/m ³]	Value	0.000555	0.000433	1.2 µg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of PM _{2.5} [µg/m ³]	Value	0.000127	0.000097	0.6 µg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of NO ₂ [µg/m ³]	Value	0.016056	0.012200	1.2 µg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93KM	

TABLE 14: COMPARISON WITH LIMITS – SCENARIO A

POLLUTANT	TYPE	RESULT - MAX CONC ON DOMAIN	RESULT - MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of TVOC [mg/m ³]	Value	0.0000074333	0.0000011322	TVOC - 10 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
	Value	0.0000008920	0.0000006793	HCl - 6 mg/m ³

POLLUTANT	TYPE	RESULT - MAX CONC ON DOMAIN	RESULT - MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of HCl [mg/m ³]	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of HF [mg/m ³]	Value	0.0000001487	0.0000001132	HF - 1 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of SO ₂ [mg/m ³]	Value	0.0000044600	0.0000033965	SO ₂ - 30 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average hourly value of NOx [mg/m ³]	Value	0.0000178398	0.0000135858	NOx - 120 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of NH ₃ [µg/m ³]	Value	0.0000014867	0.0000011322	NH ₃ - 10 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of CO [µg/m ³]	Value	0.0000074333	0.0000056608	CO - 50 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93KM	

3.6.2 Scenario B

TABLE 15: COMPARISON WITH LIMITS – SCENARIO B

POLLUTANT	TYPE	RESULT – MAX CONC ON DOMAIN	RESULT – MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of Group 1 elements [ng/m ³]	Value	0.00501	0.003840	Cd – 0.15 ng/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of Group 2 elements [ng/m ³]	Value	0.00499	0.003807	Hg – 1.5 ng/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of Group 3 elements [ng/m ³]	Value	0.0076	0.005963	Pb – 15 ng/m ³ As – 0.18 ng/m ³ Ni – 0.60 ng/m ³ Cr – 0.50 ng/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of PCDD/F+ PCB [fg WHO-TE/m ³]	Value	0.01994	0.015183	70 fg WHO-TE/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average hourly value of PM ₁₀ [µg/m ³]	Value	0.00093	0.000726	1.2 µg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of PM _{2.5} [µg/m ³]	Value	0.00021	0.000162	0.6 µg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of NO ₂ [µg/m ³]	Value	0.02691	0.020500	1.2 µg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93KM	

TABLE 16: COMPARISON WITH LIMITS – SCENARIO B AND C

POLLUTANT	TYPE	RESULT – MAX CONC ON DOMAIN	RESULT – MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of TVOC [mg/m ³]	Value	0.0000024921	0.0000018979	TVOC – 10 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of HCl [mg/m ³]	Value	0.0000014953	0.0000011400	HCl – 6 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of HF [mg/m ³]	Value	0.0000002492	0.0000001898	HF – 1 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of SO ₂ [mg/m ³]	Value	0.0000074763	0.0000056936	SO ₂ – 30 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average hourly value of NO _x [mg/m ³]	Value	0.0000299053	0.0000227743	NO _x – 120 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
Average Hourly value of NH ₃ [µg/m ³]	Value	0.0000024921	0.0000014867	NH ₃ – 10 mg/m ³
	Receptor/ distance from chimney	0.78km	R10 – 2.93km	
	Value	0.0000124606	0.0000094893	CO – 50 mg/m ³

POLLUTANT	TYPE	RESULT - MAX CONC ON DOMAIN	RESULT - MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of CO [$\mu\text{g}/\text{m}^3$]	Receptor/ distance from chimney	0.78km	R10 - 2.93KM	

3.6.3 Scenario C

TABLE 17: COMPARISON WITH LIMITS – SCENARIO C

POLLUTANT	TYPE	RESULT - MAX CONC ON DOMAIN	RESULT - MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of Group 1 elements [ng/m^3]	Value	0.00501	0.003840	Cd - 0.15 ng/m^3
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of Group 2 elements [ng/m^3]	Value	0.00499	0.003807	Hg - 1.5 ng/m^3
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of Group 3 elements [ng/m^3]	Value	0.0076	0.005963	Pb - 15 ng/m^3 As - 0.18 ng/m^3 Ni - 0.60 ng/m^3 Cr - 0.50 ng/m^3
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of PCDD/F+ PCB [$\text{fg WHO-TE}/\text{m}^3$]	Value	0.01994	0.015183	70 $\text{fg WHO-TE}/\text{m}^3$
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average hourly value of PM_{10} [$\mu\text{g}/\text{m}^3$]	Value	0.00093	0.021800	1.2 $\mu\text{g}/\text{m}^3$
	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
	Value	0.00021	0.004854	0.6 $\mu\text{g}/\text{m}^3$

POLLUTANT	TYPE	RESULT - MAX CONC ON DOMAIN	RESULT - MAX CONC ON RECEPTORS	LIMIT AS PER EIA TORs
Average Hourly value of PM _{2.5} [µg/m ³]	Receptor/ distance from chimney	0.78km	R10 - 2.93km	
Average Hourly value of NO ₂ [µg/m ³]	Value	0.02691	0.020500	1.2 µg/m ³
	Receptor/ distance from chimney	0.78km	R10 - 2.93KM	

3.7 CALIBRATION

The second phase of the study a 6-week monitoring was conducted to establish the baseline values of PM₁₀ (*Skypost*) and 6-week monitoring was conducted to establish the baseline values of NO₂ (*Passam*), the results obtained from the monitoring are reported in this chapter.

3.7.1 Baseline results of PM₁₀

The PM₁₀ concentrations detected by monitoring from 23 September 2024 to 9 November 2024 were influenced, on some days, by "Sahara Dust" and are therefore excluded from the scope of this work.

Following the acquisition of results, PM₁₀ concentration data were retrieved from ERA's website¹ () to evaluate trends observed across the four meteorological stations located in Maltese territory (see figure below). Several peak concentrations were recorded concurrently at all four sites. These peaks were subsequently cross-checked against laboratory results. In addition, forecasts from the Barcelona Dust Regional Centre (Daily Dust Products — WMO Barcelona Dust Regional Center (aemet.es) were consulted, which indicated a high likelihood that the elevated PM₁₀ levels measured on the 3rd, 9th and 10th of October were attributable to the presence of Saharan dust (see Figure 23)).

¹ <https://era.org.mt/air-quality-widget/>

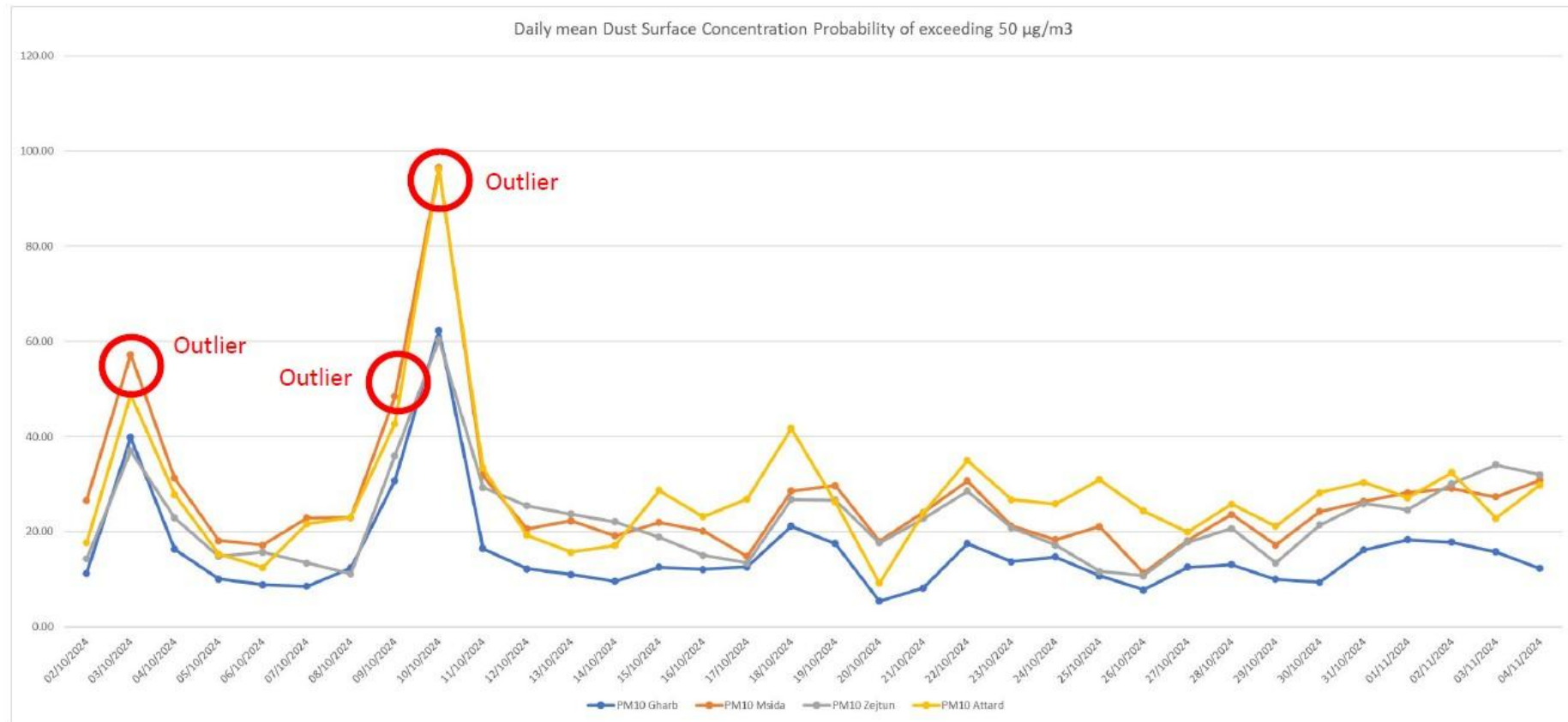


FIGURE 3: DAILY MEAN SURFACE CONCENTRATION IN THE STATION OF GHARB, MSIDA, ZETJUN AND ATTARD ([HTTPS://ERA.ORG.MT/AIR-QUALITY-WIDGET/](https://era.org.mt/air-quality-widget/))

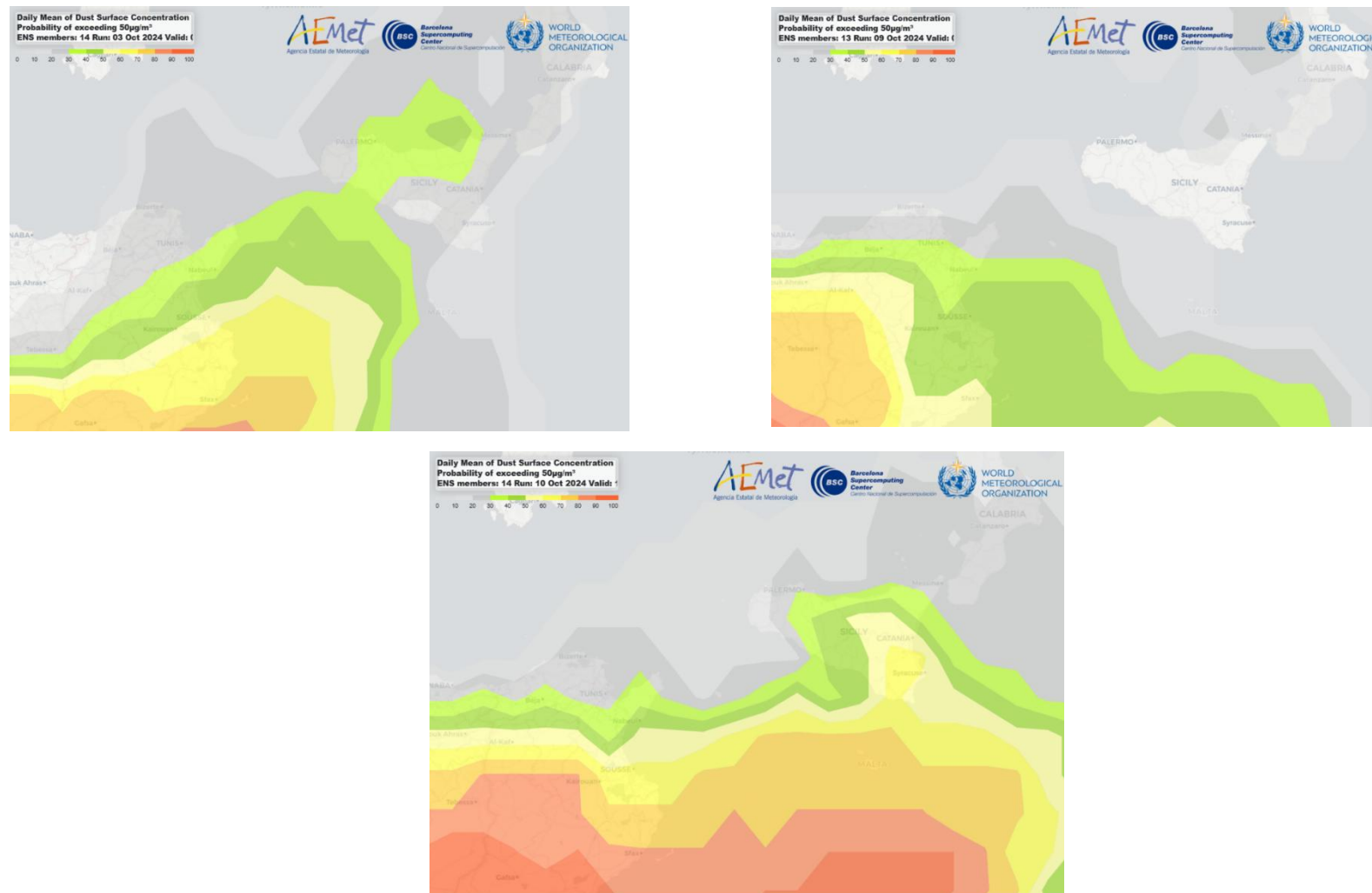


FIGURE 23: INTERACTIVE MAPS DOWNLOADED FROM THE WMO WEBSITE ON 3RD, 9TH AND 10TH OCTOBER (DAILY DUST PRODUCTS — WMO BARCELONA DUST REGIONAL CENTER (AEMET.ES))

The analytical results obtained in the six weeks of PM₁₀ monitoring by the Skypost sequential sampler installed on site are shown below. Readings affected by Sahara dust events are marked with an asterisk (*) as they were discarded from this analysis. Such events were observed on the 3rd, 9th, and October 10th 2024. For this reason, three additional days of monitoring were conducted, for a total of 45 days.

TABLE 18: PM₁₀ AIR QUALITY RESULTS OBTAINED FROM THE 6 WEEK SAMPLING CAMPAIGN

DATE	CONCENTRATION $\mu\text{G}/\text{M}^3$
23/09/2024	33
25/09/2024	34
26/09/2024	41
28/09/2024	29
29/09/2024	34
30/09/2024	29
01/10/2024	28
02/10/2024	52
03/10/2024	110*
04/10/2024	65
05/10/2024	31
06/10/2024	37
07/10/2024	35
08/10/2024	50
09/10/2024	63*
10/10/2024	134*
11/10/2024	75
12/10/2024	39
13/10/2024	35
14/10/2024	49
15/10/2024	41
16/10/2024	48
17/10/2024	71
18/10/2024	41
19/10/2024	30
20/10/2024	22
21/10/2024	35
22/10/2024	32
24/10/2024	83
25/10/2024	33
26/10/2024	65
27/10/2024	33
28/10/2024	26
29/10/2024	18
30/10/2024	32
31/10/2024	54

DATE	CONCENTRATION $\mu\text{g}/\text{M}^3$
01/11/2024	47
02/11/2024	43
03/11/2024	45
04/11/2024	69
05/11/2024	53
06/11/2024	30
07/11/2024	88
08/11/2024	22
09/11/2024	48

The statistical parameters obtained from the aforementioned baseline readings are summarised below:

TABLE 19: STATISTICAL PARAMETERS

AVERAGE	90,4° PERCENTILE	MIN	MAX	DEV.ST	MEDIAN
42.98	69.13	18.00	88.00	16.67	38.00

Considering a baseline value equal to $42.98 \mu\text{g}/\text{m}^3$, the annualization factor 0.85 the result of the CAA calculation is equal to $36.53 \mu\text{g}/\text{m}^3$.

3.7.2 Baseline Results of NO_2

The analytical results obtained in the six weeks of NO_2 monitoring are shown below.

Test Report Air Pollution Measurement

NO2

Nitrogen dioxide measurement by means of passive sampler

passam ag

air quality monitoring

customer information

customer: AIS Environment Ltd.
customer ID: MAI
contact person: Sacha Dunlop
project: Air Quality Study for EPCM -
reference: for Thermal Treatment Facility

passive samplers

date received: 06.11.2024
type: tube (Palms)
pollutant: NO2
limit of detection: 0.5 µg/m3 (14 days)
sampling rate: 0.734 [ml/min]
protective filter: yes

analysis

method: SP01 photometer, Salzmann
analyte: NO2-
date: 12.11.2024
place: passam ag

test report

created on: 13.11.2024
created by: K. Bodei
checked on: 13.11.2024
checked by: T. Hangartner
file name: MAI012401
pages: 1

ISO 17025
ACCREDITED

note: applies to the sample as received; results below the detection limit are indicated with "<" and the associated value; this method is accredited to ISO/IEC 17025 measurement uncertainty <25%; sampling rate related to 20 °C; further information at [www.passam.ch](#)

measuring site	passive sampler		measuring period				exp. time [h]	measurement			result		Comment on the analysis
			start		end			blank	dilution	sample value	m analyte/ sampler	C NO2	
	label	lot no.	date	time	date	time		[ABS]		[ABS]	[µg]	[µg/m3]	
35 938010, 14 449480	MAI-1	45482	23/09/2024	13:45	14/10/2024	14:08	504.4	0.002	1	0.113	0.25	11.1	
35 938010, 14 449480	MAI-10	45482	23/09/2024	13:45	14/10/2024	14:08	504.4	0.002	1	0.113	0.25	11.1	
35 938010, 14 449480	MAI-3	45482	14/10/2024	14:08	04/11/2024	13:45	503.6	0.002	1	0.132	0.29	13.0	
35 938010, 14 449480	MAI-4	45482	14/10/2024	14:08	04/11/2024	13:45	503.6	0.002	1	0.131	0.29	12.9	

The statistical parameters obtained from the aforementioned baseline readings are summarised below:

TABLE 20: STATISTICAL PARAMETERS NO₂

AVERAGE	99,8° PERCENTILE	MIN	MAX	DEV.ST	MEDIAN
12.04	13.02	11.1	13.03	1.08	12.02

Considering a baseline value equal to $12.04 \mu\text{g}/\text{m}^3$, the annualization factor 0.96 the result of the CAA calculation is equal to $11.56 \mu\text{g}/\text{m}^3$.

3.8 IMPACT ASSESSMENT AT RECEPTORS

The thematic maps shown in the following figures describe the spatial distribution of the sensitive receptors with respect to the survey area and the relationships between each receptor and the calculated concentrations of PM₁₀, and NO₂.

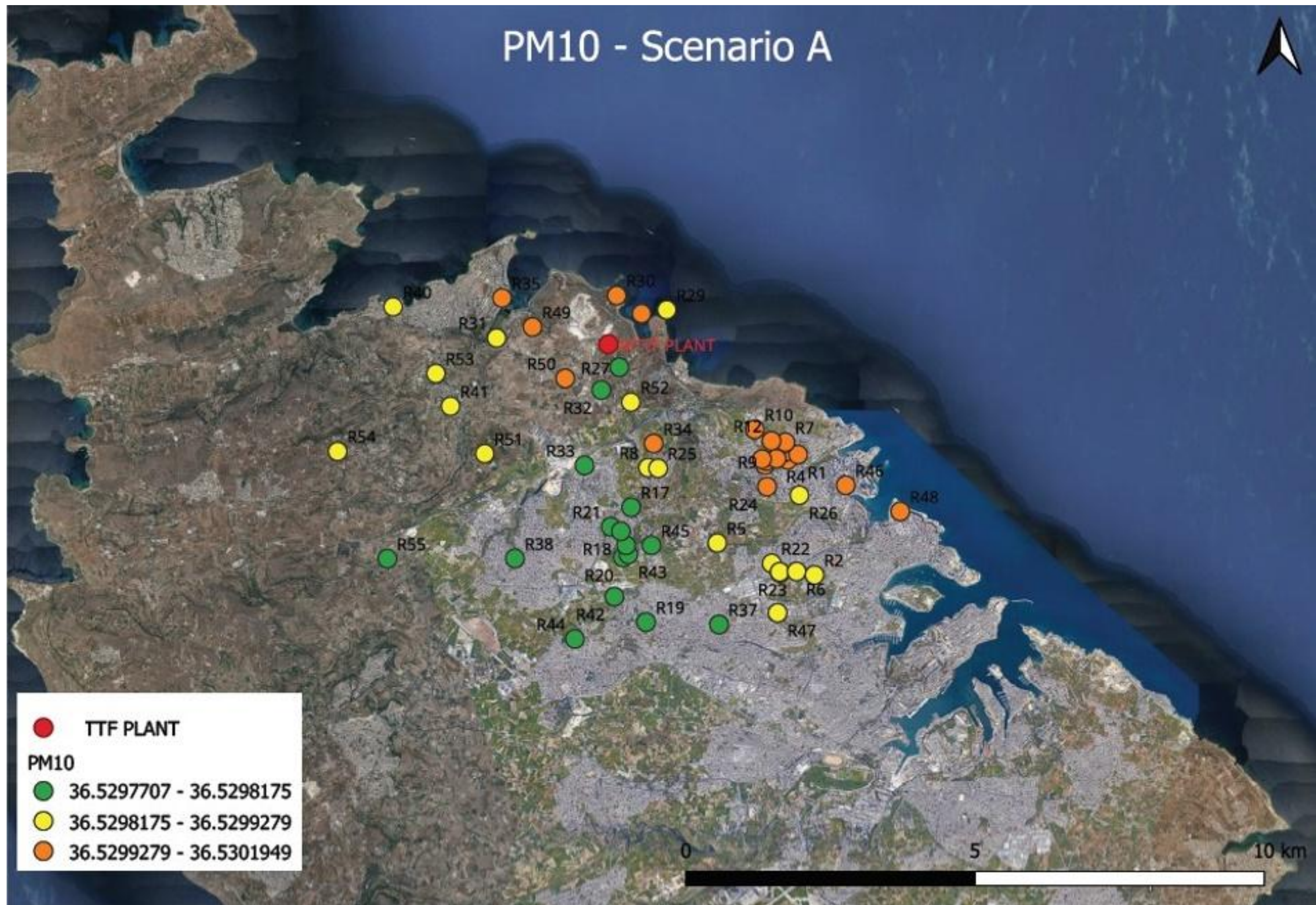
A summary table was also drawn up where the concentration value calculated by the model and integrated with the values obtained from monitoring was reported.

A color scale was used to emphasize the most disturbed sensitive receptors, the color scale varies from green (lower concentrations) to red (higher concentrations).

TABLE 21: IMPACT ASSESSMENT – SCENARIO A

RECEPTOR NO.	BASELINE PM ₁₀ (CAA)	PREDICTED PM ₁₀	CHANGE PM ₁₀ (DAA)	IMPACT ¹		BASELINE NO ₂ (CAA)	PREDICTED NO ₂	CHANGE NO ₂ (DAA)	IMPACT ¹
	µG/M ³	µG/M ³	µG/M ³			µg/m ³	µg/m ³	µg/m ³	
R1 to R55	36.53	36.530	0.00001 - 0.00043	N/S		11.56	11.558 - 11570	0.000259 - 0.0122	N/S

¹ Not Significant (N/S), Minor (MI), Moderate (MO), Major (MA)

FIGURE 24: PM₁₀ RESULTS – SCENARIO A

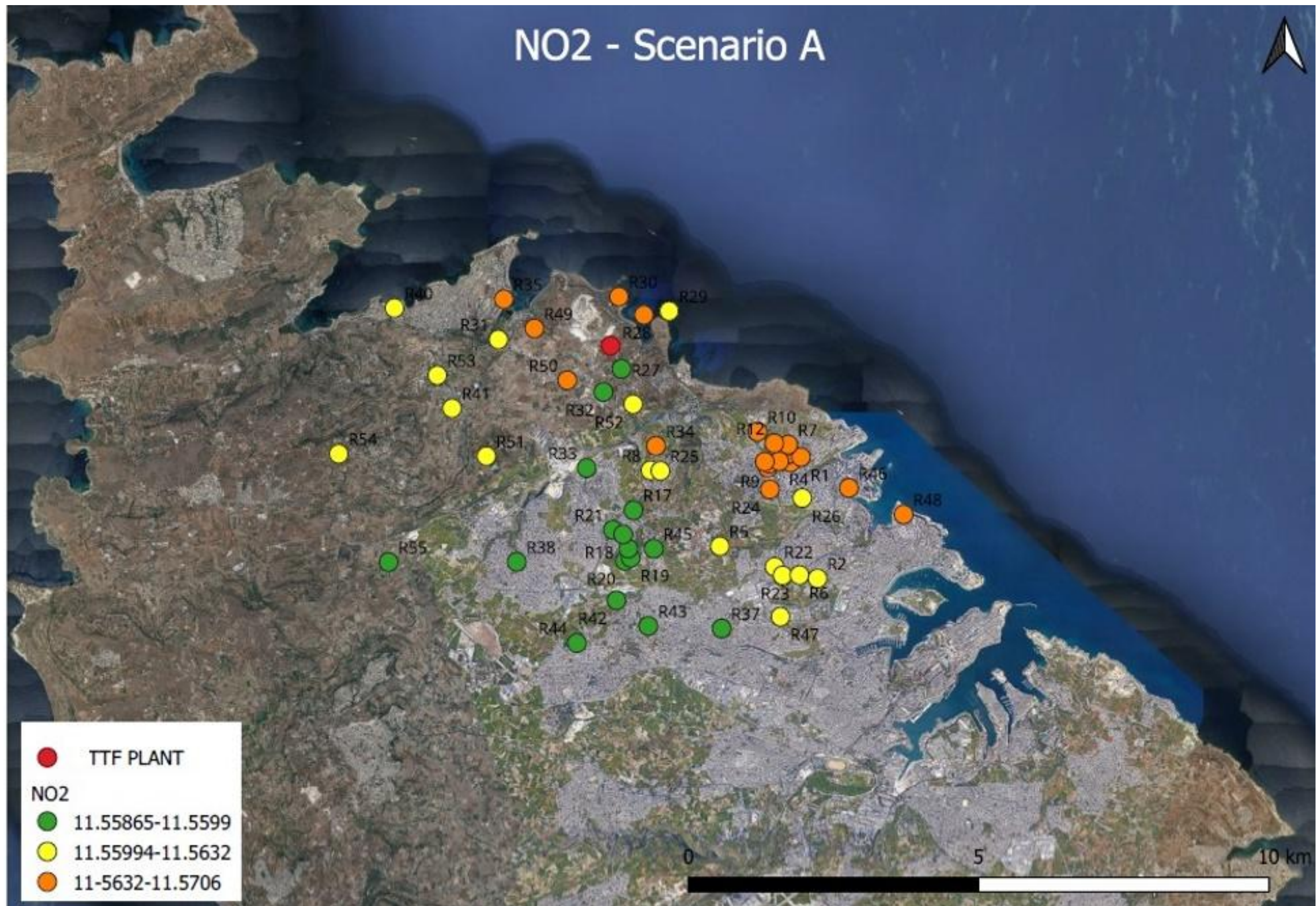
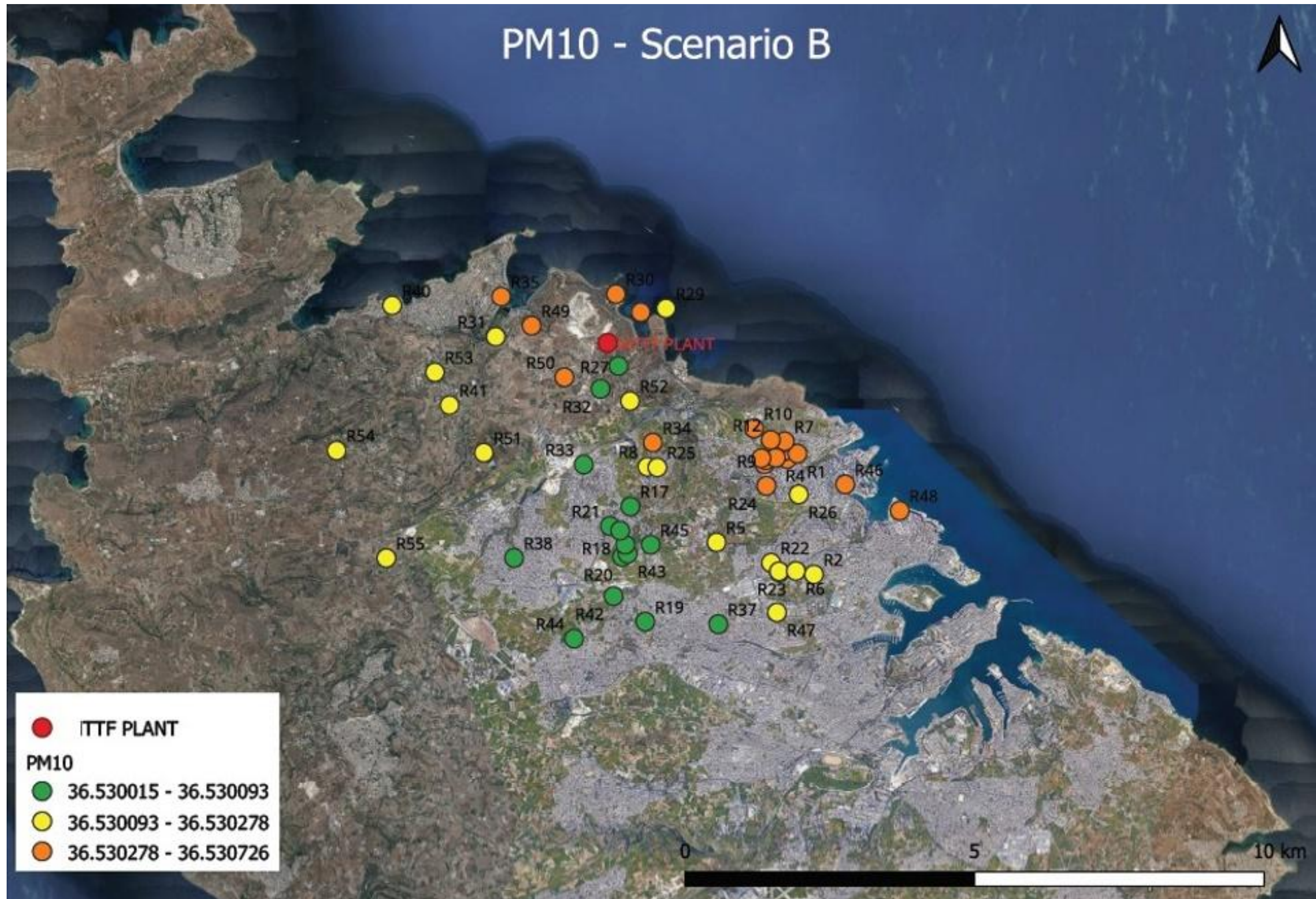


FIGURE 25: NO2 RESULTS – SCENARIO A

TABLE 22: IMPACT ASSESSMENT – SCENARIO B

RECEPTOR NO.	BASELINE PM ₁₀ (CAA)	PREDICTED PM ₁₀	CHANGE PM ₁₀ (DAA)	IMPACT ¹		BASELINE NO ₂ (CAA)	PREDICTED NO ₂	CHANGE NO ₂ (DAA)	IMPACT ¹
	µG/M ³	µG/M ³	µG/M ³			µg/m ³	µg/m ³	µg/m ³	
R1 to R55	36.53	36.530 - 36531	0.00001 - 0.00073	N/S		11.56	11.558 - 11578	0.00043 - 0.0205	N/S

¹Not Significant (N/S), Minor (MI), Moderate (MO), Major (MA)

FIGURE 26: PM₁₀ RESULTS – SCENARIO B

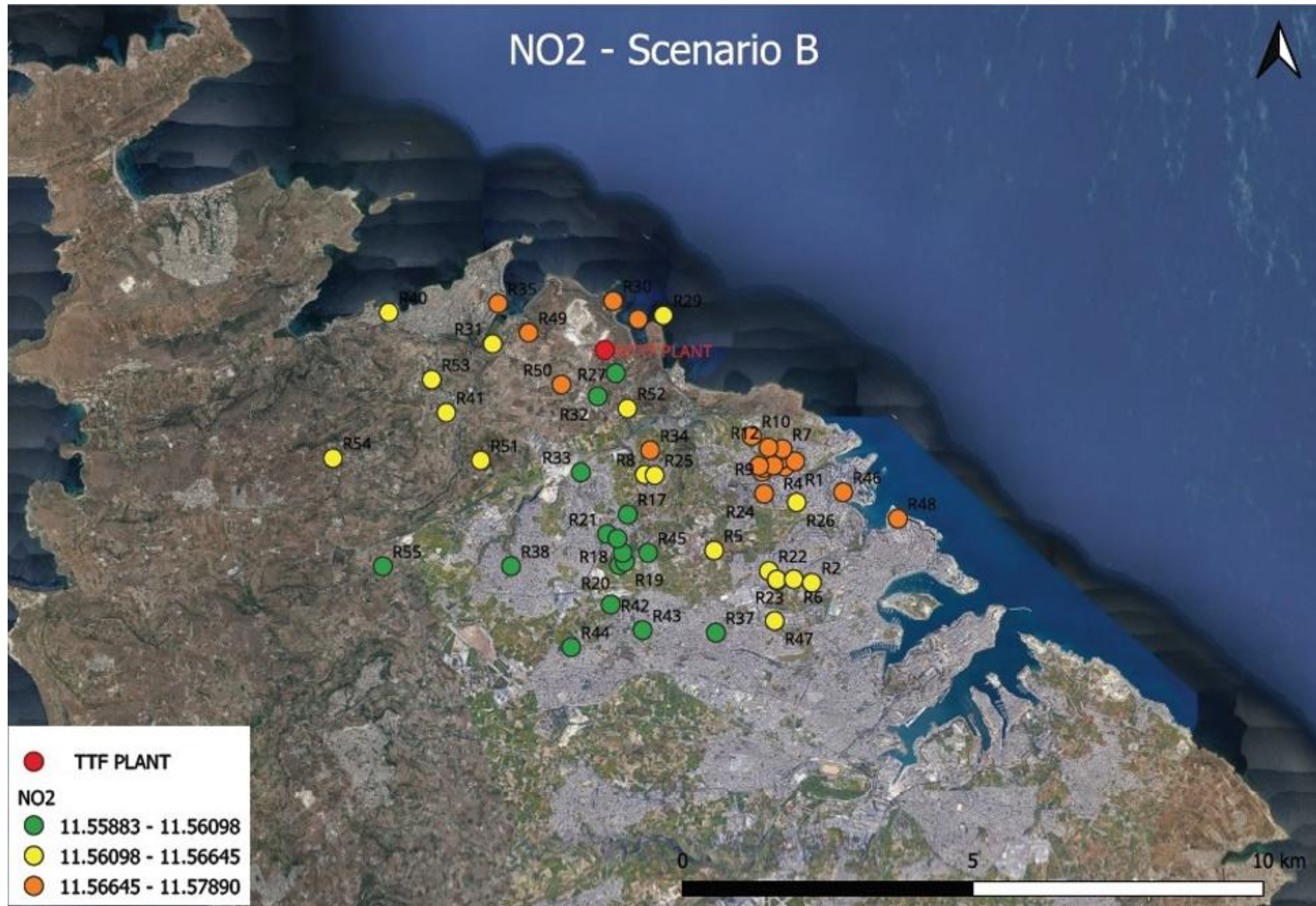


FIGURE 27: RESULTS NO2 - SCENARIO B

TABLE 23: IMPACT ASSESSMENT – SCENARIO C

RECEPTOR NO.	BASELINE PM ₁₀ (CAA)	PREDICTED PM ₁₀	CHANGE PM ₁₀ (DAA)	IMPACT ¹		BASELINE NO ₂ (CAA)	PREDICTED NO ₂	CHANGE NO ₂ (DAA)	IMPACT ¹
	µG/M ³	µG/M ³	µG/M ³			µg/m ³	µg/m ³	µg/m ³	
R1 to R55	36.53	36.530 - 36551	0.00044 - 0.0218	N/S		11.56	11.558 - 11578	0.000435 - 0.0205	N/S

¹ Not Significant (N/S), Minor (MI), Moderate (MO), Major (MA)

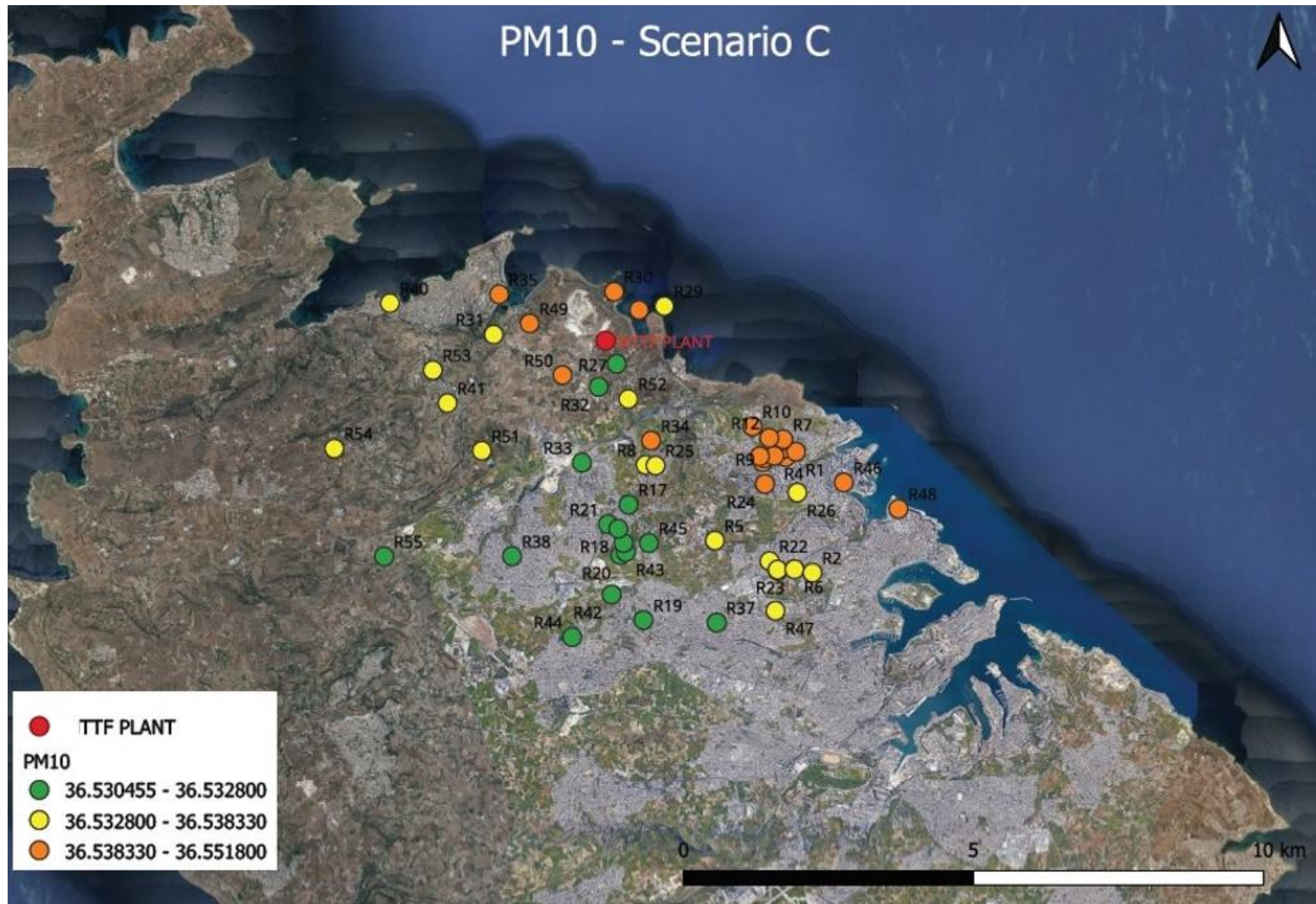


FIGURE 28: PM10 RESULTS – SCENARIO C

3.8.1 Summary of Impact table

TABLE 24: SUMMARY OF IMPACTS TABLE

IMPACT TYPE AND SOURCE			IMPACT RECEPTOR		EFFECT & SCALE							PROBABILITY OF IMPACT	OVERALL IMPACT SIGNIFICANCE	PROPOSED MITIGATION MEASURES	RESIDUAL IMPACT SIGNIFICANCE	OTHERS REQUIREMENTS
IMPACT TYPE	SPECIFIC INTERVENTION LEADING TO IMPACT	PROJECT PHASE (CONSTRUCTION/ OPERATION/ DECOMMISSIONING)	RECEPTOR TYPE	SENSITIVITY & RESILIENCE TOWARD IMPACT	DIRECT/ INDIRECT/ CUMULATIVE	BENEFICIAL/ ADVERSE	SEVERITY	PHYSICAL/ GEOGRAPHIC EXTENT OF IMPACT	SHORT- / MEDIUM- / LONG-TERM	TEMPORARY (INDICATE DURATION)/ PERMANENT	REVERSIBLE (INDICATE EASE OF REVERSIBILITY)/ IRREVERSIBLE					
Emissions from stack	Hazardous waste incineration plant	Operation	Residential areas, Agricultural land and disturbed ground Natura2000 Sites of Community Importance (SCI) Natura2000 Special Protection Area (SPA) Natura2000 SPA and SCI Tree Protected Areas	High	Direct	Adverse	High	Immediate surroundings	Long-term	Temporary combustion phases	Reversible with some difficulty	Remote	Not significant	Monitoring of the pollutants levels around the Scheme to ensure that they are within limits, and periodic monitoring and maintenance of the abatement technologies	Not significant	N/A

In conclusion, the impact for the three simulation scenarios, corresponding to three different plant operations, is the same and therefore not significant.

3.9 CUMULATIVE IMPACT

The cumulative impacts of the project were assessed with those of other existing and/or approved projects and other waste management plants identified within the Waste Management Plan Waste (2021 -2030). This assessment takes into account existing environmental problems, areas of particular environmental importance that may be affected and the use of natural resources. Specifically, the cumulative impact was assessed between the Thermal Treatment Facility built (TTF) plant project with the Maghtab Waste to Energy Facility (WtE).

The results obtained show that the cumulative impact of the project and the Waste to Energy facility can be considered for:

- Scenario A
 - Not Significant for NO₂;
 - Not Significant for PM₁₀, except in the R27 receptor where the change in the annual PM₁₀ (dAA) levels due to scheme is equal to 0,4 µg/m³ and the Impact result is Minor.
- Scenario B
 - Not Significant for NO₂;
 - Not Significant for PM₁₀, except in the R27 receptor where the change in the annual PM₁₀ (dAA) levels due to scheme is equal to 0,4 µg/m³ and the Impact result is Minor;
- Scenario C
 - Not Significant for NO₂;
 - Not Significant for PM₁₀, except at R27 receptor where the change in the annual PM₁₀ (dAA) levels due to scheme is equal to 0,4 µg/m³ and the Impact result is Minor;

The overlap of the emissions from two production plants (WtE and TTF) does not show a substantial variation in the fallout calculated at the sensitive receptors identified in the investigated areas, compared to what was obtained only from the TTF.

The results obtained show that the operation of the TTF plant adjacent to the WtE plant, does not produce a significant worsening of the atmospheric impact on the identified receptors.

The results obtained show for NO₂ and PM₁₀ concentrations higher than 0.3 µg/m³ occurred up to a distance of approximately 1.35 km from the chimney in a north-east and north-west direction, specifically at the R27 - R28 - R29 - R30 - R49 - R50 - R52 receptors, but the value is significantly lower than the 40.0 µg/m³ limit (ALV), thus contributing to a negligible adverse impact.

TABLE 25: CUMULATIVE IMPACT – SCENARIO A

RECEPTOR	BASELINE PM ₁₀ (CAA)	PREDICTED PM ₁₀	CHANGE PM10 (DAA) TTF+WTE	IMPACT ¹	BASELINE NO ₂ (CAA)	PREDICTED NO ₂	CHANGE NO ₂ (DAA) TTF+WTE	IMPACT ¹
	µG/M ³	µG/M ³	µG/M ³		µG/M ³	µG/M ³	µG/M ³	
R1 to R26	36.53	36.57 – 36.69	0.04 – 0.16	N/S	11.56	11.60 – 11.73	0.04 – 0.17	N/S
R27		37.000	0.470	MI		12.281	0.721	N/S
R28		36.880	0.350	N/S		12.105	0.545	N/S
R29		36.850	0.320	N/S		12.065	0.505	N/S
R30		36.880	0.350	N/S		12.106	0.546	N/S
R31 to R48		36.58 – 36.78	0.05 – 0.25	N/S		11.60 – 11.81	0.04 – 0.255	N/S
R49		36.840	0.310	N/S		12.049	0.489	N/S
R50		36.890	0.360	N/S		12.126	0.566	N/S
R51		36.640	0.110	N/S		11.673	0.113	N/S
R52		36.840	0.310	N/S		12.042	0.482	N/S
R53 to R55		36.60 – 36.66	0.07 – 0.130	N/S		11.63 – 11.69	0.07 – 0.133	N/S

¹ Not Significant (N/S), Minor (MI), Moderate (MO), Major (MA)

TABLE 26: CUMULATIVE IMPACT – SCENARIO B

RECEPTOR	BASELINE PM ₁₀ (CAA)	PREDICTED PM ₁₀	CHANGE PM10 (DAA) TTF+WTE	IMPACT ¹	BASELINE NO ₂ (CAA)	PREDICTED NO ₂	CHANGE NO ₂ (DAA) TTF+WTE	IMPACT ¹
	µG/M ³	µG/M ³	µG/M ³		µG/M ³	µG/M ³	µG/M ³	
R1 to R26	36.53	36.57 – 36.69	0.04 – 0.16	N/S	11.56	11.60 – 11.74	0.04 - 0.18	N/S
R27		37.000	0.470	MI		12.281	0.721	N/S
R28		36.880	0.350	N/S		12.108	0.548	N/S
R29		36.850	0.320	N/S		12.066	0.508	N/S
R30		36.880	0.350	N/S		12.110	0.550	N/S
R31 to R48		36.57 – 36.78	0.04 – 0.25	N/S		11.60 - 11.81	0.04 - 0.259	N/S
R49		36.840	0.310	N/S		12.055	0.495	N/S
R50		36.890	0.360	N/S		12.130	0.570	N/S
R51		36.640	0.110	N/S		11.674	0.114	N/S
R52		36.840	0.310	N/S		12.044	0.484	N/S
R53 to R55		36.60 – 36.66	0.07 - 0.130	N/S		11.63 – 11.69	0.07 - 0.135	N/S

¹ Not Significant (N/S), Minor (MI), Moderate (MO), Major (MA)

TABLE 27: CUMULATIVE IMPACT – SCENARIO C

RECEPTOR	BASELINE PM ₁₀ (CAA)	PREDICTED PM ₁₀	CHANGE PM10 (DAA) TTF+WTE	IMPACT ¹	BASELINE NO ₂ (CAA)	PREDICTED NO ₂	CHANGE NO ₂ (DAA) TTF+WTE	IMPACT ¹
	µG/M ³	µG/M ³	µG/M ³		µG/M ³	µG/M ³	µG/M ³	
R1 to R26	36.53	36.57 – 36.71	0.04 – 0.18	N/S	11.56	11.60 – 11.74	0.04 - 0.185	N/S
R27		37.000	0.471	MI		12.281	0.721	N/S
R28		36.888	0.358	N/S		12.108	0.548	N/S
R29		36.858	0.328	N/S		12.068	0.508	N/S
R30		36.891	0.361	N/S		12.110	0.550	N/S
R31 to R48		36.57 – 36.78	0.04 – 0.25	N/S		11.60 - 11.81	0.04 - 0.259	N/S
R49		36.840	0.325	N/S		12.055	0.495	N/S
R50		36.890	0.370	N/S		12.130	0.570	N/S
R51		36.640	0.114	N/S		11.674	0.114	N/S
R52		36.840	0.314	N/S		12.044	0.484	N/S
R53 to R55		36.60 – 36.66	0.07 - 0.130	N/S		11.63 – 11.69	0.07 - 0.133	N/S

¹ Not Significant (N/S), Minor (MI), Moderate (MO), Major (MA)

4 EMISSIONS IN TONS

The annual emission loads in tons have been estimated assuming that the incinerator complies with the daily limit values in Table 3 of EIA TOR (Appendix 4B). The limit values in the TORs are expressed as dry gas at 273.15 K, 101.3 kPa, and 11% oxygen.

TABLE 28 – DAILY LIMIT VALUE OF TABLE 3 OF EIA TORs

POLLUTANTS	LIMIT VALUE 1 [mg/Nm ³]	LIMIT VALUE 2 [mg/Nm ³]	LIMIT VALUE 3[mg/Nm ³]
Dust	1	5	10
SO ₂	1	40	50
NO _x	30	100	200
TOC	1	10	-
NH ₃	1	10	-

The annual emission loads in tons have been estimated multiplying the values in the TORs, relating to LIMIT VALUE 1, with the mass flow of:

- Scenario A equal to 2.29 Nm³/s;
- Scenario B and Scenario C equal to 3.83 Nm³/s.

TABLE 29 – ANNUAL EMISSION LOADS IN TONS ESTIMATED MULTIPLYING THE LIMIT VALUE 1 WITH THE MASS FLOW OF SCENARIO A

POLLUTANTS	LIMIT VALUE 1 [TON/YEAR]
Dust	0.072112
SO ₂	0.072112
NO _x	2.163370
TOC	0.072112
NH ₃	0.072112

TABLE 30 – ANNUAL EMISSION LOADS IN TONS ESTIMATED MULTIPLYING THE LIMIT VALUE 1 WITH THE MASS FLOW OF SCENARIO B/C

POLLUTANTS	LIMIT VALUE 1 [TON/YEAR]
Dust	0.120884
SO ₂	0.120884
NO _x	3.626509
TOC	0.120884
NH ₃	0.120884

The EIA TOR of 08/05/2024 also specifies the need to estimate the annual emission loads in tons based on the daily emission contribution foreseen by the TTF for dust, SO₂, NO_x, TVOC and NH₃.

The annual emission loads in tons were estimated on the basis of the daily emission contribution foreseen by the TTF for dust (PM_{2.5} and PM₁₀), SO₂, NO_x, TVOC and NH₃.

The maximum concentration values present in the calculation domain were considered and subsequently multiplied by the mass flow rate.

TABLE 31 – THE ANNUAL MISSION LOADS IN TONS ESTIMATED ON TTF'S DOMAIN OF SCENARIO A

POLLUTANTS	[TON/YEAR]
PM _{2.5}	0.0000091261
PM ₁₀	0.0000400335
SO ₂	0.0003216177
NO _x	0.0012864708
TOC	0.0001072059
NH ₃	0.0001072059

TABLE 32 – THE ANNUAL MISSION LOADS IN TONS ESTIMATED ON TTF'S DOMAIN OF SCENARIO B

POLLUTANTS	[TON/YEAR]
PM _{2.5}	0.0000256450
PM ₁₀	0.0001124967
SO ₂	0.0009037657
NO _x	0.0036150633
TOC	0.0003012553
NH ₃	0.0003012553

TABLE 33 – THE ANNUAL MISSION LOADS IN TONS ESTIMATED ON TTF'S DOMAIN OF SCENARIO C

POLLUTANTS	[TON/YEAR]
PM _{2.5}	0.0007693475
PM ₁₀	0.0033748978
SO ₂	0.0009037657
NO _x	0.0036150633
TOC	0.0003012553
NH ₃	0.0003012553

5 CONCLUSIONS

A 6-week air quality monitoring campaign was developed which made it possible to know the average daily concentrations of PM_{10} . Similarly, a 6-week air quality monitoring campaign was developed which made it possible to know the average daily concentrations of NO_2 .

The concentration values obtained formed the basis for evaluating the possible interferences between the sensitive receptors identified in the survey area and the repercussions due to the new Maghtab Thermal Treatment Facility.

A significance criteria table was used to determine the significance of the impact at all sensitive receptors and at any point within the investigated area, the results obtained made it possible to reach the following conclusions:

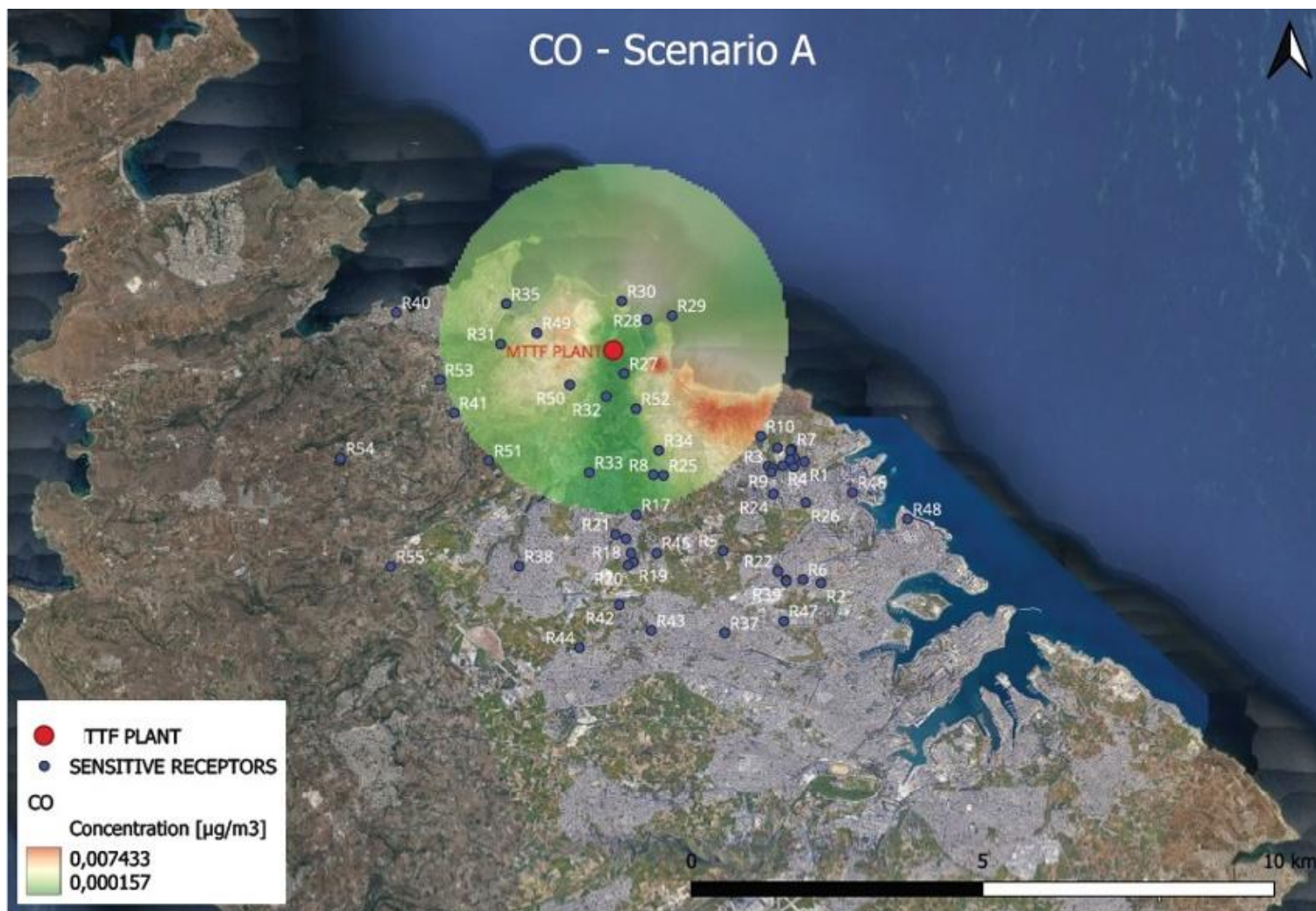
For PM_{10} , the annualization factor 0.85 achieved a CAA value equal to $36.53 \mu\text{g}/\text{m}^3$. This value is significantly lower than the Annual Limit Value ALV ($40 \mu\text{g}/\text{m}^3$) of PM_{10} therefore contributing to a non-significant impact for each Scenario simulated at each sensitive receptor considered.

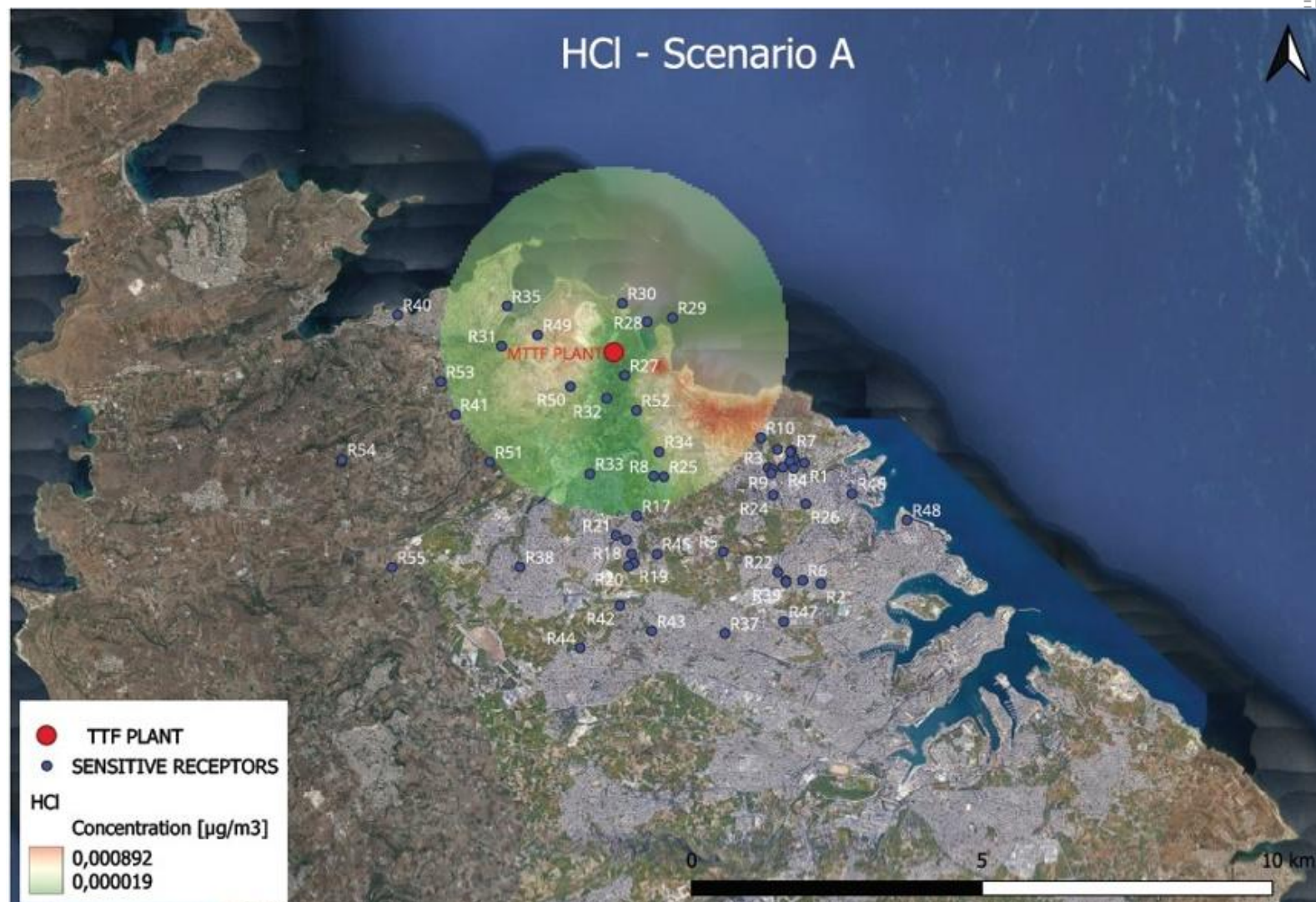
For NO_2 , the annualization factor 0.96 achieved a CAA value equal to $11.56 \mu\text{g}/\text{m}^3$. This value is significantly lower than the Annual Limit Value ALV $40 \mu\text{g}/\text{m}^3$ of NO_2 therefore contributing to a non-significant impact for each Scenario simulated at each sensitive receptor considered.

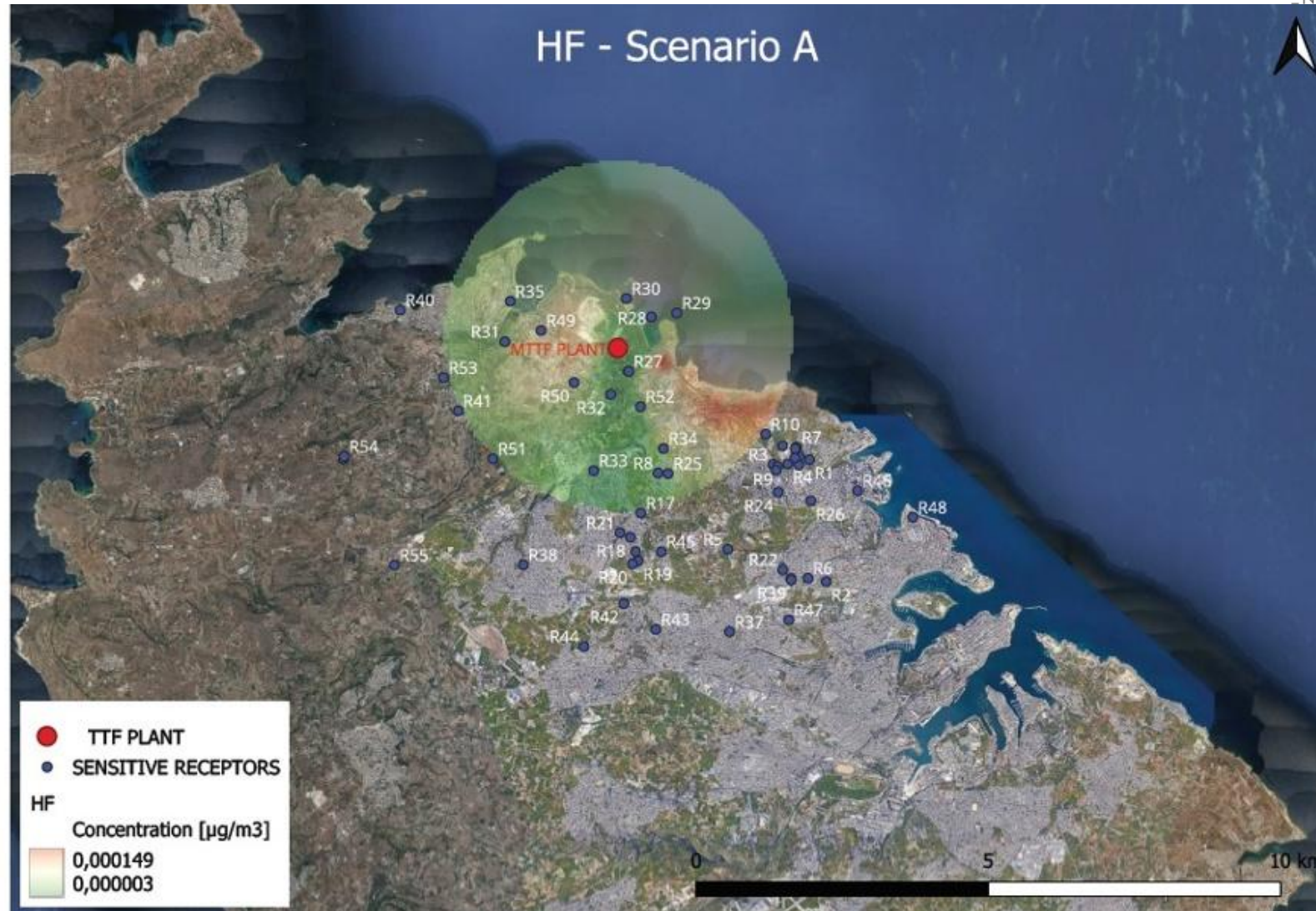
The development of the deposition fallout model carried out across the three scenarios at a stack height of 25m shows that there are no significant variations in the impacts on air quality.

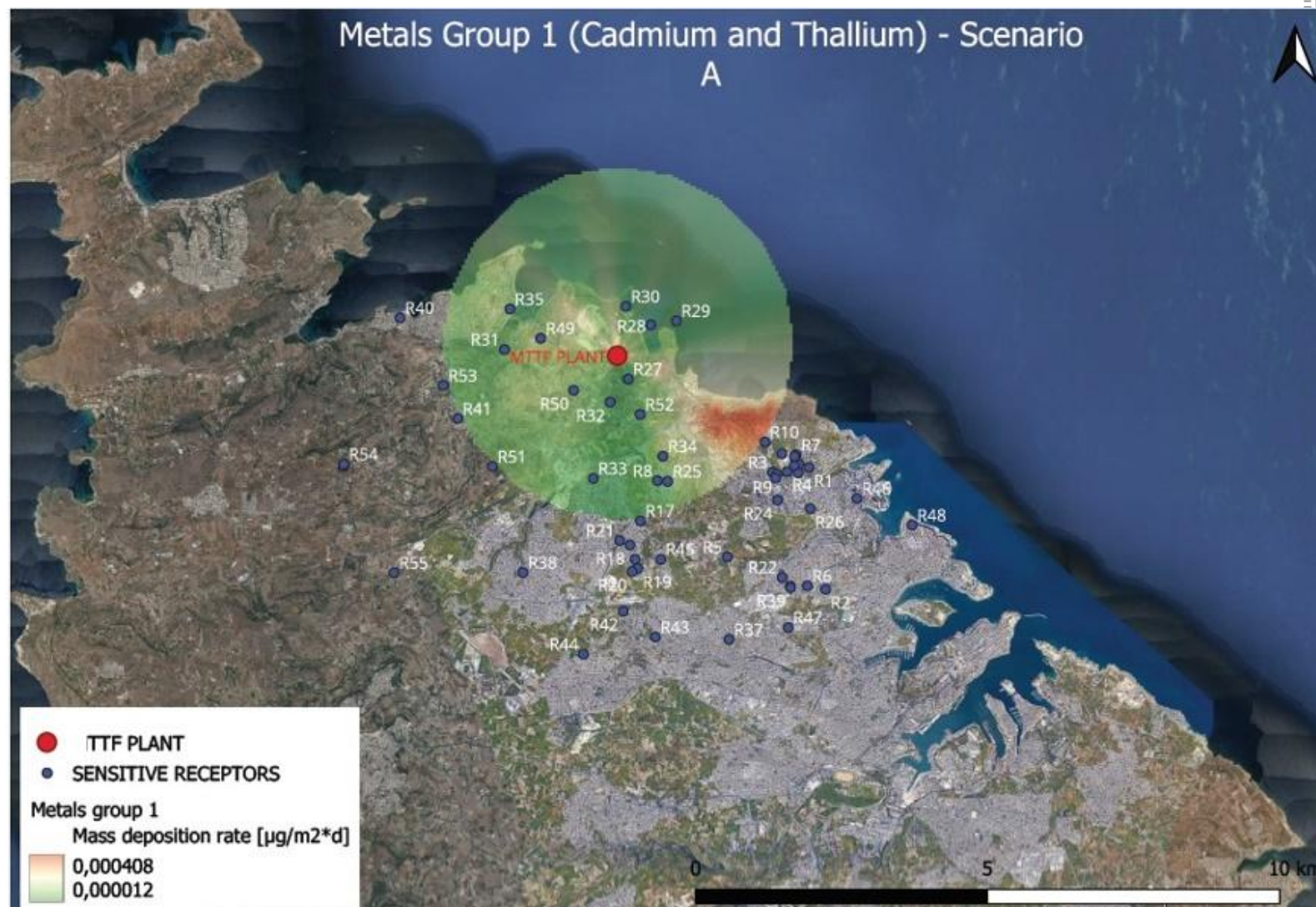
A minor adverse impact is predicted at R27 located 0.43km away from the chimney stack at all three Scenario when considering the cumulative impact of the simultaneous operation of the TTF and the adjacent WtE facility.

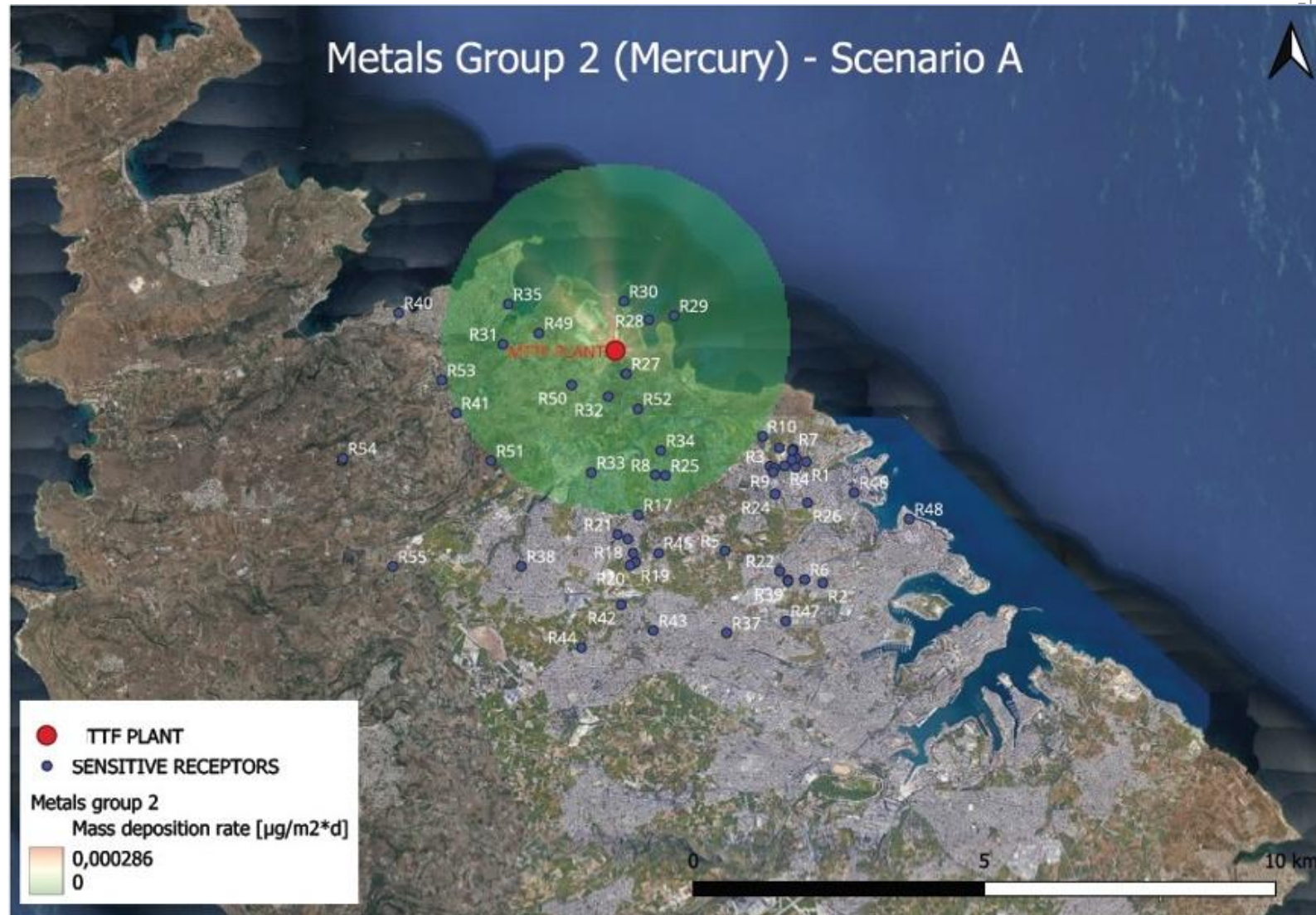
APPENDIX 1 - MODEL OUTPUTS

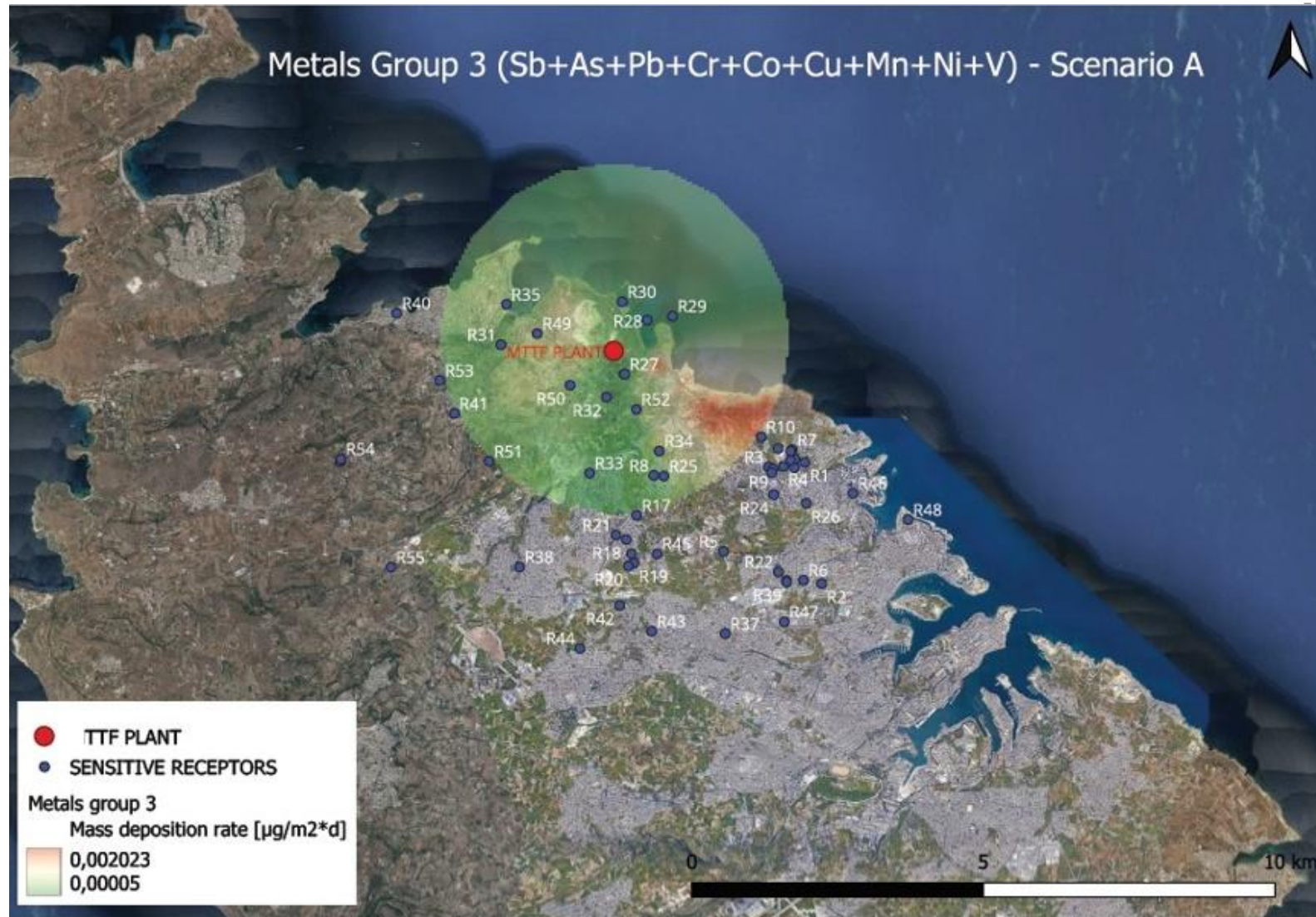


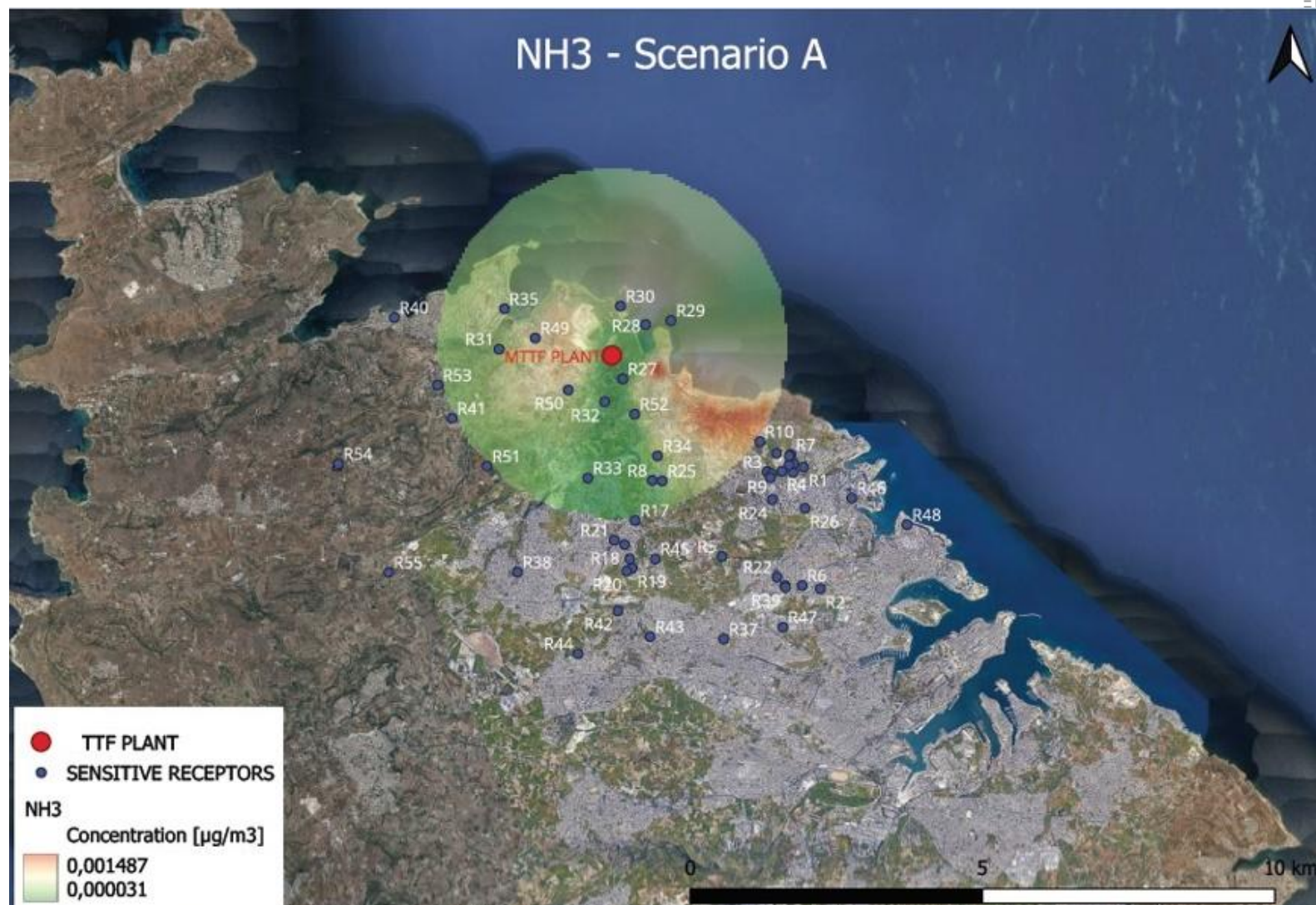


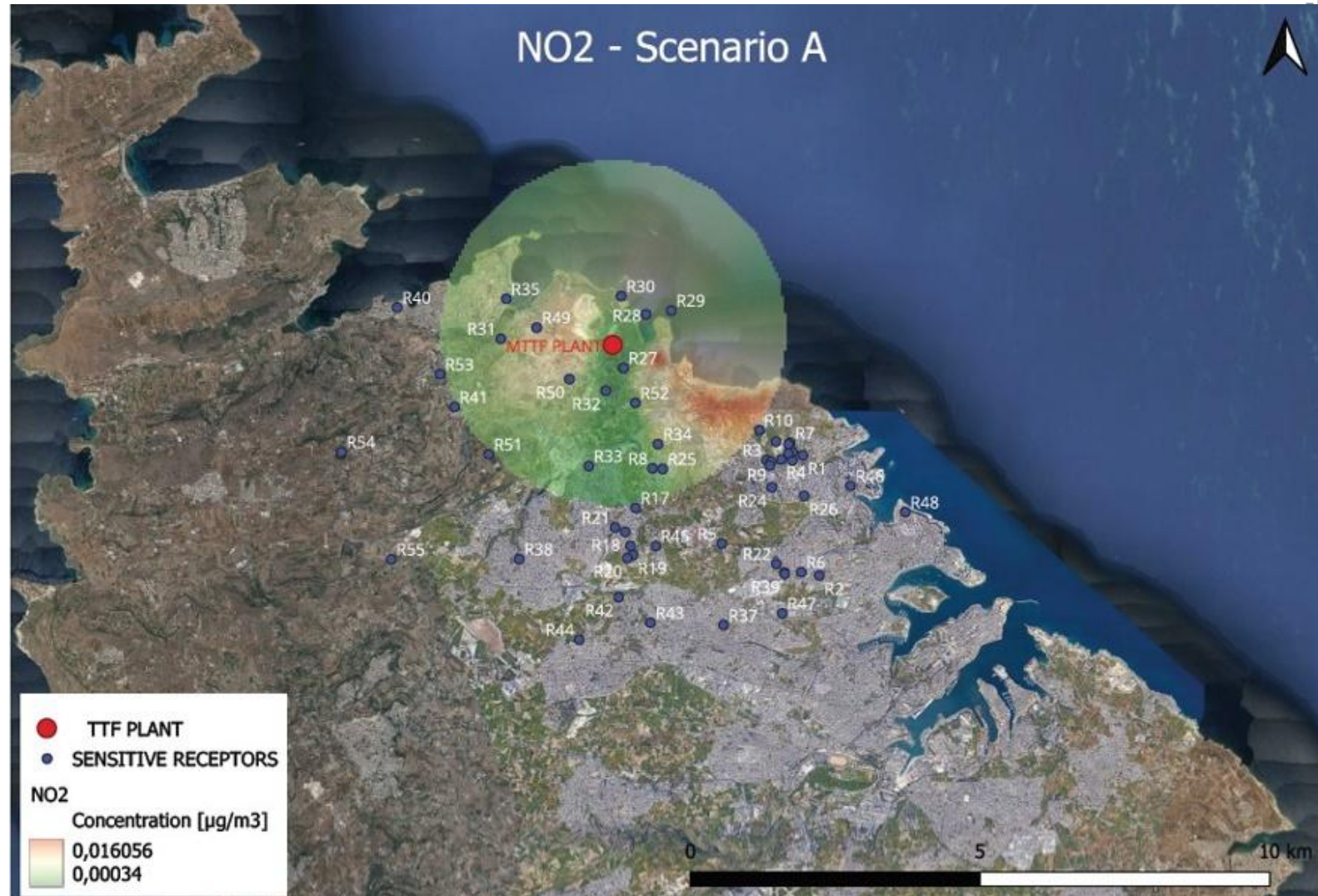


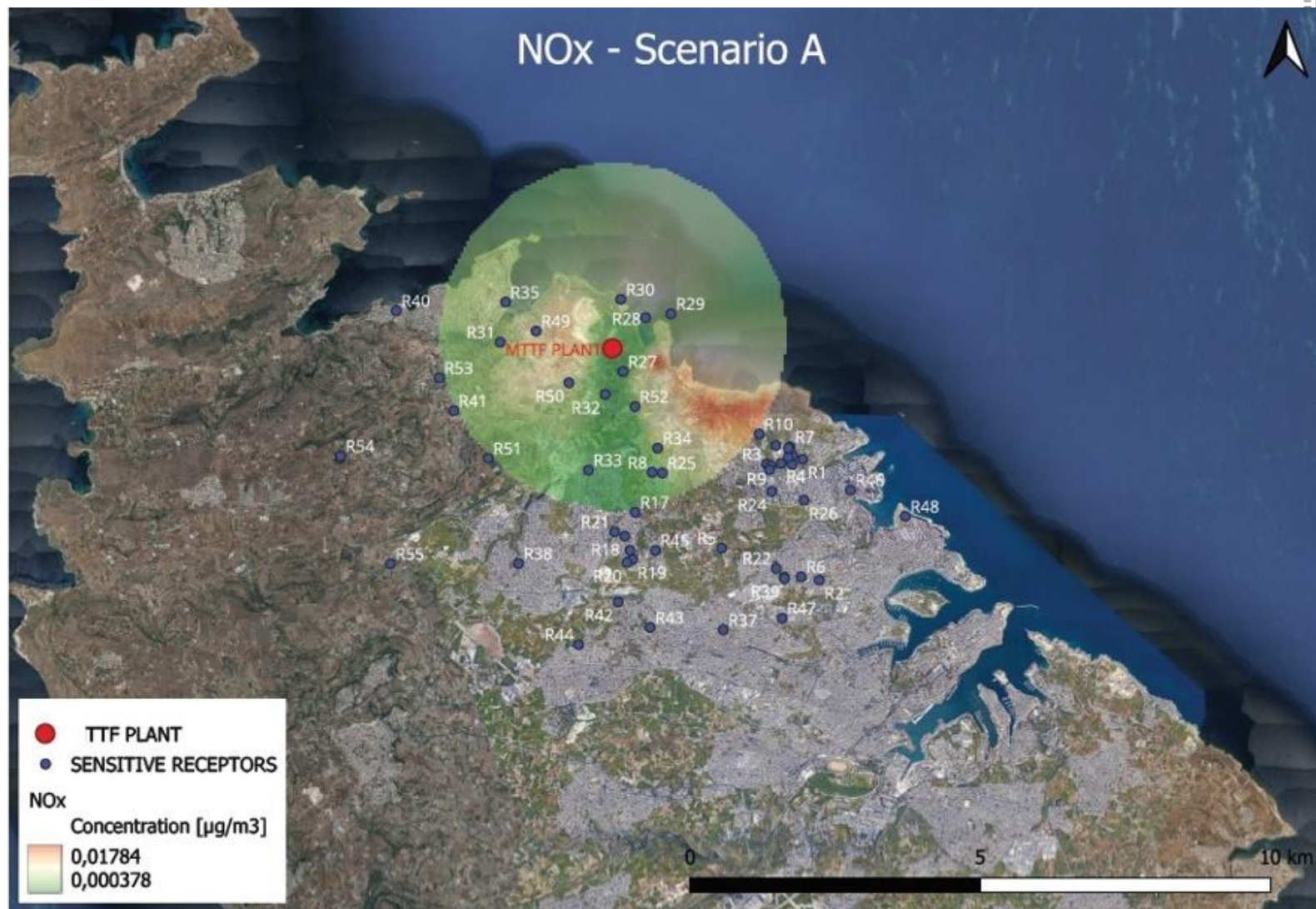


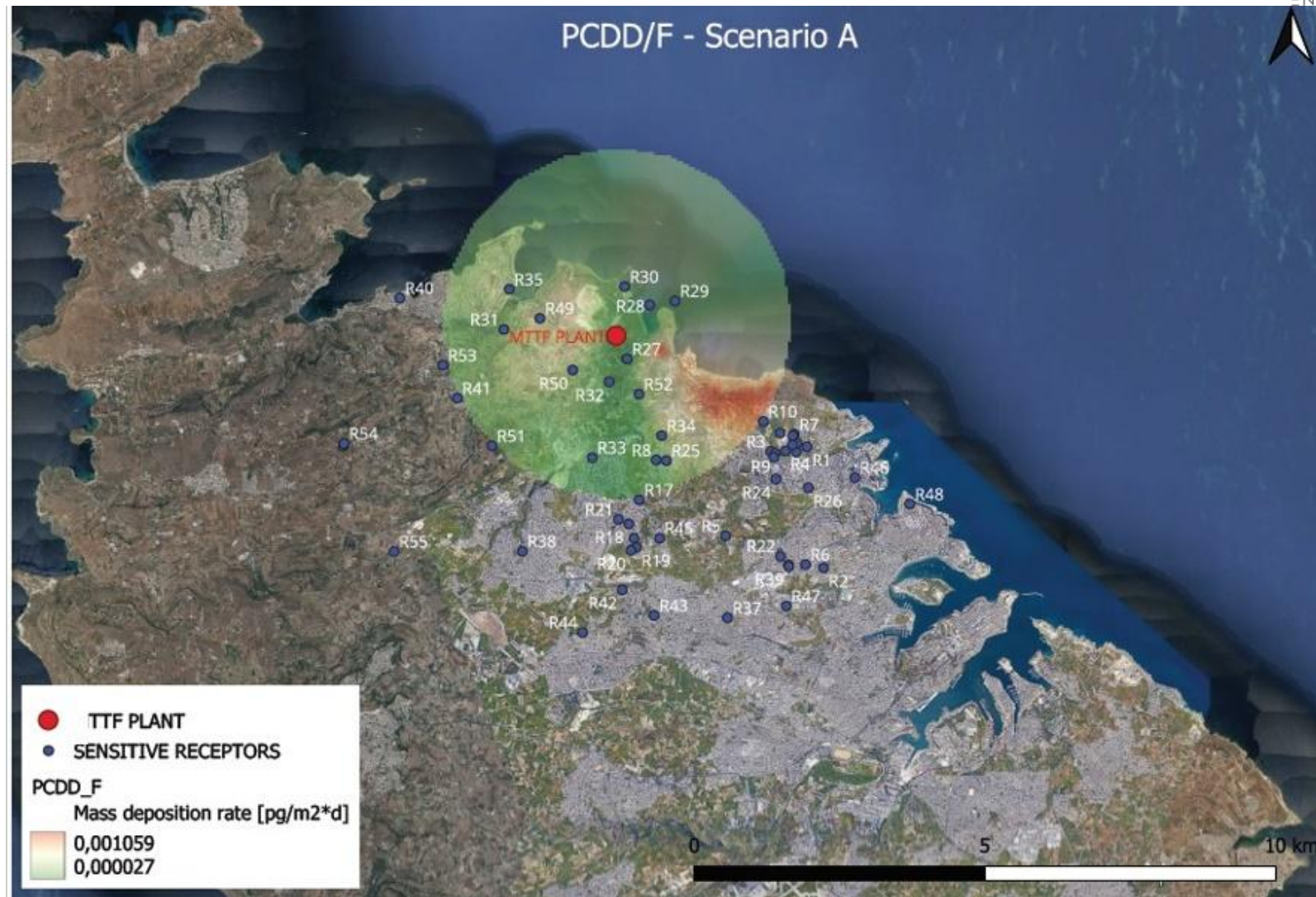


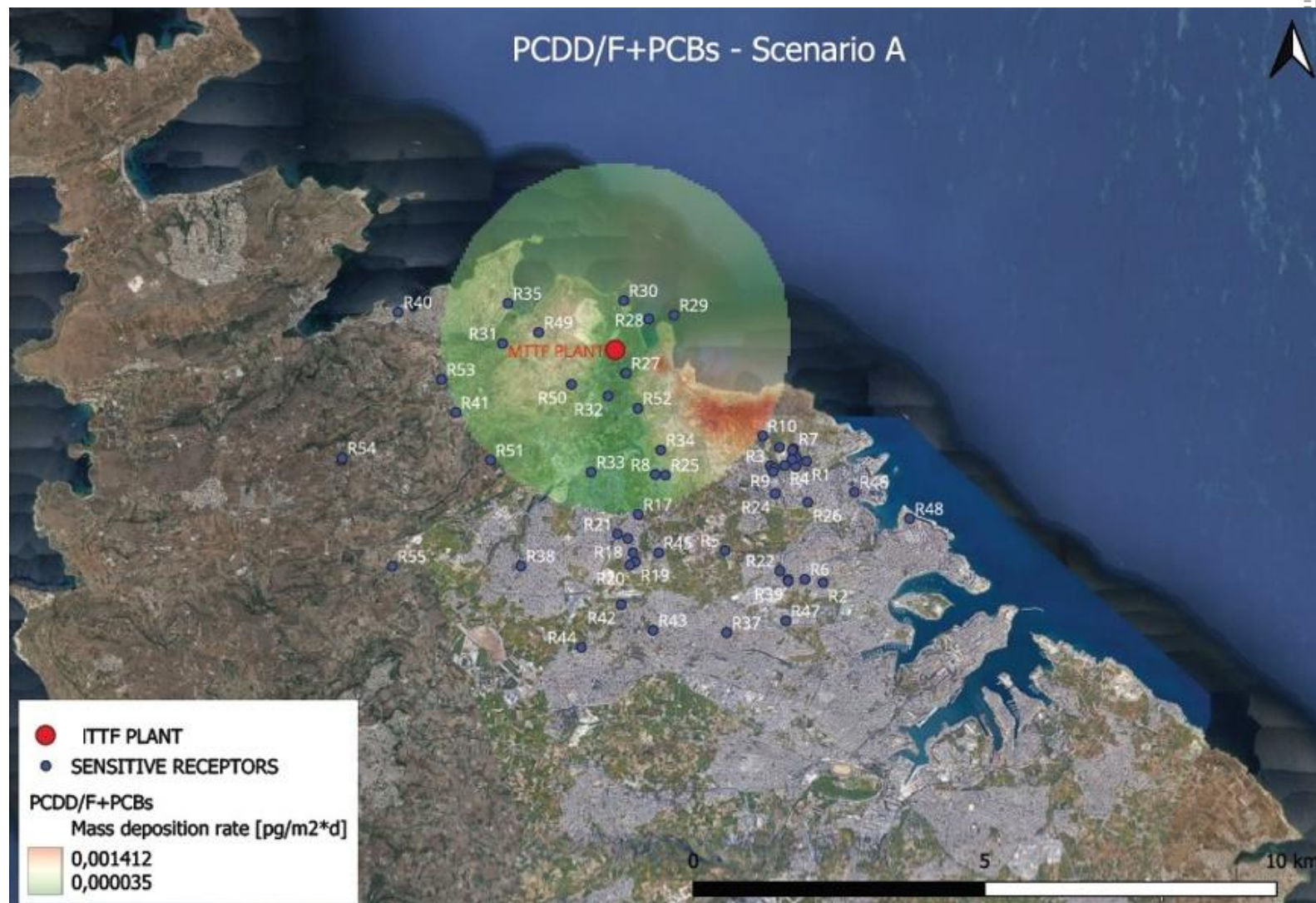


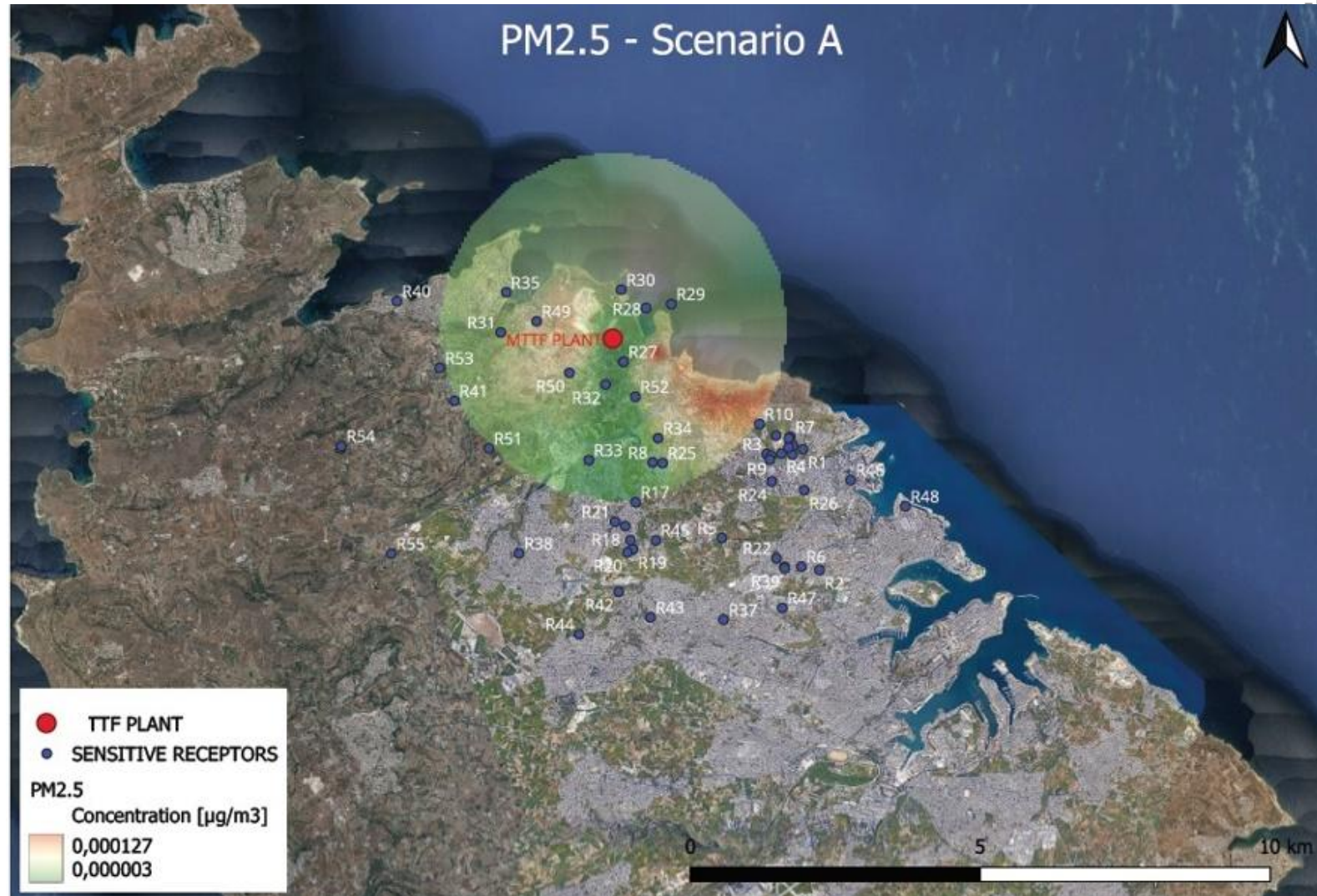


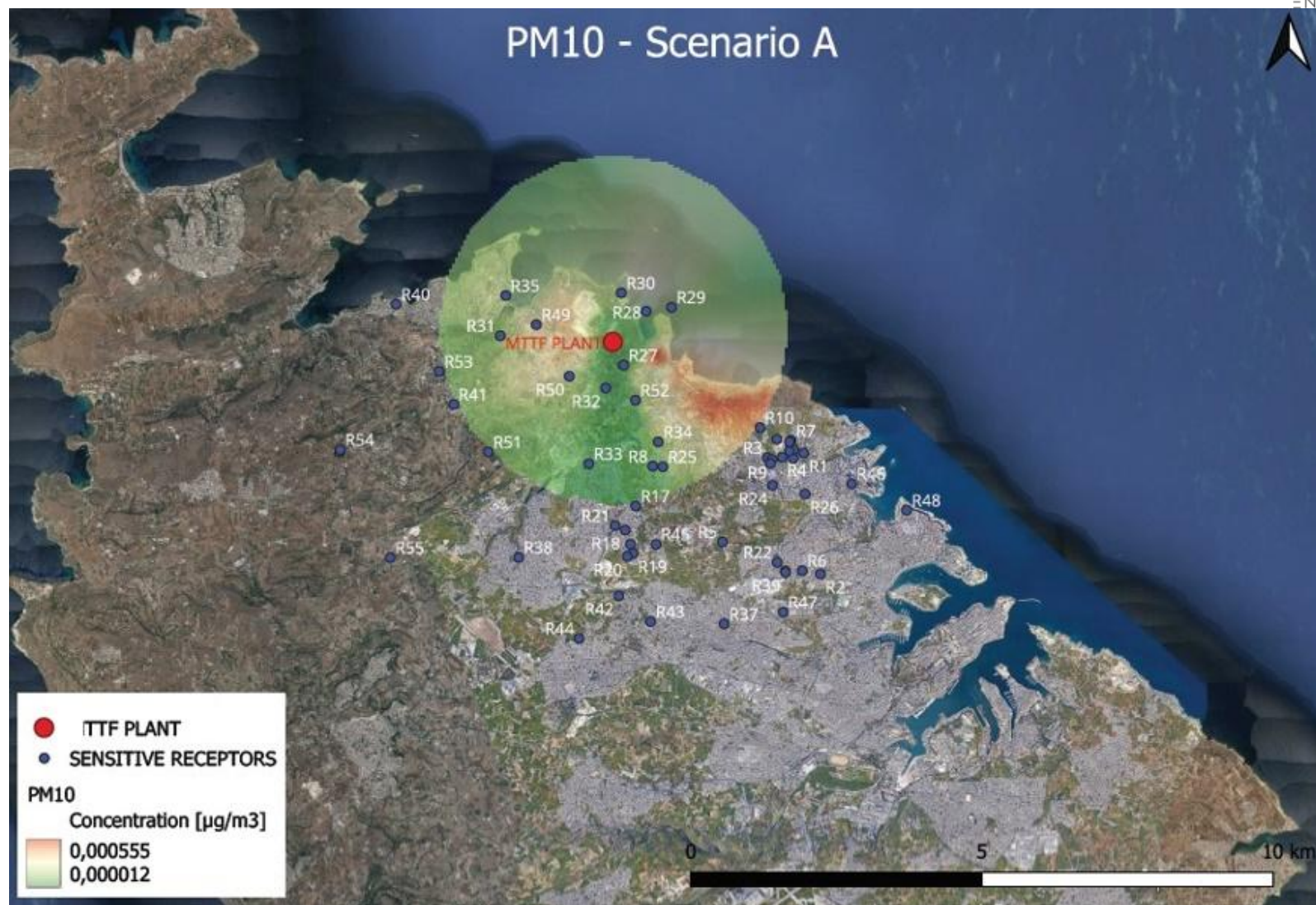


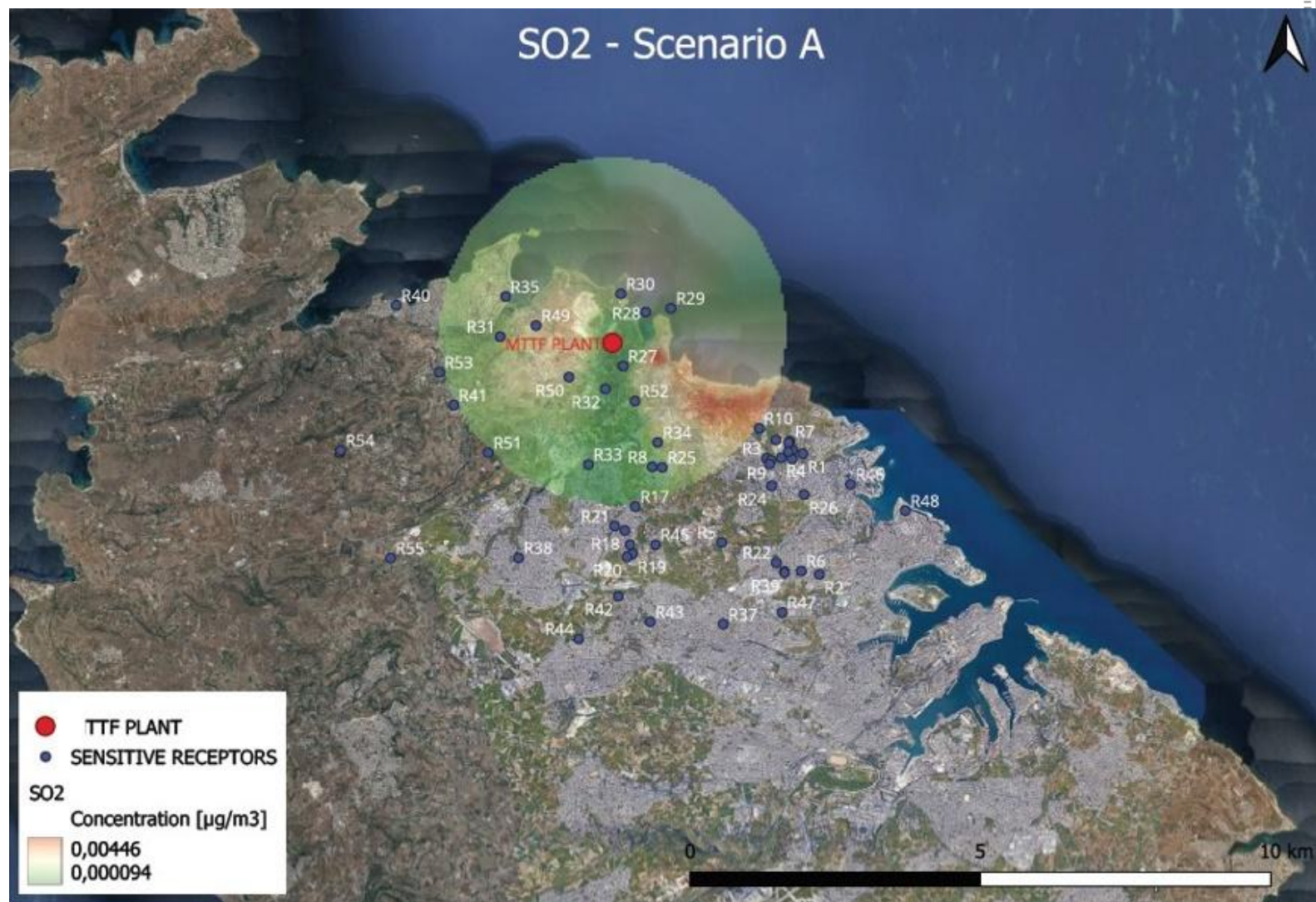


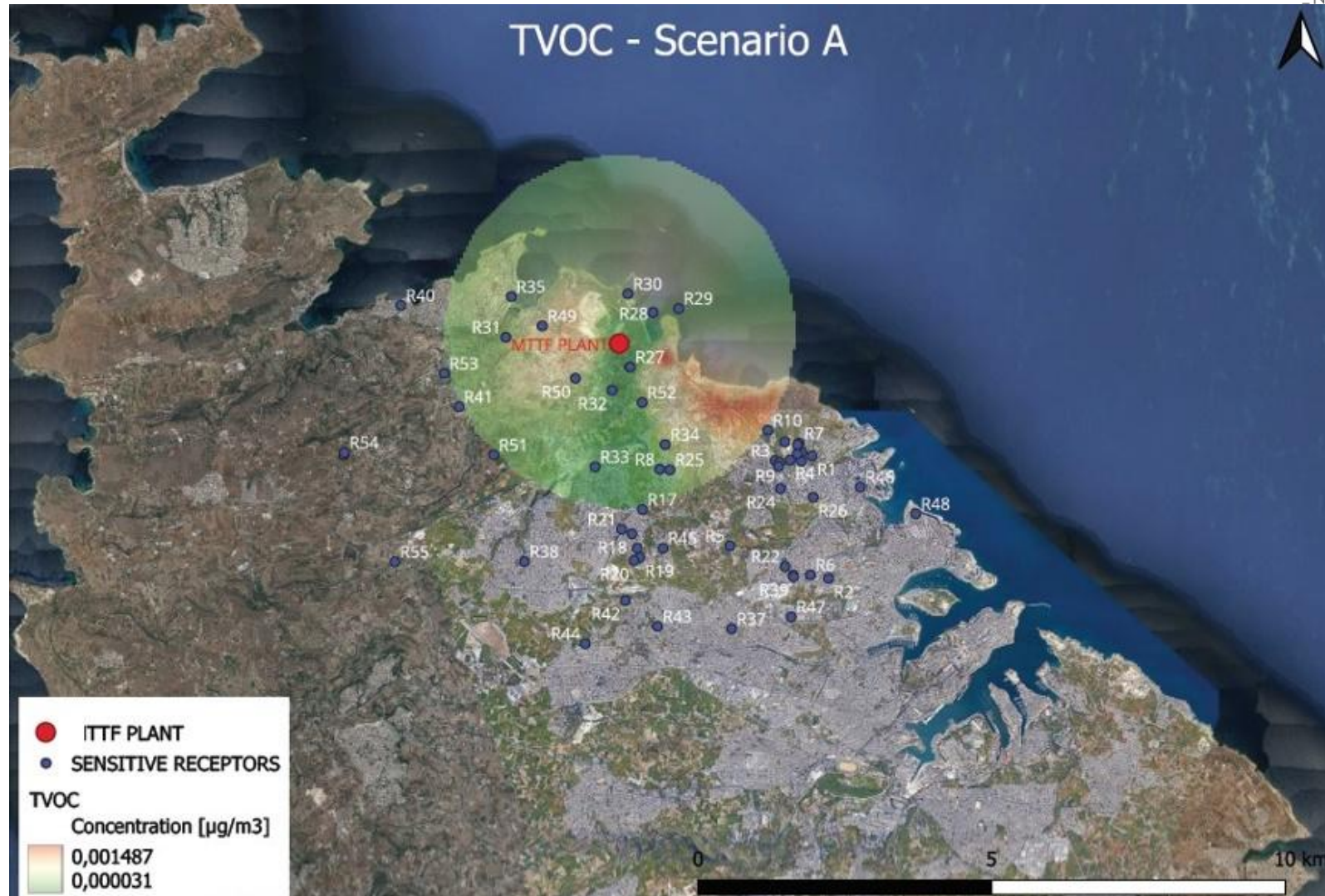


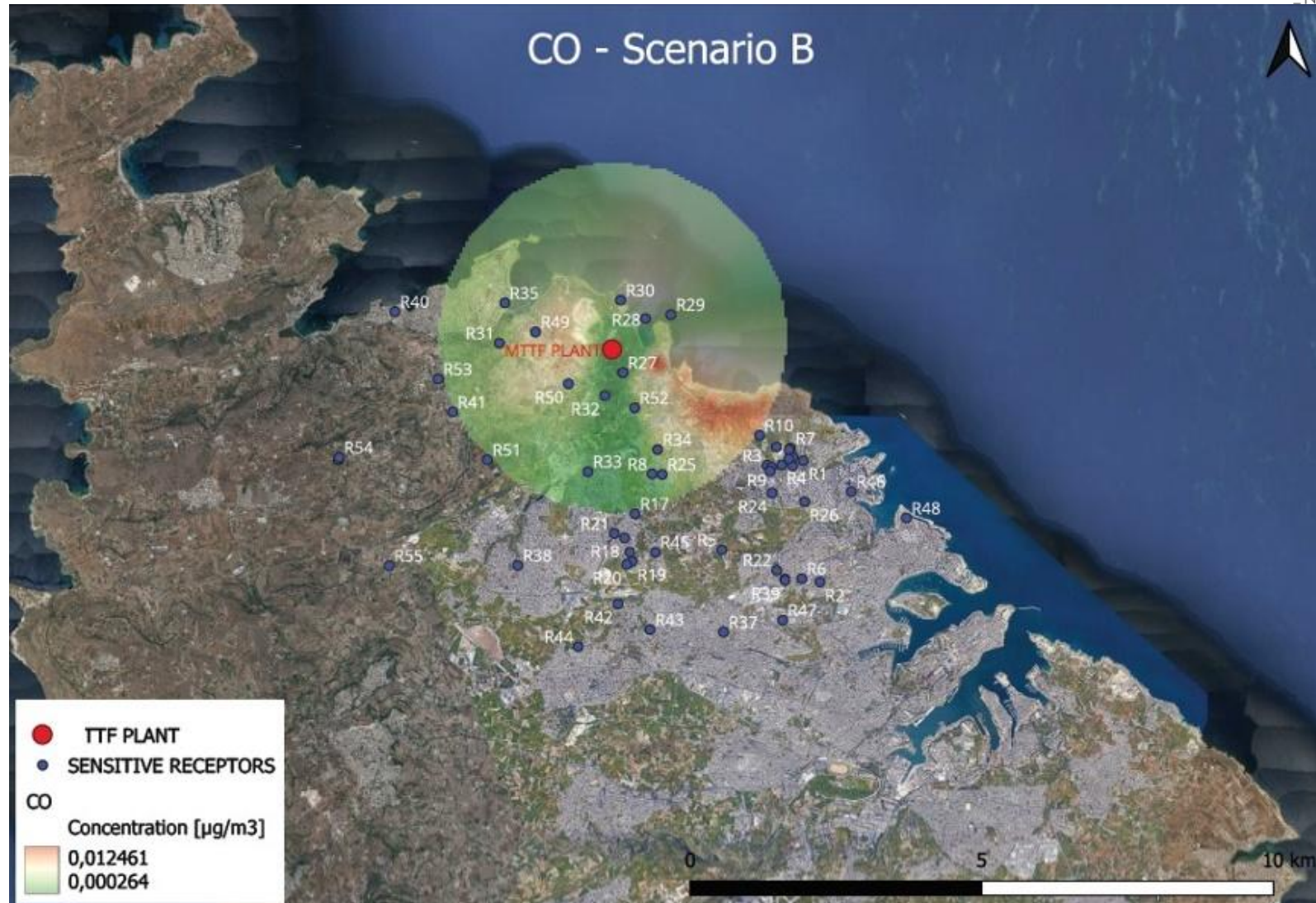


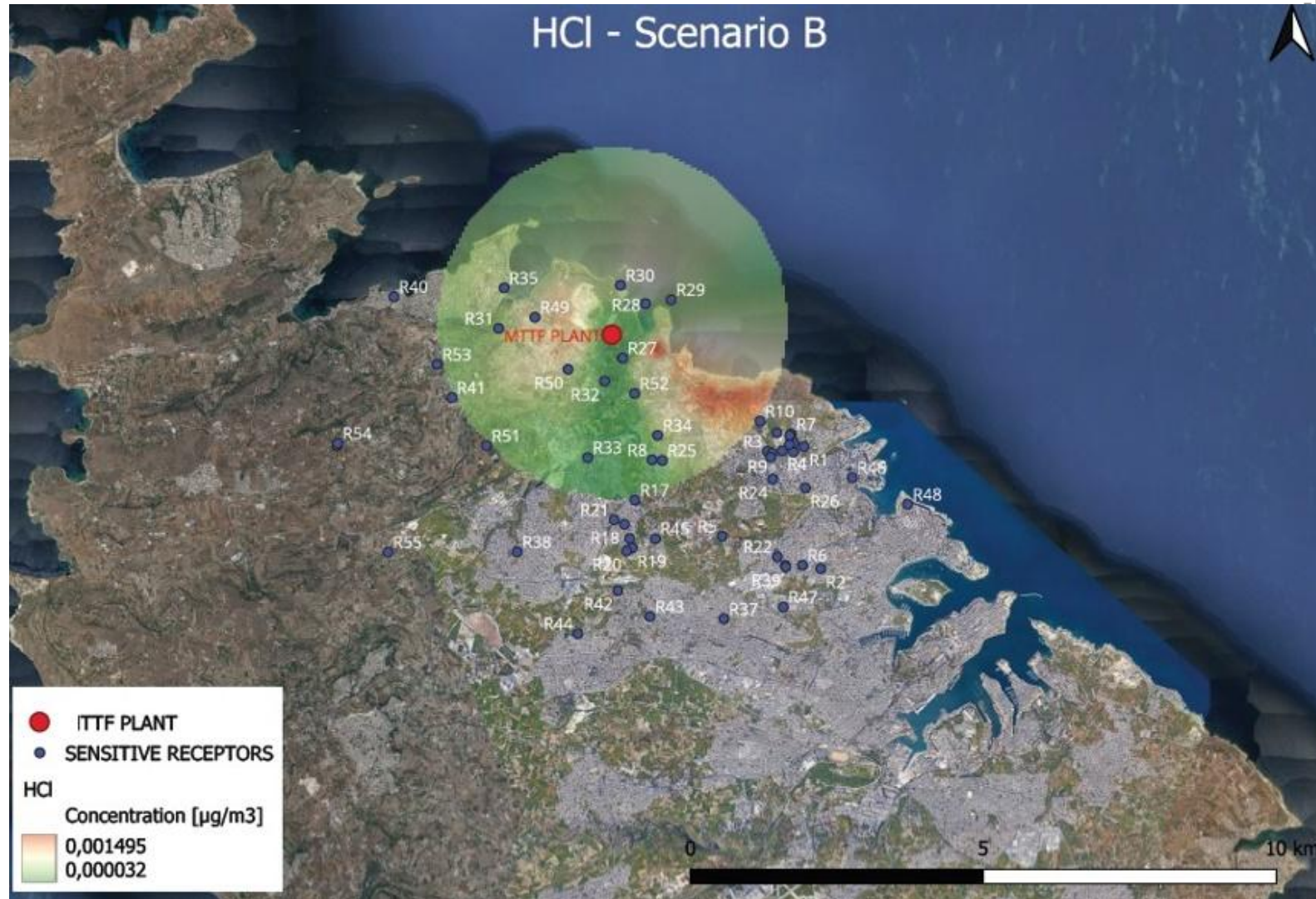


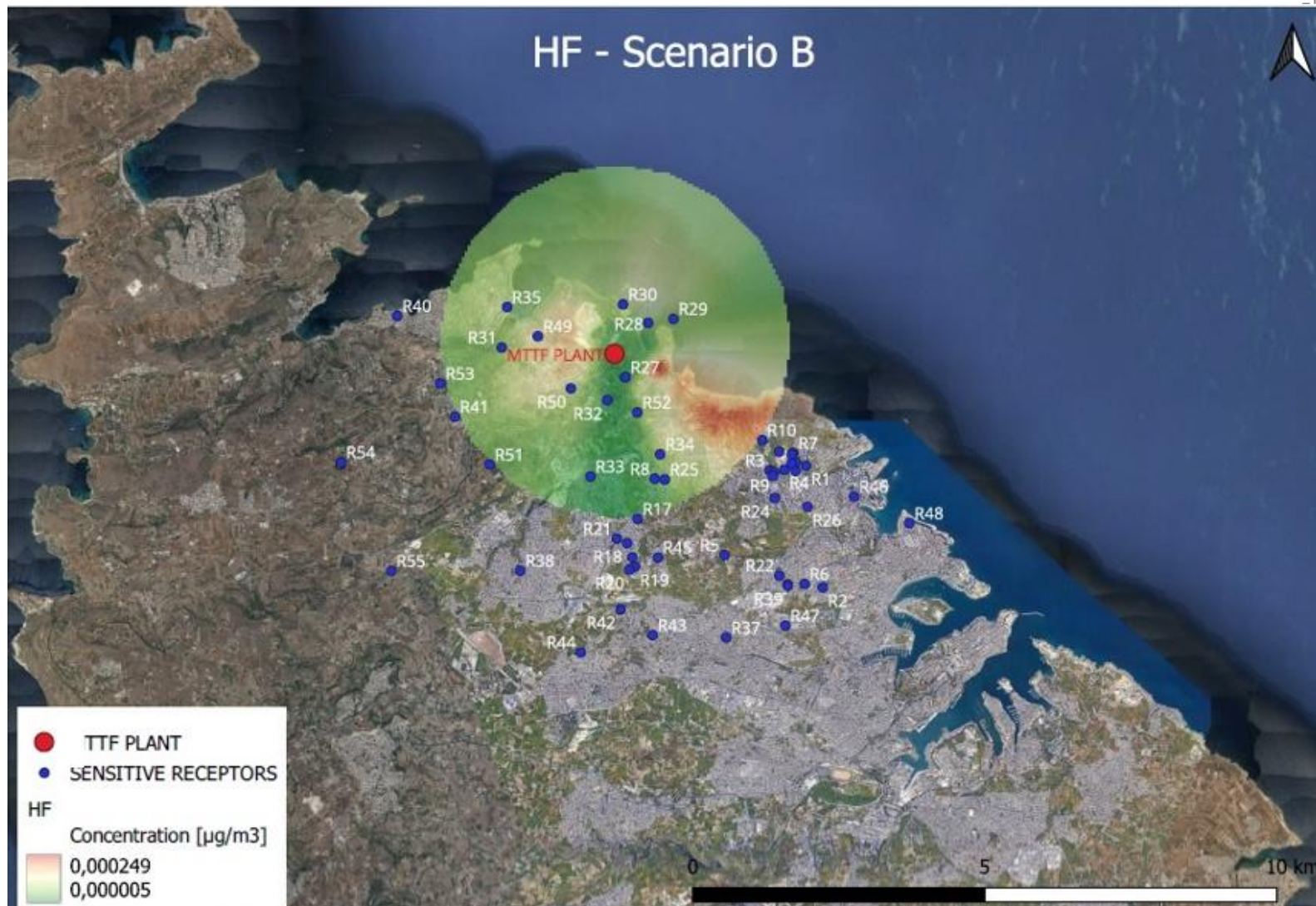


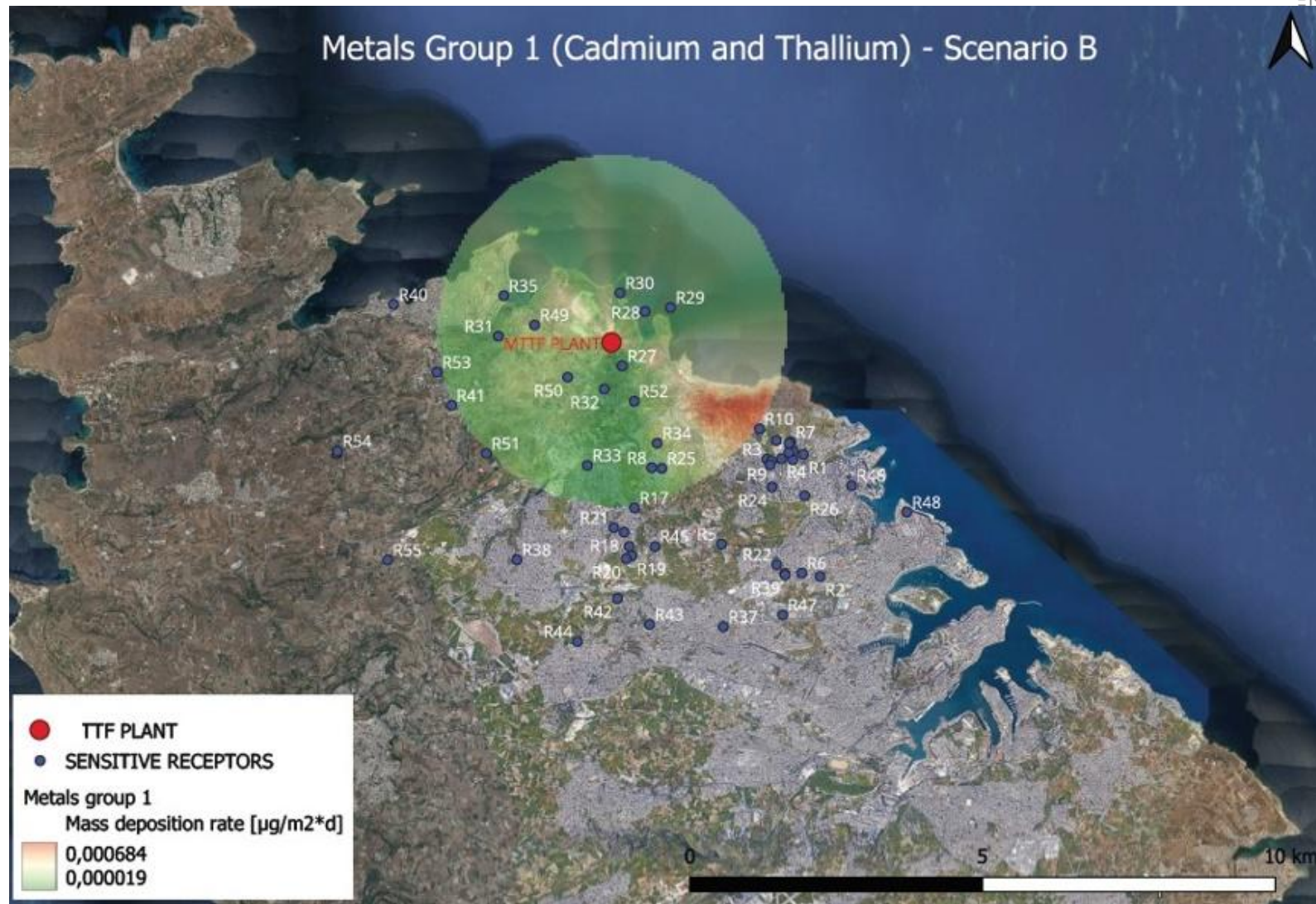


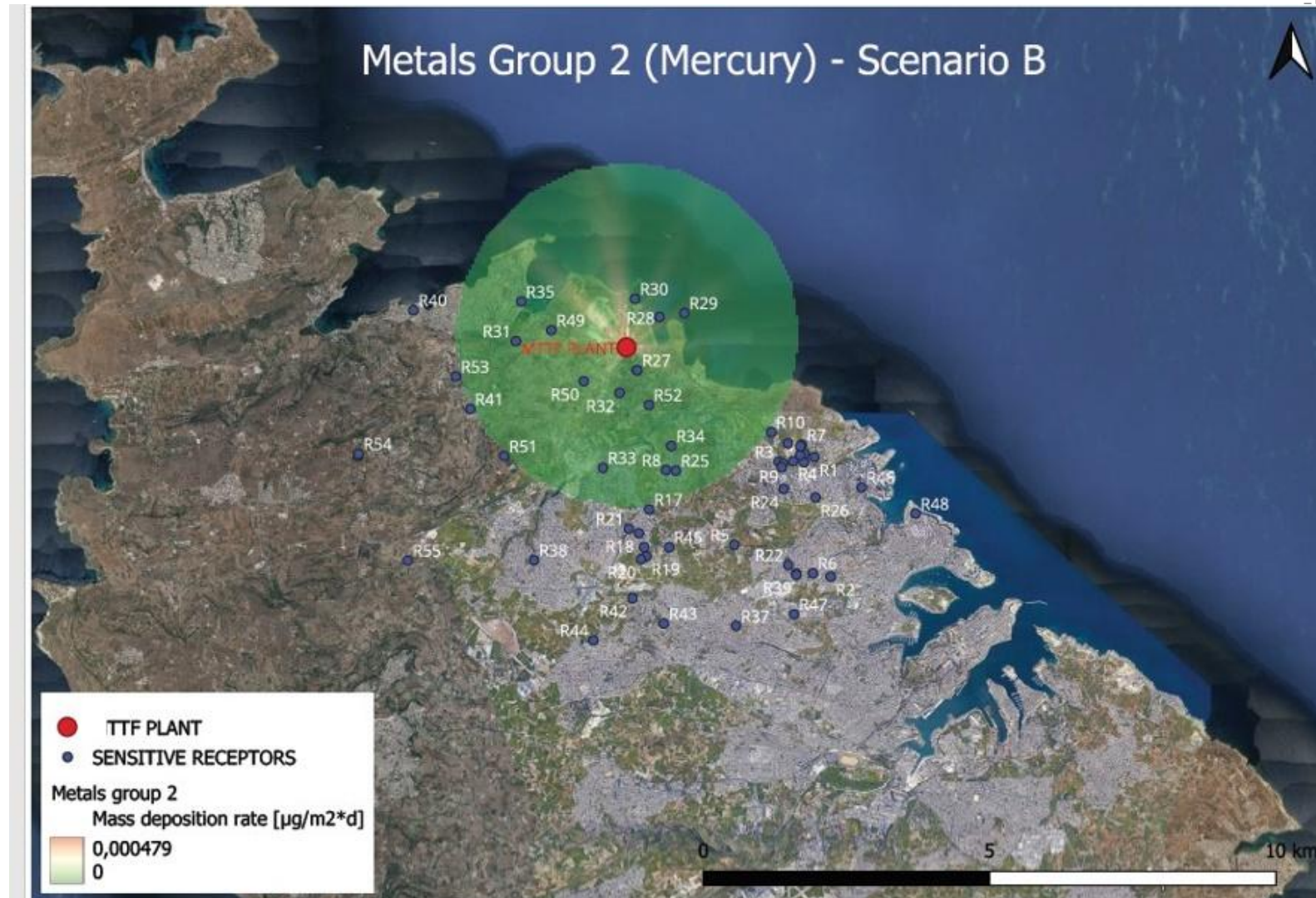


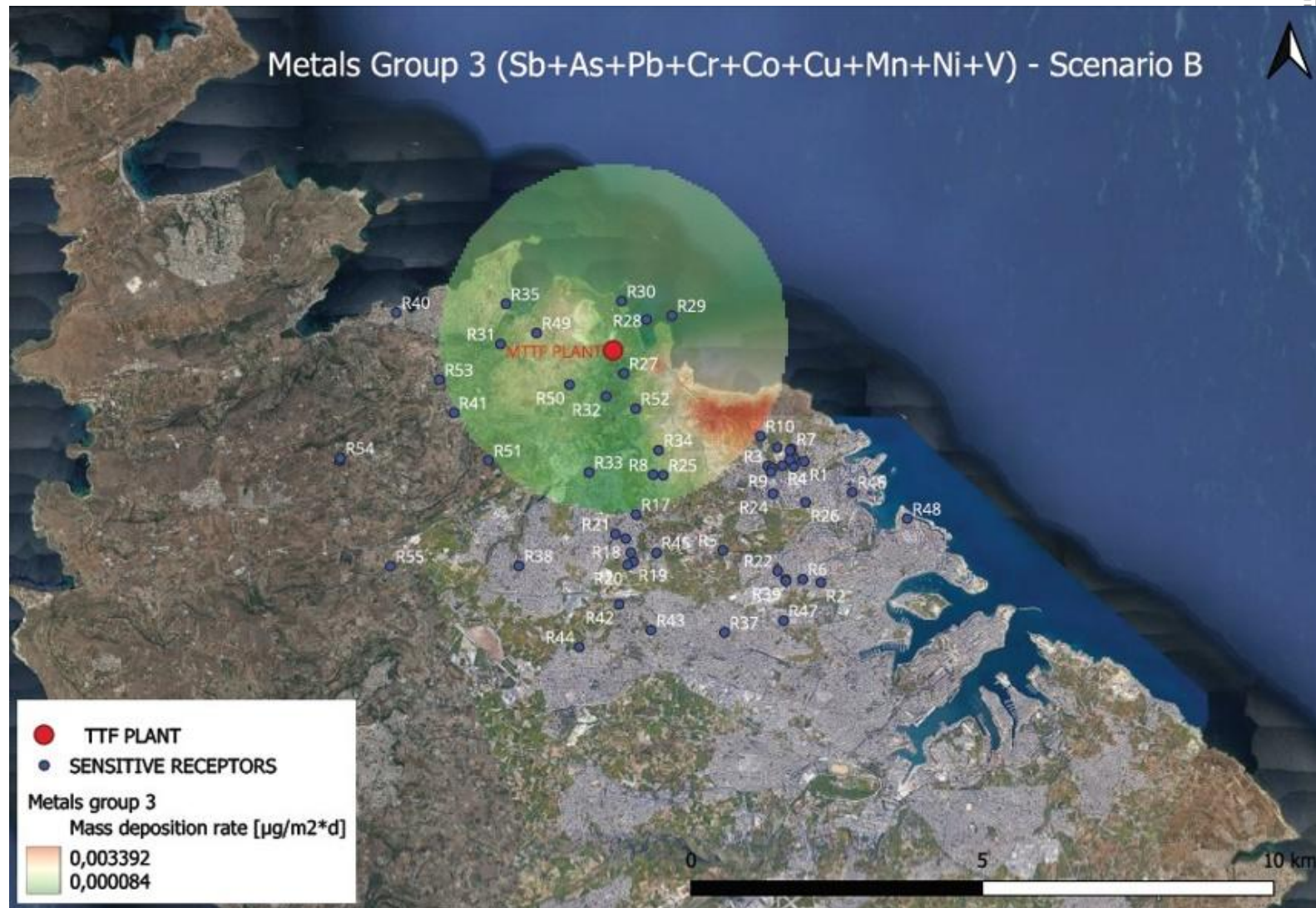


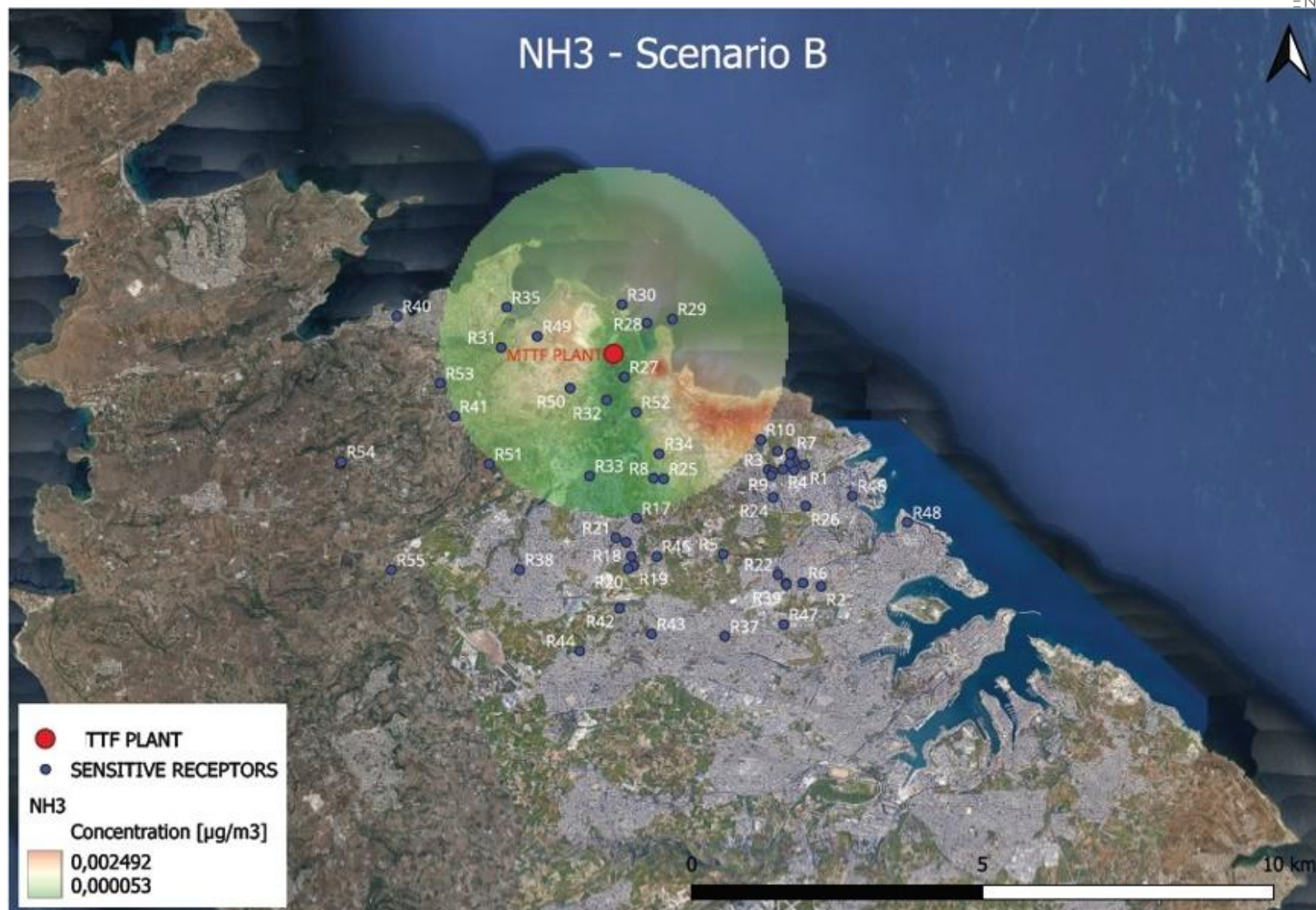


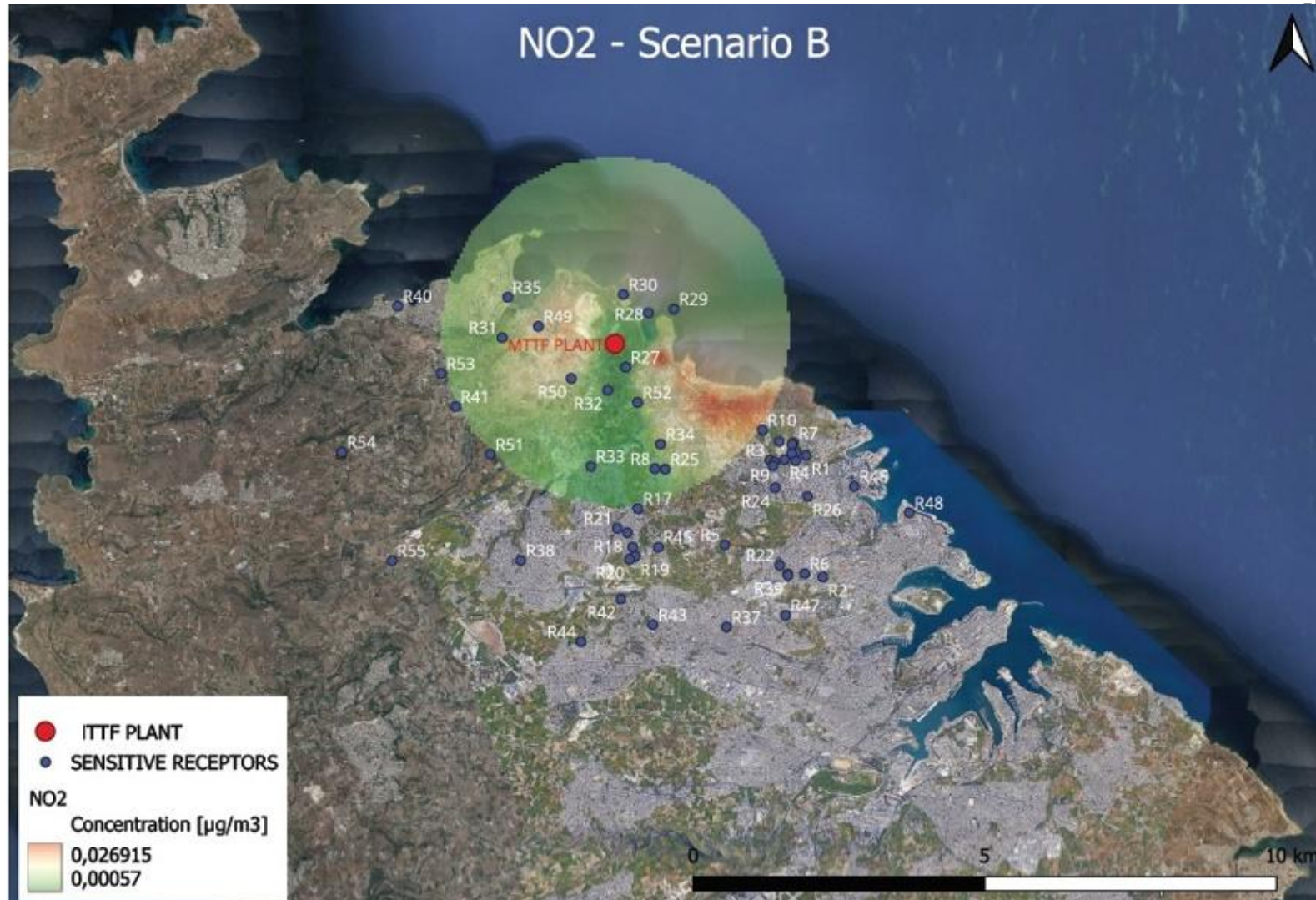


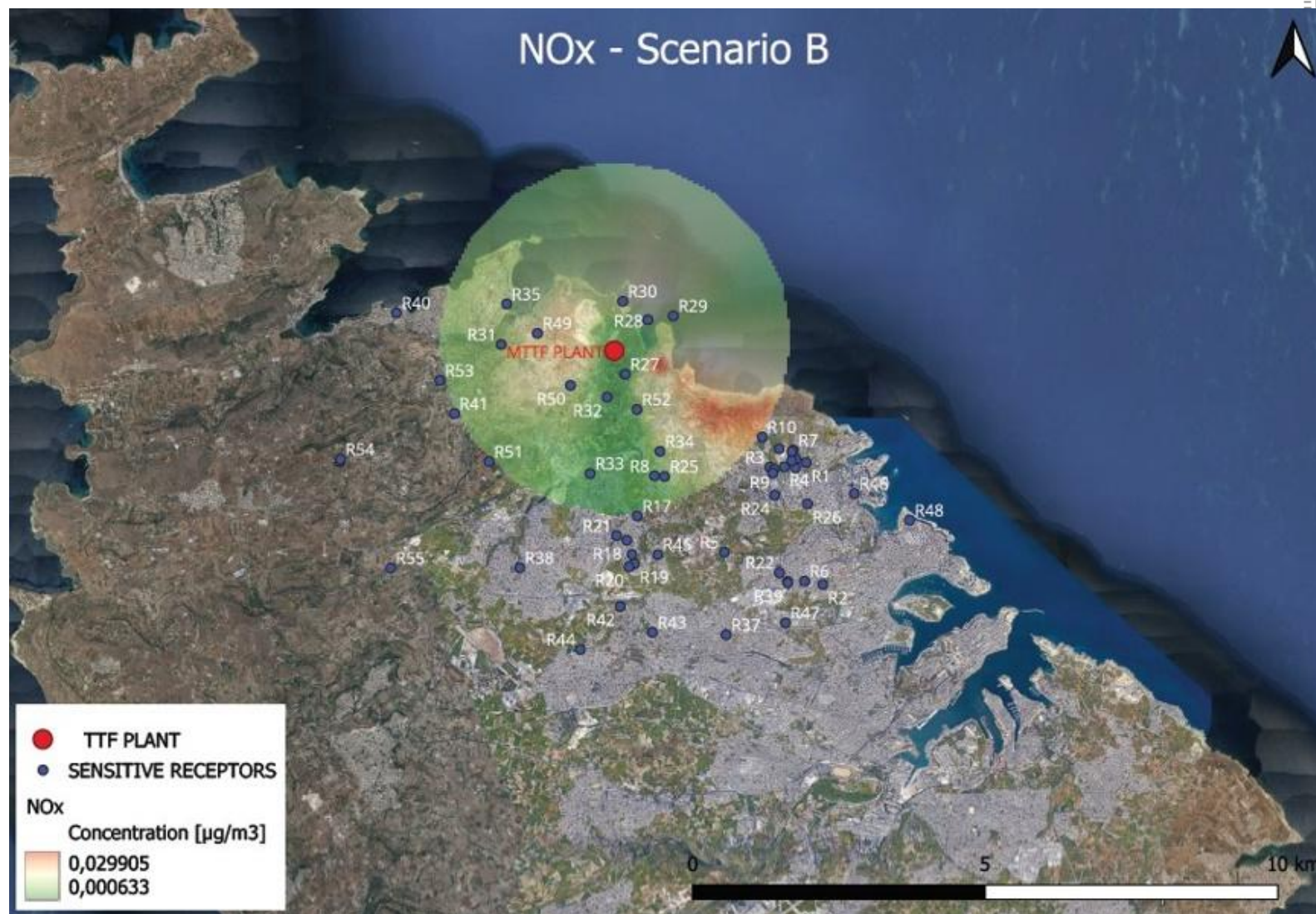


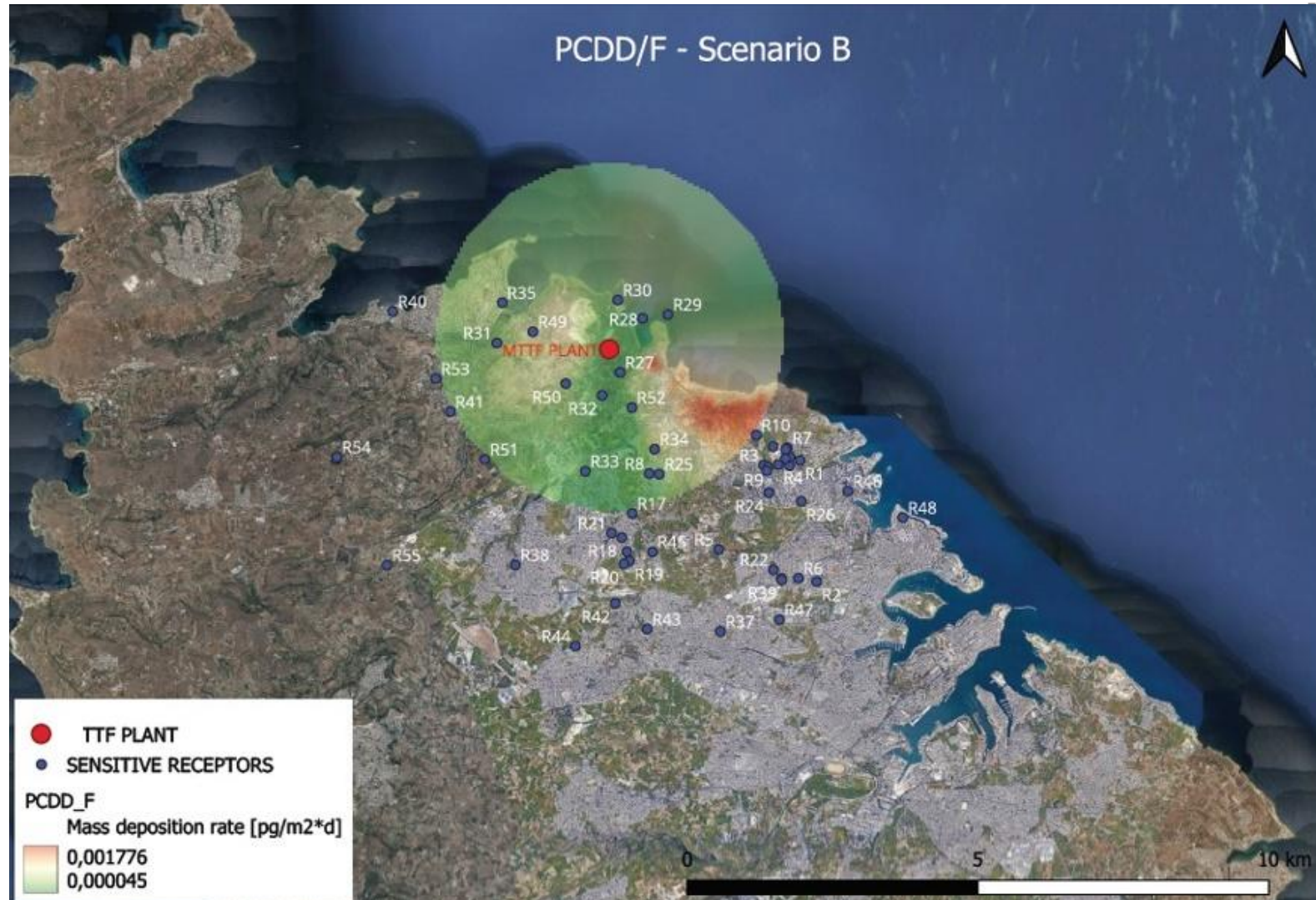


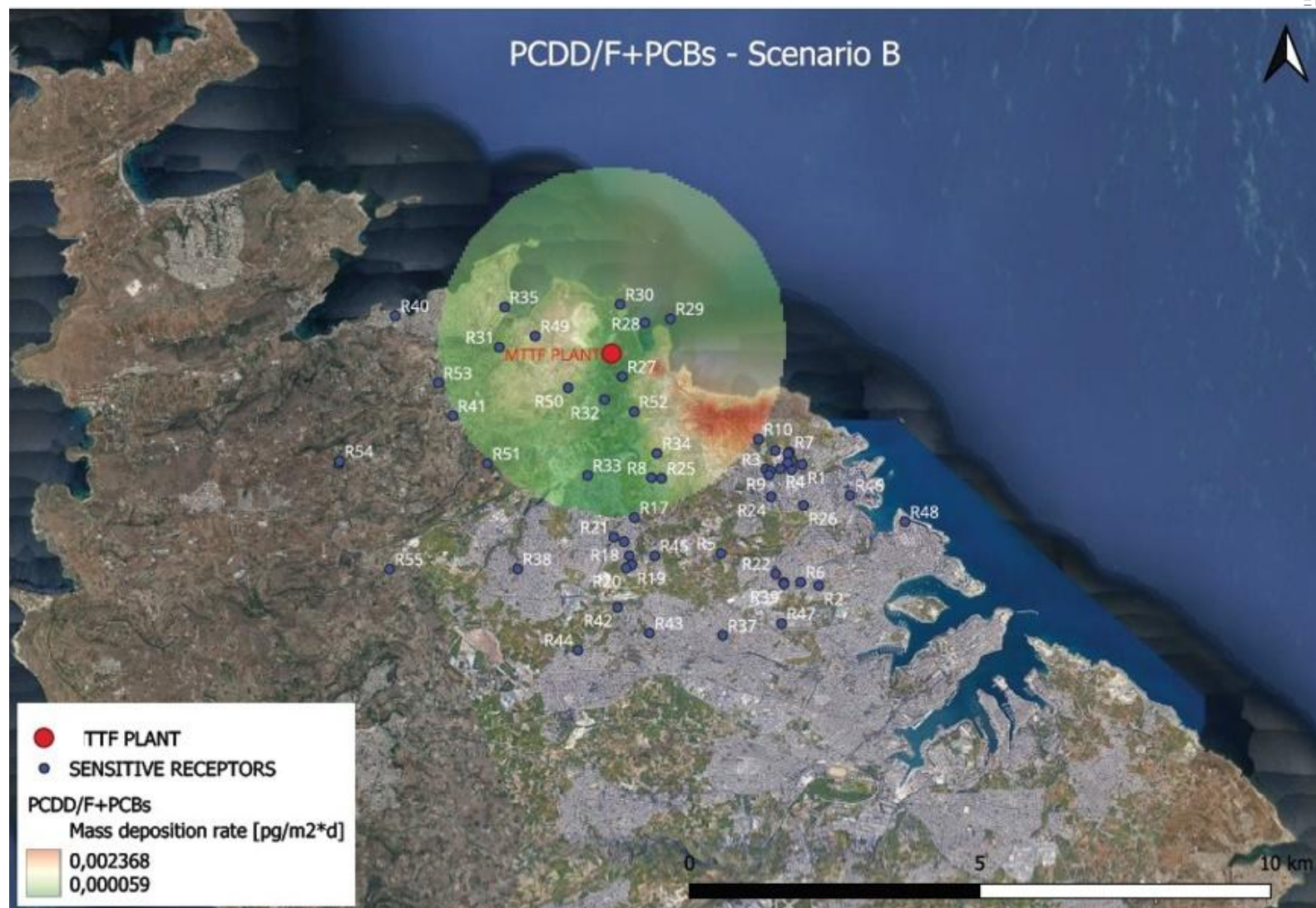


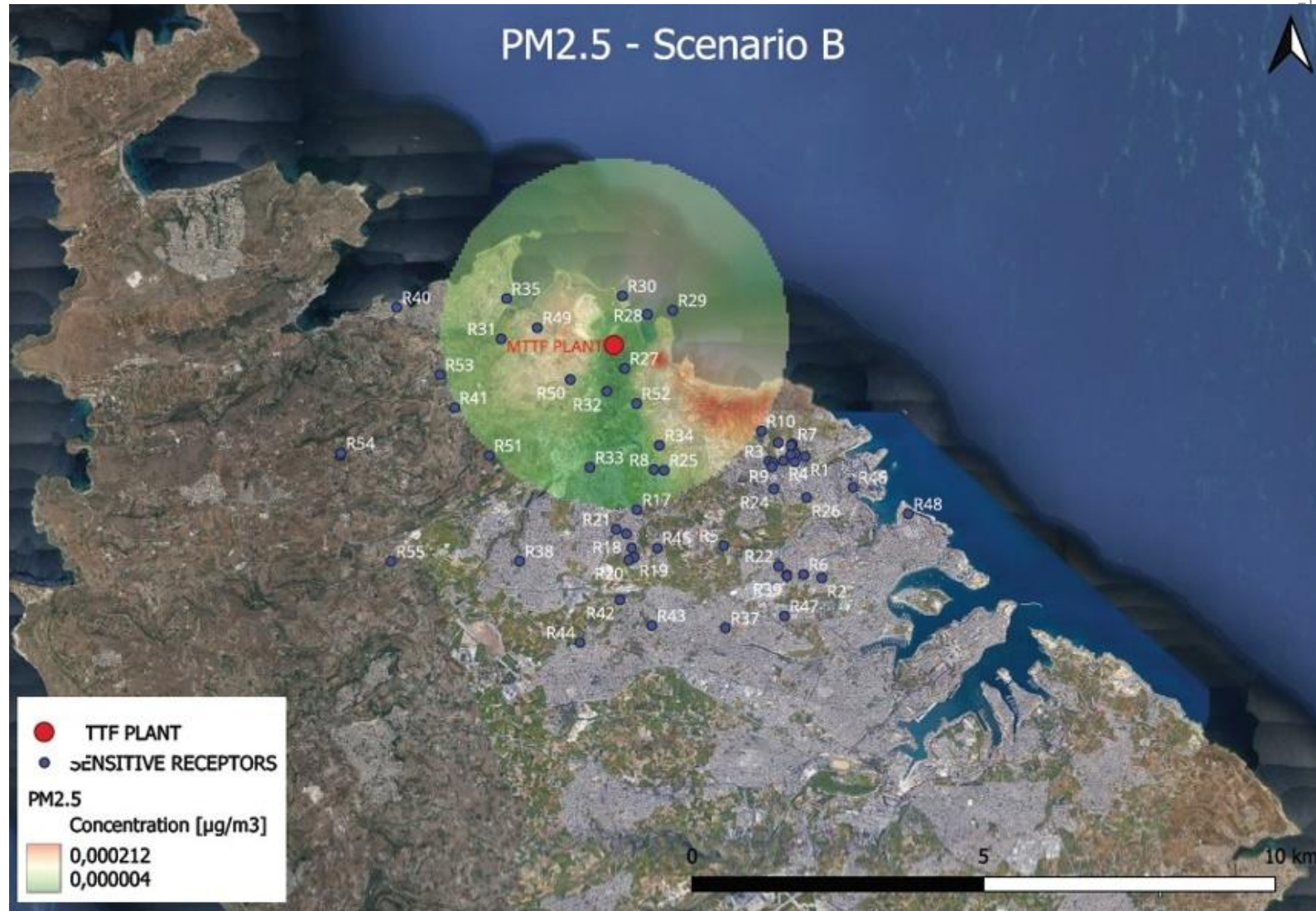


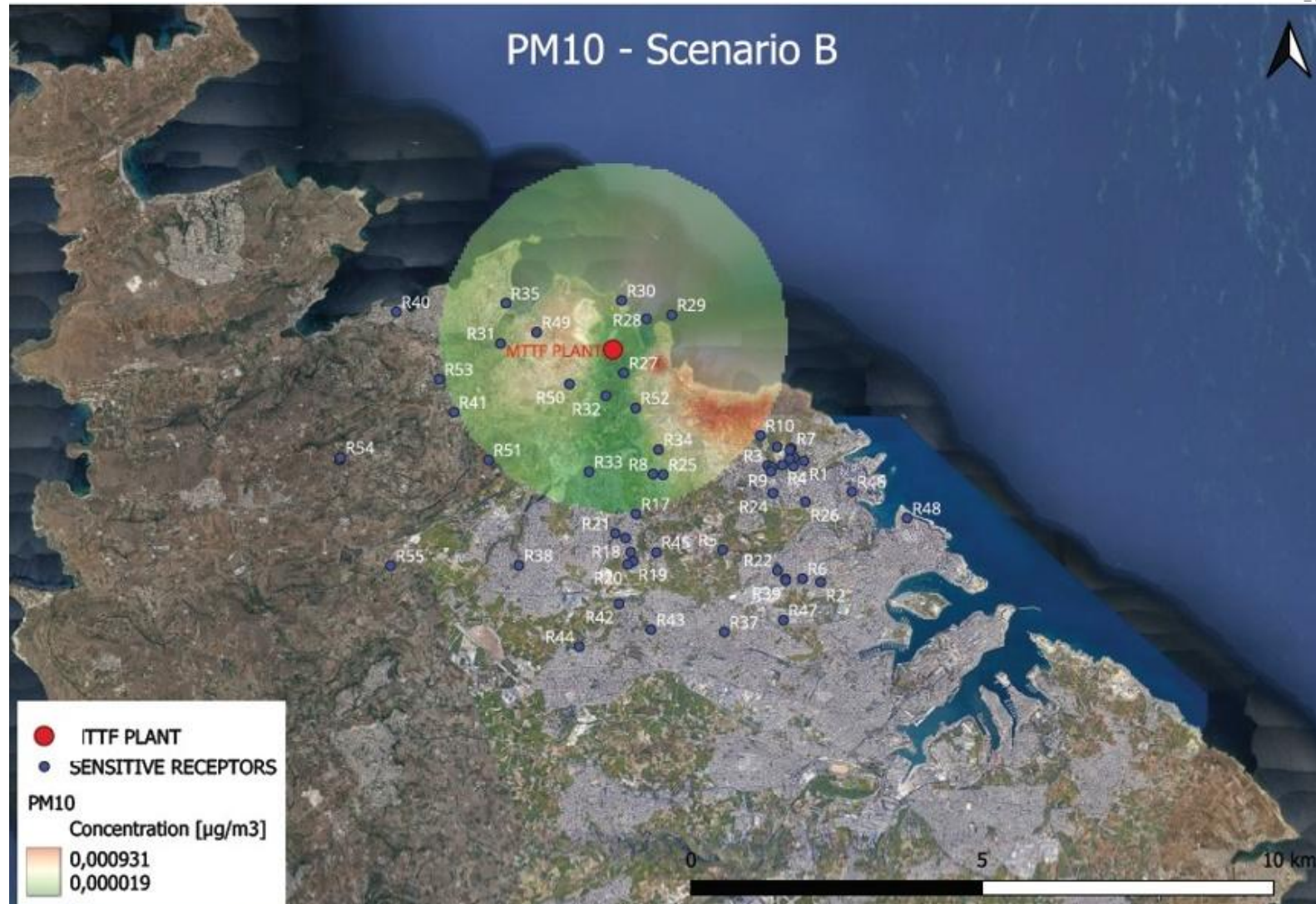


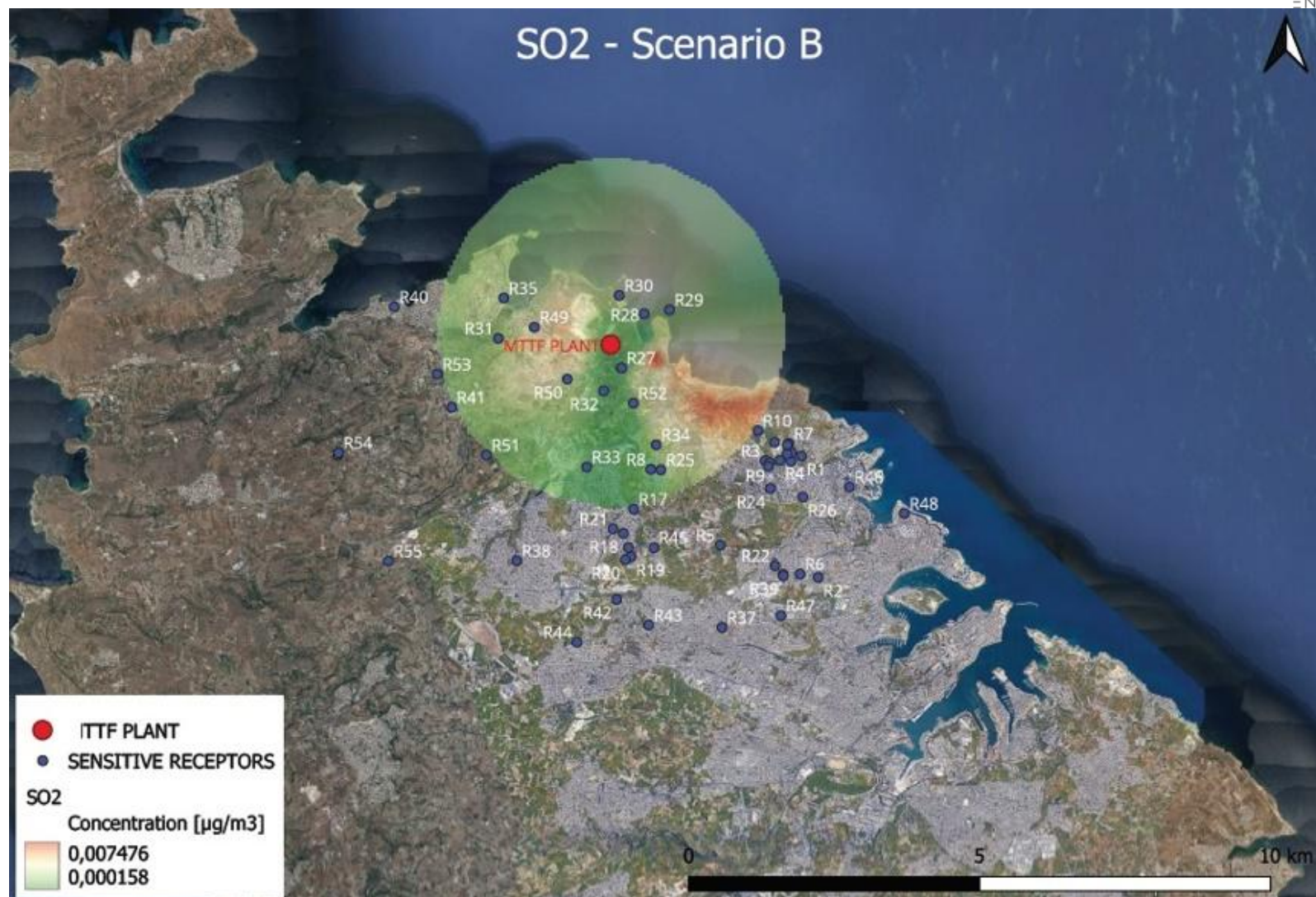


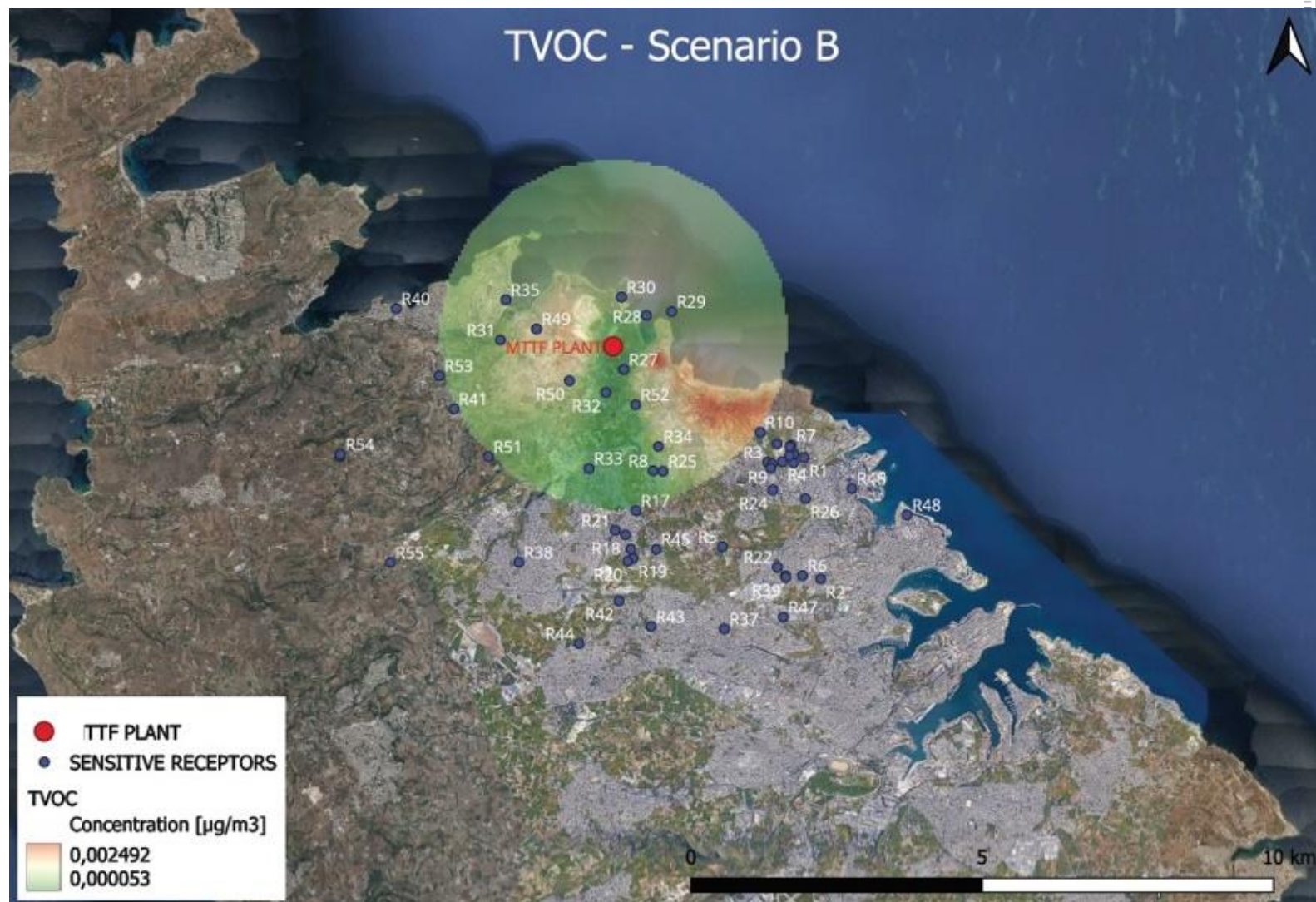


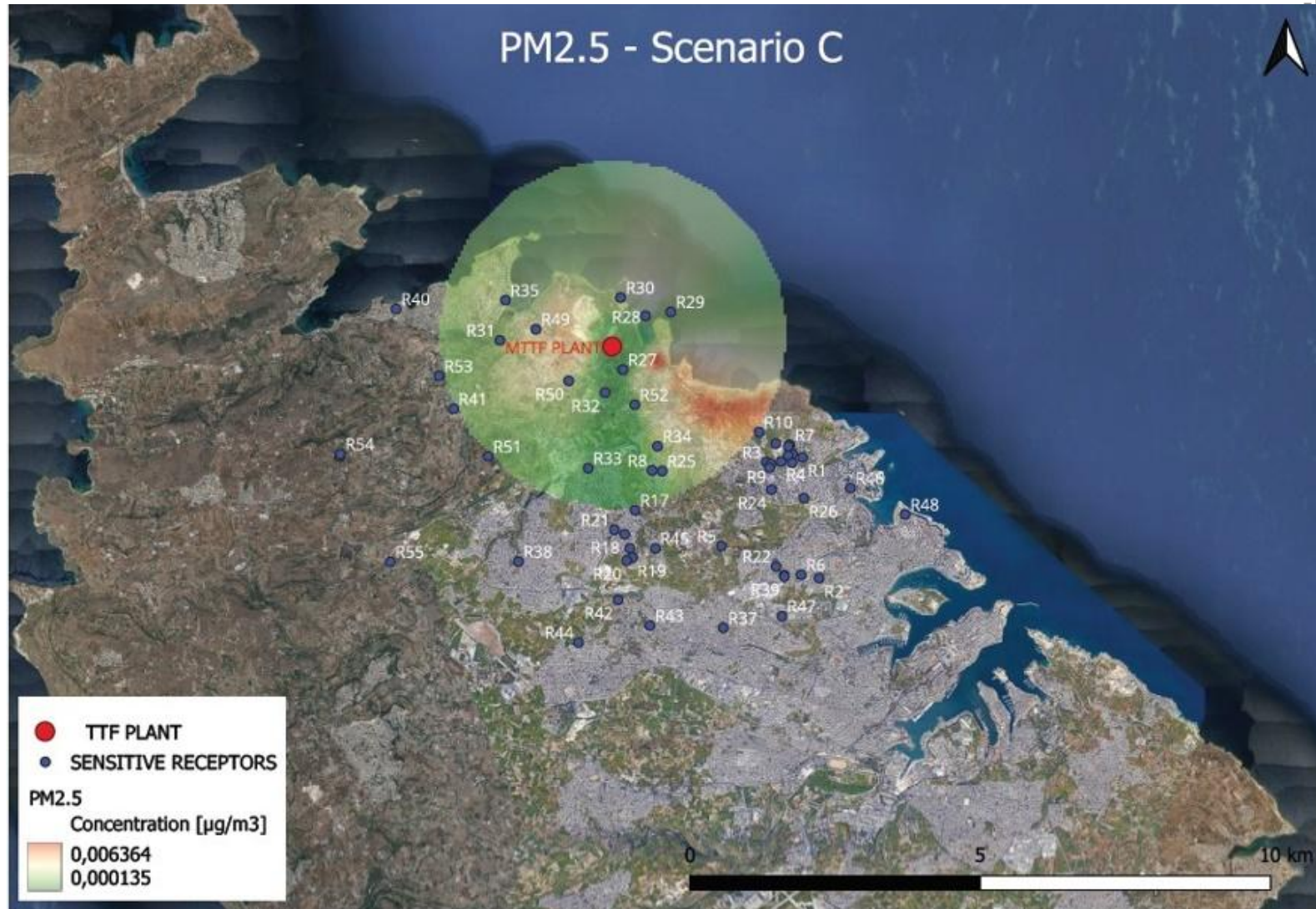


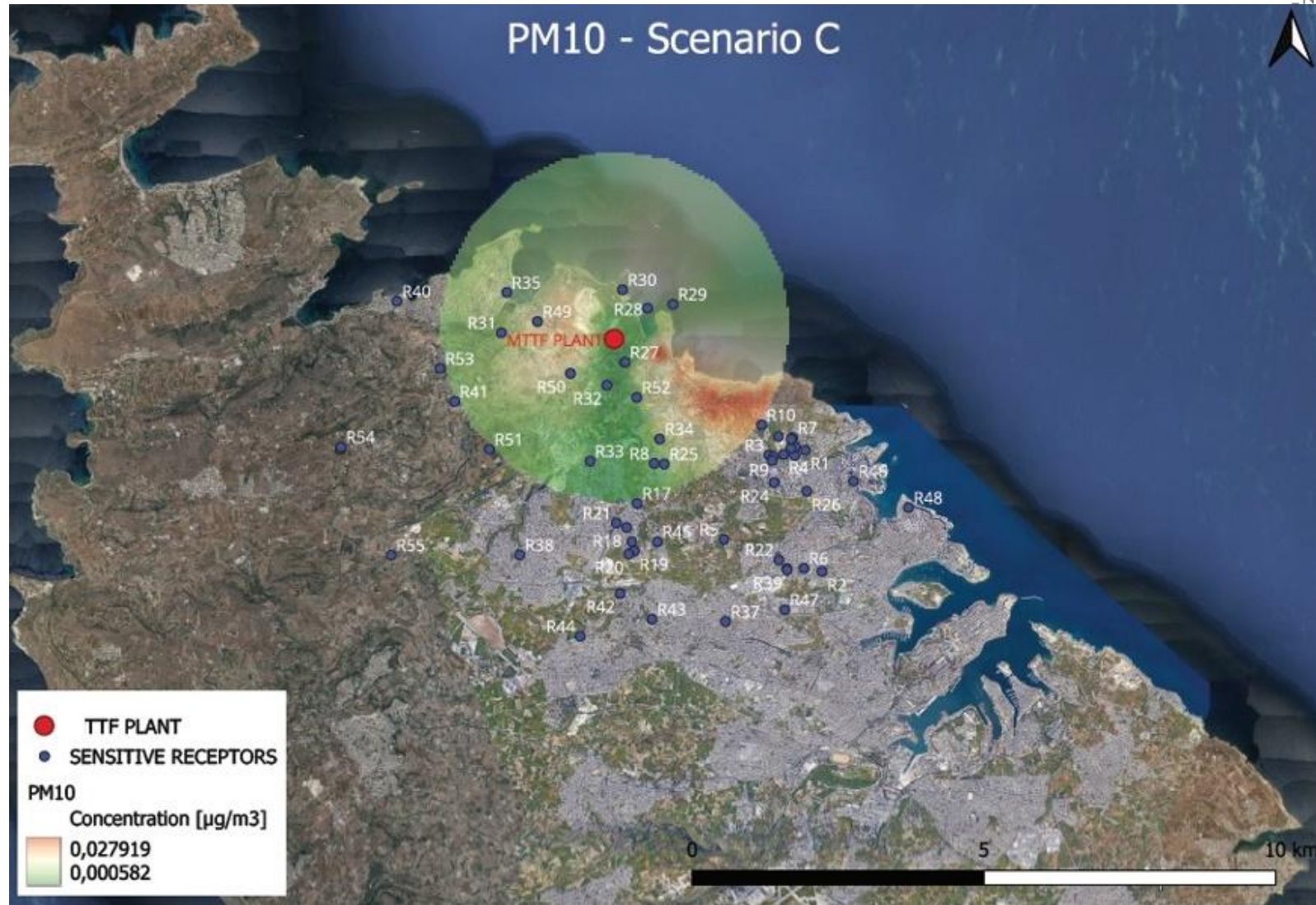












APPENDIX 2 - TORs

Part A. Stack height and effect of stack emissions on deposition rates and emissions loads

A.1 SCOPE

To use dispersion modelling suites, in order to assess for the likelihood of significant effects on ambient air quality (including exceedances of the ambient limit values in SL.549.59) as well as on the deposition levels of particular components, due to the operation of a Thermal Treatment facility. The analysis should focus on the area of influence of the facility, and should include the sensitive receptors in this area. For the deposition levels, the sensitive receptors shall include ALL farms within this area.

The study shall be repeated at predetermined intervals and using in-stack emissions data from the plant.

A.2 DEFINITION

The “area of influence - AOI” means the contour around the plant in which the contribution of the plant to the annual ambient levels of NO₂, PM₁₀ or PM_{2.5} is 0.3 µg/m³ for NO₂ or 0.3 µg/m³ for PM₁₀ or 0.19 µg/m³ for PM_{2.5}, whichever results in the largest AOI. If the area of the AOI is < 113 km² then the AOI shall be assumed to be a circle of radius 6 km centred on the chimney.

A.3 TECHNICAL SPECIFICATIONS

A.3.1 Point source modelling

The modelling suite used throughout this exercise shall be capable of incorporating all the substances included in these terms of reference. Any emission factors used shall be European emission factors preferably based on plants similar (same manufacturer and operating conditions) to the one under study. The model must be capable of predicating the dispersion and deposition of pollutants under variable meteorological conditions ranging from the most favourable to the least favourable.

The modelling suite shall model annual levels of the required parameters.

A few examples of acceptable dispersion models are ADMS, AERMOD, and IMMIS. Other dispersion models may be accepted provided that the requirements in this document are met. The spatial resolution achievable by the model shall be 5 × 5 m², to enable the identification of impacts at sensitive receptors.

The model shall include a meteorological processor and a terrain processor (i.e. capable of modelling dispersion over a complex terrain).

Rather than using the Pasquill-Gifford stability classes, the model shall rely on the use of the Monin-Obukov lengths.

The model shall be capable of modelling the effect of the interaction of the pollutant(s) from the plant with natural or man-made structures (e.g. aerodynamic downwash, cavity and wake effects, amongst others).

The consultants shall provide documentation that the chosen model has been utilised in any one of the 27 EU member states, for regulatory applications involving the local scale effects of point sources on air quality.

For particulate matter, both primary and secondary particulate shall be modelled.

In addition, the total deposition of certain pollutants shall be modelled.

The consultants shall be obliged to follow industry best practice standards in respect of quality assurance requirements of the dispersion model and in order to ensure that the final report satisfies its intended objectives in respect of resolution, accuracy and reliability.

The dispersion modelling study shall assume that the incinerator⁷ always operates at full capacity assumed to be operating at the maximum input load, 24 hours/day over the course of a full year, and the reference conditions are 273.15 K, 101.3 kPa, 0% water and 11% oxygen.

A.3.2 Specific requirements

The dispersion modelling study shall establish the AOI.

The dispersion modelling study shall establish the combination of chimney height and abatement measures required in order to ensure that the contribution of the plant to annual levels of PM_{2.5}, PM₁₀, NO₂ and benzo(a)pyrene in PM₁₀ within the AOI is nowhere higher than the value indicated in

Table 2 below. These values represent 3% of the respective annual limit or target values, where these are available.

The model shall also be used in order to determine the likelihood of exceedances of the limit values for PM₁₀, PM_{2.5} and NO₂ at the sensitive receptors within the AOI, due to the operation of the plant. In this context, the consultants will be required to carry out at their own expense any baseline monitoring studies for these pollutants. The sites used for these studies as well as the monitoring methods are to be agreed upon with ERA. For PM₁₀, the consultants shall also estimate the 90.4th percentile of the daily readings using the following equation:

$$P = (1.46 \times A) + 0.03$$

Whereby P is the 90.4th percentile of the daily readings and A is the annual average of the daily readings.

In addition, the dispersion model shall establish chimney height and abatement measures required in order to ensure that ambient levels of dioxins and furans within the AOI are kept below the level indicated in

Table 2.

Furthermore, the dispersion model shall establish the chimney height and abatement measures required to ensure that annual bulk deposition rate for dioxins and furans as well as for the metals, particularly in any nearby farms and these shall be below the limit in Table 4.

The dispersion model shall establish the points at which the annual averaged daily bulk deposition rates are the highest.

The model shall determine the appropriate in-stack limit values, which would enable the achievement of the limits in

Table 2 and Table 4 below and those set out in

Table 3 which are based on Schedule 2 of S.L.549.81 - The Industrial Emissions (Waste Incineration) Regulations, and Commission Implementing Decision (EU) 2019/2010 of 12 November 2019 establishing the best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for waste incineration, whichever is the strictest. The proposed technology should strive to achieve the strictest achievable level within the BAT-AEL range (or lower). These concentrations shall be expressed at the reference conditions mentioned above.

Emissions from the site shall be assessed initially considering typical operations, which shall be determined by the expected throughput of the facility. Secondly, they shall be assessed under maximum operating conditions. Lastly, emissions shall be assessed under abnormal operating conditions as detailed in footnote 3.

⁷ Task 6 – Basic Design report for Maghtab Hazardous waste incineration facility, May 2023’ - A common stack shall be installed. The stack shall be with three separate flue gas ducts.

TABLE 2⁸: LIMIT VALUES TO BE COMPLIED TO AND WHICH REFER TO 3% OF THE LIMIT VALUES OR TARGET VALUES ESTABLISHED IN DIRECTIVE 2008/50/EC ON AMBIENT AIR QUALITY AND CLEANER AIR FOR EUROPE

Pollutant	Limit
Fine particulate matter (PM _{2.5})	0.6 µg/m ³
Coarse particulate matter (PM ₁₀)	1.2 µg/m ³
Nitrogen dioxide (NO ₂)	1.2 µg/m ³
Benzo(a)pyrene (B[a]P) in PM ₁₀	0.36 pg/m ³
Lead (Pb) in PM ₁₀	15 ng/m ³
Cadmium (Cd) in PM ₁₀	0.15 ng/m ³
Arsenic (As) in PM ₁₀	0.18 ng/m ³
Nickel (Ni) in PM ₁₀	0.60 ng/m ³
Chromium (Cr) in PM ₁₀	0.50 ng/m ³
Hexavalent chromium (Cr (VI)) in PM ₁₀	51 pg/m ³
Mercury (Hg) total	1.5 ng/m ³
Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F)	70 fg WHO-TE/m ³

TABLE 3: TENTATIVE LIMIT VALUES UNDER NORMAL OPERATING CONDITIONS BASED ON BAT AND IED

Daily Average Values	Limit	
Total dust	5 mg/Nm ³	
Total volatile organic carbon (TVOC)	10 mg/Nm ³	
Hydrochloric acid (HCl)	6 mg/Nm ³	
Hydrogen fluoride (HF)	1 mg/Nm ³	
Sulphur dioxide (SO ₂)	30 mg/Nm ³	
Nitrogen oxides (NO _x expressed as NO ₂)	120 mg/Nm ³	
Ammonia (NH ₃)	10 mg/Nm ³	
Half-hourly Averages Values	Limit	
	(100%)	(97%)
Total Dust ⁹	30 mg/Nm ³	10 mg/Nm ³
Total volatile organic carbon (TVOC)	20 mg/Nm ³	10 mg/Nm ³
Hydrochloric acid (HCl)	60 mg/Nm ³	10 mg/Nm ³
Hydrogen fluoride (HF)	4 mg/Nm ³	2 mg/Nm ³
Sulphur dioxide (SO ₂)	200 mg/Nm ³	50 mg/Nm ³
Nitrogen oxides (NO _x expressed as NO ₂)	400 mg/Nm ³	200 mg/Nm ³
Average value over 30 min to 8 hours ¹⁰	Limit	
Cadmium and Thallium and their compounds, expressed as Cadmium (Cd) and Thallium (Tl)	Total: 0.02 mg/Nm ³	
Total Metals and their compounds, expressed as their native elements (As, Cr, Co, Cu, Mn, Pb, Sb, V & Ni)	Total: 0.03 mg/Nm ³	

⁸ It is to be noted that, the Ambient Air Quality Directive is currently under revision. The ambient air quality limit values indicated in such are subject to change and will become stricter as of 2030.

⁹ Total dust emissions may not exceed 150 mg/m³ as a half-hourly average under any circumstance.

¹⁰ These average values cover also the gaseous and the vapour forms of the relevant heavy metal emissions as well as their compounds.

Mercury and its compounds, expressed as Mercury (Hg)	0.02 mg/Nm ³⁽¹¹⁾	
Average value over 6 to 8 hours¹²	Limit	
Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F)	< 0.06 ng I-TEQ/Nm ³	
Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F) + dioxin-like polychlorinated biphenyls (PCBs)	< 0.08 ng WHO-TEQ/Nm ³	
Average value	Limit	
	Daily	30 min
Carbon monoxide (CO)	50 mg/Nm ³	100 mg/Nm ³

TABLE 4: LIMIT VALUES FOR BULK DEPOSITION

Pollutant	Limit
Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F)	4 pg WHO-TE/m ² .day (bulk deposition)
Cadmium (Cd)	2 µg/m ² day (bulk deposition)
Arsenic (As)	4 µg/m ² day (bulk deposition)
Mercury (Hg)	1 µg/m ² day (bulk deposition)
Nickel (Ni)	15 µg/m ² day (bulk deposition)
Lead (Pb)	100 µg/m ² day (bulk deposition)
Thallium (Tl)	2 µg/m ² day (bulk deposition)

The model used shall incorporate terrain, land coverage and wind speed and wind direction (at least a year's data) ideally from the site. However, if this is not possible data should be sourced from a weather station nearby.

Various meteorological conditions, ranging from most frequently occurring to the most adverse, shall be modelled for both ambient air quality and deposition levels.

A.3.3 Emissions in tons

The consultants shall also estimate the annual emission loads in tons based on the envisaged daily emission contribution of the TTF for Dust, SO₂, NO_x, TVOC and NH₃.

The emission loads will assist ERA in setting a cap on the emission loads of PM_{2.5}, SO₂, NO_x, NMVOC and NH₃ from the incinerator in order to ensure compliance with Malta's 2025 and 2030 obligations under both European and International environmental law.

A.3.4 Submission of report

The final report shall as a minimum contain the following sections:

1. Non-technical summary
2. Introduction
3. Scope of work
4. Site description
5. Methodology
6. Identification of sensitive receptors
7. Dispersion models
8. Comparison with limits in legislation
9. Limitations of study
10. Conclusions and recommendations
11. Appendices.

¹¹ Daily average or average over the sampling period. Continuous monitoring may be imposed, half-hourly averages 35µg/Nm³

¹² Either the limit for PCDD/F or PCDD/F+ dioxin-like PCBs applies

The consultants may also be required to present the methodology and results of these studies to *inter alia* members of the public, the ERA Board Members, etc.

Part B. Effect of stack on compliance with the air quality limit values

This part of the study should be carried out once the AOI for emissions from the stack has been determined. The total effect of all stacks within the ECOHIVE complex, including the Waste-to-Energy facility, must be computed based on the assumption that they operate at maximum input load 24 hours a day for an entire year. Once this is completed, the consultants should revert to ERA for direction.

Part C. Qualifications of the person carrying out the Dispersion study

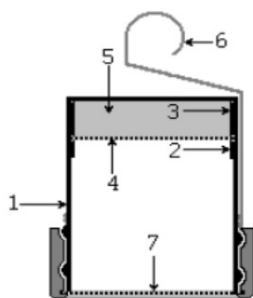
At least an MQF Level 7 in Atmospheric Physics/Chemistry, Environmental Engineering, Air Quality Modelling or similar with experience in modelling for regulatory applications. Should have a demonstrable knowledge of the requirements of Directives 2008/50/EC and Directive 2010/75/EU (Chapter IV).

Modelling experience to be specifically related to the modelling of the effect of large combustion sources on air quality and on deposition rates and should be accompanied by a list of completed projects.

APPENDIX 3 - ARTICLE

Review of the application of diffusive samplers in the European Union for the monitoring of nitrogen dioxide in ambient air

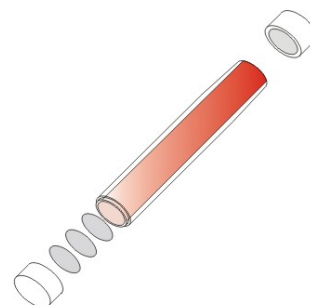
T. Hafkenscheid, A. Fromage-Mariette, E. Goelen, M. Hangartner, U. Pfeffer, H. Plaisance, F. de Santis, K. Saunders, W. Swaans, Y.S. Tang, J. Targa, C. van Hoek and M. Gerboles



Analyst



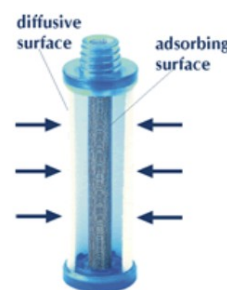
Ogawa



Palmes tube



Passam



Radiello

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Executive summary

A number of diffusive samplers that are used for long-term monitoring of nitrogen dioxide in the European Union were subjected to a review of their use and performance characteristics. The information collected was used:

- To draft conclusions about the feasibility of using the samplers for the long-term monitoring of nitrogen dioxide, with the particular aim of checking compliance with the European Union annual limit value of $40 \mu\text{g.m}^{-3}$ (at 20 °C and 101,2 kPa);
- To draft a proposal method for monitoring nitrogen dioxide using diffusive samplers that could be later used by the CEN Technical Committee 264 “Air Quality” Working Group 11 “Diffusive Samplers” to prepare a CEN standard devoted to the measurement of nitrogen dioxide in ambient air.

The main criteria for assessing sampler feasibility for both purposes were:

- Validation level of the samplers based either on application of EN 13528 part 2 or the Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods, including information about the uncertainty of results obtained using the samplers;
- Potential to meet European Air Quality Directive data quality objectives for indicative and/or fixed measurements;
- Extent or lack of information available to underpin the validity of results obtained using the different samplers;
- Number of different sources providing the above information;
- Differences in performance depending on site type (tube type): traffic, urban, rural;
- Possibility for users to analyse the samplers, e.g., based on procedures specified by manufacturers;
- Their current use throughout the European Union for measuring ambient air quality related to concentrations of nitrogen dioxide.

Of the samplers investigated, two tube-type samplers and a radial sampler were found to be used throughout the European Union for monitoring nitrogen dioxide in ambient air. Other samplers exist that are used mainly for other purposes. In addition, the tube-type samplers are used in monitoring networks for supplementary measurements to the fixed measurements at the level of an indicative method.

Based on the findings of the review, the samplers used in the European Union for ambient air quality monitoring purposes should be of the tube-type design with triethanolamine as sorbent. Sufficient information was available to underpin its potential for meeting European Union data quality objectives, at least for indicative measurements of nitrogen dioxide in ambient air. For other samplers, more supporting information would be needed to draw a similar conclusion.

In conclusion, it is recommended that the proposed method for monitoring nitrogen dioxide using diffusive samplers should be based on the tube-type sampler. If more information becomes available on the performance of the radial sampler, then this sampler could also be included in the standard.

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1 Introduction

Ambient air quality problems associated with levels of nitrogen dioxide (NO₂) are largely due to exceedances of annual limit values. Short-term limit values are only occasionally exceeded in the EU. Diffusive sampling would be an ideal technique for the assessment of compliance with long-term (i.e., annual) limit values for NO₂.

Recent developments indicate that earlier fundamental problems associated with diffusive sampling of NO₂ may have been overcome. Due to modifications in the design of the samplers, potential variations in sampler performance have been eliminated [1,2].

These developments should support the application of diffusive sampling for the assessment of NO₂ in ambient air. Already networks are in operation for routine measurements in many European countries (including Belgium, France, Germany, Switzerland and United Kingdom).

An additional stimulus for applying diffusive sampling is a provision in the ambient air quality directive 2008/50/EC [3] that the number of fixed monitoring sites may be reduced by up to 50 % in zones and agglomerations where supplementary methods for assessment such as modelling and indicative measurements are used. Prerequisites are that:

- The supplementary methods provide sufficient information for air quality assessment;
- The number of sampling points to be installed and the spatial resolution are sufficient to meet the relevant data-quality objectives.

Diffusive sampling methods should be capable of meeting these requirements.

However, the full validation of diffusive sampling methods e.g. according to EN 13528-2, and/or the demonstration of their equivalence with the reference method for NO₂ requires special facilities that are only available to well-equipped institutes/laboratories.

Other smaller institutes and monitoring networks wishing to apply diffusive sampling have to rely on external assistance from commercial/public laboratories. Although small-scale validation experiments and comparisons of diffusive samplers can be performed, it is not clear what the quality and comparability of the results produced by these laboratories could be.

In addition, suppliers of samplers may require that analysis of samplers provided is performed only by themselves. Although perhaps justifiable from a viewpoint of the experience required to correctly perform such analysis, this requirement imposes severe restrictions on the potential application of diffusive sampling.

The availability of a properly validated standard method for the measurement of NO₂ by diffusive sampling would permit the unrestricted use of diffusive samplers by all interested parties.

In August 2006, a New Work Item describing the standardization of a method for the measurement of NO₂ using diffusive sampling methods was submitted to CEN Technical Committee 264 "Air Quality". The proposed New Work Item was accepted.

In order to facilitate the drafting of a future CEN standard, the European Commission made available funding for a group of experts to draft a proposal method for monitoring NO₂ in ambient air with diffusive samplers. The group of experts carried out a literature review of existing information about NO₂ diffusive samplers, to be used as a basis for the subsequent development of the proposal method.

This report summarizes the findings of the literature review. Several different types of diffusive samplers in general use were identified. They may be classified as samplers based on sorption of NO₂ on triethanolamine (TEA), and "other" samplers.

In the chapter devoted to TEA-based samplers, four different samplers are described separately: two tube-type samplers, a badge-type sampler, and a radial-type sampler. In the chapter devoted to other samplers, one badge-type sampler is described.

Other samplers are known to exist, but are not described in this report due to a lack of information. A comprehensive list of samplers may be found in [4].

This report is not intended to specify the various applications of diffusive samplers. Relevant information may be found, e.g., in references [5] and [6].

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2 Samplers based on sorption by triethanolamine

2.1 Introduction

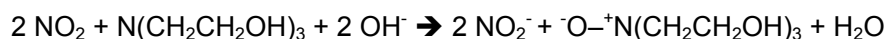
Since their introduction in 1976 for measuring personal exposure to nitrogen dioxide (NO₂) [1], diffusive samplers employing triethanolamine (TEA) as sorbent have been used. Diffusive samplers are an inexpensive method for measuring NO₂ in air over periods from one day to several weeks.

The characteristics of these samplers will be described in separate sections of this report. This section gives an overview of the general properties of TEA-based samplers.

2.2 The sorbent: triethanolamine

Triethanolamine (2,2',2''-nitrilotriethanol (C₂H₄O)₃N, TEA) is a hygroscopic pale yellow liquid with a melting point of 21,6 °C. It has been used as a sorbent for sampling NO₂ since the 1970s, initially in solution in a bubbler or impinger, or in the solid phase on molecular sieve [2]. Its capacity to remove NO₂ from the sampled air is high (90-100 %), as demonstrated using sequential sampling.

The proposed reaction pathway is the following [3].



The collected NO₂ is extracted as nitrite using water. The resulting extract may be analyzed by:

- Colorimetry after derivatization of the nitrite, using the Griess-Saltzman method [4];
- Ion chromatography with conductivity detection [5].

The stoichiometry of the above reaction is dictated to a large extent by the presence of water in the sampled air [3, 6]. The sudden decrease in sampling efficiency below -8 °C [7] suggests that a minimum of around 3 g H₂O m⁻³ is required for TEA to be effective as a sorbent in diffusive samplers.

2.3 Interferences

In addition to its reaction with NO₂, TEA also traps and reacts with other molecules to produce NO₂⁻ ions on extraction into aqueous solution. The two most important potential positive interferences, apart from the reaction of NO with O₃ during sampling, are from peroxyacetyl nitrate (PAN) and nitrous acid (HONO). Dosing of TEA absorbent with NO₃⁻ ions does not produce interference [8]. There is a negligible effect of exposure to O₃ alone in the short term; an atmosphere of 200 ppb of O₃ for 12 h converted less than 10 % of trapped (reacted) NO₂ to NO₃⁻ [9]; active co-sampling of 130 ppb O₃ and 10 ppb NO₂ using TEA on a filter at a relative humidity (RH) of 50 % produced no interference [10].

Interference from PAN is important in that PAN is quantitatively converted to NO₂⁻ on (naturally alkaline) TEA [11]. For tube-type samplers, interference from PAN was lower than 5 % (ppb:ppb) [12]. In practice, interference from PAN is likely to be very small under most exposure conditions, particularly in northern Europe [13]. However, it could be a significant interference in regions with high levels of photochemistry [14].

HONO gives 100 % interference, producing NO₂⁻ on reaction with TEA [10]. However, HONO concentrations in the EU air are likely to be small; even in cities they account for only a few percents of NO₂ concentrations [15].

Not unimportantly, both PAN and HONO would also be measured quantitatively as positive interference by a chemiluminescence NO_x analyzer using thermal conversion of NO₂ (also PAN and HONO) to NO, and would not lead to positive interferences when diffusive samplers are compared with continuous automatic samplers.

Ozone has been reported to interfere through reacting with nitrogen monoxide in the diffusion path of tube-type samplers [16]. However, this finding has not been confirmed by other studies [27].

Sulfur dioxide was found not to interfere with the measurement of NO₂ using tube-type samplers [17].

2.4 Effects of meteorological conditions

2.4.1 Temperature

One of the earliest tests of tube-type samplers showed a 15 % decrease in uptake rate between 27 °C and 15 °C, compared with a theoretical change of less than 2 %. This was attributed to a phase change from solid to liquid of TEA at 21 °C [18]. However, the role of the melting point of TEA was challenged by a later study [19], which showed that TEA solutions did not freeze, but formed a gel even at temperatures as low as -10 °C.

The effectiveness of TEA as a sorbent appears to be dependent on humidity. Some of the reported effects of temperature on uptake rate may be confounded by simultaneous changes in absolute humidity [20], leading to low effective uptake rates at low temperatures that are caused by a lack of water vapour rather than low temperatures *per se* [10, 21, 22]

One laboratory study (designed to evaluate tube-type samplers for use in Greenland) showed almost constant uptake rates from 20 °C down to -8 °C, then a linear decrease to around 30 % of the constant rate, at -28 °C [7]. Another laboratory study found no temperature dependence between 5 and 45 °C [20], while another study found an effect of extremes of temperature and relative humidity on uptake rates, and low uptake rates in the field in winter (by comparison with an automatic monitor) [24].

For short-path 'badge' type samplers the effectiveness of the absorbent may be limited by the rate of diffusion in the liquid phase [25], but this is unlikely to be an issue for the tube type, which has much slower uptake rates. Comparisons of a short path sampler with an active sampler suggest a dependence on temperature of around 1 % per °C [26]. Different designs of sampler have different temperature responses, which must be characterised before they can be used [27].

2.4.2 Relative humidity

The effect of humidity on uptake rate appears to be related to the use of TEA as a sorbent for NO₂, rather than any effect on the diffusion process. Most laboratory studies have used relative humidity (RH) as a measure of water vapour concentration, rather than absolute humidity, which may be more important. Early studies showed no effect of RH between 20 % and 60 % on a short path sampler at room temperature [28]. This was confirmed by subsequent studies with RH higher than 20 % at ambient temperatures [23, 29]. Studies with tube-type samplers between 5 % and 85 % RH at room temperatures (above 22 °C) showed a weak linear dependence of the uptake rate equivalent to an 18 % change in uptake rate between 20 % and 80 % RH [30].

Recent studies demonstrated a dependence on absolute humidity, expressed in terms of the uptake rate for a membrane-capped tube [27], equivalent to a 23 % change in uptake rate between 20 % and 80 % RH at 20 °C.

The effects of variations in absolute humidity on a short path sampler were also reported, with significant reductions in uptake at low RH at low temperature [20, 22].

Effects of humidity on tube-type sampler performance in the field were noted [31], with uptake changing by 17 % between 20 % and 80 % RH at 20 °C with wind velocity of 1 m.s⁻¹. If the uptake rate is dependent on absolute humidity, the above figures may not present a true picture of the dependence on temperature and relative humidity, because RH is a function of water vapour concentration (absolute humidity) and temperature.

However, in comparing results from diffusive samplers with those from automatic analyzers, it is important to note that automatic NO₂ analyzers also have a dependence on humidity, which may not

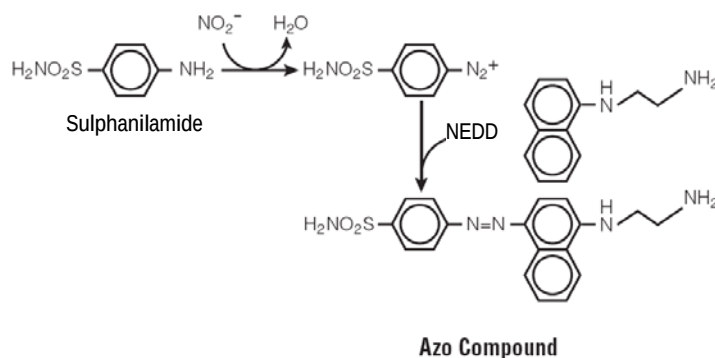
have been allowed for in comparing the response of diffusion tubes relative to automatic methods. The response of a chemiluminescence analyzer typically decreases by 0,5 % per g/m^3 of water vapour [32]. This is equivalent to a change of 5 % between 20 % and 80 % RH at 20 °C.

2.4.3 Air velocity

The effects of air velocity are highly dependent on the sampler design and will be discussed in the sampler-specific sections of the report.

2.5 Analysis of TEA-based samplers

The original method used by Palmes [1] for measurement of the trapped NO_2 relied on the colorimetric determination of NO_2^- using the diazotisation reaction with acidified sulphanilamide and N-(1-naphthyl)-ethylene diamine dihydrochloride (NEDD, sometimes also referred to as NEDA), with detection and quantification of the pink colour produced using photometric absorption spectroscopy at 537 - 542 nm. This colour reagent, or 'Saltzman reagent' has long been used for the quantification of NO_2^- in solution.



However, several authors used ion chromatography (IC) to quantify NO_2 uptake. The benefit of using IC was recognised over 20 years ago, in terms of a greatly improved limit of detection using tube-type samplers, compared with colorimetric analysis [5]. Using gradient elution IC, the limit of detection for tube-type samplers was measured as 4 ppb.hour, compared with 33 ppb.hour for a colorimetric method [12]. Other authors have shown a 14-fold decrease in the limit of detection [33].

2.6 Conclusions

Diffusive sampling of NO_2 using TEA-based samplers dates back 35 years. Meanwhile, a substantial number of studies have been devoted to investigating the behaviour of TEA-based diffusive samplers and their dependence on environmental conditions (presence of interferences, temperature, humidity).

Humidity is probably the most important environmental variable that affects the performance of diffusive samplers using TEA as absorbent. TEA does not perform quantitatively at low humidity. The data of Hansen et al. [7] suggest a loss of efficiency below -8 °C, equivalent to an air concentration of water vapour of about 3 g.m^{-3} , or 35 % RH at 5 °C. At any given temperature, the effect of a change in relative humidity between 20 % and 80 % is to change uptake rates by about ± 15 % relative to the values at 50 % RH. In practice, the dependence on humidity has rarely been tested in the field, and the interaction between humidity and the reaction of TEA with NO_2 has not been investigated systematically.

The dependence of uptake rate on temperature is small and predictable, except in cold dry air. This deviation from theory is related to the use of TEA as the sorbent and appears to be caused by a lack of sufficient water vapour to ensure quantitative conversion of trapped NO_2 to NO_2^- ions. The availability of water is crucial to the way in which TEA reacts with NO_2 . As noted above, the sudden decrease in sampling efficiency below -8 °C suggests that a minimum of around $3 \text{ g H}_2\text{O.m}^{-3}$ is required for TEA to be effective as the sorbent in diffusive samplers. This is unlikely to be a problem under most EU conditions, except for very cold, dry weather.

A number of compounds, particularly PAN and HONO are known to produce positive biases when co-sampled with NO₂. However, under typical EU conditions the biases are expected to be small.

Moreover, the current reference method for the measurement of NO₂ in ambient air which is based on thermal conversion of NO₂ to NO with detection of chemiluminescence, suffers from similar biases. Consequently, when comparing TEA diffusive samplers with this reference method, the effects of the interference cannot be quantified.

2.7 References

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3 The Palmes tube

3.1 Sampler design

The traditional NO_2 Palmes tube consists of an acrylic tube (of 71,16 $\pm$ 0,20 mm long and 10,91 $\pm$ 0,15 mm internal diameter) open at one end and two or three stainless steel mesh discs coated with a solution containing triethanolamine (TEA) at the closed end (see figure 3.1, a). A removable cap is used to close the open end of the tube after exposure. The NO_2 molecules diffuse through the air into the tube, following the concentration gradient and are trapped as nitrite ion on TEA. In a recent study, Gerboles et al. [1] proposed a modification of the traditional Palmes diffusion tube by fitting a Teflon membrane at the open end of the tube (see figure 3.1, b). This membrane was used to obtain a sampler free of wind speed effect. In the United Kingdom, a Teflon mesh is used instead of a membrane [2]. All ready-to-use Palmes tube components are commercially available.

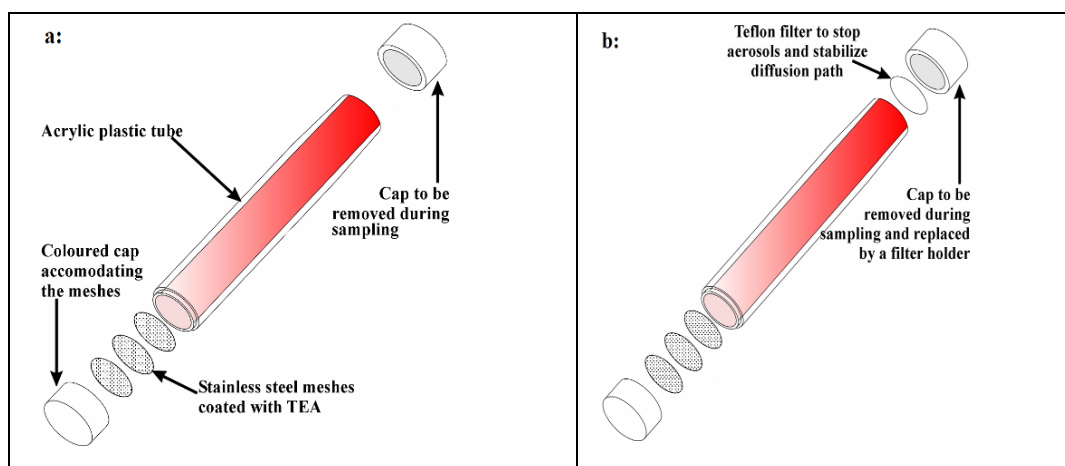


Figure 3.1.a: The traditional Palmes diffusion tube, b: The membrane-closed Palmes tube proposed by Gerboles et al. [1].

The coloured cap needs to be completely opaque and without cracks [2].

Samplers are mounted vertically, with the cap containing the coated discs uppermost. Positions allowing unrestricted movement of air around the sampler are selected. Diffusion tube samplers are fixed by spring clips to the supports (pylons or posts) using supports or spacers of different types. The samplers are, as far as practicable attached at 3-4 meter above the ground in order to avoid vandalism. To attenuate the effect of wind turbulence and improve the precision of measurements by Palmes tubes, it is recommended to use a protective device as for example, shown in Figure 3.2.



Figure 3.2: Cylindrical protective box

The decision to use a protective device should come first (before using a spacer). Criteria to use the protective box may be:

- To prevent exposure to direct sunlight;
- To prevent turbulence in the tube entrance (but at least $0,2 \text{ m.s}^{-1}$ should be ensured);
- To avoid ingress of rain.

In the case of the membrane-closed Palmes tube proposed by Gerboles et al. [1], the protective box is not necessary since the membrane introduced at the open end of tube is intended for isolating the molecular diffusion path from air movements.

3.2 Sampler preparation

The Palmes tube described here needs to be assembled from individual parts. The tube, Teflon membrane and caps are cleaned in a glass container filled with ultra high purity water under magnetic stirring and changing the water every half an hour for 3 h. All components are then placed in an oven at 45°C until they are completely dry. The stainless-steel mesh discs are cleaned in an ultrasonic bath at 60°C for 5 h, with the water changed every half an hour. They are then placed in an oven and flushed with nitrogen at 125°C until they are completely dry. Three clean and dry discs are placed in the coloured cap with tweezers. Then, a tube is placed onto the coloured cap [1].

In practice, this procedure may be quite tedious. Less stringent procedures are described in [3] and [4].

In addition, the coating of the sampling substrate needs to be performed by the user itself. Different procedures for preparation are described [e.g. 5]. Methods of proven validity are:

- 50 % solution of TEA in acetone, grids dipped into solution and dried before assembly;
- 20 % solution of TEA in deionised water, 50 μl of solution pipetted onto grids already placed in end cap;

- 10 % solution of TEA in deionised water with 0,3 % of wetting agent (e.g. Brij-35), 40 µl of solution pipetted onto grids already placed in end cap.

3.3 Extraction and analysis

To determine the quantity of nitrite sampled by the Palmes tube, the Griess-Saltzman method is generally used. The Saltzman reagent consists of a solution of sulphanilamide (2 % w/v) and N-(naphthyl-1) ethylene diamine dihydrochloride (0,007 % w/v) in 5 % v/v ortho-phosphoric acid. A known volume of colorimetric reagent solution is introduced into the tube, and extraction is effected either by:

- Vortex shaking for a minimum of 15 s;
- Vibrating for a minimum of 10 min at 750 rpm.

Nitrite reacts in the phosphoric acid solution with sulphanilamide to give a diazonium salt that couples with naphthalene derivative to form an azo dye. It is recommended to allow the colour to develop at ambient temperature in the dark for a minimum time of 1 h. The absorbance of the azo dye is measured at 542 nm [4].

3.4 Expression of the NO₂ concentration

To calculate the airborne NO₂ concentration, the equation 3.1 is generally applied.

$$C_{NO_2} = \frac{(m_s - m_b)}{v \times t \times 10^{-6}} \quad (\text{eq. 3.1})$$

where

C_{NO_2} = NO₂ concentration in µg.m⁻³ at actual average temperature and pressure during the exposure;

m_s = mass of nitrite measured in the exposed sampler in µg;

m_b = mass of nitrite in the blank in µg;

v = uptake rate in cm³.min⁻¹;

t = sampling time in min.

Several authors also prefer to use equation 3.2 for the calculation of NO₂ concentration, with the uptake rate expressed in ng.ppb⁻¹.min⁻¹.

$$C_{NO_2} = 1,91 \frac{(m_s - m_b)}{u \times t} \quad (\text{eq. 3.2})$$

where

C_{NO_2} = NO₂ concentration in µg.m⁻³ at 20 °C and 101,3 kPa;

m_s = mass of nitrite measured in the exposed sampler in ng;

m_b = mass of nitrite in the blank in ng;

u = uptake rate in ng.ppb⁻¹.min⁻¹;

t = sampling time in min.

The coefficient 1,91 is used to convert ppb to µg.m⁻³ at 20 °C and 101,3 kPa.

3.5 Application range and conditions

The Palmes tube may be exposed for 1 to 5 weeks sampling periods according to results of field validation tests obtained from many sites across Europe [1, 2, 6-9]. Some users have exposed tubes for up to 8 weeks [10].

Results of validation studies described below suggest that the Palmes tube sampler, when properly prepared and exposed with sufficient protection from adverse influences, may be used over a temperature range from -5 °C to 40 °C, and a relative humidity range from 30% to 95%.

Detection limits for a one-week sampling period were found to be 1,4 [1] and 1,9 $\mu\text{g}\cdot\text{m}^{-3}$ [3], depending on the preparation procedure (see section 3.2). In a field experiment, the upper limit for NO_2 that was found in practice to lead to valid results for 5-week sampling was 150 $\mu\text{g}\cdot\text{m}^{-3}$ [2].

When stored in a clean refrigerator at 4°C before exposure, an unexposed tube may be stable for up to 1 year [11].

Stability tests of Palmes tubes after exposure were performed by Gerboles et al. [11] in a feasibility study of the preparation and certification of a reference material for NO_2 in diffusive samplers. The Palmes tubes were stored under two different conditions: at room temperature (22°C) in the dark and at 4°C in a refrigerator. It was demonstrated that the samples may be stable for at least one year under both conditions of storage. The results were in agreement with those obtained previously by Palmes et al. [12], where the samplers were found to be stable for at least 6 months.

3.6 Uptake rate

For the traditional Palmes diffusion tube without membrane, the theoretical uptake rate (72,8 $\text{cm}^3\cdot\text{h}^{-1}$) calculated using the diffusion coefficient of NO_2 in air and the dimensions of the sampler is currently the most common value. It has also been confirmed by test results in exposure chambers under standard conditions ($T=20^\circ\text{C}$, $\text{RH}=50\%$ and wind speeds between 0,1 and 0,3 $\text{m}\cdot\text{s}^{-1}$) [8].

The uptake rate is dependent on the air temperature and pressure during exposure. In appendix 2 of reference [2], a correction for the uptake rate is proposed (equation 3.3). Temperature correction raised to the power 1,5 instead of 1,81 have been proposed by other authors [4]. In most cases, the pressure correction may be neglected.

$$v_{T,P} = v_{\text{ref}} \left(\frac{273,2 + T}{273,2 + T_{\text{ref}}} \right)^{1,81} \frac{P_{\text{ref}}}{P} \quad (\text{eq. 3.3})$$

where

$v_{T,P}$ = uptake rate in $\text{cm}^3\cdot\text{min}^{-1}$ at temperature T and pressure P during sampling;

v_{ref} = uptake rate in $\text{cm}^3\cdot\text{min}^{-1}$ at the reference temperature and pressure;

T = actual temperature during sampling in $^\circ\text{C}$;

T_{ref} = reference temperature in $^\circ\text{C}$ at which v_{ref} rate is given (for example if v_{ref} was calculated using a value of 0,154 $\text{cm}^2\cdot\text{s}^{-1}$ for the diffusion coefficient of NO_2 in air, the reference temperature is 21,1 $^\circ\text{C}$);

P = actual pressure during sampling in kPa;

P_{ref} = reference pressure in kPa at which v_{ref} is given, in general 101,3 kPa.

To improve the accuracy of measurements by Palmes tubes, some authors established empirical equations to estimate the uptake rate as a function of influential environmental parameters. These equations were defined from the results of complete programs of tests in exposure chamber.

Plaisance et al. [8] proposed a first equation which allows the effects of temperature and humidity to be taken into account on the uptake rate of the open Palmes tube exposed in cylindrical box for 2-week sampling:

$$v = 72,8 \times (2,85 \times 10^{-3} \times [T] - 1,62 \times 10^{-4} \times [\text{RH}] + 4,96 \times 10^{-5} \times [T] \times [\text{RH}] + 0,9) \quad (\text{eq. 3.4})$$

where

v = uptake rate in $\text{cm}^3\cdot\text{h}^{-1}$;

T = temperature in $^\circ\text{C}$.

Buzica et al. [9] provided another model-predicted uptake rate. It was deduced from tests in exposure chamber carried out by applying a fractional factorial plan of experiments with 5 factors at two levels

(wind speed, temperature, humidity, NO₂ concentration level and sampling time). The equation predicts the uptake rate of the Palmes tube without membrane exposed from 1 to 2 weeks:

$$v = 7,4 \times 10^{-4} + 2,72 \times 10^{-5} \times T + 1,43 \times 10^{-5} \times RH + 5,81 \times 10^{-4} \times w \quad (\text{eq. 3.5})$$

where

v = uptake rate in ng.ppb⁻¹.min⁻¹;
 T = temperature in °C;
 RH = relative humidity in %;
 w = wind speed in m.s⁻¹.

For the Palmes tube equipped with a Teflon membrane proposed by Gerboles et al. [1], the membrane introduced a resistance to molecular diffusion. Therefore the uptake rate of the sampler could not be determined using the first Fick's law, but was instead estimated by laboratory experiments in exposure chamber. Gerboles et al. carried out the same program of tests as described in [9] and derived a model-predicted uptake rate for the membrane-closed Palmes tube exposed from 3 to 14 days:

$$v = \frac{1}{2} (134 + 0,86RH - 0,00130 t + 1,28T + 3,18w) 10^{-5} \times \left(1 + \sqrt{1 - \frac{0,64 \cdot 10^{-5} m}{t ((134 + 0,86RH - 0,00130 t + 1,28T + 3,18w) 10^{-5})^2}} \right) \quad (\text{eq. 3.6})$$

where

v = uptake rate in ng.ppb⁻¹.min⁻¹;
 T = temperature in °C;
 RH = relative humidity in %;
 w = wind speed in m.s⁻¹;
 m = mass of nitrite in ng;
 t = exposure time in min.

3.7 Environmental effects

3.7.1 Air velocity

Some studies [8, 9, and 13] reported that the greatest effect on the uptake rate of a traditional open Palmes tube may be attributed to wind velocity. An increase in uptake rate was observed with increasing air velocities usually following a logarithmic trend [8, 13]. The effect starts from very low wind velocities (between 0,1 m.s⁻¹ and 0,2 m.s⁻¹).

The magnitude of the uptake increase was found to be about 60 % over the wind velocity range of 0 m.s⁻¹ to 7 m.s⁻¹ [13]. Other authors [8, 9] confirmed that the increase rate was high, about 40 % from 1 m.s⁻¹ to 2.8 m.s⁻¹. An effective and practical way for reducing the effect of air turbulence was demonstrated by the use of a cylindrical protective box (figure 3.2).

Buzica et al. [9] observed that for the open Palmes tube the effect of the wind speed was ±25 % of the average uptake rate, while the effects of the relative humidity and temperature were smaller, at ±10 % and ±7 %, respectively.

Gerboles et al. [1] proposed the addition of a porous membrane at the open end of the Palmes tube. It removes the high influence of wind speed and wind direction on uptake rate. With the addition of the membrane, the wind becomes a minor influencing factor.

3.7.2 Temperature and relative humidity

Temperature and humidity were found to have a smaller influence on the response of the sampler (see above) with the uptake rate increasing linearly by 0,3 %.°C⁻¹, in agreement with the theoretical dependence of the diffusion coefficient of NO₂ on temperature.

A maximum bias in the uptake rate of nearly +10 % was observed under particularly extreme conditions (temperature higher than 30 °C and relative humidity higher than 80 %) [8].

3.7.3 Interferences

Potential interferences from nitrous acid (HONO) and peroxyacetyl nitrate (PAN) which give rise to nitrite ion must be recognised. However, neither compound is likely to be present at sufficient concentrations or over sufficiently long periods to cause serious interferences in most situations. Gair et al. [14] found only a positive interference lower than 6 % which they considered non-significant.

Heal et al. [15] and Jenkins [16] showed that the chemical reaction between O₃ and NO within diffusion tubes may lead to an overestimation of the measured NO₂ concentration. The light transmission characteristics of the acrylic tube used for sampling showed some attenuation in the photochemically important region, possibly leading to changes in the photochemical equilibrium in the air actually inside the sampler.

This information, together with ozone data, was used to model the system for typical conditions of exposure of urban and rural areas. The model showed an increase in NO₂ of about 11 % in rural and 6 % in urban areas. The photochemical reaction is only of importance during daylight and even in the more sensitive rural areas the effect would be difficult to detect.

In field tests carried out by Atkins et al. [17] and Bush et al. [18], no differences were found in the performance of the diffusion tube at rural and urban locations. Likewise, the laboratory experiments in an exposure chamber [1] revealed no bias of O₃ on the NO₂ measurements by Palmes tubes.

3.8 Validation of sampler performance

3.8.1 Comparisons with reference methods

Palmes tubes were validated for outdoor use in several studies. The first extended outdoor evaluation was carried out by Atkins et al. [17] at two sites (rural and urban locations) using the Palmes tubes (10 % TEA/water solution with 0,3 % of the wetting agent Brij-35) and the theoretical uptake rate.

Precision was found to be satisfactory with coefficients of variation for batches of 10 Palmes tubes between 5 % and 8 % for NO₂ concentrations above 5 ppb, which appeared to be independent of NO₂ level and sampling duration (1 week or 4 weeks). Parallel measurements using chemiluminescence analysers and diffusion tubes revealed a good agreement between the two methods. Regression analysis on 42 paired measurements produced a line with a slope not significantly different to 1 and a correlation coefficient above 0,98, over a range of concentrations of 3 ppb to 60 ppb. There was no difference in the performance of the Palmes tube at the rural (NO₂ lower than 30 ppb) and urban (NO₂ higher than 30 ppb) locations.

Glasius et al. [6] confirmed the good agreement between NO₂ measurements carried out with Palmes tube and co-located chemiluminescence analysers at three sites in Denmark and Italy. However, samplers (33 % TEA/acetone solution) at sheltered locations slightly overestimated NO₂ (less than 10 % of overestimation) at concentration levels above 15 ppb. An opposite trend was found at concentrations lower than 15 ppb.

Heal et al. [15] observed overestimations of NO₂ measured by Palmes tubes (50 % TEA/acetone solution) against co-located chemiluminescence analyser at an urban site in Edinburgh (UK). The average ratios of Palmes tube to analyser NO₂ were 1,27 (n=22), 1,16 (n=34) and 1,11 (n=7) for exposures of 1, 2 and 4-weeks, respectively. Based on further modelling of the diffusion, the authors concluded that the overestimation of NO₂ by Palmes tubes could be explained by the generation of excess NO₂ due to the reaction of NO with O₃ inside the tube.

Bush et al. [18] co-located Palmes tubes (50 % TEA/acetone solution) with chemiluminescence analysers at 17 urban monitoring stations in the UK for a one year period. Highly significant correlations (above 0,95) were found between all Palmes tube exposure types (sampling time of 2

and 4 weeks with sheltered and unsheltered samplers) and co-located chemiluminescence analysers. The uncertainty calculated from the overall differences between Palmes tube measurements and the chemiluminescence measurements of NO₂ was estimated to be between ±24 % and 38 % for individual Palmes tube measurements, but reduced between ±10 % and 18 % for annual averages. Differences due to the exposure period and exposure procedure were found, but these were not large.

Tang et al. [10] compared measurement results obtained with Palmes tubes (both open and equipped with a membrane, using protective shelters consisting of a sheet of curved stainless steel painted black, open to the air on 3 sides) with those from chemiluminescence reference analyzers. Comparative measurements were performed at 5 sites: 3 urban sites and 2 rural sites.

Exposure periods were 1, 2, 4 and 8 weeks. In general, it was found that open tubes overestimated NO₂ concentrations at urban sites (average levels around 20 ppb) by almost 30 % to 35 % on average. At the rural site (average levels around 4 ppb) the results agreed much better (ratios between 0,98 and 1,03).

Results obtained with membrane tubes were 10 % lower on average than the reference values for the 4-week sampling period, but were in excellent agreement with those obtained over an 8-week exposure period. At the rural site, the membrane tubes yielded levels that were about 75 % of those of the reference analyzers.

During 2001-2002, CEN/TC264 WG11 (Diffusive sampling) performed a small-scale pilot study at two locations in which 6 replicate samplers of different types of diffusion samplers were exposed for two weeks, in parallel with measurements from a chemiluminescence analyser. These results have not been published and were provided by CEN for the purpose of the present report. Samplers were analysed by the suppliers. The results for two Palmes tube samplers are reported in table 3.1.

Table 3.1: Results of CEN pilot study for Palmes tube samplers

Willebroek	NO ₂ (µg.m ⁻³)	Ratio Palmes/reference
<i>Reference</i>	40,8	
Palmes 1	52,8	1,30
Palmes 2	57,1	1,40
Teddington	NO ₂ (µg.m ⁻³)	Ratio Palmes/reference
<i>Reference</i>	13,8	
Palmes 1	17,6	1,28
Palmes 2	18,7	1,36

Both Palmes tubes were found to overestimate NO₂ concentrations.

Buzica et al. [19] organized a series of 4 comparisons in which different samplers operated by different laboratories were exposed both under laboratory and field conditions. Each sampler was exposed in replicate (6) for a period of 14 days, except in the laboratory trial “high” (see table 3.2).

Table 3.2: Laboratory conditions (intercomparison of Buzica et al.)

Parameter	High	Low
Exposure time (d)	7	14
Concentration (µg.m ⁻³)	80	40
Air velocity (m.s ⁻¹)	2,5	1,0
Temperature (°C)	25	5
Relative humidity (%)	75	30

Five laboratories participated with different implementations of the Palmes tube (with and without shelter; with membrane). The results obtained for the samplers are presented in table 3.3.

Table 3.3: Results field tests, (intercomparison of Buzica et al.)

Lab high	NO₂ (µg.m⁻³)	Ratio Palmes/reference
<i>Chemiluminescence</i>	76,8	
Palmes open 1	125,8	1,64
Palmes open 2	138,5	1,80
Palmes sheltered 1	96,5	1,26
Palmes sheltered 2	97,0	1,26
Palmes membrane	71,5	0,93
Lab low	NO₂ (µg.m⁻³)	Ratio Palmes/reference
<i>Chemiluminescence</i>	43,5	
Palmes open 1	46,0	1,06
Palmes open 2	37,2	0,86
Palmes sheltered 1	32,6	0,75
Palmes sheltered 2	35,8	0,82
Palmes membrane	40,4	0,93
Genevilliers	NO₂ (µg.m⁻³)	Ratio Palmes/reference
<i>Chemiluminescence</i>	41,6	
Palmes open 1	45,2	1,09
Palmes open 2	42,5	1,02
Palmes sheltered 1	47,2	1,14
Palmes sheltered 2	40,5	0,97
Palmes membrane	40,5	0,97
Fontainebleau	NO₂ (µg.m⁻³)	Ratio Palmes/reference
<i>Chemiluminescence</i>	14,1	
Palmes open 1	13,1	0,93
Palmes open 2	12,4	0,88
Palmes sheltered 1	11,6	0,82
Palmes sheltered 2	11,8	0,83
Palmes membrane	12,4	0,88

Apart from the results of the laboratory trial “high”, the results are comparable with those of the reference method (chemiluminescence, CLS).

The precision of the replicate measurements ranged from 3 % to 9 %, except for the laboratory trial “high”, where some values exceeded 10 %.

Plaisance et al. [8] produced a large series of comparison data (n = 52) between diffusion tubes (10 % TEA/water solution with 0,3 % of the wetting agent Brij-35) with and without protection device (cylindrical box) and the chemiluminescence analyser carried out at four French urban monitoring stations for ten months. No systematic differences in measurements were observed between the two techniques, using both the theoretical uptake rate and model-predicted uptake rate (see section 3.6).

A lower scattering of points around the regression line (the slope was not significantly different from 1) was found for Palmes tubes set in the protective device and with the model-predicted uptake rate, revealing a significant improvement in the precision of measurements.

The ISO 13752 standard (1998) was used to evaluate the expanded uncertainty of the Palmes tubes under field conditions. Using the model-predicted uptake rate and the protective device, the expanded uncertainty is reduced to < 25%, implying that this diffusion sampler fulfils the uncertainty requirement for indicative measurements of EU Directive 2008/50/EC.

Buzica et al. [9] investigated the performance of Palmes tube (10 % TEA/water solution with 0,3 % of the wetting agent Brij-35) at one background location in comparison with the chemiluminescence analyser. The use of the theoretical uptake rate gave a high coefficient of correlation ($r^2 = 0,97$) between the measurements of two methods, but resulted in a substantial underestimation (slope 0,75) of the NO_2 concentration measured by the Palmes tube. By applying the model-predicted uptake rate established in this study (see section 3.6), this bias was corrected. For individual measurements, the Palmes tube was shown to comply with the 25% uncertainty requirement.

Gerboles et al. [1] carried out the field tests of the membrane-closed Palmes tube (10 % TEA/water solution with 0,3 % of the wetting agent Brij-35) at the EMEP station in Ispra (I). Forty pairs of data (passive samplers vs chemiluminescence) were collected over a range of concentrations from 8 to 45 $\mu\text{g.m}^{-3}$. Data were analysed to evaluate the equivalence of this sampler to the reference method for NO_2 (chemiluminescence method) in accordance to the Guide to the Demonstration of Equivalence of ambient air monitoring methods [20]. The relative between sampler uncertainty was found to be 3,7%, a value that satisfies the requirement for NO_2 ($\leq 5\%$) defined in the Guide.

The regression line obtained by applying the method of ISO 6143 (2001) for the reference results of the chemiluminescence analyzer versus those of the membrane-closed Palmes tube revealed no systematic bias in measurements (a slope of $1,05 \pm 0,045$ and an intercept of $-0,24 \pm 0,93$).

To determine the NO_2 concentrations measured by the membrane-closed Palmes tube, the model-predicted uptake rate was used (see section 3.6). From the results of these field tests and in accordance with the Guide of Demonstration of Equivalence, the expanded uncertainty was calculated to be 17% for an individual sampler measurement when the NO_2 concentrations were higher than 20 $\mu\text{g.m}^{-3}$. For the estimation of annual average concentrations, the relative expanded uncertainty was found to be 12% at the limit value of 40 $\mu\text{g.m}^{-3}$, satisfying the data quality objective for indicative measurements (25%). According to these experiments, the membrane-closed Palmes tube for NO_2 could become equivalent to the reference method even for fixed measurements [21].

Through AEA Technology (United Kingdom), annual average data for a large number of monitoring sites for both Palmes tube samplers and reference monitors [22] were provided. In summary, two methods were used for the preparation of the sampler substrates:

- 50 % solution of TEA in acetone, grids dipped into solution and dried before assembly;
- 20 % solution of TEA in deionised water, 50 μl of solution pipetted onto grids already placed in end cap.

The two datasets derived from different preparation methods were evaluated according to the methodology of the Guide for the Demonstration of Equivalence [20]. By applying an orthogonal regression forced through the origin (0,0), the results given in the figures 3 and 4 were obtained. One may notice that using an orthogonal regression forced through the origin, the intercept is still be slightly different from (0,0).

<i>REGRESSION OUTPUT</i>		
slope, b	1,023	
uncertainty of b	0,014	
intercept, a	0,6	
uncertainty of a	0,59	
number of data pairs	83	
<i>EQUIVALENCE TEST RESULTS</i>		
random term	5,2	$\mu\text{g.m}^{-3}$
bias at LV	1,5	$\mu\text{g.m}^{-3}$
combined uncertainty	5,4	$\mu\text{g.m}^{-3}$
relative uncertainty	13,6%	
reference uncertainty	1,0	$\mu\text{g.m}^{-3}$
limit value	40	$\mu\text{g.m}^{-3}$

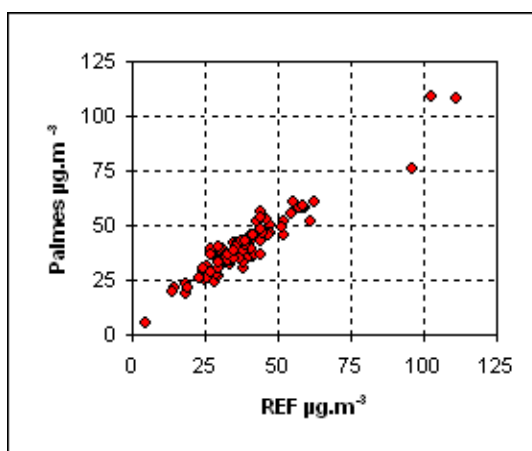


Figure 3.3: Uncertainty for annual averages according to the Guide to the Demonstration of Equivalence, Palmes substrate 20 % TEA in water vs chemiluminescence analyser

<i>REGRESSION OUTPUT</i>		
slope, b	0,906	
uncertainty of b	0,014	
intercept, a	-0,3	
uncertainty of a	0,71	
number of data pairs	116	
<i>EQUIVALENCE TEST RESULTS</i>		
random term	7,6	$\mu\text{g.m}^{-3}$
bias at LV	-4,1	$\mu\text{g.m}^{-3}$
combined uncertainty	8,6	$\mu\text{g.m}^{-3}$
relative uncertainty	21,6%	
reference uncertainty	1,0	$\mu\text{g.m}^{-3}$
limit value	40	$\mu\text{g.m}^{-3}$

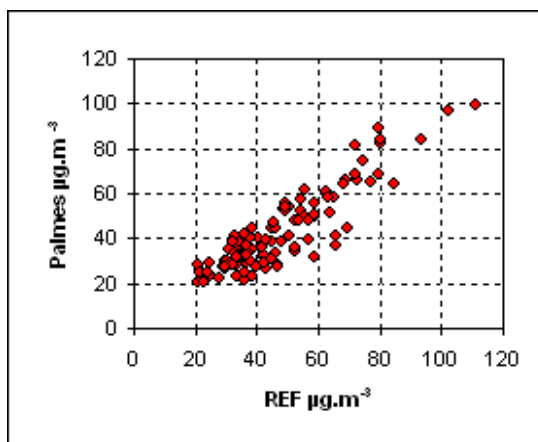


Figure 3.4: Uncertainty for annual averages according to the Guide to the Demonstration of Equivalence, Palmes substrate 50 % TEA in acetone vs chemiluminescence analyser

The results suggest that preparation of the sampling substrate using 20 % TEA in water leads to a better comparability with reference data.

Currently, a comparison is ongoing in the United Kingdom in which Palmes tube samplers and Radiello samplers are exposed at a traffic site in London. Results of this comparison were not available at the time of the drafting of this report.

3.9 Measurement uncertainty

3.9.1 GUM approach

A French Guide [24] is fully devoted to the assessment of measurement uncertainty from the application of the Palmes tube for measurement of NO_2 . In a fully worked example based on practical data, the relative expanded uncertainty at NO_2 concentration of $37 \mu\text{g.m}^{-3}$ was calculated to be 32 % for a single measurement of 2 weeks duration.

The main contribution to this uncertainty (around two thirds of total uncertainty) was from the uptake rate. The uncertainty of the uptake rate was assessed from tests performed by JRC using Palmes

tubes with a cylindrical protective box in an exposure chamber, under two extreme environmental conditions, yielding low and high values of uptake rate [19] which represented worst case scenarios. Hence, the 32 % represents a worst-case estimate. Practical values are expected to be lower.

3.9.2 Direct approach

From the comparisons described above, estimates of the uncertainty associated with NO₂ measurements performed with Palmes tubes were made.

Based on a series of 52 comparison data using an ISO 13752 approach, Plaisance et al. [8] estimated the expanded uncertainty to be < 25 % for a sampler in protective box, using a model-predicted uptake rate.

This finding was confirmed by Gerboles et al. [1], and by Buzica et al. [21], again when using a modelled uptake rate. For the membrane tube, the relative expanded uncertainty of individual measurement results at the level of the annual limit value (40 µg.m⁻³) was estimated to be 17 %.

When aggregating individual results to form an annual average, the relative expanded uncertainty reduced to 12 %. To reach this level of uncertainty, knowledge of average temperature, pressure and relative humidity and wind speed during exposure is a prerequisite.

3.10 Application in EU monitoring networks

Palmes tube samplers are extensively used e.g. in Denmark, France, the Netherlands, Spain and the United Kingdom for supplementary measurements to fixed measurements at the level of an indicative method. Other applications include identification of hot spots, mapping, zoning, trend analysis, source apportionment, impact on vegetation, assessment of exposure of population, verification of dispersion models etc.

3.11 Conclusions

The Palmes tube-type diffusive sampler is suitable for long-term monitoring of NO₂ in ambient air. Exposure periods of 1 to 8 weeks are feasible. The lower detection limit for a 1-week sampling period varied with the meticulousness of the sampler preparation procedure, and generally was between 1,4 µg.m⁻³ and 2 µg.m⁻³. The upper limit for a 5-week exposure period was at least 150 µg.m⁻³.

Information about the precision of the sampler showed that it is usually better than 5 % when using a barrier or shelter to reduce effects of wind-induced turbulence. Without these, the precision was generally higher.

Comparisons of sampler results with those obtained from reference monitors (chemiluminescence) gave varying results; however, the results are generally consistent within the uncertainties of the methods. At urban sites, where unprotected open tubes were used, a tendency was observed towards overestimation of NO₂ concentrations.

When using membrane-capped tubes in combination with model equations describing the uptake rate as a function of temperature, humidity, wind speed etc. the comparability improved.

When the uncertainty associated with the measurement results was evaluated according to the Guide to the Expression of Uncertainty in Measurement, the relative expanded uncertainty of individual results was estimated to be 32 % for worst-case conditions (when using a single value for the uptake rate independent of environmental conditions). When assessing measurement uncertainty by direct approaches, e.g., from parallel measurements with the reference method for measurement of NO₂, better results were obtained (generally < 25 %).

These findings suggest that the Palmes tube is at least suitable for performing long-term measurements of NO₂ for indicative purposes, and possibly even for fixed measurements.

When aggregating results to form annual average values, the relative expanded uncertainty may be further reduced to levels below 15 % due to the reduction of random effects on uncertainty.

3.12 References

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4 The Passam sampler

4.1 Sampler design

The Passam sampler, which is based on the Palmes tube design, is shown in figure 4.1 and consists of an opaque polypropylene tube. The tube is slightly conical. The dimensions of the tube have been measured by Ecole de Mines de Douai [1, p. 46] (see figure 4.1).

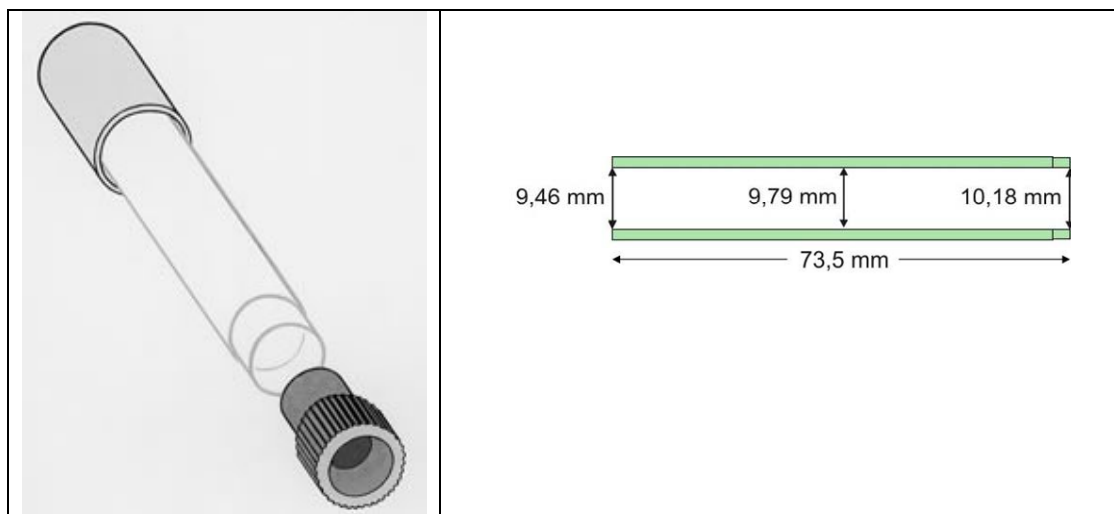


Figure 4.1: Passam tube design

At the narrow end, 3 stainless steel screens are mounted, which are coated by dipping into a solution of TEA - acetone 1:7. Shelf life of the sampling substrate of up to 2 years has been found [2]. Passam tubes are exposed in specific shelters [3]. These shelters are designed to protect the samplers from environmental factors such as rain, excessive radiation and wind. The shelters are an integral component of the measurement method (see figure 4.2).



Figure 4.2: Passam protective shelter

In order to reduce the effect of wind-induced turbulence the sampler may be equipped with a membrane or a glass frit [4].

4.2 Extraction and analysis

The manufacturer describes the determination of the collected NO₂ by colorimetry, after reaction with sulphanilic acid and N-1-naphthylethylenediamine [3].

4.3 Application range and conditions

Information on application ranges and conditions given in table 4.1 was provided by the manufacturer [3].

Table 4.1: Application ranges and conditions

Parameter		Application ranges/Conditions
Sampling time		1 – 4 weeks
Working range		1 – 200 µg.m ⁻³
Detection limit		0,8 µg.m ⁻³ for 1-week exposure 0,4 µg.m ⁻³ for 2-week exposure
External influences	Wind speed	Influence of wind speed < 10 % up to 4,5 m.s ⁻¹ when using protective shelter
	Turbulence at kerb sites	Use of membrane recommended because of potential increase of uptake rate
	Temperature	No effect between 5 and 40 °C
	Humidity	No effect between 20 and 80 % RH
Storage	Before use	12 months
	After exposure	4 months
Cross sensitivity		Nitric oxide and sulfur dioxide do not interfere
		Presence of PAN will lead to high results

Field studies showed that exposure periods of up to 6 weeks are feasible without introducing differences [4].

4.4 Uptake rate

The uptake rate of the Passam tube was determined in a series of laboratory experiments [5] designed as prescribed in EN 13528 part 2. In addition, the results of a series of comparisons performed by Buzica *et al.* [6] were used to validate these earlier results.

The manufacturer reported a nominal uptake rate of 0,85 cm³.min⁻¹ ± 11 % for a reference temperature of 9 °C and a reference pressure of 950 mbar.

When applying Fick's first law of diffusion, an uptake rate of 0,947 cm³.min⁻¹ was calculated at a temperature of 21 °C and pressure of 101,3 kPa [1, p. 47].

For practical purposes, users may correct the uptake rate to actual conditions of temperature and pressure by applying equation 3.3. In most cases, the pressure correction may be neglected. Other authors proposed e.q. 4.1 with a temperature correction raised to the power of 1.5 instead of 1.81 ([1], page 74):

$$v_{T,P} = v_{ref} \left(\frac{273,2 + T}{273,2 + T_{ref}} \right)^{1,5} \frac{P_{ref}}{P} \quad (\text{eq. 4.1})$$

where

- $v_{T,P}$ = uptake rate in cm³.min⁻¹ with temperature T and Pressure P during sampling;
- v_{ref} = uptake rate in cm³.min⁻¹ at reference temperature and pressure;
- T = actual temperature during sampling in °C;
- T_{ref} = reference temperature in °C at which v_{ref} rate is given;
- P = actual pressure during sampling in kPa

P_{ref} = reference pressure in kPa at which v_{ref} is given.

When applying a glass frit [4] to reduce effects of wind-induced turbulence, the uptake rate reduces to $0,827 \text{ cm}^3 \cdot \text{min}^{-1}$.

4.5 Environmental effects

4.5.1 Air velocity

The migration of NO_2 molecules to the absorption layer at the lower end of the diffusive sampler is determined by the length of the diffusion path. Eddies created by wind turbulence can shorten the diffusion path, thereby increasing the uptake rate and producing higher results. This phenomenon can be eliminated in one of two ways:

- by using protective shelters;
- by equipping the sampler inlet with a membrane.

Protective shelters

Protective shelters reduce the wind velocity at the sampler openings (the sampler and the shelter are an integral system): $0,5 \text{ m} \cdot \text{s}^{-1}$ outside corresponds to about $0,1 \text{ m} \cdot \text{s}^{-1}$ inside the shelter [3, 6] (see figure 4.3).

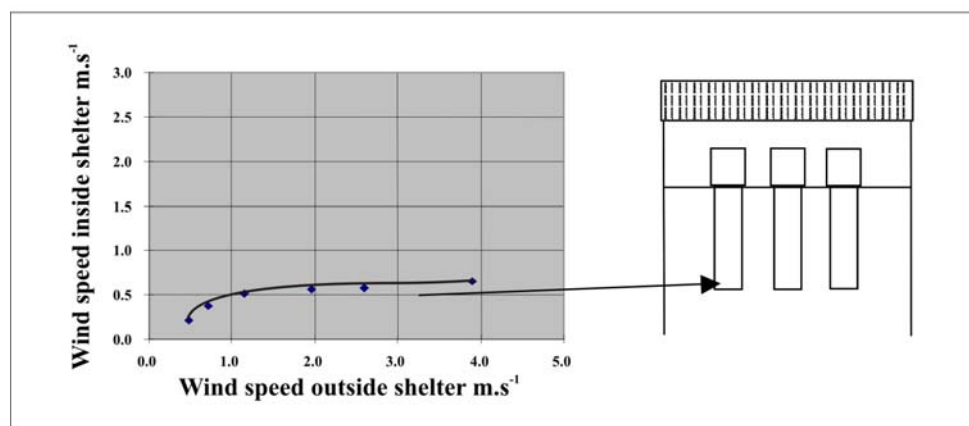


Figure 4.3: Effect of protective shelter on wind velocity inside the shelter

Effect of diffusion barrier like membranes or glass frit

The effect of using a polyethylene membrane on the relative uptake rate is illustrated in the figure 4.4.

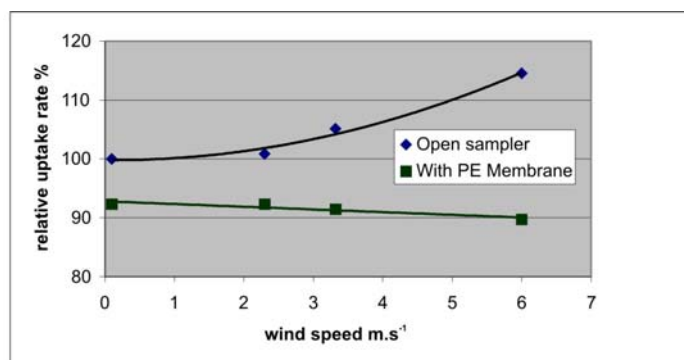


Figure 4.4: Relative uptake rate with and without membrane.

However, membranes affect the uptake rate of a diffusive sampler. The tested membranes (Fluoropore $1 \mu\text{m}$, Glass fibre EPM 2000 and Polyethylene $15\text{--}45 \mu\text{m}$) produced a decrease around

10% $\pm$ 4%. The results of the tests with different membranes are reported in table 4.2. The tests were conducted in a glass chamber with concentrations of 50 and 100 $\mu\text{g.m}^{-3}$ and wind speeds of 0,01 and 0,5 m.s^{-1} . By using membranes, an additional resistance to the diffusion of NO_2 towards the absorbent is introduced (see section 3.7.1). This resistance tends to change with sampling conditions and creates another source of uncertainty. However, this uncertainty was found to be lower than the effect of wind velocities above 2 – 3 m.s^{-1} for open tubes without protective shelters.

Table 4.2: Uptake rate for membrane closed Passam samplers relative to open tube

Membrane type	50 $\mu\text{g.m}^{-3}$ 0,5 m.s^{-1}	100 $\mu\text{g.m}^{-3}$ 0,01 m.s^{-1}	100 $\mu\text{g.m}^{-3}$ 0,5 m.s^{-1}
Fluoropore 1 μm	90 %	95 %	94 %
Glass fibre EPM 2000	91 %	93 %	94 %
Polyethylene 14-45 μm	87 %	90 %	89 %

4.5.2 Relative humidity

No influence of relative humidity between 20 and 80% was observed [8]. No data are available for extreme conditions such as dry desert areas and wet tropic areas.

Under European climatic conditions, no humidity effects were reported [9].

4.5.3 Temperature

To investigate the influence of temperature, two glass chambers were set up in series. Six laboratory tests were performed. One chamber was always set at a controlled temperature of 20°C, while the second one was set at different temperatures between -15 and 50 °C (see figure 4.5). For each test, paired uptake rates (one at 20 °C and one at the temperature under test) were determined by exposure and analysis of several samplers in the chambers. For each paired uptake rate, a relative difference with reference to the uptake rate at 20 °C was calculated. Figure 4.5 shows that in the range of 5 to 40 °C, the uptake remained nearly constant and that it does not need any correction [8] according to temperature during exposure.

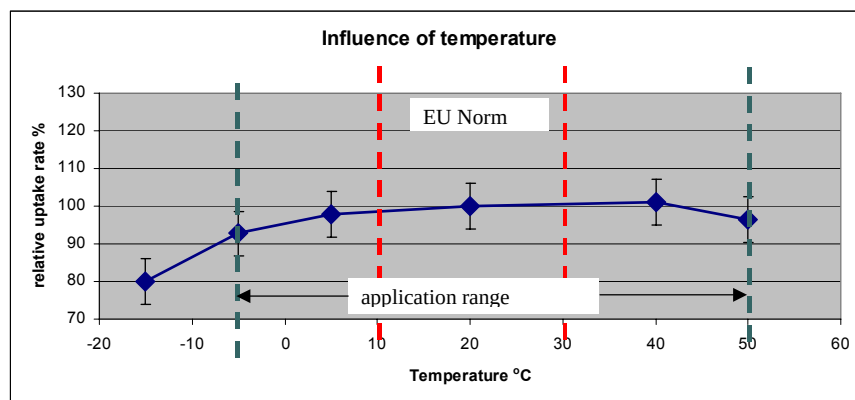


Figure 4.5: Effect of temperature on uptake rate, error bars represent the standard deviation of the relative uptake rates

In a year-long study conducted in Switzerland at 3 monitoring sites, where meteorological data were collected, comparisons between measurements by Passam samplers and chemiluminescence analysers were carried out [8]. A correlation analysis was performed between the meteorological factors and the ratios of NO₂ concentrations measured by the analysers to the diffusive sampler values. In total, 78 2-week pairs of measurements were available. All samplers were equipped with protective shelters. No influence of wind velocity and radiation was observed (see table 4.3). There was a slight correlation with temperature and humidity, although the median test was negative in all cases.

Table 4.3: Correlation coefficients of meteorological parameters with the ratios of NO₂ measurements carried out with chemiluminescence analyses out of diffusive samplers

	Temperature	Humidity	Wind speed	Radiation
Unit	°C	% rel.	m/sec	Watt/m ³
Correlation r	0.136**	0.113**	0.021	-0.019
Range _{min}	-0.7	42	0.7	15
Range _{max}	23	85	2.6	273
Median	11.2	67	1.4	112
Median test	n.s.	n.s.	n.s.	n.s.

** = 99% significance level.

In a Swiss alpine Valley 1800 m above sea level, a measurement comparison between a chemiluminescence monitor and the Passam samplers was performed. The mean temperature in the coldest season was -4,1 °C. No differences in results of the two methods were observed for temperatures above - 5 °C [3].

4.5.4 Pressure

A pressure effect of 0,5 % decrease in uptake rate with an increase in ambient air pressure of 10 mbars has been observed [8].

4.5.5 Interferences

Burri has studied the interferences of NO, SO₂ and ozone. No effects could be shown when single substances were applied [10].

4.6 Validation of sampler performance

4.6.1 Comparisons with reference methods

Basic validation studies 1986 – 1988

To validate the diffusive sampling system, comparisons with continuous monitors were performed [10]. The comparisons were made at 5 different monitoring sites over one year. 184 weekly monitoring pairs were collected. The concentration values of the monitors were standardized to 9 °C and 950 mbar. The results are compiled in figure 4.6.

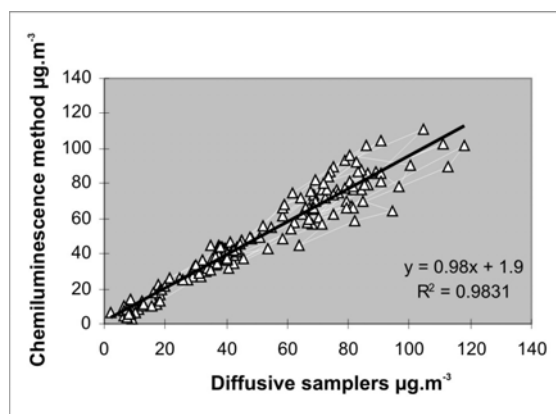


Figure 4.6. Relationship between results of Passam and chemiluminescence monitors

Reports from cantons of Switzerland

Comparisons of yearly means

In figure 4.7, the results of comparisons of annual NO_2 averages are shown. Each point is characterized by 50 to 70 diffusive sampler measurements over one year and a complete data set of chemiluminescence analyser results. The exposure period was two weeks. Under these conditions, varying meteorological factors such as humidity, wind, temperature etc. were automatically considered.

The 95 % confidence interval was calculated to be $\pm 4 \mu\text{g.m}^{-3}$ at the level of the Swiss long-term limit value of $30 \mu\text{g.m}^{-3}$. This figure is valid for the investigations conducted from 1987 to 1994. Figure 4.7 shows that the uptake rate of the sampler remained constant from 1987 to 1994 and from 1995 to 2000. The ratio of NO_2 measured by samplers vs monitors was 0,98 from 1987 to 1994. The same ratio (1,01), was not significantly different from 1995 to 2000. The difference in R^2 values may be explained by the larger range of NO_2 concentrations measured between 1987 and 1994.

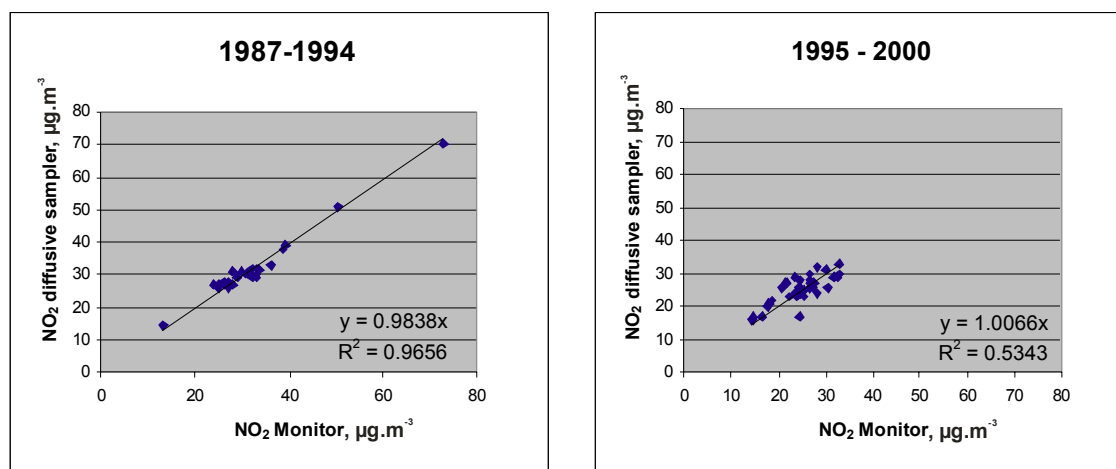


Figure 4.7. Relationship between results of Passam and chemiluminescence monitors

Comparisons of single pairs

Table 4 gives a regression analysis for individual NO_2 concentrations measured using Passam samplers and chemiluminescence analysers. The data were communicated by the Environmental Agencies of the cantons of Grison, Basel and Bern (CH). For each sampling site, the slope/intercept of the regression line, the percentage of variation expressed by the regression line (R^2) and the number of samples are given. Samplers were exposed for 2 weeks.

Table 4.4: Comparisons of individual NO₂ measurements by Passam samplers and chemiluminescence analyser at field sites. Results of environmental agencies in Grison, Basel and Bern (CH)

Canton	Type of site	Year	Slope	Intercept	R ²	n
Bern	city background	2005	1,15	-3,4	0,939	26
		2006	0,96	-0,91	0,975	26
		2007	0,94	-0,03	0,928	26
	agglomeration, highway	2005	1,49	-25	0,780	26
		2006	1,12	-9,1	0,889	26
		2007	1,22	-12,7	0,889	26
Basel	city	2001/02	1,15		0,954	124
Grison	industrial	2001-2003	0,94	-6,8	0,700	166
	traffic		0,94	-3,1	0,840	54
	rural		0,9	-1,1	0,890	113
	mountain city, suburb		1,09	-0,9	0,850	128
	mountain city, traffic		1,08	-7,3	0,860	41
	traffic		1,12	-11,4	0,570	25
	mountain		1,16	-11,1	0,750	24
	highway		0,97	-1,2	0,740	231
	mountain village		1,26	-5,8	0,930	15
	highway		0,26	16,4	0,130	58
Neuchatel	city	2005	1,13	0	0,927	27

Near highways and in cities, site-specific discrepancies were sometimes observed (see figure 4.8). In general, an overestimation of the concentration of NO₂ in the vicinity of highly trafficked streets was observed [11]. The deviations are most likely due to traffic-induced vertical air turbulence.

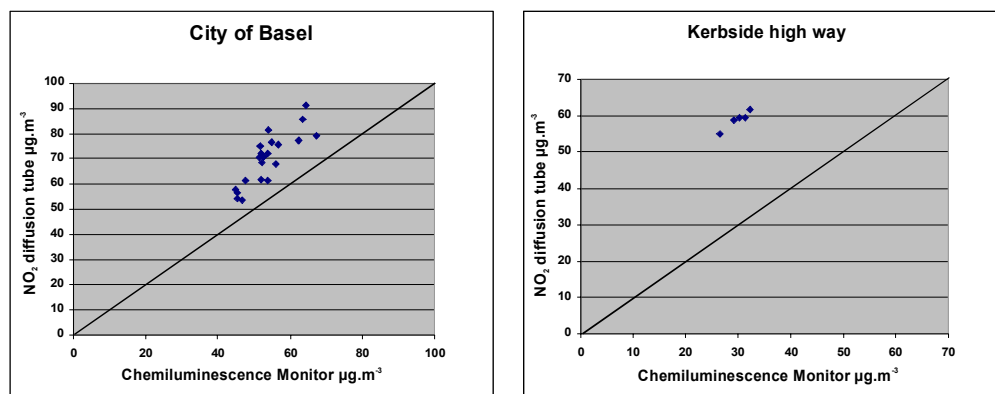


Figure 4.8. Examples of relationships between results of Passam and chemiluminescence monitors for specific city and highway conditions

Reports from outside Switzerland

In 2001-2002, CEN/TC264 WG11 performed a small-scale pilot study at two locations in the UK. At each location, 6 replicate samplers of different NO₂ passive samplers were exposed for two weeks, in parallel with measurements from a reference chemiluminescence analyser. Samplers were provided and analysed by the suppliers. The unpublished results for the exposed Passam samplers are reported in table 4.5.

Table 4.5: Results of CEN pilot study for Passam samplers

Willebroek	NO ₂ (µg.m ⁻³)	Ratio Passam/reference
Reference	40,8	
Passam	55,0	1,35
Teddington	NO ₂ (µg.m ⁻³)	Ratio Passam/reference
Reference	13,8	
Passam	20,2	1,46

Passam samplers were found to overestimate NO₂ concentrations.

Experiments in France at various sites also concluded that the Passam tubes overestimated NO₂ concentrations, when using the uptake rate of 0,85 cm³.min⁻¹ (see figure 4.9). In order to obtain correct values, a uptake rate of 0,947 (21 °C, 101,3 kPa) should be used, reducing the results of the Passam tubes by about 11 %. [1, p. 47].

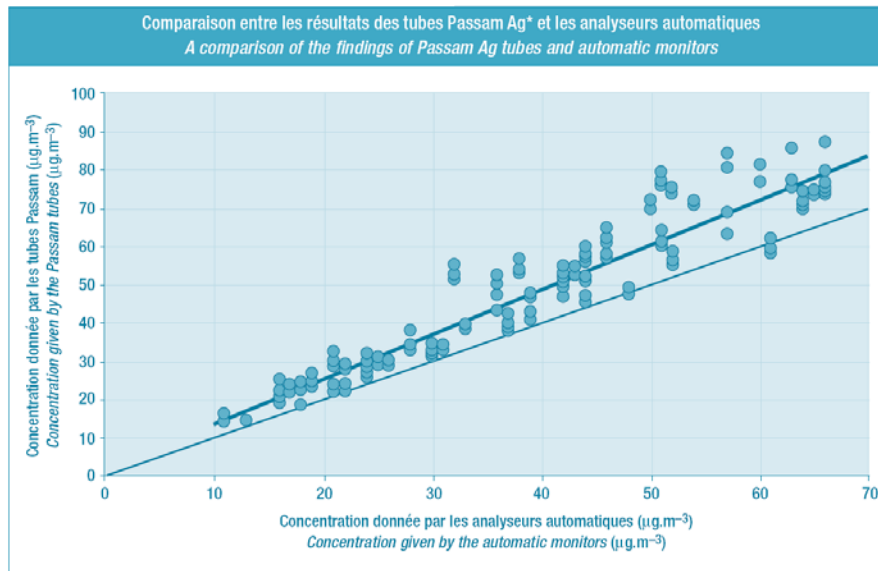


Figure 4.9: Relationship between results of Passam and chemiluminescence monitors

ASPA (the French air quality Alsace network) reported slopes of linear regressions between results of chemiluminescence monitors and Passam tubes from 0,95 to 1,15 (see table 4.6). The NO₂ concentrations were corrected to 20 °C and 1013 mbar according to equation 4.1. The slope/intercept of the regression line, the percentage of variation expressed by the regression line (R²) and the number of samples are given. Samplers were exposed for 2 weeks.

Table 4.6: Comparisons of individual NO₂ measurements by Passam samplers and chemiluminescence analyser at field site. Results of ASPA in France

ASPA	Type of site	Year	Slope	Intercept	R ²	n
1	agglomeration	2005	1,15	-3,42	0,939	25
2	rural	2005	0,964	-0,91	0,975	25
3	agglomeration	2005	0,953	-0,03	0,928	25
4	city centre	2005	1,006	1,29	0,963	25
5	city centre	2005	1,023	2,36	0,989	25

Buzica et al. [6] organized a series of 4 comparisons in which different samplers operated by different laboratories were exposed both under laboratory and field conditions. Each sampler type was exposed in batches of 6 samplers for a period of 14 days, except in the laboratory trial “high” (see table 4.7).

Table 4.7: Laboratory conditions (intercomparison of Buzica et al.)

Parameter	High	Low
Exposure time (d)	7	14
Concentration ($\mu\text{g.m}^{-3}$)	80	40
Air velocity (m.s^{-1})	2,5	1,0
Temperature ($^{\circ}\text{C}$)	25	5
Relative humidity (%)	75	30

The results obtained for the Passam sampler (implemented by an external laboratory following the Passam protocol), are presented in table 4.8.

Table 4.8: Results of Passam sampler analysed by an external laboratory (intercomparison of Buzica et al.)

Location	CLS ($\mu\text{g.m}^{-3}$)	Passam ($\mu\text{g.m}^{-3}$)	Ratio
Laboratory, high	76,8	97 ± 5	1,27
Laboratory, low	43,5	$39,5 \pm 0,7$	0,91
Genevilliers	41,6	$53,1 \pm 0,3$	1,28
Fontainebleau	14,1	$15,7 \pm 0,4$	1,11

CLS: chemiluminescence method

The Passam tubes were found to overestimate NO_2 concentrations, confirming the findings reported in [1] (see table 4.8). This was attributed to the use of an uptake rate for reference conditions differing considerably from the exposure conditions.

In 2004-2005, Pfeffer et al. [4] performed an extensive study into the use of Passam tubes. Tubes were exposed for periods from 2 to 6 weeks at 10 different sites in North-Rhine Westphalia in Germany (LANUV network)). In this investigation, a diffusion barrier consisting of a porous glass membrane was fitted at the open end of all samplers. The uptake rate of the tubes, derived from the comparison with reference method according to EN 14211 was $0,8270 \pm 0,0085 \text{ cm}^3.\text{min}^{-1}$. When comparing concentrations measured with the reference method and the modified Passam sampler by linear regression, the site-specific slope derived for each monitoring site generally did not differ significantly from the slope calculated from the complete data set at the 95% confidence level. The site-specific slopes varied between 0,93 and 1,11. The between-sampler uncertainty obtained from replicate sampling was $1,2 \mu\text{g.m}^{-3}$. The tubes were subsequently used in the LANUV monitoring network. They were further investigated for consistency with the reference method. No deviations were observed when comparing 789 data pairs of results [12].

In France, Passam samplers were extensively compared to the chemiluminescence reference method [13]. During the years 2005, 2007 and 2008 samplers were exposed side-by-side with the reference method at 6 locations (5 in 2005) with exposure periods of 4 weeks, resulting in a total of 181 valid data pairs. From the results reported, it was observed that the data capture of the Passam samplers (100%) was higher than that of the reference method (95,5%). Further, when subjecting the data to the evaluation of equivalence [14], the results presented in figure 4.10 were found. The evaluation revealed excellent agreement between the results of both methods. The resulting uncertainty, 13 % for a 95 % confidence level, fulfils the 15 % uncertainty requirement for fixed measurements of NO_2 . The ratio of the overall means of diffusive sampling results and reference results was 0,98.

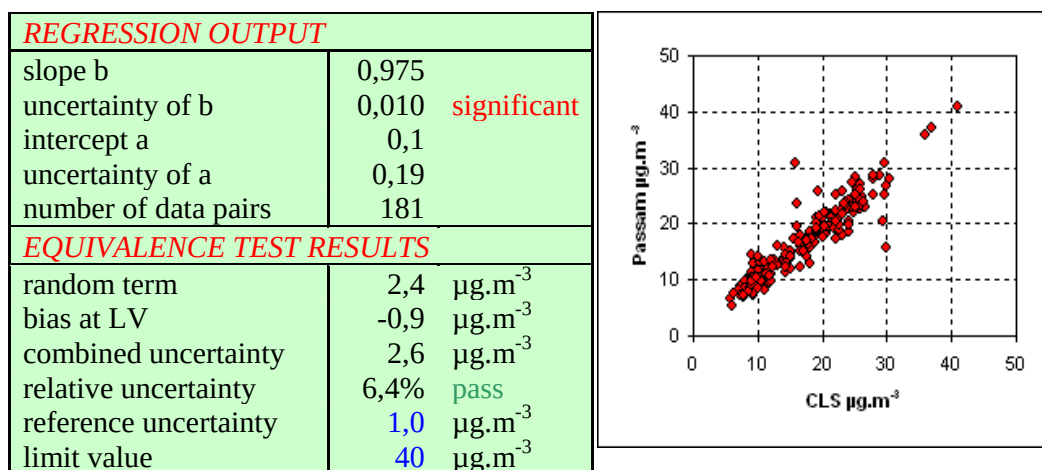


Figure 4.10: Uncertainty for annual averages according to the Guide to the Demonstration of Equivalence, Passam sampler vs chemiluminescence analyser

4.7 Measurement uncertainty

4.7.1 GUM approach

Passam applied the (indirect) GUM approach for the evaluation of the uncertainty associated with the measurement of NO_2 using the Passam tube [15]. The uncertainty assessment was based on the following measurement equation:

$$C_{\text{NO}_2} = \frac{(m_d - m_b) \cdot 10^6}{v \cdot t} \quad (\text{eq 4.2})$$

where

C_{NO_2} = ambient concentration in $\mu\text{g.m}^{-3}$;
 m_d = mass of desorbed analyte in μg ;
 m_b = blank of analyte in μg ;
 v = diffusive uptake rate in $\text{cm}^3.\text{min}^{-1}$;
 t = exposure time in min.

The input quantities and their uncertainties are defined as follows:

u_{md} : Uncertainty of the mass of measured nitrite. The standard uncertainty is characterised by the standard deviation of the calibration function;
 u_{mb} : Blank values: the variation of blank value has to be added to u_{md} in absolute terms;
 u_v : Uncertainty of uptake rate. The variation of this term is given by the standard deviation of repeated verification experiments in standard atmospheres;
 u_t : Exposure time. This term is in general negligible at exposure times of more than one week.

An additional term is introduced, which covers the uncertainties associated with between-sampler precision, micro-environmental factors, variations in the geometry of samplers etc.

u_P : Variation of multiple samples at the same site. The size of this term is estimated by the median of triplicate samplers in the field.
 u_{ext} : External influences such as temperature, wind speed, humidity. This term has to be taken into account, if the samplers are used in extreme conditions. This term has to be estimated.

The combined uncertainty u_c is calculated using equation 4.3.

$$u_c^2 = u_v^2 + u_{md}^2 + u_{mb}^2 + u_p^2 + u_t^2 + u_{ext}^2 \quad (\text{eq. 4.3})$$

The expanded uncertainty is calculated by using a coverage factor of 2. Detailed figures for u_v , u_p and u_{mb} are given in [16]. The coefficient of variation of replicates is reported in [17] to be 1,7 %. The uncertainty figures are re-evaluated every year [16].

The expanded uncertainty calculated in the above manner varies between 20 % and 25 % (see figure 4.11). The data quality objective of EU Directive 2008/50/EC for indicative measurements is generally fulfilled.

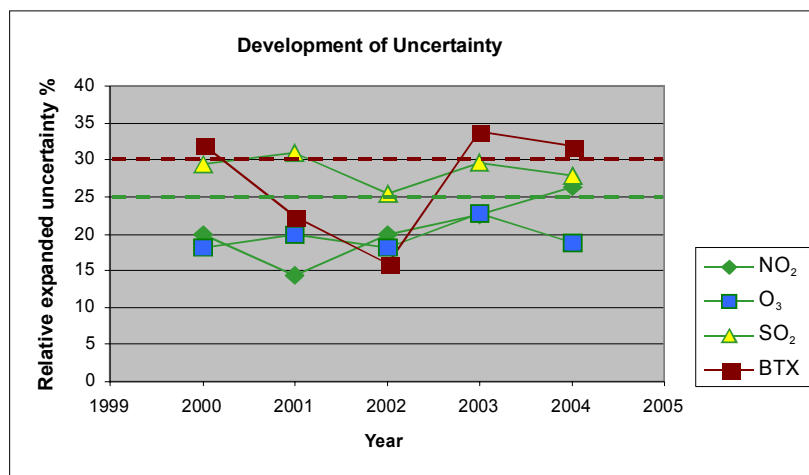


Figure 4.11: Relative expanded uncertainty of Passam results from 2000 to 2004 as monitored by the manufacturer

4.7.2 Direct approach

A comprehensive uncertainty evaluation using a direct approach was performed by Pfeffer et al. [4]. At 10 monitoring sites, parallel measurements were performed with Passam samplers and the EU reference method (EN 14211) for more than one year. A modified Passam tube equipped with a porous glass membrane was used.

From the comparisons with reference values obtained from the chemiluminescence monitors, a relative expanded uncertainty for single results between 21 % and 25 % at $40 \mu\text{g.m}^{-3}$ was calculated for exposure periods of 2 to 6 weeks. Calculation according to the guide to demonstration of equivalence for 4-weeks exposure resulted in an expanded uncertainty of 22 %. In this calculation, the uncertainty of the reference method results was set to zero. Consequently, the uncertainty represents the worst case [18].

It is unlikely that these results were biased, since the estimation of the uptake rate was based on NO₂ values measured using the reference method (EN 14211). The estimation of the uptake rate was performed using measurements at 10 different monitoring sites and over 14 months (as the slope of the mass uptake versus sampled dose, see figure 4.12). With all these different sampling conditions, the influencing parameters (either chemical or meteorological) encompassed a large range of possible values. It is therefore likely that most of the sources contributing to the uncertainty of the reference method and of the diffusive sampling method were randomised. For this reason, it seemed to be justified to divide the uncertainty of single values by the square root of 12 when calculating annual averages from 12 monthly values. Consequently, the uncertainty of annual averages based on monthly measurements should be less than 10 %. This means that the EU data quality objective of 15 % is safely met for annual means.

In 2004/2005, the uptake rate was evaluated by parallel measurements with chemiluminescence analysers. It was found to be $0.827 \text{ cm}^3.\text{min}^{-1}$ (see figure 4.12). At this time, the monitors in the

monitoring network were logically not type approved according to the new CEN standard EN 14211 published in 2005.

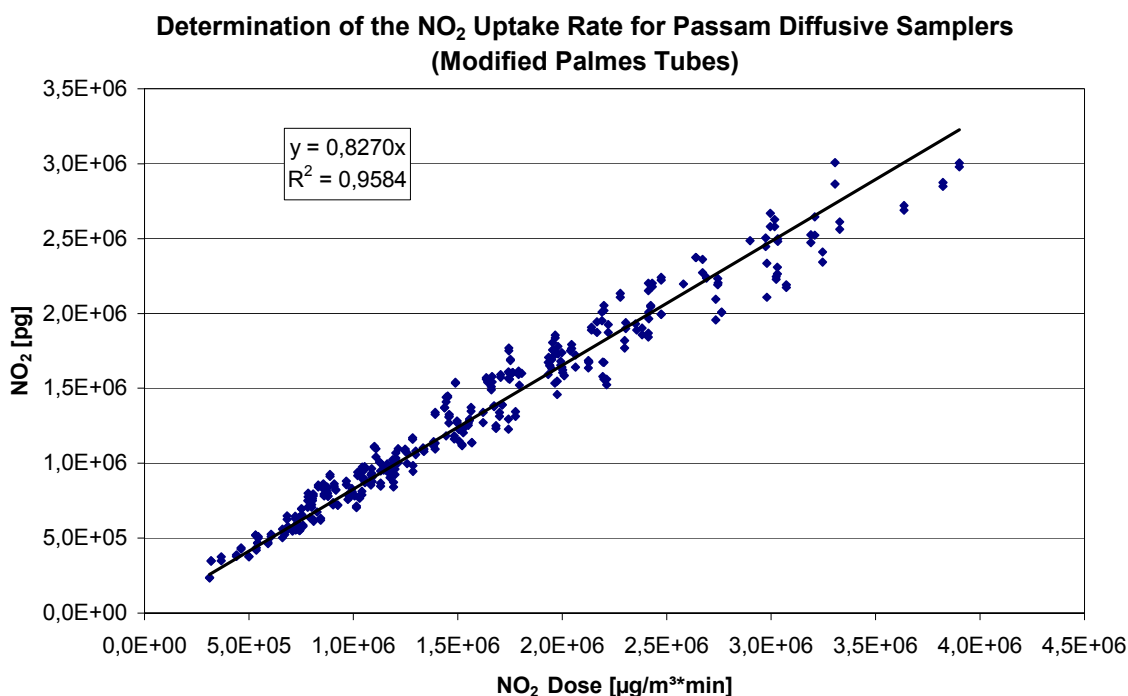


Figure 4.12: Relationship between mass of NO₂ obtained by analysis and NO₂ dose sampled

The uptake rate found in the validation experiments was continuously checked by ongoing parallel measurements with the chemiluminescence method from 2006 to 2008 at six to eight stations. Results for 2006 showed an excellent congruence of the annual averages measured by the chemiluminescence method and with the diffusive samplers [12, 18].

In 2007 and 2008, slight and increasing differences were found at various stations showing higher values of the continuous measurements compared with the diffusive samplers [12].

Comprehensive investigations were performed to find technical reasons for this phenomenon. It was shown that all handling details of the diffusive sampler technique remained unchanged over the years. But in the network of continuous analysers, old instruments were replaced stepwise by new monitors that were type approved according to EN 14211 in order to meet the requirements of Annex VI D of the new European directive 2008/50/EC. The new generation of instruments therefore appears to give higher results for NO₂ in some situations, especially in high ambient humidity conditions. Similar effects were found during inter-laboratory comparisons in the German networks [19].

When sufficient data of parallel measurements are available, it may be necessary to adjust the uptake rate of the diffusive samplers accordingly.

ASPA performed parallel measurements with Passam samplers and the EU reference method (EN 14211) at 5 monitoring sites (rural to city sites) for 1 year using two-week exposure periods [1] (see figure 4.13). The raw data of diffusive samplers, delivered by Passam, were corrected for temperature and pressure according to equation 4.1. Applying the direct approach described in EN-ISO 20988, an expanded uncertainty of 14,4 % at 40 µg.m⁻³ was obtained. This figure is similar to the results obtained when evaluating uncertainty for the 3-year data set of monthly measurement results provided by Lig'air [13].

This shows that the uncertainty tends to meet the data quality objective of EU Directive 2008/50/EC for fixed measurements.

NO₂: Comparison with reference method: France

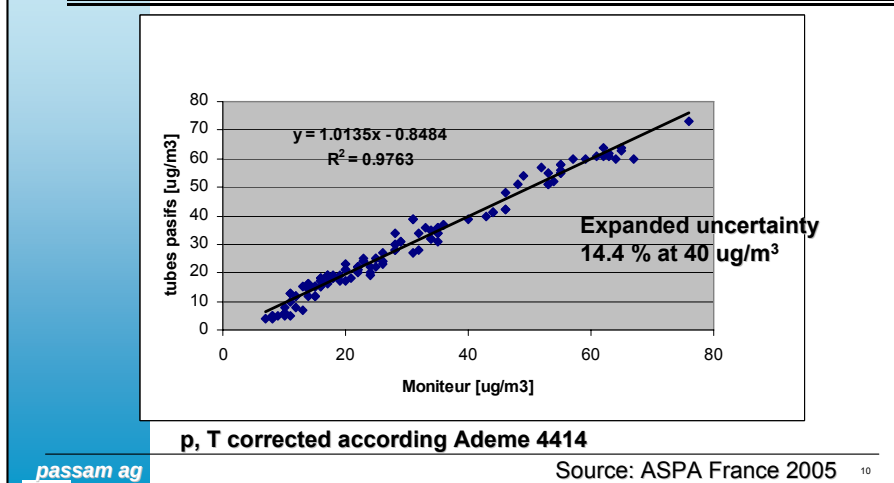


Figure 4.13: Relationship between results of Passam tubes and chemiluminescence monitors, Field site in France (ASPA)

4.8 Application in EU monitoring networks

Passam tube samplers are used e.g. in Cyprus, France, Germany, Italy, Lithuania and Romania for supplementary measurements to the fixed measurements at the level of an indicative method. Other applications include identification of hot spots, mapping, zoning, trend analysis, source apportionment, impact on vegetation, assessment of exposure of population, verification of dispersion models etc.

4.9 Conclusions

The Passam tube-type diffusive sampler is suitable for long-term monitoring of NO₂ in ambient air. Exposure periods of 1 to 6 weeks are feasible. The lower detection limit for a 2-week sampling period is reported to be 0,4 µg.m⁻³.

Information about the precision of the sampler indicates that this is usually better than 5 %.

The comparability of sampler results with those obtained from continuous reference monitors (chemiluminescence) vary somewhat, with ratios of average results generally ranging from 0,9 to 1,3. This variability may be reduced, when :

- Uptake rates are converted to actual conditions of temperature and pressure;
- Membranes are introduced into the sampler inlet, particularly for traffic-related sites.

When the uncertainty associated with the measurement results is evaluated according to the Guide to the Expression of Uncertainty in Measurement, relative expanded uncertainties of individual results were between 20 and 25 %. When assessing measurement uncertainty by direct approaches, e.g., from parallel measurements with the reference method for measurement of NO₂, similar and even better results were obtained.

These findings suggest that the Passam tube is at least suitable for performing long-term measurements of NO₂ for indicative purposes and possibly even for fixed measurements.

When aggregating results to form annual average values, the relative expanded uncertainty may be further reduced to levels below 15 % due to the reduction of random effects on uncertainty.

4.10 References

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5 The Ogawa badge

5.1 Sampler design

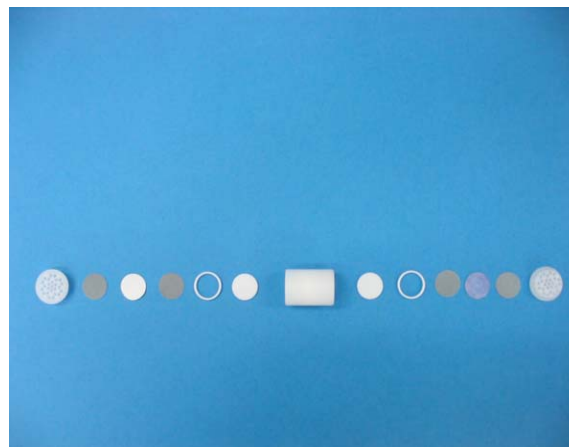
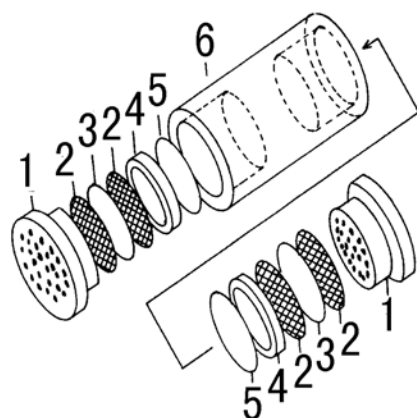


Figure 5.1: Ogawa sampler design

1. Diffuser end cap
2. Stainless steel mesh
3. Sampling filter (14,5 mm ϕ)
4. Teflon ring
5. Teflon disk
6. Body (15 mm ID; 19 mm OD; 6 mm length)

The Ogawa sampler [1] (see figure 5.1) is a badge-type sampler that can be equipped with a sampling filter on either side of the sampler body. Sampling filters consist of cellulose fibre. Both filters can be coated with triethanolamine (TEA) for the sampling of NO_2 in ambient air. Coated filters may be supplied by the manufacturer. However, literature reveals that filters may also be coated by users themselves [2].

The presence of a second filter permits the simultaneous collection of NO_2 and nitrogen oxides equal to the concentration of nitrogen monoxide (NO) plus NO_2 . In this case, the second filter is coated with TEA and 2-phenyl-4,4,5,5-tetramethyl imidazoline-3-oxide-1-oxyl (PTIO), which is a specially prepared reagent for oxidising NO to NO_2 . This filter then collects both species as NO_2 . The concentration of NO can be obtained as a difference in NO_2 concentrations found on the two differently coated filters.

5.2 Extraction and analysis

The manufacturer recommends the determination of the collected NO_2 by colorimetry after reaction with sulphanilamide and N-1-naphthylethylenediamine. However, literature reveals the use of ion chromatography for the measurement of nitrite on the filter [3,4]. In that case, co-sampled sulfur dioxide can also be simultaneously measured.

5.3 Application range and conditions

The manufacturer recommends exposure periods from 24 to 168 hours, but indicates that for low concentrations it is possible to sample for up to 30 days. In practice, samplers have been exposed for up to 4 weeks [4].

Although not explicitly stated in [1], the information provided suggests that the samplers may be used over a temperature range from $-10\text{ }^{\circ}\text{C}$ to $40\text{ }^{\circ}\text{C}$, and a relative humidity range from 50 % to 80 %.

The sampler should always be exposed with a shelter as provided by the manufacturer.

Detection limits given by the manufacturer are 2,3 ppb for 24-hour sampling, and 0,32 ppb for 1-week sampling. The upper limit for 1-week sampling is reported to be 3600 ppb.

The manufacturer specifies the following conditions for storage of coated filters, samplers and sampled filters upon refrigeration:

- Coated filters sealed in original glass vial with aluminium pouch : 90 days
- Sampler loaded with coated filter(s) placed in bag in sealed brown vial : 60 days
- Exposed sampler placed in bag in sealed brown vial : 14 days*
- Filter extract in sealed amber glass vial : 90 days.

* Filters should be analyzed as soon as possible after exposure.

5.4 Uptake rate and environmental effects

The Ogawa Protocol [1] provides information about the uptake rate of the sampler in the form of a coefficient α , which is a function of temperature and relative humidity. After analysis of an Ogawa sampler, NO_2 is calculated using equation 5.1

$$C_{\text{NO}_2} = \alpha \cdot \frac{m}{t} \quad (\text{eq. 5.1})$$

where

C_{NO_2} = concentration of NO_2 in ppb;

α = dose according to the uptake mass in $\text{ppb} \cdot \text{min} \cdot \text{ng}^{-1}$, (converse of an uptake rate);

m = mass of nitrite determined by analysis on a single filter in ng;

t = exposure time in min.

α may be calculated for a given temperature and relative humidity using the semi-empirical equation 5.2.

$$\alpha = \frac{10^4}{0,677 \cdot P \cdot RH + 2,009 \cdot T + 89,8} \quad (\text{eq 5.2})$$

where

RH = ambient air relative humidity in %;

T = ambient temperature in °C.

P is calculated using equation 5.3.

$$P = \left[\frac{2P_n}{P_T + P_n} \right]^{\frac{2}{3}} \quad (\text{eq. 5.3})$$

where

P_n = saturated water vapour pressure at 20 °C in mm of Mercury (Hg) = 17,53

P_T = saturated water vapour pressure at temperature T in mmHg.

The variation of α as a function of temperature and relative humidity is presented in table 5.1 and figure 5.2.

Table 5.1: Variation of α in ppb.min.ng-1 as a function of temperature and relative humidity

RH (%) / T (°C)	0	5	10	15	20	25	30	35	40
20	92,4	85,3	79,3	74,2	69,7	65,7	62,2	59,0	56,0
30	85,2	79,4	74,5	70,3	66,5	63,2	60,2	57,4	54,8
40	79,0	74,3	70,3	66,8	63,7	60,9	58,3	55,8	53,5
50	73,6	69,8	66,5	63,6	61,0	58,7	56,5	54,4	52,4
60	68,9	65,8	63,1	60,7	58,6	56,7	54,8	53,0	51,3
70	64,8	62,2	60,0	58,1	56,4	54,8	53,2	51,7	50,2
80	61,2	59,0	57,2	55,7	54,3	53,0	51,8	50,5	49,2
90	57,9	56,1	54,7	53,5	52,4	51,4	50,4	49,3	48,2

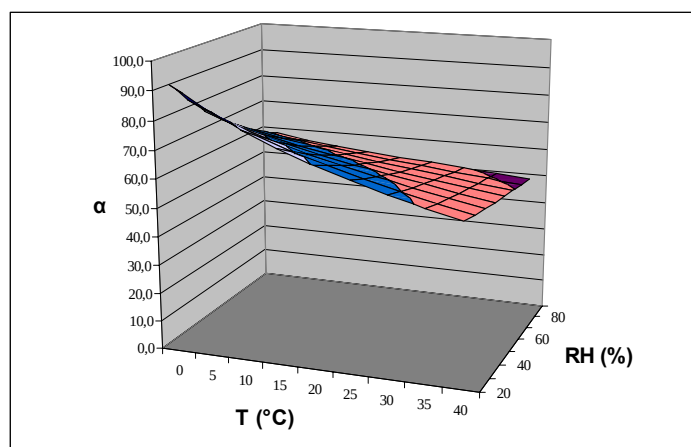


Figure 5.2: Variation of α in ppb.min.ng-1 according to Temperature (T) and relative humidity (RH)

In order to calculate a uptake rate in more common units of $\text{cm}^3 \cdot \text{min}^{-1}$, equation 5.4 can be used for the conversion.

$$V = \frac{10^3}{\alpha} \cdot \frac{V_{m,air}}{46,0055} \quad (\text{eq. 5.4})$$

where

$V_{m,air}$ = molar volume of the sampled air.

5.5 Validation of sampler performance

5.5.1 Comparisons with reference methods

The Ogawa protocol describes a comparison between the results of the sampler and a reference method performed within the frame of the original validation of the sampler (Yokohama City Research Institute of Environmental Science, Yokohama, Japan, Report No. 128, March 1997; see [1]). The results are presented in figure 5.3. The y-axis represents results obtained with the sampler, the x-axis results of the reference method. Unfortunately, the sampling period is unknown.

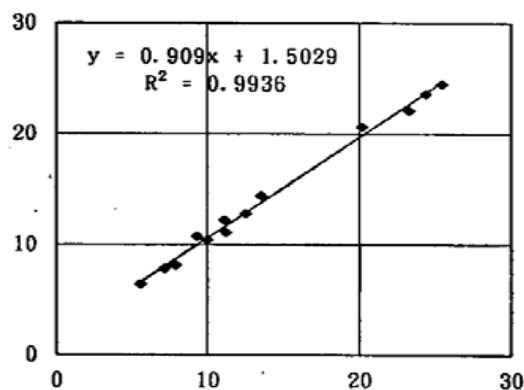


Figure 5.3: Comparison between results of the Ogawa sampler with the chemiluminescence method. X and y axis represent the results of the diffusive sampling method and reference method, respectively

In a further Japanese report supplied by Ogawa USA (no reference available), a comparison was reported between the Ogawa sampler and chemiluminescence monitoring at Funakoshi environmental station. Samplers were exposed during two 5-week periods in July/August 1999 and January/February 2000. Sampling periods of 1, 2, 3, 4 and 5 weeks were used, samplers being exposed in triplicate. The sampler results obtained were internally consistent over the 5-week period. Ratios of results of samplers and chemiluminescence monitors ranged between 0,95 and 1,16, with better comparability observed in the winter period. No information was provided of sampler precision.

Bytnerowicz et al. [5], in a study devoted to the measurement of several air pollutants in Sequoia National Park, measured NO₂ over the period of May to October 1999 both by the chemiluminescence method and by using the Ogawa sampler. The samplers were exposed in duplicate for consecutive two-week periods. The mean values found by the Ogawa sampler and the chemiluminescence method were 2,6 and 2,0 ppb, respectively. The precision of mean value determined by the Ogawa sampler was 5,6 %.

Buzica et al. [6] organized a series of 4 comparisons in which different samplers operated by different laboratories were exposed both under laboratory and field conditions. Each sampler type was exposed in batches of 6 samplers for a period of 14 days, except in the laboratory trial “high” (see table 5.2).

Table 5.2: Laboratory conditions (intercomparison of Buzica et al.)

Parameter	High	Low
Exposure time (d)	7	14
Concentration (µg.m ⁻³)	80	40
Air velocity (m.s ⁻¹)	2,5	1,0
Temperature (°C)	25	5
Relative humidity (%)	75	30

The results obtained for the Ogawa sampler operated by Lab L – following the Ogawa protocol – are presented in table 5.3.

Table 5.3: Results of Ogawa sampler operated by Lab L (intercomparison of Buzica et al.)

Location	CLS (µg.m ⁻³)	Ogawa (µg.m ⁻³)	Ratio
Laboratory, high	76,8	132 ± 19	1,72
Laboratory, low	43,5	46,4 ± 2,6	1,07
Genevilliers	41,6	41,4 ± 0,9	1,00
Fontainebleau	14,1	14,8 ± 3,1	1,05

CLS: chemiluminesce method

Apart from the results of the laboratory trial “high”, the results were comparable with those of the reference method (chemiluminescence, CLS). An explanation for the aberrant results at high air velocity may be that Lab L did not use a protective cover in the laboratory trials. The laboratory “high” trial yielded large variations in results for all participants, with mean results ranging from 54 to 188 $\mu\text{g.m}^{-3}$. The precision of the results was also variable, ranging from 2 % to 20 %.

Singer et al. [7] validated the samplers e.g. by parallel measurements with a chemiluminescence analyser. Samplers were exposed for 1 week. They reported a good correlation, with samplers producing slightly lower results (8 % on average). They reported the precision for the sampler to be better than 5 %. The detection limit for a 1-week sampling period was reported to be 0,2 ppb (analysis performed by colorimetry).

Swaans and Goelen [8] reported the results of field tests in Belgium in which a number of diffusive samplers were compared by parallel measurements with a reference monitor. The exposure period was 14 days; each sampler was exposed in triplicate. The results are presented in table 5.4.

Table 5.4: Results field tests in Belgium

Location	CLS ($\mu\text{g.m}^{-3}$)	Ogawa ($\mu\text{g.m}^{-3}$)	Ratio
Borgerhout	44,7	47,3 $\pm$ 5,2	1,06
Gent	21,0	22,4 $\pm$ 2,1	1,07
Borgerhout	51,4	50,6 $\pm$ 0,2	0,98
Gent	27,3	25,6 $\pm$ 2,7	0,94

Again, results obtained with the Ogawa sampler were comparable to those obtained with the chemiluminescence method. However, the precision of the triplicate results was rather high for 3 trials (≈ 10 %).

Additional work performed by these authors involved a comparison of analyses by ion chromatography and colorimetry. The colorimetric method was found to give a lower detection limit (factor 3). Otherwise, the results obtained were similar.

Sather et al. [9] compared results of 24- and 96-hour diffusive samplers with those from a chemiluminescence analyser. Correlations were good, improving with prolonged sampling duration. Duplicate samplers yielded mean absolute differences of 1,6 to 1,9 ppb for average levels of 22 ppb to 23 ppb.

Sather et al. [4] performed parallel measurements of Ogawa samplers with the US-EPA Federal Reference Method (FRM: the chemiluminescence method) for one year at 6 locations in El Paso, Texas. The extensive dataset resulting from these comparisons was kindly made available by Dr. Sather of US-EPA. Unfortunately, the results received were rounded which may affect comparability at low levels.

The samplers were exposed for different periods: 2, 3 and 4 weeks. All samplers were exposed in duplicate. The mean average difference found between sampler pairs is 0,3 ppb. All results of the trials are presented in tables 5.5 to 5.7.

Table 5.5: Measurement by the US Federal Reference Method (FRM) and Ogawa sampler at two monitoring sites. Exposure period: 2 weeks; results in ppb. Bold figures represent averages.

UTEP			Skyline		
<i>FRM</i>	<i>Ogawa</i>	<i>Ratio</i>	<i>FRM</i>	<i>Ogawa</i>	<i>Ratio</i>
25	29	1,16	17	17	1,00
22	23	1,05	12	13	1,08
23	25	1,09	13	12	0,92
23	25	1,09	15	13	0,87
18	19	1,06	9	10	1,11
19	19	1,00	11	11	1,00
14	16	1,14	7	7	1,00
17	18	1,06	8	8	1,00
16	16	1,00	8	7	0,88
15	14	0,93	7	7	1,00
14	14	1,00	6	5	0,83
14	12	0,86	6	6	1,00
12	12	1,00	6	6	1,00
14	13	0,93	7	6	0,86
12	12	1,00	6	5	0,83
15	14	0,93	7	6	0,86
14	14	1,00	8	6	0,75
13	14	1,08	7	6	0,86
20	21	1,05	10	9	0,90
13	15	1,15	7	6	0,86
16	17	1,06	8	9	1,13
17	20	1,18	8	12	1,50
18	20	1,11	8	11	1,38
19	21	1,11	10	12	1,20
23	26	1,13	13	16	1,23
23	25	1,09	14	17	1,21
17,3	18,2	1,06	9,2	9,3	1,02

Table 5.6: Measurement by the US Federal Reference Method (FRM) and Ogawa sampler at two monitoring sites. Exposure period: 3 weeks; results in ppb. Bold figures represent averages.

Ascarate			Santa Teresa		
<i>FRM</i>	<i>Ogawa</i>	<i>Ratio</i>	<i>FRM</i>	<i>Ogawa</i>	<i>Ratio</i>
21	26	1,24		7	
22	23	1,05	6	6	1,00
22	22	1,00	5	4	0,80
18	19	1,06	5	4	0,80
16	18	1,13	3	3	1,00
19	16	0,84	2	1	0,50
16	13	0,81	1	0	
18	13	0,72	1	0	
13	12	0,92	3	2	0,67
10	9	0,90	3	2	0,67
13	12	0,92	4	3	0,75
15	14	0,93	3	3	1,00
18	17	0,94	5	5	1,00
18	17	0,94	4	3	0,75
19	20	1,05	6	6	1,00
20	20	1,00	6	6	1,00
26	26	1,00	7	7	1,00
17,9	17,5	0,98	4,0	3,6	0,91

Table 5.7: Measurement by the US Federal Reference Method (FRM) and Ogawa sampler at two monitoring sites. Exposure period: 4 weeks; results in ppb. Bold figures represent averages.

Socorro			Desert View		
FRM	Ogawa	Ratio	FRM	Ogawa	Ratio
17	20	1,18	14	14	1,00
17	18	1,06	12	11	0,92
14	14	1,00	11	10	0,91
13	12	0,92	7	5	0,71
12	9	0,75	8	6	0,75
12	8	0,67		3	
7	7	1,00		4	
9	8	0,89		6	
10	9	0,90		6	
12	11	0,92	11	9	0,82
14	14	1,00	9	8	0,89
15	15	1,00	12	13	1,08
19	19	1,00	15	15	1,00
13,2	12,6	0,94	11,0	8,5	0,90

By studying the ratios of the mean results obtained by the FRM and the Ogawa sampler, their comparability was evaluated. It was observed that results were comparable for a 2-week exposure period, with the samplers slightly overestimating the reference concentrations. Sampler results for 3- and 4-week periods were generally lower than those of the FRM.

Using this extensive dataset, an attempt to evaluate the equivalence of the sampler with the reference method according to the Guide to the Demonstration of Equivalence [10] was made. The results are presented in figure 5.4.

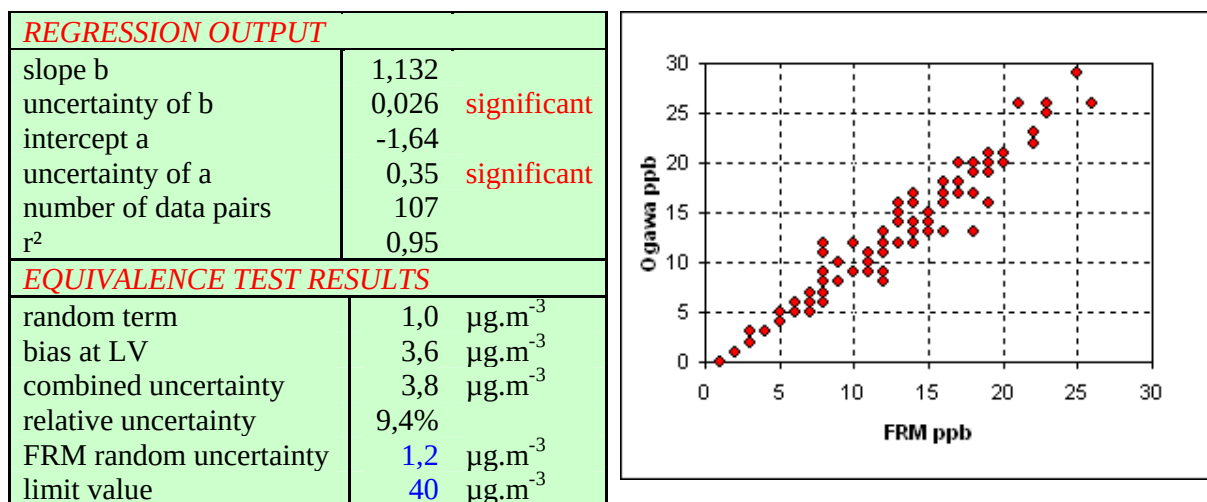


Figure 5.4: Uncertainty for annual averages according to the Guide to the Demonstration of Equivalence, Ogawa sampler vs chemiluminescence analyser (FRM)

The evaluation indicated that, without a recalibration of the uptake rate, keeping the slope and intercept results obtained, this sampler did not meet the data quality objective (DQO) of the EU directive for fixed measurements, as its expanded uncertainty exceeds 15 %, but satisfied the DQO for indicative measurements.

Mosqueron et al. [11] performed a comparison between the sampler and reference method within the frame of quality assurance of an indoor and ambient air exposure study.

The ratio between the means of 49 paired results was 0,97 for an exposure period of 48 hours. When exposing the sampler at both ends, a good correlation was observed between the two results.

Sarnat et al. [12] determined a series of performance characteristics for the sampler when sampling for a period of 24 hours. They found detection limits of 6,4 and 10,8 ppb depending on the sampling season. By measuring with a collocated reference method they determined the precision and accuracy of the sampler to be 17 % and 106 %, respectively.

Van Roosbroeck et al. [13] performed a comparison between the sampler and reference method within the frame of quality assurance of the application of the sampler.

They reported a mean relative difference of 3 %, and a correlation coefficient of 0,96 for an exposure period of 48 hours. The precision of duplicate sampler measurements was reported to be < 5 %.

5.5.2 Miscellaneous information about performance characteristics

A number of publications reported additional information about practical detection limits and precision of the sampler.

Gilbert et al. [3] used samplers to study levels of NO₂ near highways. Employing ion chromatography for analysis, they reported a detection limit for 1-week sampling of 0,7 ppb. The precision of results for duplicate samplers ranged from 6 to 20 %.

Yang et al. [14] used samplers to measure concentrations of NO₂ in indoor air and the penetration of NO₂ from outside to indoor air. Samples were taken over 24-hour periods. Each week duplicate measurements were performed, resulting in an average precision of 8,3 %.

Mukerjee et al. [15] performed a field comparison between samplers and reference monitors. The samplers were exposed for 3, 4 and 7 days for 3 consecutive weeks, with 7-day sampling paralleling 3+4-day sampling. Due to monitor malfunctioning, no definitive conclusions about correlations between results were presented. The study provided information about repeatability and detection limits. Unfortunately, the authors did not report the internal consistency of the 3+4- and 7-day results. The sampler precision was found to be better than 5 %. The detection limit found was lower than 1,3 ppb.

5.6 Measurement uncertainty

No information was found in the literature of (systematic) assessments of measurement uncertainties associated with the use of the Ogawa sampler, e.g., performed according to the Guide to the Expression of Uncertainty in Measurement. When using results from [4] and [6] to make a direct estimation of uncertainties, results found are between 3 % and 23 % expanded relative uncertainty indicating the suitability of the sampler for indicative long-term monitoring of NO₂. However, further systematically obtained information is needed to substantiate such a claim.

5.7 Application in EU monitoring networks

The Ogawa sampler has been used in Spain. To date, there is no reference found of the sampler being used for ambient air monitoring purposes in the EU. Applications are in the field of indoor air monitoring.

5.8 Conclusions

The Ogawa badge-type diffusive sampler is suitable for long-term monitoring of NO₂ in ambient air. Exposure periods of 2 to 4 weeks are feasible. Lower detection limits reported vary somewhat, but are certainly below 1 µg.m⁻³ for a 2-week exposure period.

Information provided about the precision of replicate samples again is variable. Results range from 2 to 20 %. However, frequently precisions better than 5 % are reported.

It is not always clear, though, whether the results of duplicated measurements are based on application of two separate samplers or on analysis of the two filters on either side of the sampler.

When exposed for 14 days or more in the field, the comparability of sampler results to those obtained with continuous reference monitors (chemiluminescence) were good, with ratios of average results ranging from 0,90 to 1,07. The availability of sampler results upon long-term exposure is better than 90 %. Absence of data in comparisons is due to malfunctioning of reference monitors rather than malfunctioning of the sampler.

When using the methodology of the EU Guide to the Demonstration of Equivalence to the results of the US-EPA El Paso study, the sampler is found to pass the uncertainty requirement for indicative measurements. The random uncertainty found for the relation between sampler results and reference method indicate that by correcting the uptake rate the sampler may pass the criterion for fixed measurements. However, the study has been performed in conditions that are atypical of the EU.

No information has been found about any uncertainty assessment of the results obtained with the sampler, e.g., according to the Guide to the Expression of Uncertainty in Measurement.

5.9 References

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6 The Radiello radial sampler

6.1 Sampler design

The Radiello sampler is a radial-type diffusive sampler that was developed by Fondazione Salvatore Maugeri in Italy [1]. Its cylindrical outer surface acts as diffusive membrane: the gaseous molecules move axially parallel towards an adsorbent bed which is cylindrical too and coaxial to the diffusive surface [2] (see figure 6.1).

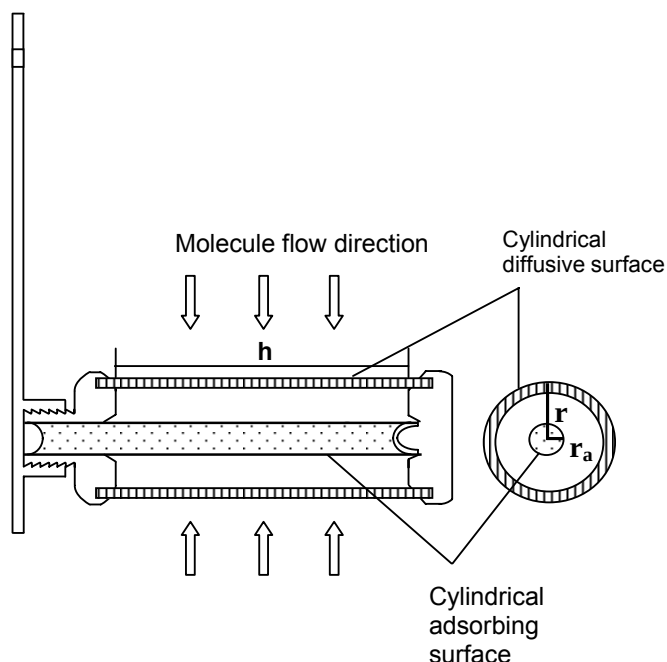


Figure 6.1: Radiello sampler design

According to manufacturer's general instructions, exposure for a long time in a wet atmosphere generally does not affect the sampling performances of the Radiello sampler. Nevertheless the sorption of large quantities of water by the cartridges can sometimes affect the sampler performance. Therefore a shelter is important to protect Radiello samplers from rain.

For outdoor exposures, a mountable polypropylene shelter is available (see figure 6.2). It was designed to be mounted easily and without any tool in the field. The shelters are open on three sides. Pylons and posts are recommended as carriers [3]. Once assembled, it ensures the best compromise between protection against rain and wind. It can house up to four samplers and is able to fit a wide range of pole diameters.



Figure 6.2: Radiello shelter

The diffusive body can be fitted on a supporting plate either in a vertical or horizontal position as shown in figure 6.3.



Figure 6.3: Supporting plate for the Radiello sampler

The adsorbing cartridges are impregnated with a mixture of TEA/water, which also contains traces of ethanol. Further details on the coating and preparation protocol were requested from the manufacturer, but were not provided due to reasons of confidentiality.

The manufacturer recommends and describes the determination of the collected NO₂ by colorimetry after reaction with sulphanilamide and N-1-naphthylethylenediamine [4].

6.2 Application range and conditions

According to the manufacturer [4], the uptake rate of NO₂ is constant in the range from 2000 µg.m⁻³.min to 10⁷ µg.m⁻³.min (1 ppb to 500 ppb NO₂ for 7-day exposure or 0,5 ppb to 250 ppb for 14-day exposure). The limit of quantification after 7 days exposure is 1 ppb.

The range of meteorological conditions where the use of the Radiello sampler is applicable is given in table 6.1. Exposures up to 15 days are feasible for NO₂, but if relative humidity is higher than 70 % for the entire sampling duration, the manufacturer recommends a sampling time shorter than or equal to 7 days. Due to the fact that TEA is very hygroscopic, even if water does not actually interfere with sampling or analysis, the excess water adsorbed by the cartridge could cause some loss of adsorbing medium by percolation.

Table 6.1: Application range of NO₂ Radiello sampler [4]

Parameter	Range where no effect on uptake rate is observed
Temperature	-10 °C to 40 °C
Relative humidity	15 % to 90 % (maximum RH value 70 % for 14-day exposure); avoid moisture condensation upon the membrane
Wind speed	0,1 m.s ⁻¹ to 10 m.s ⁻¹ The outdoor shelter is required for ambient air measurements
Sampling duration	Up to 15 days If RH>70 %: preferably not longer than 7 days

According to the manufacturer [4], the cartridges are stable for at least 12 months before and 4 months after exposure, if stored in the dark at 4 °C. Expiry date is printed on the plastic bag. At least two cartridges belonging to the same lot should be kept as blanks.

6.3 Extraction and analysis

Information on procedures for extraction of sampler cartridges and analysis of sample extracts are available from the manufacturer [4]. The analytical procedures comprise both colorimetry using the Griess-Saltzman method for NO₂ and ion chromatography for SO₂. An alternative ion chromatographic procedure is available from Swaans et al. [5]. The extraction procedure appears to be a critical factor. During a laboratory and field comparison of NO₂ diffusive samplers by the Joint Research Centre [6], extraction of nitrite from the Radiello cartridge using a vortex shaker for 1 minute at 2500 rpm was found not to be sufficient and needed 1 or 2 repetitions before complete extraction. Another method based on ultrasonic extraction for 25 minutes of the cartridge placed in a glass container with 10 ml of Millipore water gave complete recovery of nitrite.

After tubes were vigorously shaken for two minutes, the contact period between absorption liquid and cartridge was also extended to 1,5 hours by Swaans et al. [5] to ensure complete extraction of nitrite.

6.4 Expression of the NO₂ concentration

To calculate the airborne NO₂ concentration, equation 6.1 is generally applied:

$$C_{\text{NO}_2} = 1,91 \frac{(m_s - m_b)}{u \times t} \quad (\text{eq 6.1})$$

where

C_{NO_2} = NO₂ concentration in µg m⁻³ at 20 °C and 101,3 kPa;
 m_s = mass of nitrite measured in the exposed sampler in ng;
 m_b = mass of nitrite measured in a blank sampler in ng;
 u = uptake rate in ng.ppb⁻¹.min⁻¹;
 t = sampling time in min.

The coefficient 1,91 is used to convert the NO₂ concentration from ppb in µg m⁻³ at 20 °C and 101,3 kPa.

6.5 Uptake rate

The uptake rate was determined by the manufacturer as 31,5 cm³.min⁻¹ at 25 °C (corresponding to 0,141 ng.ppb⁻¹.min⁻¹). The laboratory validation data used for the current model of Radiello NO₂ sampler were supplied by the manufacturer. They are presented in table 6.2. They included the results of two sets of exposure tests at two temperature levels (25 °C and 2 °C) each including three sets of six samples exposed for variable sampling time (approx. 3, 5, 7 days). For one temperature level (9,5 °C), an average value was given while for the other two levels all the individual values were reported.

Table 6.2: Validation data of the Radiello sampler supplied by the manufacturer

First test: temperature 25 °C									
Exposure 1									
<i>Camp</i>	<i>μg</i>	<i>T</i> (°C)	<i>NO₂</i> (ppb)	<i>Exposure time</i> (min)	<i>NO₂</i> (ppb*min)	<i>ν</i> (ng/ppb*min)	<i>ν</i> mean	<i>St.</i> <i>dev.</i>	<i>% rsd</i>
1°-1	12,90	25,1	22,5	3684	82852	0,156			
1°-2	9,67	25,1	22,5	3684	82852	0,117			
1°-3	11,76	25,1	22,5	3684	82852	0,142			
1°-4	10,24	25,1	22,5	3684	82852	0,124			
1°-5	11,38	25,1	22,5	3684	82852	0,137			
1°-6	7,84	25,1	22,5	3684	82852		0,135	0,015	11,4
Exposure 2									
<i>camp</i>	<i>μg</i>	<i>T</i> (°C)	<i>NO₂</i> (ppb)	<i>Exposure time</i> (min)	<i>NO₂</i> (ppb*min)	<i>ν</i> (ng/ppb*min)	<i>ν</i> mean	<i>St.</i> <i>dev.</i>	<i>% rsd</i>
2°-1	20,54	25,1	23,2	6777	157125	0,131			
2°-2	23,89	25,1	23,2	6777	157125	0,152			
2°-3	22,50	25,1	23,2	6777	157125	0,143			
2°-4	18,52	25,1	23,2	6777	157125	0,118			
2°-5	22,69	25,1	23,2	6777	157125	0,144			
2°-6	21,62	25,1	23,2	6777	157125	0,138	0,138	0,012	8,7
Exposure 3									
3°-1	30,21	25,0	22,9	9650	220877	0,137			
3°-2	35,78	25,0	22,9	9650	220877	0,162			
3°-3	30,53	25,0	22,9	9650	220877	0,138			
3°-4	32,11	25,0	22,9	9650	220877	0,145			
3°-5	37,48	25,0	22,9	9650	220877	0,170			
3°-6	33,50	25,0	22,9	9650	220877	0,152	0,151	0,013	8,7
						<i>ν overall</i> <i>mean</i>	0,141		
Second test: temperature 2 °C									
Exposure 1									
<i>camp</i>	<i>μg</i>	<i>T</i> (°C)	<i>NO₂</i> (ppb)	<i>Exposure time</i> (min)	<i>NO₂</i> (ppb*min)	<i>ν</i> (ng/ppb*min)	<i>ν</i> mean	<i>St.</i> <i>dev.</i>	<i>% rsd</i>
1°-1	8,91	2,2	27,0	3962	107008	0,083			
1°-2	7,21	2,2	27,0	3962	107008	0,067			
1°-3	6,83	2,2	27,0	3962	107008	0,064			
1°-4	7,52	2,2	27,0	3962	107008	0,070			
1°-5	9,04	2,2	27,0	3962	107008	0,084			
1°-6	4,99	2,2	27,0	3962	107008		0,074	0,009	12,8
Exposure 2									
2°-1	12,77	2,1	27,0	6900	186166	0,069			
2°-2	15,99	2,1	27,0	6900	186166	0,086			
2°-3	14,41	2,1	27,0	6900	186166	0,077			
2°-4	17,00	2,1	27,0	6900	186166	0,091			
2°-5	14,54	2,1	27,0	6900	186166	0,078			
2°-6	17,19	2,1	27,0	6900	186166	0,092	0,082	0,009	11,2

Table 6.2: Validation data of the Radiello sampler supplied by the manufacturer (continued)

Exposure 3									
<i>camp</i>	μg	<i>T</i> (°C)	<i>NO</i> ₂ (ppb)	<i>Exposure time</i> (min)	<i>NO</i> ₂ (ppb*min)	ν (ng/ppb*min)	ν <i>mean</i>	<i>St. dev.</i>	<i>% rsd</i>
3°-1	17,95	2,1	26,9	9688	260828	0,069			
3°-2	21,93	2,1	26,9	9688	260828	0,084			
3°-3	20,29	2,1	26,9	9688	260828	0,078			
3°-4	24,08	2,1	26,9	9688	260828	0,092			
3°-5	23,20	2,1	26,9	9688	260828	0,089			
3°-6	26,80	2,1	26,9	9688	260828		0,082	0,009	11,3
						ν <i>overall mean</i>	0,080		
Third test: temperature 9,5 °C									
<i>T</i> (°C)	<i>NO</i> ₂ (ppb)	<i>Exposure time</i> (min)		<i>NO</i> ₂ (ppb*min)	ν (ng/ppb*min)		ν <i>mean</i>		
9,5	22	10080		221760			0,100		

6.6 Environmental effects

6.6.1 Air velocity

The uptake rate was reported to be invariant with wind speed between 0,1 m.s⁻¹ and 10 m.s⁻¹ [4].

6.6.2 Relative humidity and temperature

The uptake rate was reported to be invariant with humidity in the range 15 % to 90 % [4].

However, a significant effect of temperature and relative humidity on uptake rate was observed by Swaans et al. [5]. The temperature effect from 10 °C to 30 °C corresponds to the temperature effect given by the supplier of the samplers (see section 6.7.1). High relative humidity (70 % to 80 %) caused a strong non-reproducible decrease of uptake rate for NO₂ at 24 hour experiments, but this effect was not observed at longer exposures except for the tests at -5 °C. At temperature below zero, in combination with high relative humidity, the sampler showed anomalous behaviour for NO₂. The possible effect of concentration level and exposure time for NO₂ needs further research.

The NO₂ uptake rate at 25 °C and 101,3 kPa should be corrected so as to reflect the actual sampling conditions. According to the manufacturer's instruction manual [4], the temperature effect for NO₂ on the uptake rate is taken into account using equation 6.2.

$$\nu_T = \nu_{25} \left(\frac{273+T}{273+T_{ref}} \right)^{7,0} \quad (\text{eq. 6.2})$$

where

ν_T = uptake rate at the temperature T ranging from -10 to 40 °C in ng.pp⁻¹.min⁻¹;

ν_{25} = reference uptake rate at 25 °C; 0.141 ng.pp⁻¹.min⁻¹;

T = temperature ranging from -10 to 40°C;

T_{ref} = reference temperature of 25 °C.

The exponential coefficient of 7,0 is derived from the results of the laboratory validation study performed by the manufacturer (see section 6.5).

6.6.3 Pressure

The effect of atmospheric pressure (P) on the uptake rate of the Radiello sampler (ν) is usually insignificant. Even though ν linearly depends on P, the extent of variation of atmospheric pressure

rarely exceeds 3 kPa about the average value of 101,3 kPa at sea level. An error of $\pm 3 \%$ on uptake rate and usually within $\pm 1,5 \%$ results if no correction for pressure is applied.

6.7 Validation of sampler performance

6.7.1 Laboratory tests

During the course of year 2002, the NO₂ Radiello sampler was changed by the manufacturer. Since then the cartridges have been made from microporous polyethylene instead of polyester fibre. Afterwards the sampler's manual was also modified a number of times.

Consequently, the results from studies performed using the old type of Radiello cannot be considered in this review. This concerns e.g. results from validation studies performed by the Joint Research Centre Institute for Environment and Sustainability [11], and results from the Resolution project¹. The validation data presented here relate to the latest version of the Radiello NO₂ diffusive sampler.

In 2005, a validation study of Radiello combined NO₂-SO₂ diffusive sampler [5] was performed by the Flemish Institute for Technological Research (VITO, Belgium). This was the result of lack of agreement between NO₂ samplers and chemiluminescence analyzers from the VMM automatic network, particularly in case of frost, after changes to the sampler by the supplier. The sampler was first validated under controlled laboratory conditions and subsequently compared with NO₂-(SO₂) results of 3 other type of samplers in a field comparison at two locations: Ghent-Mariakerke and Borgerhout in Flanders.

Laboratory exposures at different temperatures (-5, 10 and 30 °C) and relative humidities (0, 50 and 80 % RH) in combination with varying concentration levels and exposure times were carried out, with a focus on extreme conditions (see table 6.4). Typical environmental levels at the monitoring locations of the VMM network for acidic deposition during former campaigns were 10, 20 and 40 µg.m⁻³ NO₂. Under laboratory conditions, exposures were carried out at higher concentrations levels during shorter times within the linear range of 3000–5.10⁶ ppb.min according to manufacturer's instructions [4]. By choosing this approach, a better accuracy of the generated higher gas concentrations was achieved. This made it possible to draw better conclusions about the effects on the uptake rate.

Table 6.4: Laboratory validation set up

NO ₂ (ppb)	Temperature (°C)	Relative humidity (%)	Exposure time
73	-5	80	24 h
18	-5	80	4 days
73	10	0	24 h
73	10	50	24 h
146	10	50	24 h
293	10	50	24 h
73	10	80	24 h
146	10	80	24 h
293	10	80	24 h
11	10	80	14 days (336 h)
73	30	0	24 h
73	30	50	24 h
73	30	80	24 h
18	30	0	4 days
18	30	80	4 days

¹ RESOLUTION Development of a high spatial resolution atmospheric monitoring model to verify the actual emissions reduction of ozone precursors foreseen by Auto-Oil program), LIFE99ENV/IT/081, http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.createPage&s_ref=LIFE96%2520ENV%252FIT%252F000070&area=2&yr=1996&n_proj_id=1114

The average uptake rate for NO₂ for 24 hour exposures at 10 °C and 50 % RH and tested concentration levels (73, 146 and 293 ppb NO₂) was $0,076 \pm 0,011 \text{ ng ppb}^{-1} \text{ min}^{-1}$. Uptake rates during all experiments were lower than the uptake rate given in the instruction manual of the sampler. As already mentioned in section 6.6.2, a significant effect of temperature and relative humidity on the sampler uptake rate was observed. The temperature effect from 10 to 30 °C corresponds to the temperature effect given by the supplier of the samplers. Exposures to high relative humidity (70 to 80 %) for 24 hours caused a strong non-reproducible decrease of uptake rate for NO₂ (see figure 6.3). However, this effect was not observed for longer exposures, except for the tests at -5 °C. At temperatures below zero in combination with high relative humidity, the sampler showed anomalous behaviour for NO₂.

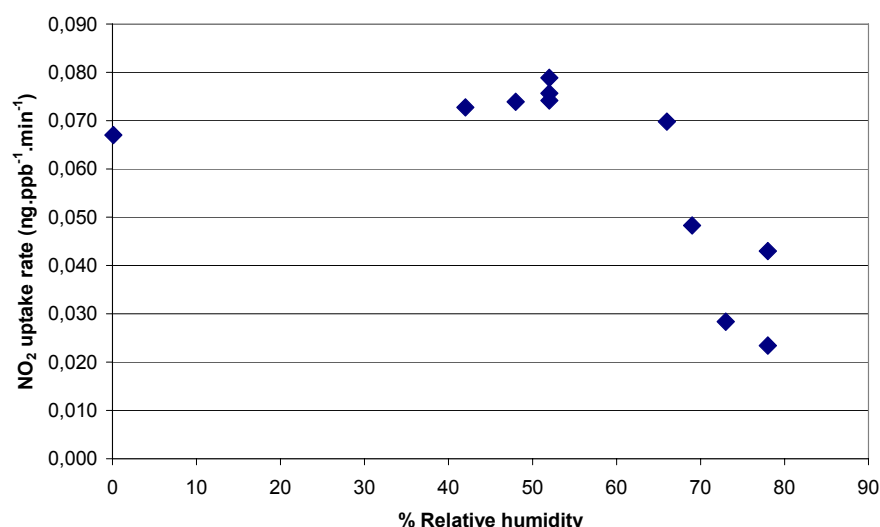


Figure 6.3: NO₂ uptake rate of Radiello sampler at 10 °C versus % relative humidity (24 h exposure)

6.7.2 Comparisons with reference methods

Buzica et al. [6] organized a series of 4 comparisons in which different samplers operated by different laboratories were exposed both under laboratory and field conditions. Each sampler type was exposed in batches of 6 samplers for a period of 14 days, except in the laboratory trial “high” (see table 6.5).

Table 6.5: Laboratory conditions (intercomparison of Buzica et al.)

Parameters	High	High
Exposure time (d)	7	14
Concentration ($\mu\text{g.m}^{-3}$)	80	40
Air velocity (m.s^{-1})	2,5	1,0
Temperature (°C)	25	5
Relative humidity (%)	75	30

The results obtained for the Radiello sampler operated by Lab H, following the manufacturer protocol, are presented in table 6.6.

Table 6.6: Results of Radiello sampler operated by Lab H (intercomparison of Buzica et al.)

Location	CLS ($\mu\text{g.m}^{-3}$)	Radiello ($\mu\text{g.m}^{-3}$)	Ratio
Laboratory, high	76,8	$54,1 \pm 1,5$	0,70
Laboratory, low	43,5	$30,0 \pm 1,0$	0,69
Genevilliers	41,6	$44,7 \pm 1,3$	1,075
Fontainebleau	14,1	$12,0 \pm 0,9$	0,85

During the laboratory tests, the samplers were not protected by a shelter, but a holder was used. For the NO₂ laboratory exposures, the uptake rate was calculated using the model equation given in the previous operating manual (2002). By applying the equation of the operational manual version 01/2003 to the laboratory tests (the one given in equation 6.2), the corrected concentrations were in closer agreement with the reference values than with those calculated with the previous model of the uptake rate.

Swaans and Goelen [5] reported the results of field tests in Belgium in which a number of diffusive samplers have been compared by parallel measurements with a reference monitor. The exposure period was 14 days; each sampler was exposed in triplicate. The results are presented in table 6.7. The Radiello samplers were desorbed using a vortex shaking method (a method based on ultrasonic desorption has also been used).

Table 6.7: Results of field tests in Belgium

Location	CLS ($\mu\text{g.m}^{-3}$)	Radiello ($\mu\text{g.m}^{-3}$)	Ratio
Borgerhout	55	52,8 ± 8,8	0,96
Gent	37	33,2 ± 7,3	0,92
Borgerhout	44,7	47,4 ± 5,1	1,06
Gent	21,0	16,0 ± 2,1	0,76
Borgerhout	51,4	35,1 ± 3,0	0,68
Gent	27,3	18,2 ± 3,5	0,67

The agreement between measurements performed with Radiello samplers and chemiluminescence analyzer was acceptable, but in some cases the relative standard deviation of the replicates exceeded 30 %. The ratios Radiello samplers/NO₂ analyzer for the different site campaigns ranged from 0,67 to 1,06. In general, the performance of the Radiello sampler was better in the field than during laboratory validation (see table 6.6), although for certain periods samplers gave lower NO₂ concentrations than the continuous analyzer. Conditions were more extreme during the laboratory validation than during the field tests.

Results of comparative measurements between NO₂ Radiello diffusive samplers and chemiluminescence analyzers from 3 French air quality monitoring networks are given in table 6.8.

The results from French studies (personal communication to the authors) confirmed that the Radiello sampler tends to underestimate the concentrations of NO₂ measured by the chemiluminescence analyzers.

Ratios found ranged from 0,57 to 0,99 with one exception (1,42) for concentrations ranging from 22 to 49 $\mu\text{g.m}^{-3}$. For a 7-day exposure period the effect appears to be larger than for 14-day exposure.

Other available validation data regarding the NO₂ Radiello sampler exist, but do not apply to the current sampler [7 - 9]. Also the data from the CEN/TC 264 WG11 pilot study date from 2000-2001 and do not apply to the current sampler since the sampler was changed in 2002.

Currently, a comparison is ongoing in the United Kingdom in which Palmes tube samplers and Radiello samplers are exposed at a traffic site in London. Results of this comparison were not available at the time of the drafting of the report.

Table 6.8: Results of French studies

Laboratory	Sampling site	Nb of samplers	Sampling time (days)	Start	End	NO2 tube (ppb)	NO2 tube ($\mu\text{g.m}^{-3}$)	NO2 chemiluminescence ($\mu\text{g.m}^{-3}$)	Ratio Tube / Chemiluminescence	Température	Mass of nitrite (μg)
ATMOSF/AIR Bourgogne		1	7	23/10/07	30/10/07	12,8	20,9	36,9	0,57	8,4	0,171
ATMOSF/AIR Bourgogne		1	7	30/10/07	6/11/07	13,5	21,7	36,6	0,59	6,6	0,168
ATMOSF/AIR Bourgogne		1	7	13/11/07	20/11/07	16,8	25,5	41,2	0,62	1,3	0,158
ATMOSF/AIR Bourgogne		1	7	20/11/07	27/11/07	19,8	31,7	49,0	0,65	6,5	0,168
ATMOSF/AIR Bourgogne		1	7	27/11/07	4/12/07	15,6	24,6	38,1	0,64	4,6	0,164

Laboratory	Site	Nb of samplers	Exposure	Start	End	NO2 $\mu\text{g}/\text{m}^3$ - tube 1	NO2 $\mu\text{g}/\text{m}^3$ - tube 2	NO2 chemiluminescence ($\mu\text{g.m}^{-3}$)	Ratio Tube / Chemiluminescence
LIM/AIR	Urban	2	14	10/10/06	24/10/06	37,4	26,1	22,4	1,42

	Site	Nb of samplers	Exposure	Start	End	NO2 $\mu\text{g}/\text{m}^3$ tube 1	NO2 $\mu\text{g}/\text{m}^3$ tube 2	NO2 $\mu\text{g}/\text{m}^3$ - tube 3	NO2 chemiluminescence in $\mu\text{g}/\text{m}^3$	Ratio Tubes mean / Chemiluminescence	Ratio Tube 1 / Chemiluminescence	Ratio Tube 2 / Chemiluminescence	Ratio Tube 3 / Chemiluminescence
	ARLES												
AIRFOBEP	Urban	2	14	2/23/2007	3/9/2007	20,3	25,4		27,4	0,84	0,74	0,93	
AIRFOBEP	Urban	1	14	3/9/2007	3/26/2007	21,3			27,8	0,77	0,77		
AIRFOBEP	Urban	2	14	3/26/2007	4/11/2007	25,9	26,3		31	0,84	0,84	0,85	
AIRFOBEP	Urban	1	14	10/24/2007	11/7/2007		28,3		33	0,86		0,86	
	SALON												
AIRFOBEP	Urban	2	14	2/23/2007	3/9/2007	21,5	18,2		21,7	0,91	0,99	0,84	
AIRFOBEP	Urban	2	14	3/9/2007	3/26/2007	26,4	25,2		28,8	0,9	0,92	0,88	
AIRFOBEP	Urban	2	14	3/26/2007	4/11/2007	31,8	30,4		31,4	0,99	1,01	0,97	
AIRFOBEP	Urban	2	14	10/24/2007	11/7/2007	17,7	15,5		26,4	0,63	0,67	0,59	
	MARIGNANE												
AIRFOBEP	Urban	3	14	2/23/2007	3/9/2007	38	43,4	37,9	42,3	0,94	0,9	1,03	0,9
AIRFOBEP	Urban	3	14	3/9/2007	3/26/2007	27,2	25,7	26,7	32,9	0,81	0,83	0,78	0,81
AIRFOBEP	Urban	2	14	3/26/2007	4/11/2007	38,6	38,4		44,3	0,87	0,87	0,87	
AIRFOBEP	Urban	2	14	10/24/2007	11/7/2007	38,3		39	46,9	0,82	0,82		0,83

6.8 Measurement uncertainty

6.8.1 GUM approach

The manufacturer in its instruction manual reports an uncertainty of 11,9 % for NO₂ measurements for a probability of 95 % that the true value is within the resulting interval. The method of calculation was requested from the manufacture but was not available.

VITO estimated the NO₂ expanded uncertainty as being 30 % at a 95 % confidence level for the Radiello sampler used to simultaneously determine NO₂ and SO₂ [5]. This uncertainty was estimated using the results of 24-hours laboratory experiments performed in an exposure chamber at 10 °C and 50 % of relative humidity. The estimation was carried out according to the GUM method based on equation 6.3. The contributions of all parameters affecting the uncertainty of measurements are given in table 6.9.

$$C = 1,91 \frac{(m_d - m_b) \cdot 10^6}{v \cdot t} \quad (\text{eq. 6.3})$$

where

C = ambient concentration in $\mu\text{g} \cdot \text{m}^{-3}$;
 m_d = mass of desorbed analyte in μg ;
 m_b = blank of analyte in μg ;
 v = diffusive uptake rate in $\text{ng ppb}^{-1} \cdot \text{min}^{-1}$;
 t = exposure time in min.

Table 6.9: Uncertainty of NO₂ measurements by Radiello calculated using VITO laboratory experiments

Uncertainty source	x	u(x)	u(x)/x
nitrite in desorption liquid mg/l	1,3	0,02	0,02
volume of desorption liquid (ml)	6,00	0,08	0,01
absolute amount of nitrite on sampler (μg)	7,62	0,2	0,02
nitrite in desorption liquid from blank sampler (mg/l)	0,09	0,009	0,1
volume of desorption liquid (ml)	6,00	0,08	0,01
absolute amount of nitrite on blank sampler (μg)	0,54	0,05	0,1
nitrite mass after blank-correction (μg)	7,08	0,2	0,03
temperature (T) during measuring period (K)	277,2	1	0.0036
uptake rate ($\text{ng ppb}^{-1} \cdot \text{min}^{-1}$) at T	0,064	0,010	0,151
sampling duration (min)	20108	10	0,0005
NO₂ Concentration in ambient air (ppb)	5,46	0,8	0,15

The relative standard uncertainty of the measured NO₂ concentration is 15 %, the expanded uncertainty at a 95 % confidence level ($k=2$) is then 30 %. This measurement uncertainty is not valid in case of sampling time of 24 hours combined with high relative humidity since a strong decrease of uptake rate may occur under these exposure conditions.

The major source of uncertainty is found to be the uptake rate.

6.8.2 Direct approach

When combining data reported in tables 6.6, 6.7 and 6.8 for all field comparisons of Radiello samplers exposed for 14 days with the chemiluminescence reference method, a total of 26 sets of comparison data were available. These were used to make an estimate of the uncertainty of NO₂ concentrations

measured with the Radiello sampler by applying the approach described in the Guide to the Demonstration of Equivalence [10]. The result of this estimation is given in figure 6.4.

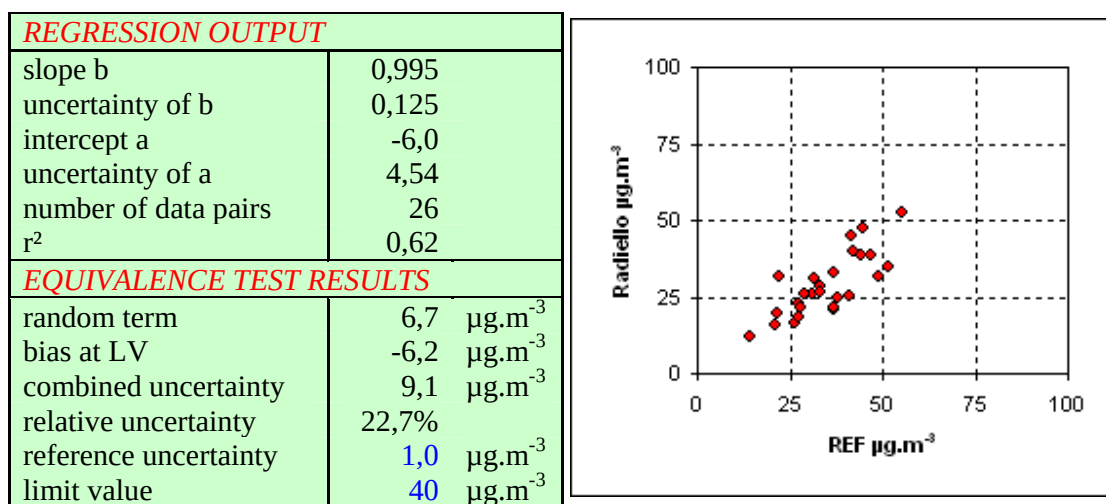


Figure 6.4: Uncertainty for annual averages according to the Guide to the Demonstration of Equivalence, Radiello sampler vs chemiluminescence analyser (REF)

The relative standard uncertainty calculated in this way was 22,7 %, leading to an expanded uncertainty (95 % confidence) of 45 %. The uncertainty is affected significantly by a systematic underestimation of concentrations by about 6 $\mu\text{g.m}^{-3}$.

6.9 Application in EU monitoring networks

Radiello samplers are used e.g. in Belgium, France, Italy, Slovakia and Spain for surveys aimed at, e.g. identification of hot spots, mapping, zoning, trend analysis, source apportionment, impact on vegetation, assessment of exposure of population, verification of dispersion models etc.

6.10 Conclusions

The Radiello radial-type diffusive sampler may be used for long-term monitoring of NO_2 in ambient air. Exposure periods of 1 day to 2 weeks are feasible. The lower detection limit for a 2-week sampling period was reported to be 0,9 $\mu\text{g.m}^{-3}$. Results of a laboratory study in which the sampling period was restricted to one day showed an underestimation of NO_2 concentrations by a factor of 2 when applying the uptake rate specified by the manufacturer. The reason for this may be a transient period of sorption at the beginning of the sampling period.

Information about the precision of the sampler from field campaigns revealed that the precision relative standard deviation varied around 10 %.

The comparability of sampler results with those obtained with continuous reference monitors (chemiluminescence) varied, with ratios of average results ranging from 0,6 to 1,4. In general, Radiello showed a trend to underestimate concentrations measured by reference monitors. However, the number of field data available was too limited to be conclusive.

When the uncertainty associated with the measurement results for a one-day exposure was evaluated according to the Guide to the Expression of Uncertainty in Measurement, a relative expanded uncertainty of individual results of 31 % was found. When assessing measurement uncertainty by direct approaches, e.g., from parallel measurements with the reference method for measurement of NO_2 , similar results were obtained.

These findings suggest that the Radiello sampler did not satisfy the uncertainty data quality objective for indicative measurements of NO_2 , for which an uncertainty ≤ 25 % is required.

When aggregating results to form annual average values, the relative expanded uncertainty was further reduced to levels below 25 % due to the reduction of random effects on uncertainty.

The information collected about the uncertainty of individual measurement results did not correspond with information supplied by the manufacturer stating an expanded measurement uncertainty of 12 %. However, information about the assessment approach used by the manufacturer was (currently) unavailable.

The possible effect of concentration level, high humidity and exposure time for NO₂ needs further research.

6.11 References

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7 Other samplers : the Analyst

7.1 Sampler design

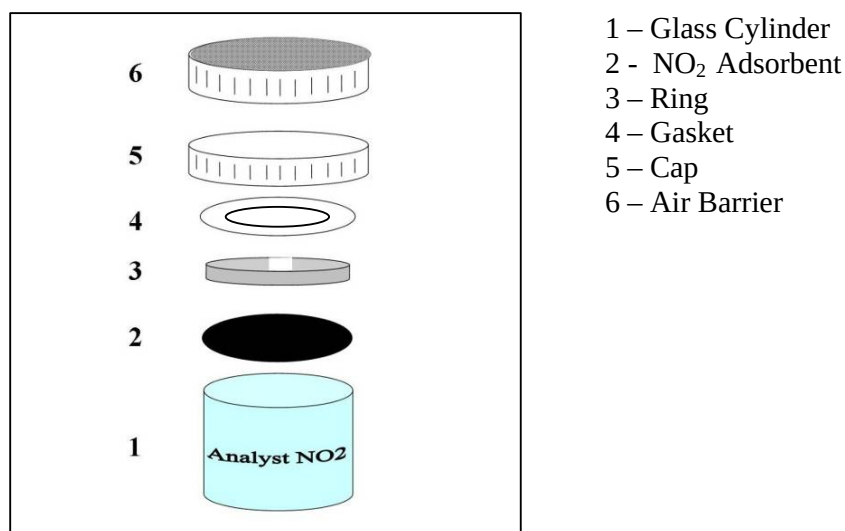


Figure 7.1: Analyst sampler design

The body of the sampler (see figure 7.1, part 1) is a cylindrical glass vial (inner =2,04 cm, length=2,54 cm) with a threaded cap at one end (parts 4 and 5). NO₂ is collected on a disc of impregnated carbon paper filter (part 2) placed at the bottom of the vial and held in position by a stainless steel ring (part 3). To avoid turbulent diffusion inside the vessel, the open end is protected during sampling using a fine stainless steel and plastic screen (part 6). Before and after sampling, the screen is replaced with a polyethylene cap (part 5), which houses a silicone gasket (part 4).

Application range and conditions

The following information was compiled for the application range and conditions of the sampler [1].

Detection limit: 1 ppb (corresponding to 3 standard deviations of 12 blanks for a one-week exposure).

Exposure time: From 1 week to 2 months. Shorter exposure times for high concentrations

Shelter: The experience gained in many monitoring study showed that a rain and wind shield (see figure 7.2 a) was sufficient for an effective protection of the Analyst sampler. When a strong influence of wind is expected it is recommended to use the shelter shown in figure b.

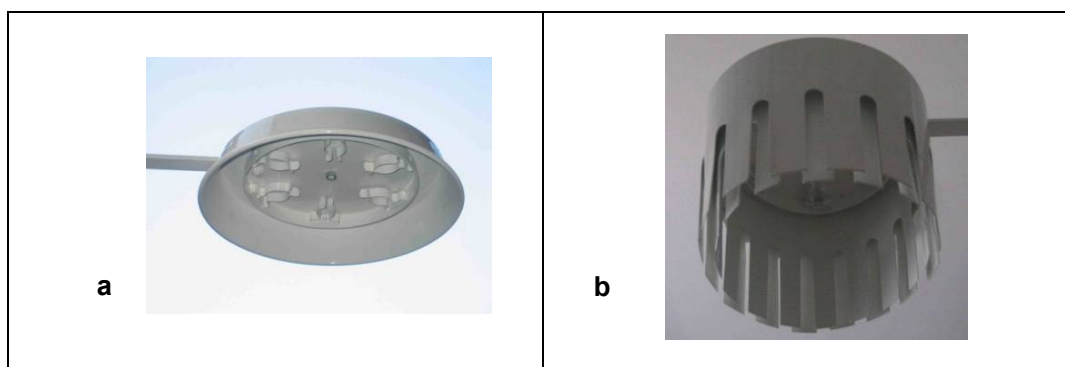


Figure 7.2: Shelters for the Analyst sampler

7.2 Sampler storage

Before use: 6 months.

After exposure: 2 months in a cold and dry place.

The stability of the nitrite collected decreases if the samplers are withdrawn from the field, when they have been recently exposed to very high relative humidity (e.g. rain). If the samplers cannot be analysed immediately (within two or three days after exposure), the manufacturer advises to collect the samplers when the weather is fine and stable for one or two days before ending the sampling. If this is not possible, the samplers must be dried over silica gel or allowed to equilibrate indoors before closing them and storing them in a fresh and dry place.

7.3 Extraction and analysis

Nitrogen dioxide, adsorbed as nitrite, can be determined by ion chromatography. A method using the standard Griess-Saltzman reaction for nitrite followed by colorimetric analysis can also be used.

After exposure, the filters are extracted with eluent (2,7 mM Na₂CO₃ and 0,3 mM NaHCO₃). The extraction of nitrite is carried out in the same sampler by adding 5 ml of the extraction solution (eluent). The nitrite ion concentration is determined using ion chromatography (Dionex equipped with a column IONPAC AS12A). The concentration of nitrite is calculated from calibration graphs with sodium nitrite standards.

Stock standard solutions of 1000 µg.ml⁻¹ may be purchased as certified solutions from different manufacturers, or can be prepared by dissolving 0,7499 g of oven-dried sodium nitrite in 0,5 l of de-ionised water. The working standard solutions for the preparation of the calibration curve are made as follows:

- 10 ml of the stock solution are added to a 200 ml flask that is filled to the mark with the Dionex eluent;
- Subsequent dilutions are carried out using a 10 ml pipette and the appropriate volumetric flasks;
- A set of standards in the range 0 to 3,0 of µg.ml⁻¹ nitrite anion are prepared to calibrate the ion chromatograph.

For low-level applications, more diluted standards may be necessary.

7.4 Calculation of ambient air concentration

Equation 7.1 is used to calculate the NO₂ concentration in air (expressed in µg.m⁻³) in which ν is 11.7 cm³.min⁻¹ at 20 °C (see 7.5).

$$C_{\text{NO}_2} = \frac{(m_s - m_b)}{\nu \times t \times 10^{-6}} \quad (\text{eq 7.1})$$

where

C_{NO_2} = NO₂ concentration in µg m⁻³ at 20 °C;

m_s = mass of nitrite measured in the exposed sampler in µg;

m_b = mass of nitrite measured in a blank sampler in µg;

ν = uptake rate in cm³.min⁻¹ at 20 °C;

t = sampling time in min.

This formula assumes that the average temperature during sampling is 20 °C. If the temperature T is significantly different, a correction to C_{NO_2} can be applied multiplying by coefficient calculated using equation 7.2.

$$\nu_{T,p} = \nu_{\text{ref}} \left(\frac{273,2 + T}{273,2 + T_{\text{ref}}} \right)^{1,8} \quad (\text{eq. 7.2})$$

where

- v_T = uptake rate in $\text{cm}^3 \cdot \text{min}^{-1}$ at temperature T during sampling;
 v_{ref} = uptake rate in $\text{cm}^3 \cdot \text{min}^{-1}$ at the reference temperature of 20 °C, 11.7 $\text{cm}^3 \cdot \text{min}^{-1}$;
 T = actual temperature during sampling in °C;
 T_{ref} = reference temperature in °C at which v_{ref} rate is given (20 °C).

7.5 Uptake rate and environmental effects

The NO_2 uptake rate may be calculated directly from the theoretical diffusion coefficient of NO_2 and the geometry of the sampler. The rate at which NO_2 is transferred through the vial depends on the average concentration in the ambient air according to Fick's law which is integrated along the diffusion path length to give equation 7.3.

$$m = \frac{(C - C_0)DA t}{L} \quad (\text{eq. 7.3})$$

where

- m = mass uptake in μg ;
 C = concentration of NO_2 in $\mu\text{g} \cdot \text{m}^{-3}$;
 C_0 = concentration of NO_2 at the surface of the sorbent in $\mu\text{g} \cdot \text{m}^{-3}$ (close to zero);
 D = diffusion coefficient of NO_2 in air in $\text{m}^2 \cdot \text{min}^{-1}$;
 A = cross-sectional area of the diffusion path in m^2 ($3,27 \cdot 10^{-4} \text{ m}^2$);
 t = exposure time in min;
 L = length of the diffusion path in cm (0,0254 cm).

By substitution and using the diffusion coefficient at 25 °C, the NO_2 uptake rate was calculated using equation 7.3 and found to be $12,3 \pm 0,5 \text{ cm}^3 \cdot \text{min}^{-1}$.

The uptake rate was also determined by comparing measurements of the chemiluminescence reference method and of the Analyst samplers for concentrations between 100 and 1300 $\mu\text{g} \cdot \text{m}^{-3}$ at 20 °C and 50 % of relative humidity. When calculating the slope of the regression line of the two methods of measurements, the uptake rate of the Analyst sampler was $11,7 \pm 0,6 \text{ cm}^3 \cdot \text{min}^{-1}$ [1].

The fairly good agreement between the estimation of the uptake rate using the theory of diffusion and by indirect measurements demonstrates both that NO_2 absorption on the carbon coated surface is very rapid and that the C_0 term in equation 7.3 must be close to zero.

A series of laboratory tests were undertaken to demonstrate the effect of fluctuating concentrations of NO_2 on the sampler response. In these experiments, dilution of NO_2 from a permeation tube was varied over the exposure time by using a pump. NO_2 changed between 50 (i.e. when the pump was on) and 500 $\mu\text{g} \cdot \text{m}^{-3}$ (i.e. when the pump was off) every hour. This concentration change was repeated overnight. The results of these experiments showed that the uptake rate of variable NO_2 concentrations was within 5 % of those obtained at constant concentration [1].

To study the influence of relative humidity on the collection efficiency of the sampler, the amount of nitrite collected per unit time and concentration was determined over a range of 20 % to 80 % relative humidity at 500 $\mu\text{g} \cdot \text{m}^{-3}$ of NO_2 for 10 h at 25 °C. The uptake rates were unaffected by relative humidity and averaged around $11,9 \pm 0,8 \text{ cm}^3 \cdot \text{min}^{-1}$.

The interference of ozone was studied by exposing samplers previously loaded with NO_2 to an ozone mixture in an exposure chamber (3 samplers were exposed to 400 $\mu\text{g} \cdot \text{m}^{-3}$ O_3 for 5 h). Ozone was measured using UV absorption analyzer. Ozone had no measurable interference effect.

7.6 Validation of sampler performance

In 2001-2002 CEN/TC264 WG11 “Diffusive samplers” performed a small-scale pilot study at two locations in which 6 samplers were exposed for two weeks, accompanied by parallel measurements with a reference monitor. The results for the exposed Analyst samplers are reported in table 7.1.

Table 7.1: Results of CEN pilot study for the Analyst sampler

Willebroek	NO ₂ (µg.m ⁻³)	Ratio Analyst/reference
Reference	40,8	
Analyst	112	2,74
Teddington	NO ₂ (µg.m ⁻³)	Ratio Analyst/reference
Reference	13,8	
Analyst	18,0	1,30

Analyst samplers were found to overestimate NO₂ concentrations. The overestimation for the experiment at Willebroek could be explained by the fact that the sampler was exposed without a shelter in very windy conditions in an open field, contrary to manufacturer recommendations.

A validation study carried out at an urban background site (Villa Ada, Rome, Italy), side-by-side with a chemiluminescence analyser, showed that the Analyst sampler for NO₂ is characterised by an expanded uncertainty lower than 21 %, well within the limit required by EU Directive 2008/50/EC for indicative measurements [1].

This field validation consisted of two elements:

- A study into the integrated response of samplers over different sampling periods;
- A comparison with a reference analyzer according to ISO 13752.

The study entailed the comparison of 35 pairs of results from the chemiluminescence analyser and the Analyst sampler over a full range of average wind-speed conditions ranging from 1,4 m.s⁻¹ to 2,0 m.s⁻¹ over fortnight sampling periods. Average daily wind velocity values ranged from 0,7 m.s⁻¹ to 4,2 m.s⁻¹.

Buzica et al. [2] organized a series of 4 comparisons in which different samplers operated by different laboratories were exposed both under laboratory and field conditions. Each sampler type was exposed in batches of 6 samplers for a period of 14 days except in the laboratory trial “high” (see table 7.2).

Table 7.2: Laboratory conditions (intercomparison of Buzica et al.)

Parameter	High	Low
Exposure time (d)	7	14
Concentration (µg.m ⁻³)	80	40
Air velocity (m.s ⁻¹)	2,5	1,0
Temperature (°C)	25	5
Relative humidity (%)	75	30

The results obtained for the Analyst sampler operated by Lab B are presented in table 7.3.

Table 7.3: Results of the Analyst sampler operated by Lab B (intercomparison of Buzica et al.)

Location	CLS (µg.m ⁻³)	Analyst (µg.m ⁻³)	Ratio
Laboratory, high	76,8	111 ± 5	1,44
Laboratory, low	43,5	43,3 ± 1,0	1,00
Genevilliers	41,6	55,9 ± 1,4	1,34
Fontainebleau	14,1	15,0 ± 0,5	1,06

These results show a somewhat “mixed” performance, although the laboratory “high” trial yielded large variations in results for all participants, with mean results ranging from 54 to 188 $\mu\text{g.m}^{-3}$. The precision of the results was good, usually within 10 %.

7.7 Measurement uncertainty

The accuracy of the samplers in comparison to the chemiluminescence technique, expressed as percent relative error was found to be better than ± 20 % at 20 ppb of NO_2 . The relative standard deviation on 12 samplers is 7 % [1].

No further information is available, e.g. assessments based on application of the Guide to the Expression of Uncertainty in Measurement.

7.8 Application in EU monitoring networks

Applications appear to be mostly in indoor air monitoring, e.g., for studies into protection of cultural heritage. No references to applications in ambient air monitoring have been found.

7.9 Conclusions

The Analyst badge-type diffusive sampler may be used for long-term monitoring of NO_2 in ambient air. Exposure periods of 1 to 2 weeks are feasible. The lower detection limit for a one-week exposure period was reported to be 1,9 $\mu\text{g.m}^{-3}$.

The precision of replicate samples was generally within 10 %. However, the number of studies reported is limited.

The comparability of sampler results with those obtained with continuous reference monitors (chemiluminescence) was acceptable, with ratios ranging from 1,0 to 1,4. However, it must be emphasized that the number of studies on which this conclusion was based is limited.

No information was available on the availability of sampler results upon long-term exposure. However, from the laboratory experiments it could be concluded that an exposure period of at least 4 months is feasible for sites characterized by concentrations up to 200 $\mu\text{g.m}^{-3}$.

When assessing measurement uncertainty by direct approaches, e.g., from parallel measurements with the reference method for measurement of NO_2 , the accuracy was reported to be ± 20 %.

No information was found about any uncertainty assessment of the results obtained with the sampler, e.g., according to the Guide to the Expression of Uncertainty in Measurement.

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8 Summary of findings, conclusions and recommendations

8.1 Summary of findings

A number of diffusive samplers that are used for long-term monitoring of nitrogen dioxide (NO₂) were subjected to a review of their use and performance characteristics. The samplers were selected on the basis of their general availability in the European Union:

- The Palmes tube sampler;
- The Passam tube sampler;
- The Ogawa badge sampler;
- The Radiello radial sampler;
- The Analyst badge sampler.

The IVL sampler, although a sampler in frequent use throughout the European Union, was not included in the review, since most information about this sampler is considered a proprietary secret by the manufacturer.

The information collected was used to:

- Draft conclusions about the feasibility of using the samplers for the long-term monitoring of NO₂, with the particular aim of assessing compliance with the European Union annual limit value of 40 µg.m⁻³ (at 20 °C and 101,2 kPa);
- Draft a proposal method for monitoring NO₂ using diffusive samplers, for future use by CEN Technical Committee 264 “Air Quality” Working Group 11 “Diffusive Samplers” as a CEN standard devoted to the measurement of NO₂ in ambient air.

Main criteria for the assessment of sampler feasibility for both purposes were:

- The validation level of the samplers, based either on application of EN 13528 part 2 or the Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods, including information about the uncertainty of results obtained using the samplers;
- From this: the potential to meet European Air Quality Directive data quality objectives for indicative and/or fixed measurements;
- The extent or lack of information available to underpin the validity of results obtained using the different samplers;
- The number of different sources providing the above information;
- Differences in performance depending on site type (tube type): traffic, urban, rural;
- The possibility for users to analyse the samplers, e.g., based on procedures specified by manufacturers;
- Their current use throughout the European Union for measuring ambient air quality related to concentrations of NO₂.

The conclusions for each individual sampler are reported below.

8.1.1 The Palmes tube sampler

Palmes tube samplers are extensively used e.g. in Denmark, France, the Netherlands, Spain and the United Kingdom for supplementary measurements to the fixed measurements at the level of an indicative method. Other applications include identification of hot spots, mapping, zoning, trend analysis, source apportionment, impact on vegetation, assessment of exposure of population, verification of dispersion models etc.

A number of methods exist for the preparation of the TEA-based sampling substrate. Only 3 of these have been proven to give reliable results in practice.

Palmer tube samplers are generally analysed by colorimetry applying the Griess-Saltzman methodology.

The Palmer tube-type diffusive sampler is suitable for long-term monitoring of NO₂ in ambient air. Exposure periods of 1 to 8 weeks are feasible. The most commonly used exposure period is 2 or 4 weeks. The lower detection limit for a 2-week sampling period will vary with the meticulousness of the sampler preparation procedure, and will generally be between 0,7 and 1 µg.m⁻³. The upper limit for a 2-week exposure period is at least 375 µg.m⁻³.

Unused and exposed samplers may be stored for several months under specific conditions (dark; air tight; reduced temperatures).

A large body of literature evidence from various sources was available about the application of Palmer tube samplers for the monitoring of NO₂ in ambient air. A considerable number of studies reported the performance in side-by-side comparisons with reference monitors (chemiluminescence).

Generally, these comparisons gave varying results; however, the results are generally consistent within the uncertainties of the methods. At urban sites, where unprotected open tubes were used, a tendency was observed towards overestimation of NO₂ concentrations.

When using membrane-capped tubes in combination with model equations describing the uptake rate as a function of temperature, humidity, wind speed etc., the comparability improved.

When the uncertainty associated with the measurement results was evaluated according to the Guide to the Expression of Uncertainty in Measurement, the relative expanded uncertainty of individual results was estimated to be 32 % for worst-case conditions (when using a single value for the uptake rate independent of environmental conditions).

Assessments of measurement uncertainty by direct approaches, e.g., from parallel measurements with the reference method for measurement of NO₂, generally gave relative expanded uncertainties below 25 %. These findings suggest that the Palmer tube is at least suitable for performing long-term measurements of NO₂ for indicative purposes, and possibly even for fixed measurements.

When aggregating results to form annual average values, the relative expanded uncertainty may be further reduced to levels below 15 % due to the reduction of random effects on uncertainty.

8.1.2 The Passam tube sampler

Passam tube samplers are used e.g. in Cyprus, France, Germany, Italy, Lithuania and Romania for supplementary measurements to the fixed measurements at the level of an indicative method. Other applications include identification of hot spots, mapping, zoning, trend analysis, source apportionment, impact on vegetation, assessment of exposure of population, verification of dispersion models etc.

The preparation of the TEA-based sampling substrate is performed by the manufacturer.

Passam tube samplers are generally analysed by colorimetry applying the Griess-Saltzman methodology.

The Passam diffusive sampler is suitable for long-term monitoring of NO₂ in ambient air. Exposure periods of 1 to 6 weeks are feasible. The lower detection limit for a 2-week sampling period is reported to be 0,4 µg.m⁻³. The most commonly used exposure period is 2 or 4 weeks.

Unused and exposed samplers may be stored for several months under specific conditions (dark; air tight; reduced temperatures).

A large body of literature evidence from various sources was available about the application of Passam tube samplers for the monitoring of NO₂ in ambient air. A considerable number of studies reported the performance in side-by-side comparisons with reference monitors (chemiluminescence).

The comparability of sampler results with those obtained with reference monitors varied somewhat, with ratios of average results generally ranging from 0,9 to 1,3. This variability may be reduced, when:

- Sampling rates are converted to actual conditions of temperature and pressure;
- Membranes are introduced into the sampler inlet particularly for traffic-related sites.

When the uncertainty associated with the measurement results was evaluated according to the Guide to the Expression of Uncertainty in Measurement, relative expanded uncertainties of individual results from 20 to 25 % resulted. When assessing measurement uncertainty by direct approaches, e.g., from parallel measurements with the reference method for measurement of NO₂, similar and even better results were obtained. When combining results from a number of studies in France, a relative expanded uncertainty of 13 % was calculated, qualifying the sampler for the fixed measurement regime of EU Directive 2008/50/EC.

These findings suggest that the Passam tube is at least suitable for performing long-term measurements of NO₂ for indicative purposes and possibly even for fixed measurements.

When aggregating results to form annual average values, the relative expanded uncertainty may be further reduced to levels below 15 % due to the reduction of random effects on uncertainty.

8.1.3 The Ogawa badge sampler

The Ogawa sampler has been used in Spain. To date, there is no reference found of the sampler being used for ambient air monitoring purposes in the EU. Applications are mainly in the field of indoor air and exposure monitoring. The preparation of the TEA-based sampling substrate is performed by the manufacturer.

Ogawa samplers are generally analysed by colorimetry applying the Griess-Saltzman methodology.

The Ogawa badge-type diffusive sampler is suitable for long-term monitoring of NO₂ in ambient air. Exposure periods of 2 to 4 weeks are feasible. Lower detection limits reported vary somewhat, but are below 1 µg.m⁻³ for a 2-week exposure period.

Unused and exposed samplers may be stored for several months under specific conditions (dark; air tight; reduced temperatures).

A number of studies from various sources were available about the application of Ogawa samplers for the monitoring of NO₂ in ambient air mainly in the United States of America. A limited number of studies reported the performance in side-by-side comparisons with reference monitors (chemiluminescence).

When exposed for 14 days or more in the field, the comparability of sampler results to those obtained with continuous reference monitors (chemiluminescence), was good, with ratios of average results ranging from 0,90 to 1,07. The availability of sampler results upon long-term exposure was better than 90 %. Absence of data in comparisons was due to malfunctioning of reference monitors rather than malfunctioning of the sampler.

No information is available about any uncertainty assessment of the results obtained with the sampler, e.g., according to the Guide to the Expression of Uncertainty in Measurement.

When using the methodology of the EU Guide to the Demonstration of Equivalence to the results of the US-EPA El Paso study, the sampler was found to pass the uncertainty requirement for indicative measurements. The random uncertainty found for the relation between sampler results and reference

method indicated that by correcting the uptake rate the sampler may pass the criterion for fixed measurements. However, the study was performed under conditions that are atypical of the EU.

8.1.4 The Radiello radial sampler

The Radiello sampler is used in the EU e.g. in Belgium, France, Italy, Slovakia and Spain for surveys aimed at, e.g. identification of hot spots, mapping, zoning, trend analysis, source apportionment, impact on vegetation, assessment of exposure of population, verification of dispersion models etc.

The preparation of the TEA-based sampling substrate is performed by the manufacturer.

Radiello radial samplers are generally analysed by colorimetry applying the Griess-Saltzman methodology.

The Radiello radial-type diffusive sampler may be used for long-term monitoring of NO₂ in ambient air. Exposure periods of 1 day to 2 weeks are feasible. The lower detection limit for a 2-week sampling period was reported to be 0,9 µg.m⁻³. Results of a laboratory study in which the sampling period was restricted to one day showed an underestimation of NO₂ concentrations of a factor of 2 when applying the uptake rate specified by the manufacturer. The reason for this may be a transient period of sorption at the beginning of the sampling period.

The comparability of sampler results with those obtained with continuous reference monitors (chemiluminescence) varied, with ratios of average results ranging from 0,6 to 1,4. In general, Radiello showed a trend to underestimate concentrations measured by reference monitors. However, the number of field data available was too limited to be conclusive.

When the uncertainty associated with the measurement results for a one-day exposure was evaluated according to the Guide to the Expression of Uncertainty in Measurement, a relative expanded uncertainty of individual results of 31 % was found. When assessing measurement uncertainty by direct approaches, e.g., from parallel measurements with the reference method for measurement of NO₂, similar results were obtained.

These findings suggest that the Radiello does not satisfy the uncertainty data quality objective for indicative measurements of NO₂, for which the uncertainty shall not exceed 25.

When aggregating results to form annual average values, the relative expanded uncertainty may be further reduced to levels below 25 % due to the reduction of random effects on uncertainty.

The information collected about the uncertainty of individual measurement results does not correspond with information supplied by the manufacturer stating an expanded measurement uncertainty of 12 %. However, information about the assessment approach used by the manufacturer is (currently) unavailable.

The possible effect of concentration level, high humidity and exposure time for NO₂ needs further research.

8.1.5 The Analyst badge sampler

Applications of the Analyst sampler appear to be mostly in indoor air monitoring, e.g., for studies into protection of cultural heritage. No references to applications in ambient air monitoring were found apart from the ones of the manufacturer.

To date, the preparation of the sampling substrate is performed by the manufacturer.

Analyst samplers are generally analysed by ion chromatographic determination of the nitrite formed after sorption on the sampling substrate.

The Analyst diffusive sampler is suitable for long-term monitoring of NO₂ in ambient air. Exposure periods of 1 to 2 weeks are feasible. The lower detection limit for a one-week exposure period is 1,9 µg.m⁻³.

The comparison of sampler results with those obtained with continuous reference monitors (chemiluminescence) showed ratios ranging from 1,0 to 1,4. On one occasion a ratio of 2,7 has been found in an early study. However, the number of studies was very limited.

No information was available on the availability of sampler results upon long-term exposure, e.g. for a period of one year.

When assessing measurement uncertainty by direct approaches, e.g., from parallel measurements with the reference method for measurement of NO₂, a single study reported the accuracy to be ± 20 %.

No further information was found about any uncertainty assessment of the results obtained with the sampler, e.g., according to the Guide to the Expression of Uncertainty in Measurement.

8.2 Conclusions and recommendations

Based on the findings summarised above, the following conclusions were drawn.

- The Palmes tube, Passam tube and Radiello radial sampler are in general use in the European Union for monitoring NO₂ in ambient air. Of these, the two tube-type samplers are used in ongoing air quality monitoring for supplementary measurements to the fixed measurements at the level of an indicative method.
- The Ogawa badge and Analyst badge are not in general use in the European Union for ambient air monitoring of NO₂.
- The extent to which results of validation studies are available differs considerably between samplers. For the tube-type samplers, a substantial number of sources were identified. For the Ogawa badge and Radiello radial sampler information was more restricted. For the Analyst badge information was even scarcer.
- The available information suggests that, in general, the tube-type samplers may at least meet the EU uncertainty data quality objectives for indicative measurements. Application of membranes or shelters generally improves their performance. In some cases uncertainties were found that would qualify the samplers for fixed measurements.
- For the Ogawa badge sampler, the current limited information available suggests a potential to meet the EU uncertainty requirement for indicative measurements. However, the conditions of the study on under which this finding is based were not really representative for average European Union conditions. More information would be needed to draw firmer conclusions about the validity of the results produced by the sampler for monitoring NO₂ in ambient air.
- For the Radiello radial sampler, the current limited information available suggests that the sampler is not able to meet the EU uncertainty requirement for indicative measurements. The sampler generally appears to systematically underestimate NO₂ concentrations. More information would be needed to draw firmer conclusions about the validity of the results produced by the sampler for monitoring NO₂ in ambient air. It is recommended to further investigate the possible effects of concentration level, high humidity and exposure time for NO₂.
- For the Analyst badge insufficient information is currently available to draw a quantitative conclusion about its potential to meet EU data quality objectives for the monitoring of NO₂ in ambient air. The limited information available gives mixed findings. More information would be

needed to draw firmer conclusions about the validity of the results produced by the sampler for monitoring nitrogen dioxide in ambient air.

On the basis of the above conclusions it is recommended that experts draft, a proposal method, based on the tube-type sampler, for monitoring nitrogen dioxide using diffusive samplers to be later used by CEN/TC 264 Working Group 11 "Diffusive Samplers" to prepare a new standard. Should further information become available in time on the performance of the Radiello radial sampler, which provides supporting evidence of its validity and its potential to meet EU data quality objectives, this sampler may still be considered and be included in the standard.

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Abstract

A number of diffusive samplers that are used for longer-term monitoring of nitrogen dioxide in the European Union were subjected to a review of their use and performance characteristics. The information collected was used to evaluate the capacity of diffusive samplers for monitoring the European Union annual limit value of 40 $\mu\text{g.m}^{-3}$.

A bibliographic review was carried out to determine the availability of validation data for these samplers, their capacity to meet the data quality objectives for indicative and/or fixed measurements of the European Directive, the possibility for users to analyse the samplers and their current use throughout the European Union for measuring ambient air quality.

Two tubes-type samplers and a radial sampler were found to be used throughout the European Union. Based on the findings of the review, only for tube-type samplers based on the application of triethanolamine as the sorbent, sufficient information was available to underpin the potential of these samplers for meeting the European Union data quality objectives for nitrogen dioxide monitoring.

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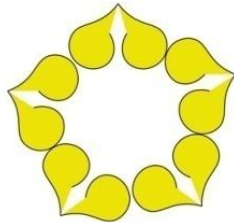
APPENDIX 4 - ALTERNATIVE STACK HEIGHTS

AIR QUALITY ASSESSMENT

Development of a Waste to Energy Facility, other waste management operations within the Maghtab Environmental Complex, Maghtab integration with a new Thermal Treatment Facility (MTTF)

Report submitted to
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1 PREMISE

This paper proposes the study of the air dispersion model (ADM), carried out for the new Maghtab Thermal Treatment Facility (MTTF), for the evaluation air quality impacts.

The modelling suite used throughout this exercise has been capable of incorporating all the substances included in the terms of reference.

Specifically, the same suite of dispersion modeling was used, in order to assess for the likelihood of significant effect on ambient air quality (including exceedances of the ambient limit values in SL549.59 and BAT on waste incineration) as well as on the deposition levels of particular components, due to the operation of the new plant MTTF.

Previously this study was developed the air dispersion model considering three different scenarios: heights of the chimney of 25 meter (scenario 1), heights of the chimney of 30 meter (scenario 2), heights of the chimney of 35 meter (scenario 3).

The results of the previous study did not highlight significant variations in the impacts on air quality for the three different scenarios, so ultimately the designers decided to consider the optimal height of the chimney that of Scenario 1 (H=25 meters) with the shortest chimney causing the least significant impacts on air quality.

The emission factors used are the provisional limit values in normal operating conditions based on “Tentative limit values under normal operating conditions based on BAT and IED” shown in the table 3 of the new EIA TORs dated 05/08/2024.

The model used in this study has been capable of predicating the dispersion and deposition of pollutants under variable meteorological conditions ranging from

the most favorable to the least favorable. The modelling suite permitted the annual calculation of the required parameters.

The spatial resolution obtained by the model has been 5 x 5 m, to enable the identification of impacts at sensitive receptors.

With this document, the impact of emissions is determined by applying a mathematical model of dispersion and atmospheric fallout, which calculates the concentration of substances emitted by the incinerator in ambient air at ground level, integrating and processing the emission data, the data meteorological and geomorphological (see figure 1). The following regulatory references have been considered for the preparation of this document:

- a. UNI EN 13725: 2004 "Air quality. Determination of odor concentration by dynamic olfactometry".
- b. UNI 10796: 2000 "Evaluation of the dispersion of aeriform effluents into the atmosphere. Guide to the selection criteria of mathematical models".
- c. UNI 10964: 2001 "Environmental impact studies. Guide to selecting mathematical models for predicting impact on air quality".

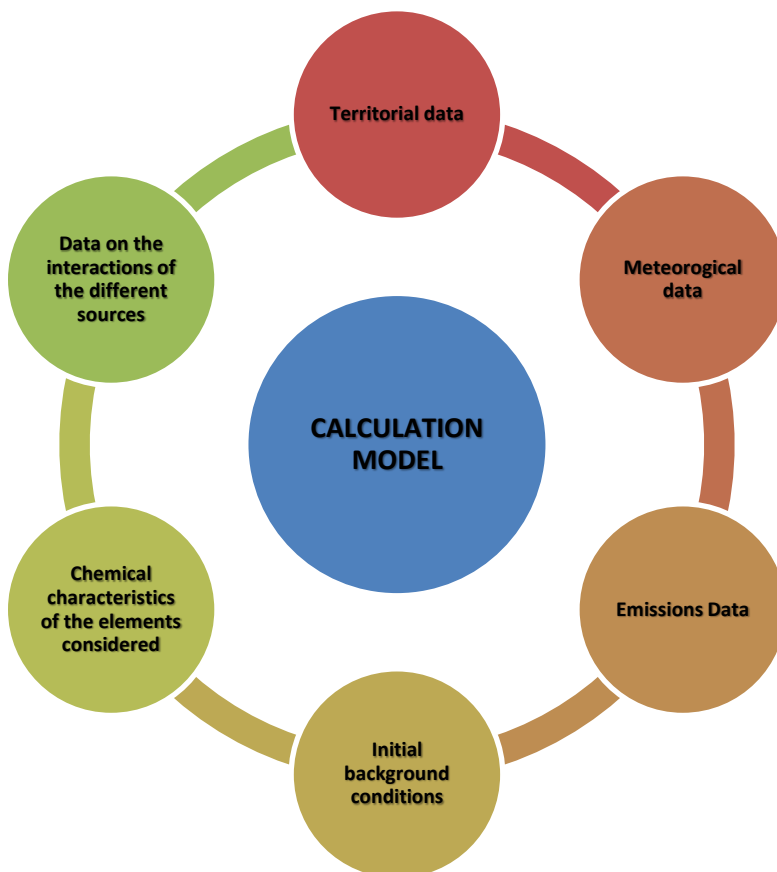


Figure 1. Schematic representation of the type of information and input data required by the model

2 AIR QUALITY MODEL

2.1 INTRODUCTION

Generally, an air quality model (or "atmospheric dispersion model") is a mathematical algorithm that has as its objective the calculation of the concentrations in the atmosphere of one or more pollutants emitted by a defined set of sources. The two main categories of models are ***stochastic*** and ***deterministic*** models.

The ***stochastic*** do not refer to physical cause-and-effect relationships but only to statistical correlations, for which they are characterized by a series of intrinsic limits and are mainly used to formulate semi-quantitative forecasts on air pollution, which must however be validated by an experienced operator.

The ***deterministic*** models, on the contrary, are made up of mathematical algorithms which reproduce (more or less according to the typology of the model itself) the diffusion, transport and chemical transformation processes to which the pollutants are subjected once emitted into the atmosphere.

The information presented here refers mainly to this second category of models: it is in fact to the deterministic models that the legislation refers (in particular the DM 261/2002 - *Regulation containing the technical directives for the preliminary assessment of the quality of the ambient air, the criteria for the preparation of the plan and the programs referred to in articles 8 and 9 of the legislative decree 4 August 1999, n.351*), as they potentially allow to face any type of simulation scenario.

Deterministic models, by their own nature, need a series of input data, which can be divided into three general types:

- d. *geographical data*, which describe the geographical characteristics of the territory in which the emissive phenomenon occurs, in particular the

topography and roughness. The territorial context in which the model is applied is called the calculation domain;

- e. *emission data*, which describe the characteristics of the sources of atmospheric pollution that are taken into consideration, in particular the quantity and type of pollutants emitted;
- f. *meteorological data*, which describe the ways in which pollutants are dispersed in the atmosphere, in particular anemology and phenomena related to turbulence and atmospheric stability. A typical set of weather data needed for an analysis is made up of an annual data set.

They provide the spatial distribution of one or more pollutants in a given area, the so-called concentration fields which, in the case of the most advanced models, have a three-dimensional character.

The most advanced air quality models require real input data pre-processing modules, in particular as regards meteorological data; in this case we speak more properly of modeling chain since the pre-processing modules of meteorological data are in turn real models that provide output fields of quantities such as: wind characteristics, temperature, atmospheric turbulence etc.

There are two basic categories of deterministic models, depending on the spatial coordinate system which they refer. The ***Eulerian models*** refer to a fixed coordinate system, while the ***Lagrangian models*** use a mobile coordinate system that follows the movements of the air masses. The Eulerian models are divided into ***analytical models***, and into ***grid models***. In the analytical ones, through the introduction of a series of simplifications, it is possible to analytically solve the general differential equation that describes transport and diffusion.

The so-called ***"plume" Gaussian models***, which constitute the simplest tool in the field, and the ***"puff" models***, belong to the analytical Eulerian models. The fundamental difference consists in the fact that the Gaussian models assume that the process is stationary (ie that in every point of the domain the variation in concentration over time is zero), while the "puff" models allow a treatment, albeit simplified, also of non-stationary processes. Both solutions assume that the

emission originates at a point in space (point source) and also the meteorological geometries considered are very simplified.

In grid models, however, the calculation domain is always three-dimensional, it is divided into a series of cells through a suitable grid and the general transport and diffusion equation is taken in a more complete (non-stationary) form that requires resolution by numerical methods. To this category belong the photochemical models capable of describing, in addition to diffusion and transport, also the phenomena of chemical transformation to which pollutants are subjected once they are released into the atmosphere.

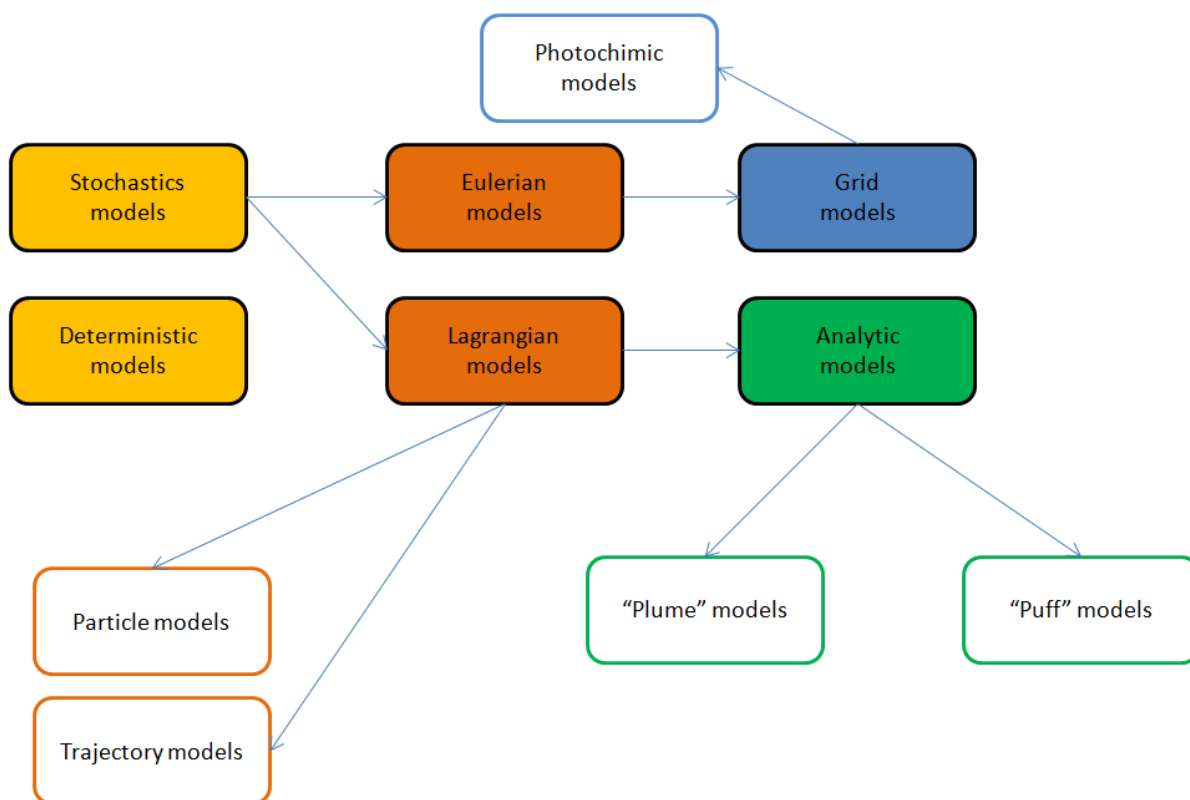


Figure 2. Main types of model

Lagrangian models, which are also capable of describing non-stationary processes, are divided into **particle** and **trajectory models**. The emission of each pollutant is represented, in the first case through a series of small units of known mass (called particles), in the second by one-dimensional vertical columns. In both cases, these are models that use a three-dimensional computation domain,

but while particle models are also suitable for simulations of high spatial detail, trajectory models are used in the study of phenomena at a very large spatial scale, of the order thousands of kilometers, as in the case of cross-border pollution.

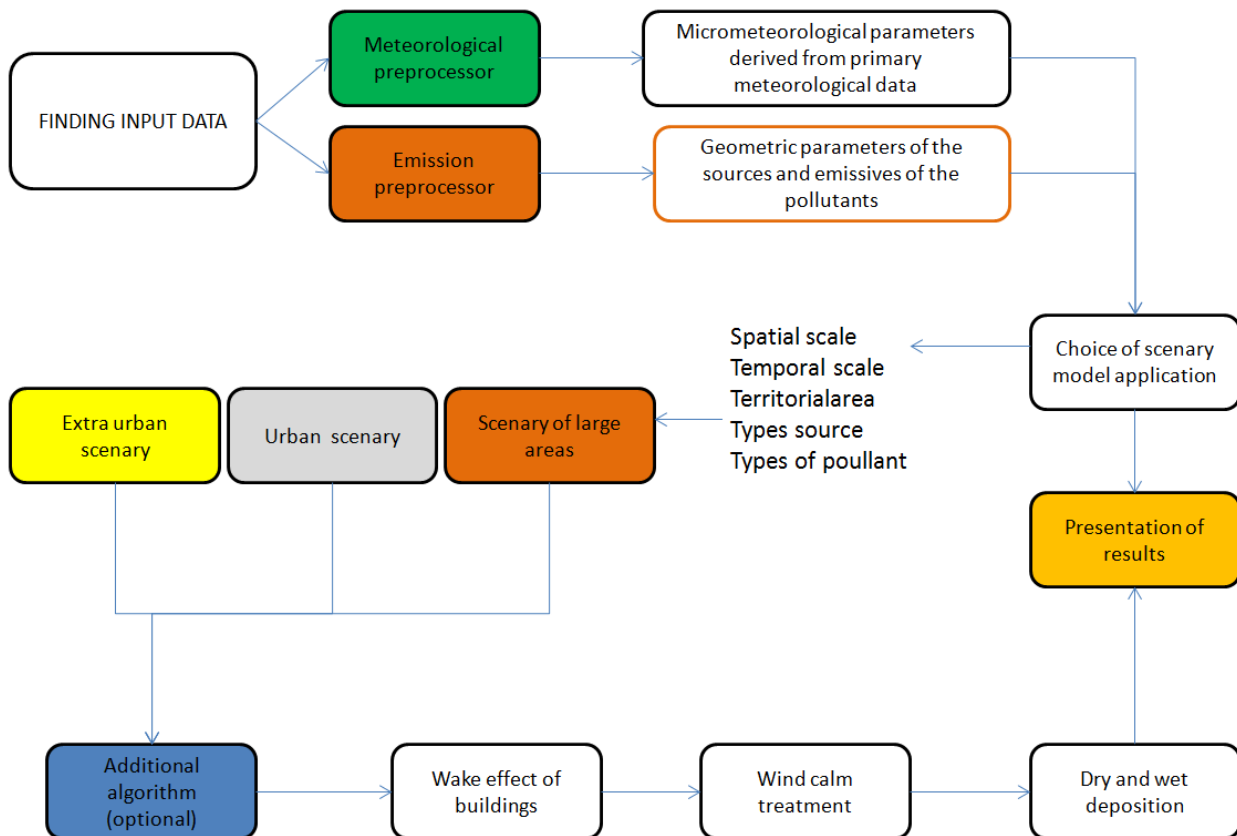


Figure 3. Realization phases of a diffusion model in the atmosphere.

2.2 MODEL APPLICATION

When making the choice of an air quality model (or a modeling chain), it is necessary to clearly bear in mind the nature of the problem to be addressed. For this purpose, the notion of scenario is very useful, that is, the set of elements that characterize a specific application. Based on the Guidelines for the selection and application of atmospheric dispersion models for assessing air quality, a scenario is defined by five elements:

the *spatial scale*, for which micro-scale applications (up to 1 km), local scale (up to 10 ÷ 20 km), mesoscale (up to 100 ÷ 200 km) are distinguished;

- the *time scale*, for which short-term (roughly a few minutes to a few days) and long-term (seasonal and annual periods) applications are distinguished.
- the *territorial context*, for which applications on a simple site (flat terrain, homogeneous territorial and meteorological characteristics) and on a complex site (complex orography, territorial and / or uneven meteorological characteristics) are distinguished.
- the *types of source* present, for which point, linear and areal sources are distinguished.
- the *types of air pollutant* taken into consideration, whereby a distinction is made between non-reactive (or reactive to the first order, that is, decay expressed by means of time constant) and reactive pollutant.

From the choice of the different types of elements, one of the three different types of possible scenarios emerges:

1. URBAN AREAS

500x500 m² spatial staircase (typical size of a block that houses buildings and roads), up to 10x10 km² (surface within which the entire urban area can be included).

This scenario is dominated by pollutants emitted above all at ground level by vehicular traffic, and is characterized by a marked spatio-temporal variability of concentrations. It can be described with analytical models that allow the treatment of linear sources in the form of a road graph and of areal sources as a composition of emissions from domestic heating or in cases where it is desired to describe the contribution of a network of roads without distinguishing the individual contributions.

2. EXTRAURBAN AREAS

This scenario is dominated by the typical emissions of a given production area (e.g. sulfur dioxide and nitrogen oxides due to the combustion processes of fossil fuels), generally conveyed into chimneys (emissions from point sources) and / or from emissions of extra-urban road arteries (emissions from linear sources).

This is the case most frequently treated with models: since the 1960s simulations of the dispersion of radionuclides emitted in the event of accidental release from nuclear plants were carried out and then the study was carried out of the behavior of plumes of pollutants emitted into the atmosphere by large industrial plants through chimneys (point sources) or from the buildings of the plants (area sources)

3. EXTENDED AREAS

This scenario is the most general one and considers the set of polluting sources located on spatial scales ranging from extended urban realities, such as large metropolitan areas to aerological basins affecting multiple regions (as in the case of the Po valley). The treated domains can therefore be of the order from 50x50km² up to 500x500km² and consider both primary and secondary pollutants.

2.3 TYPE OF SOURCES AND ASSIGNMENT CRITERIA

There are three types of sources: ***point, linear and areal.***

Generally, the assignment of a source to one of these classes takes place on the basis of several criteria: the form (typically, for example, the emissions distributed on a line such as road, air transport infrastructures etc.) fall within the line, whether or not to relocate the source in the form of point or linear. In this regard, for example, the position of large industrial plants is usually sufficiently characterized, therefore emissions are generally attributed to a specific source, vice versa, emissions from heating systems for civil use, since they cannot be georeferenced individually due to their number, are usually attributed to the emissions of the polygon corresponding to the census / municipality / province / region to which they belong according to the detail and therefore treated as areal.

A similar example concerns road traffic emissions, in fact usually the main road arches are treated individually while the secondary ones are sometimes considered as a whole, corresponding to the neighborhood or cell to which they belong. A further classification criterion involves the identification of appropriate threshold values, i.e. emission values on the basis of which to differentiate between sources that must be considered stand-alone if the emissions exceed the established threshold or can be grouped with others, similar for type of pollutant and process. On the basis of these considerations, the sources are then divided between punctual, to be considered individually, and areal.

In the impossibility of treating all the sources individually, it is evident that the choice of the threshold values sometimes depends on the resources available and the purposes of the inventory or modeling application.

2.4 EMISSIONS PREPROCESSOR

An emissions preprocessor is a SW tool that processes the information relating to the emissions necessary for the execution of an air quality model using appropriate estimation methods or from existing data (emission inventories, measurements). Usually for modeling purposes, emissions are treated as:

- punctual
- linear
- areal and volumetric

The emissions present in the simulation domain, once assigned with appropriate criteria to one of these types, must be adequately characterized according to the information required by the models. The main sources for obtaining this information are the emission inventories which are prepared both on a national scale by the APAT (Agency for the Protection of the Environment and for Technical Services), and on a local (regional, provincial etc.) scale by the related entities. The input relating to emissions generally represents one of the most complex input data to be obtained both for the small number of local inventories available on the national territory and for the complexity of the processing to be performed on the data coming from the inventories, as it is generally aimed at other purposes and not equipped with sufficient spatial and temporal detail to be directly usable by a model.

It is therefore necessary to use more or less complex emission processors depending on the availability of the initial data and the type of QA model to be applied, on which the complexity of the input to be prepared depends. The case of a three-dimensional model for reactive pollutants undoubtedly represents the most complex one since it requires the emissions specified for each cell of the grid,

for each hour of simulation, for each chemical species treated individually or combined.

A processor for the predisposition of the emissions must therefore allow to carry out:

- a. the spatial allocation to allow the passage from the territorial detail (common for example) to the cell;
- b. the temporal breakdown to allow the estimates to be reduced from annual to hourly basis;
- c. speciation to transform the overall information of VOCs and PTSs into group species required by the model;
- d. the particle size distribution to derive PTS estimates in particle size classes according to the requests of the model.

This obviously applies in a completely general way, this does not exclude that, in some cases, the available emissions may already exhaustively cover one or all four of the desired details (spatial and / or temporal and / or chemical-physical of the polluting species) and therefore the use of the processor is limited to the supply of the missing detail or to the reading / writing of the emissions in the requested IT format.

2.5 TYPE OF DATA REQUIRED BY A QA MODEL

Usually a model requires the following groups of information about the source:

- a. coordinates (coordinates of the extremes of the arc usually described by means of broken lines in the case of linear ones, coordinates of an angle in the case of areas usually treated as a composition of square-shaped area sources, of the center of gravity of the chimney in the case of points);
- b. physical-geometric parameters (height and diameter of the chimney, temperature and speed of the fumes or equivalent parameters such as the

- flow rate, in the case of the linear ones, for example, the slope may be required, if above / below high etc.);
- c. quantity of polluted emissions per unit of time or emission accruals for each pollutant. The emission accruals are usually deducted either from direct measurements or from estimates according to the reference methodologies.
 - d. a time modulation profile referring to the year / month / day.

This applies in the simplest case, for example referred to the Gaussian models. The numerical dispersion models for the study of reactive pollutants, taking instead the more complex but more significant case in order to better highlight all the critical issues, require hourly emission values for the entire simulation period, specified for each cell of the grid, and for about twenty species containing either single chemical species or group species, that is, they treat groups of compounds similar in structure and reactivity as a single chemical species. The discussion is further complicated if you also want to model the particulate matter, in which case it is necessary to know the distribution by particle size classes (knowledge of the finest particles of particular interest) and the chemical composition.

During the development and analysis of the emission pre-processors, the definition of some strictly spatial and geographical parameters, such as the coordinate system, the dimensions and plans of the receptor grid, the orographic data and the any effects of the orography if considered complex.

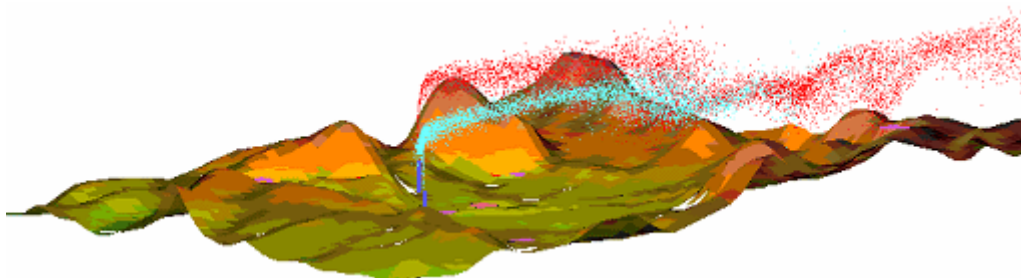
2.6 METEOROLOGICAL PREPROCESSOR

The most frequently used models for the simulation of point and linear sources from extra-urban traffic (Gaussian or "puff" analytics) generally require primary meteorological data (wind speed and direction, temperature). Stability classes (eg Pasquill-Gilford) and mixing height, micrometeorological parameters derived from primary meteorological data, are generally used to characterize stability.

To derive these quantities, it is possible to use a one-dimensional meteorological preprocessor applied to the data collected as close as possible to the release point. It is very useful to have vertical wind and temperature profiles. Since there are no on-site stations, it is possible to use meteorological information suitably processed using a three-dimensional meteorological preprocessor applied using all the meteorological information available on a given area (ground stations and radio soundings).

EXAMPLE 1 - Point source simulation

In these cases the source term is generally known or easily estimated (from the fuel used or the number of vehicles present), as well as the characteristics of the emission (emitting surface, height of release, temperature of fumes, etc.); the size of the domain of interest for assessing the impact of these sources varies from a few hundred meters for releases of cold fumes near the ground or for the estimation of concentrations near road viaducts, to a few tens of kilometers for releases from chimneys high (> 200m) of hot fumes or for the emissions of a motorway section.



The models historically developed and used for these cases are the "Gaussians"; however, it is necessary to take into account the limitations to their use: in fact the application of these models in incorrect conditions has often led to very

disappointing results in the comparison between simulated and measured concentrations. Its use can be recommended for sites that are not orographically complex, with very low percentages of calm and weak winds and for emissions close to the ground; in these cases, even with few meteorological data (the historical series of the data of an anemometer placed at altitude release is sufficient) it is possible to obtain useful indications on the concentrations on the ground; it is necessary to pay attention to the choice of the dispersion parameters and to be guided in the choice between the different families of curves (Pasquill, Briggs, etc.) by comparing them with measured data.

To simulate emissions in all other conditions (releases above 100m of hot fumes, complex sites) it is necessary to collect an adequate data-set of meteorological measurements at ground level and at altitude which describe in detail the weather-diffusive phenomena acting on the site, so to be able to activate the simulation models for the dispersion of pollutants as closely as possible to the actual conditions of the atmosphere. In these cases, puff and particle models can be used, supported by appropriate meteorological models for the reconstruction of wind fields on sites with complex orography.

Depending on the resources available, two different simulation models can be used.

- Short Term Calculation (punctual)
- Long Term calculation (climatological)

In the first, a sort of snapshot of the diffusion of a certain pollutant is represented on the basis of precise data such as direction and wind speed, and this makes it possible to calculate and evaluate any legal limits on the pollutants emitted in each receptor of the grid.

The second, on the other hand, allows to simulate a significant number of days representative of the different types of weather and therefore, based on their frequency of occurrence, to reconstruct the climatological indicators. Generally, a

temporally broad set of starting data is needed in order to characterize the "diffusion trends" in the area of pollutants according to the climatology typical of the study area.

Based on the scenario in question and the characteristics of the area, it may be necessary to calculate some downwash effects (deflection) of the flow, such as the wake effect of the chimney itself and / or the wake effect of the buildings when they are upwind at the point emission (building downwash). The effects of these phenomena therefore entail a lowering of the effective height of the plume and this can increase the spread of pollutants at lower altitudes. In defining the emissions dispersion model and in the study report, the geographical coordinates of each of the buildings and the height of the building relative to the ground must be reported for each of the buildings that generate wake effect.

2.7 WIND CALM TREATMENT

Often the more precise dispersion models have a special method for treating calm winds. Many of the available software have a significantly different algorithm from the regular one for calm winds for all those hours of the simulation time domain in which the wind speed is lower than a certain defined threshold value.

It is also necessary that the percentage of hours for which the model uses the special method is minimal, and possibly less than 2% since:

- a. the olfactory impact parameter to be expressed as the final result of the simulations is in the form of the 98th percentile;
- b. in calm wind conditions the maximum olfactory impact is often obtained, since the pollutants are less effectively mixed in the atmosphere.

Some dispersion models that operate with very rich or very poor weather data on rainy days often need to activate the calculation algorithms relating to the deposition processes that take place within the air mass. These processes are:

- a. Dry Deposition: Mechanism always present in the PBL (Planet boundary layer) which eliminates a part of the pollutant present in the plume and transfers it to the ground without intervention of the water present in the atmosphere.
- b. Wet deposition: Elimination mechanism caused by the action of rainwater on the plume.

In many case studied however, these algorithms are not often necessary and are cautiously deactivated in the modeling phase.

3 PRODUCTION PLANT

3.1 GEOLOCATION

The site on which the plant being modeled falls is located in the Maghtab, a village within the locality of Naxxar. This area forms part of the North-east coastal zone of Malta, as shown in Figure 4.



Figure 4. Satellite photo with identification of small-scale project areas

3.2 DESCRIPTION OF THE PRODUCTION PLANT (MTTF)

The ECOHIVE Complex shown in Figure 5 above, consists of several facilities within the waste management sector. To date, these facilities include the Waste to Energy (WtE) which is at ground works stage, Material Recovery Facility (MRF), Organic Processing Plant (OPP), Bio Waste Treatment Plant which is constructed and finished and the Thermal Treatment Facility (TTF).

The TTF site is an irregular shape, with the longest part measuring 220m. The total site footprint is 18,250m² of land which will undergo a change in use from non-intensive agriculture to accommodate the Thermal Treatment Facility as shown in Figure 6.



Figure 5. ECOHIVE complex



Figure 6. Render of the proposed THERMAL TREATMENT FACILITY

This scheme is being proposed to establish a new hazardous waste incineration plant and centralise all the major waste operations carried out by Wasteserv Malta. The project entails the preparation of a new hazardous waste incineration plant with two independent lines, and space for a potential third independent line in the future. The proposed development will form part of the ECOHIVE Complex and will operate in conjunction with the other waste management facilities at Maghtab.

The plant shall comprise of two independent lines, with space for an additional third line. Each line will have an incineration/boiler and Flue Gas Treatment (FGT) that can operate independently of each other.

Each line consists of a rotary kiln, a waste heat boiler with combustion air fans, economiser, FGT reactor and bag house filter.

4 FALLOUT MODEL ELABORATION

4.1 MODEL - WINDIMULA

WinDimula is a plume Gaussian model that allows performing diffusion calculations in the atmosphere of non-reactive pollutants emitted from multiple point and area sources, scattered over an area that represents the domain of calculation of the model, in the presence of complex orography. The model allows to perform both "Short Term" and "Climatological" simulations. WinDimula also allows to evaluate the effective heights of pollutants emitted by chimneys for each class of atmospheric stability. The model allows the calculation of the concentrations of pollutants in all the receptors defined within the calculation domain (both Cartesian and discrete) and of both dry and wet deposition.

A "Short Term" or punctual calculation represents a sort of "snapshot" of the diffusion of a certain pollutant based on "punctual" meteorological data (ex: hourly wind direction and speed).

The WD calculation code allows you to perform multiple point simulations in sequence; in this way it is possible to evaluate any legal limits on the pollutants emitted. In particular, if an annual sequence of hourly meteorological data is available, it is possible to perform WD on the entire sequence of data, evaluating for example in each receptor of the calculation grid the maximum hourly concentration value detected during the whole considered sequence.

With the WDPRO postprocessor it is possible to evaluate other legal limits both in terms of values and percentiles for the pollutants considered. A climatological simulation, on the other hand, does not allow to make assessments on the limits of the law but allows to evaluate the "diffusion trends" in the area of interest (calculation domain), that is those areas of the calculation domain mainly affected by the atmospheric diffusion of pollutants.

A climatological calculation is basically a set of point calculations (by sectors) weighted however with respect to their statistical occurrence frequency. Having therefore available suitable series of meteorological data it is possible to climatologically characterize a certain area through the definition of a suitable JFF (Joint Frequency Function).

The calculation model also allows to evaluate the diffusion of the pollutant into the atmosphere even in situations of "calm wind". In these cases WD integrates a suitable model (Cirillo Poli model) for calm winds. The model has no limitations. The execution times of a simulation depend on the type of calculation required, the size of the grid (number of grid nodes), the number of sources considered, the type of meteorological data used. The presence of calm wind situations always leads to an increase in the temporal performance of the execution, as this is not a directional calculation but carried out on a 360 ° angle around each source.

APAT (Italian agency for environmental protection and technical services) has included WinDimula in the models to be applied for the evaluation of air quality.

4.2 SIZE AND UNIT OF MEASURE

- Height (m)
- Internal diameter of the chimney (m)
- Flue gas temperature ($^{\circ}$ K)
- Total emission rates relating to the pollutants considered ($m(mass)/s$)
- Flow rate ($m(mass)/s$)
- Sedimentation speed (m/s)
- Wind direction (degrees) in the case of the short-term model
- Wind direction (degrees / sector) in the case of the climatological model
- Wind speed (m / s)
- Temperature ($^{\circ}$ K)
- Height of inversion (m)
- for all that information that needed georeferencing, the UTM Coordinates fused 33N Datum WGS 84 were used

For the mixing heights, rural Briggs, urban Briggs and possible roughness-dependent Briggs were taken into account.

4.3 CALCULATION DOMAIN

The calculation grid represents the geographical space within which the diffusion simulation is processed, has been defined geographically according to the following parameters:

- Abscissa and ordinate of the origin of the calculation grid: 446844 AND 3974993 N
- Number of links in x direction and y direction: 120 x, 120 y
- Reticle pitch right and right: 50 m x 50 m
- Height of ground receptors: 2 meters, indicative value obtained from the average height at which the concentration is perceived;
- Absence of discrete receptors;
- Standard control parameters, with the use of the non-conservative approach for the term of reflections in the presence of gravitational sedimentation;
- The resolution of the calculation of the concentrations/deposition is equal to 5x5m.

The figure below shows the extension of the calculation domain used for this study. The subsequent spatial elaborations were produced on a "mask" of territory adapted to the extension of the results obtained in order to emphasize the areas most affected.

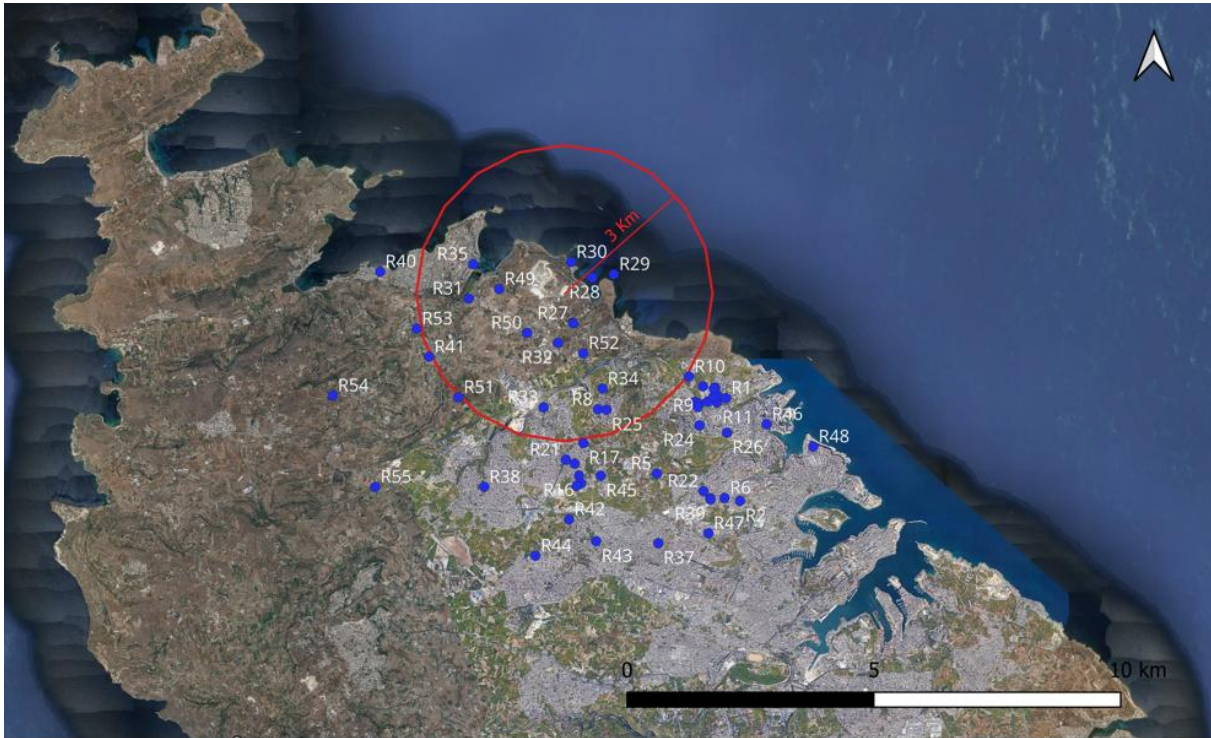


Figure 7. Calculation domain based on 3 km radius

4.4 METEOROLOGICAL DATASET

The meteorological dataset required for the development of the dispersion model have been collected from the weather station of Luqa Hourly-Malta Airport.



Luqa Hourly Meteorological Data

4.4.1 Pluvio-thermometric regime

The raw meteorological dataset acquired from weather station of Luqa Hourly, related to temperature and precipitation values for the entire year 2021, has been checked for excluding the presence of no-data values (errors and/or 0-data values), and the hourly values has been merged together using a spreadsheet management SW, to obtain the daily mean values for Temperature and Precipitation.

The time lapses taken into account are 24-hours intervals, (for example from 01/01-00:00 to 01/01-24:00), that were plotted on monthly graphs, shown below.

Final dataset was therefore plotted and represented on various histogram-type and rose diagram-type charts.

These histograms show the total annual precipitation and annual temperature, with daily frequency for both. Have been produced 13 final combined graphs (Histogram + Lines) which shows the trend monthly, as well a final summary all year long.

In these graphs, the two vertical axis allows to read at the same time the daily precipitation values expressed in millimeters (left axis) and the mean daily

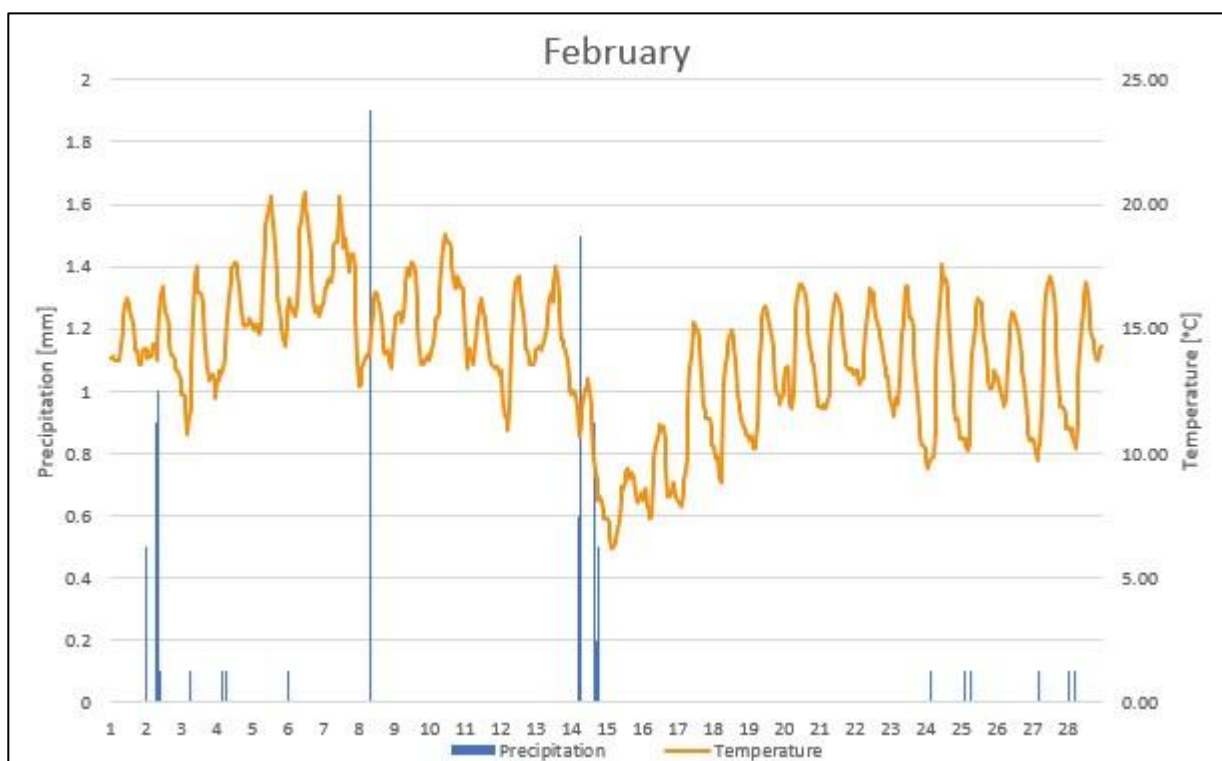
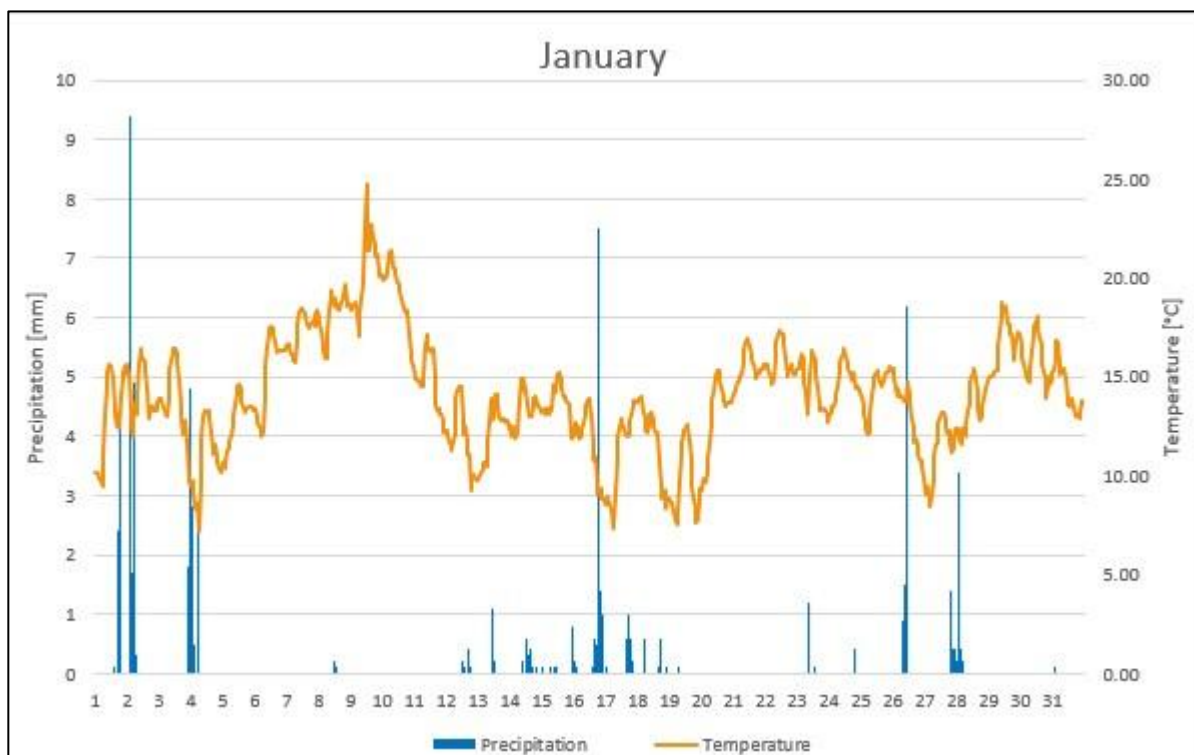
temperature expressed in Celsius degrees (right axis). The horizontal axis on the bottom shows instead the days of the corresponding month.

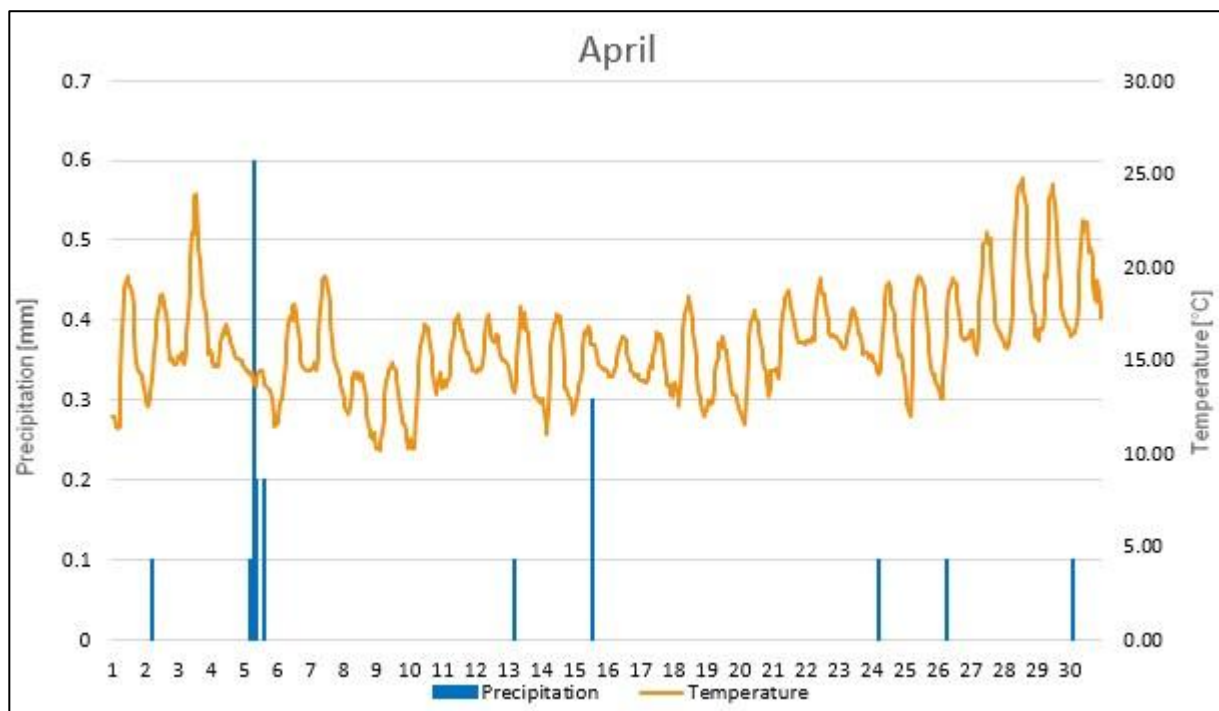
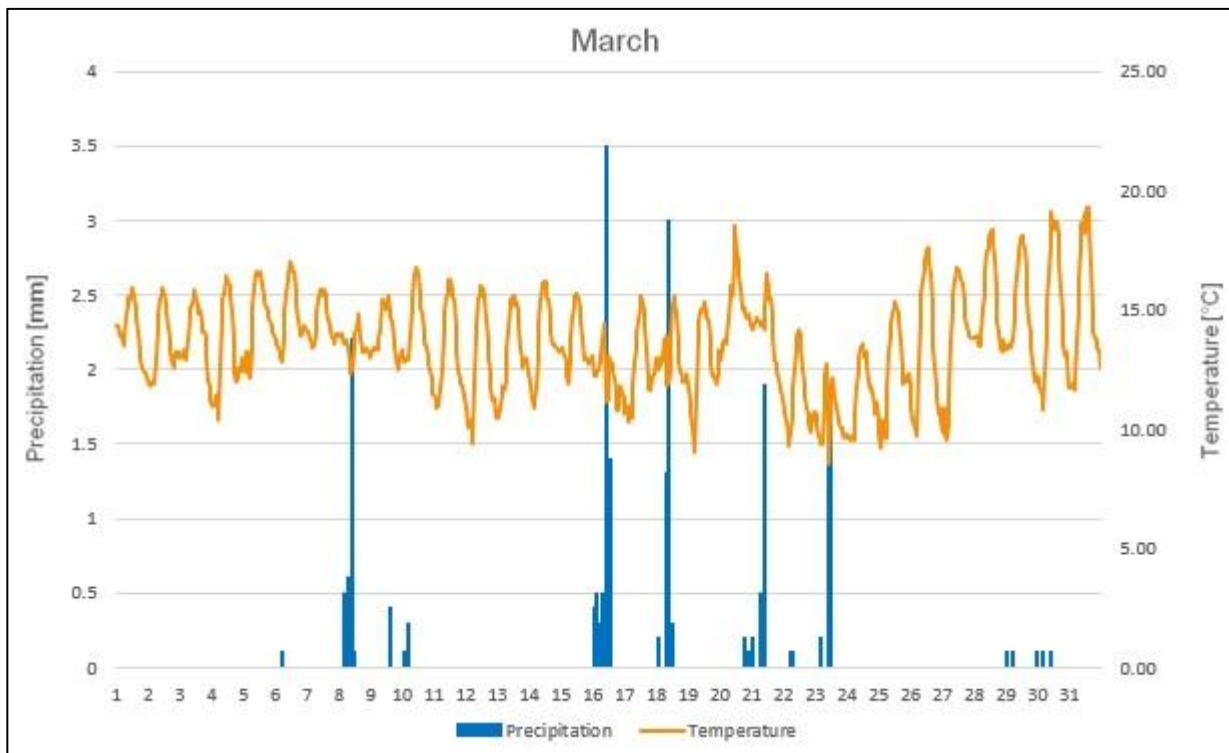
Analysis of temperature trends for example shows:

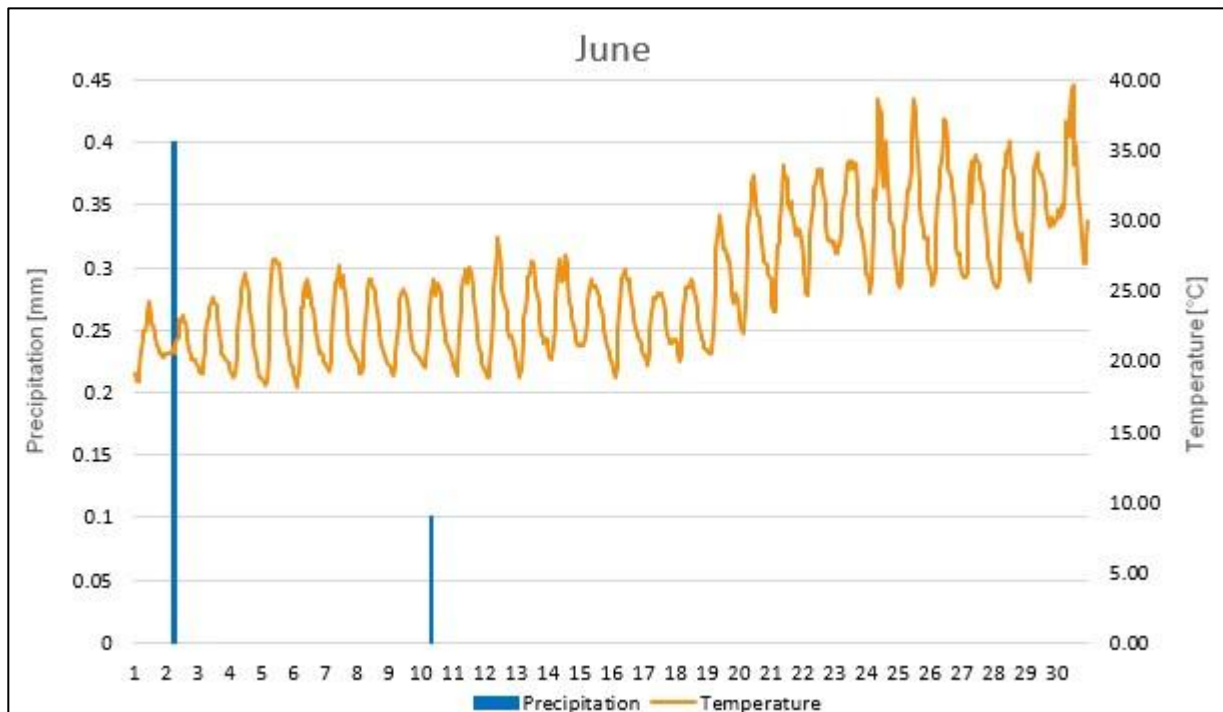
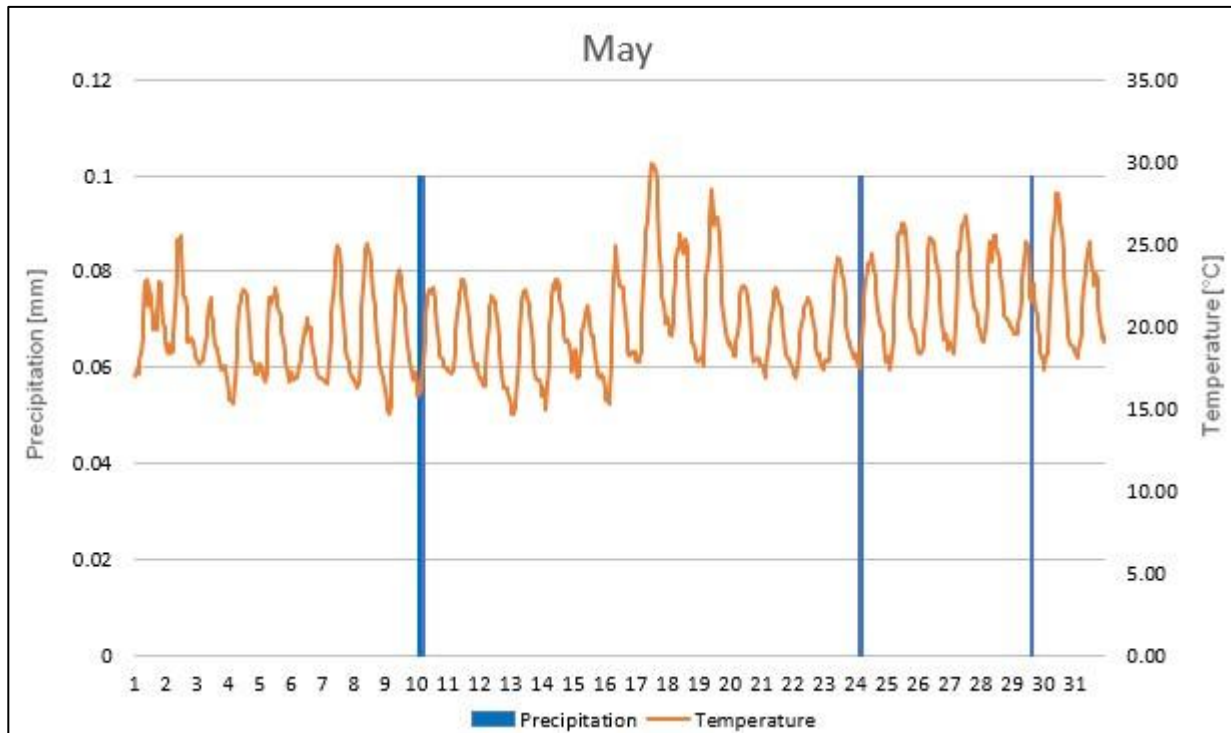
- A very regular and typical trend of mean daily temperature, which during the year follows a normal or “Gaussian” distribution. The temperature range varies from 39.60C° to + 6.20C° and indicates a strong thermal mitigating effect due to the sea proximity.

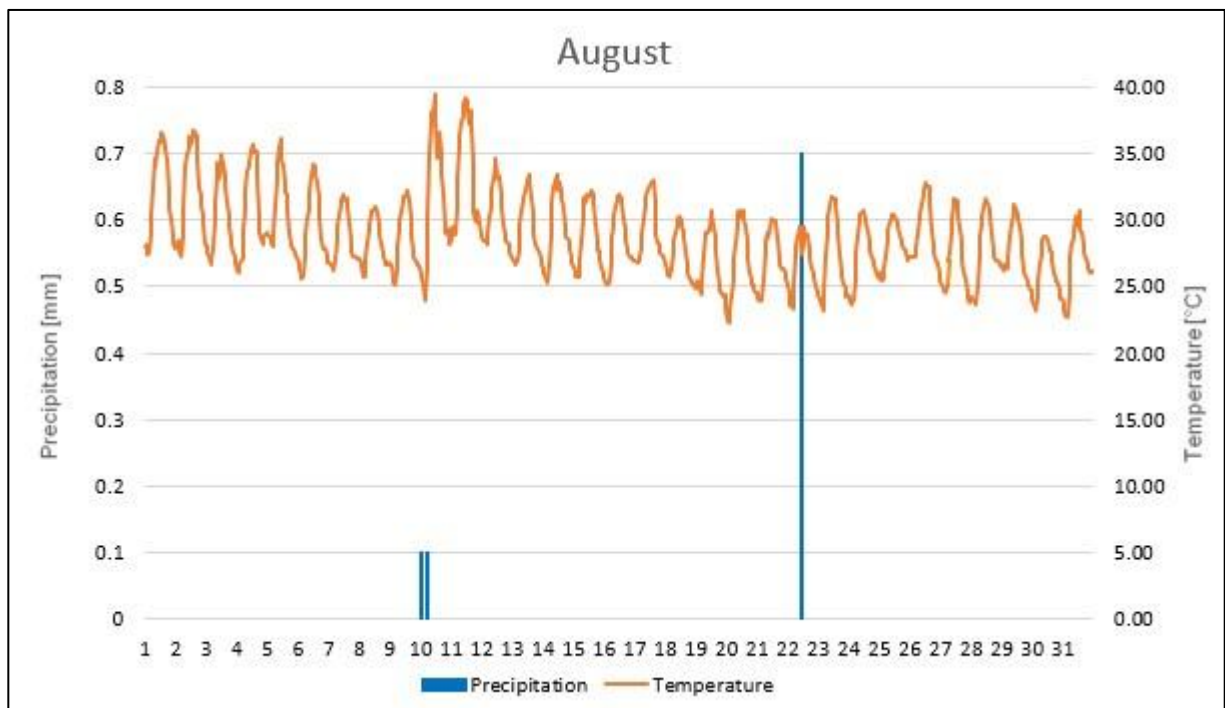
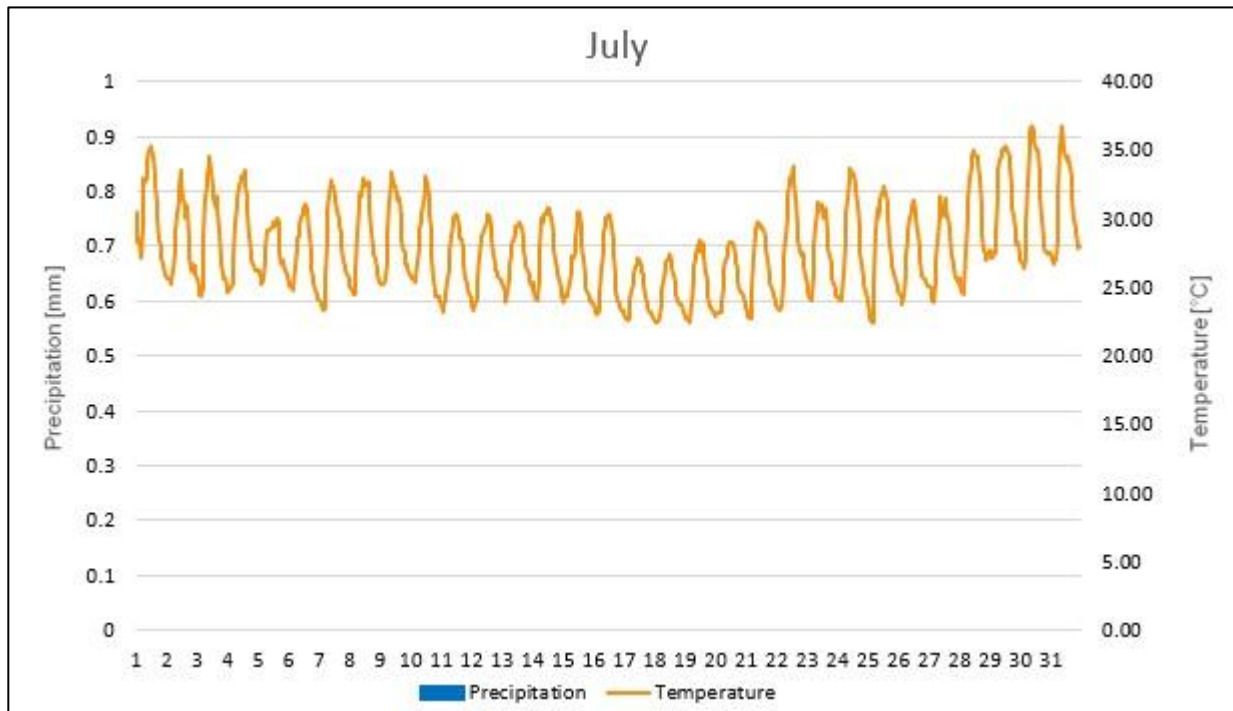
This underlined trend is typical of Mediterranean near-sea and insular areas, with poor rainfall in summer seasons and high peaks of precipitations in winter and spring seasons. The total annual rainfall in this type of climatic area are however low and above average.

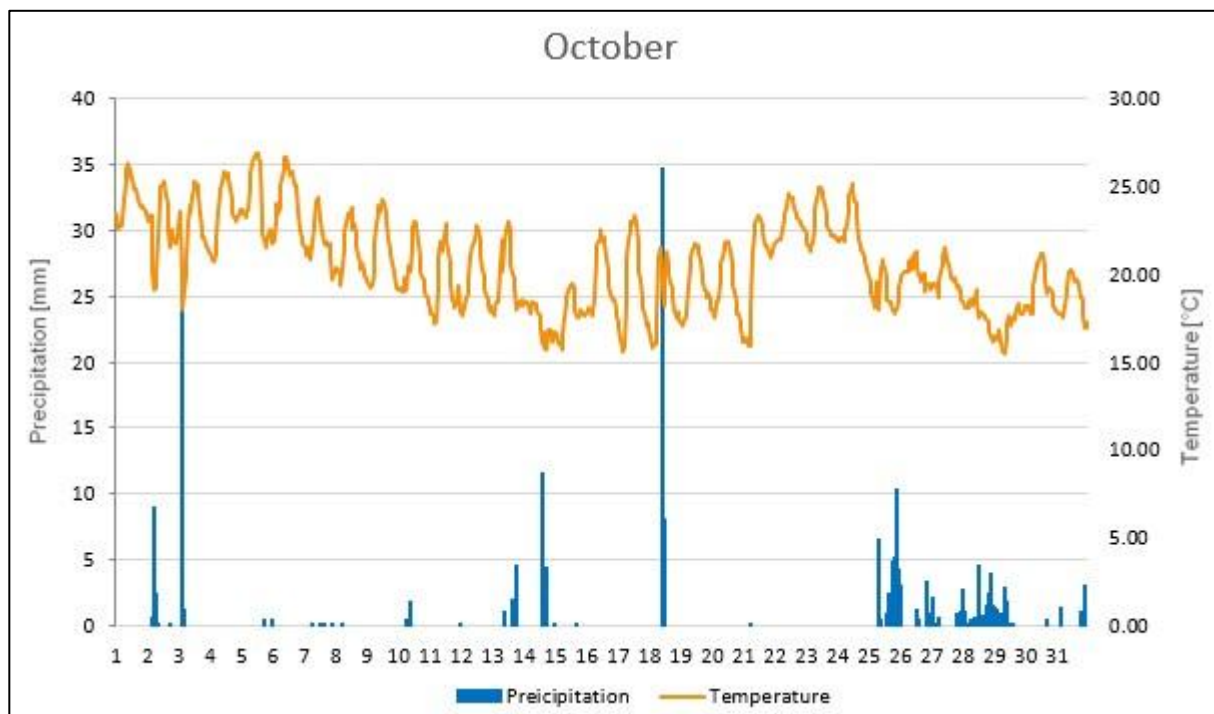
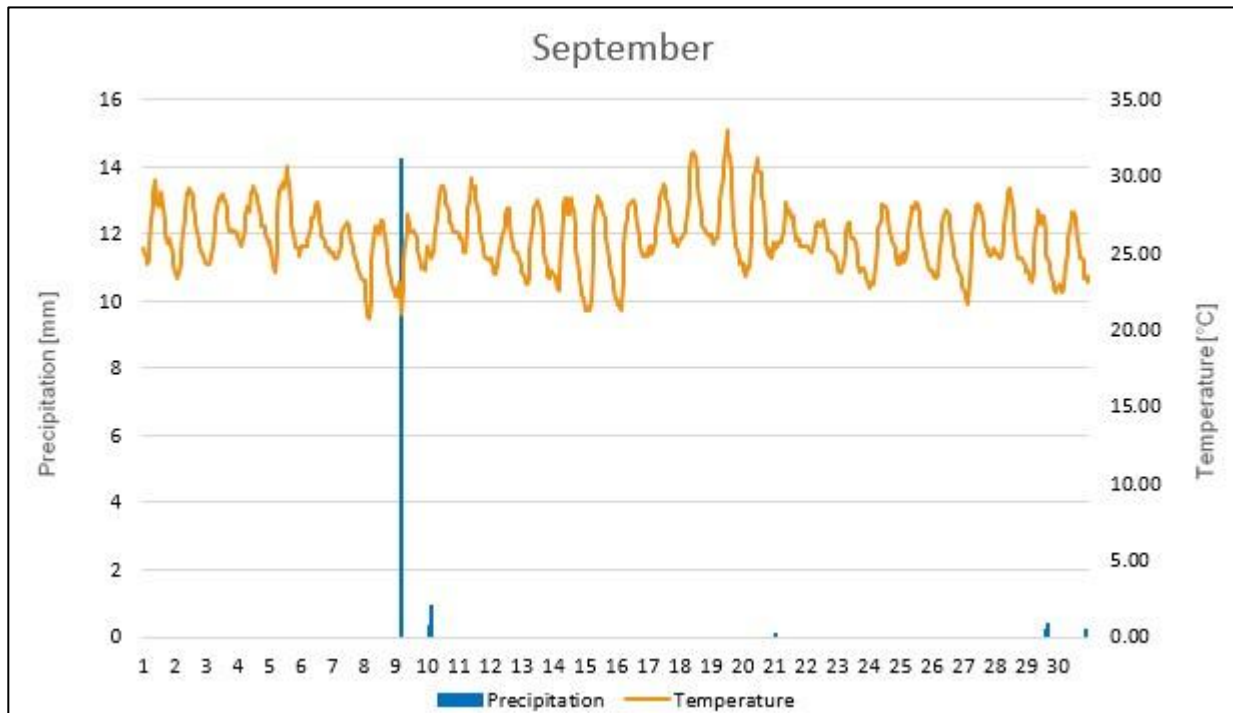
The analysis of annual precipitation or rainfall trend, shows instead the existence of one main peak of rainfall occurring in the October- November period (34-38 mm).

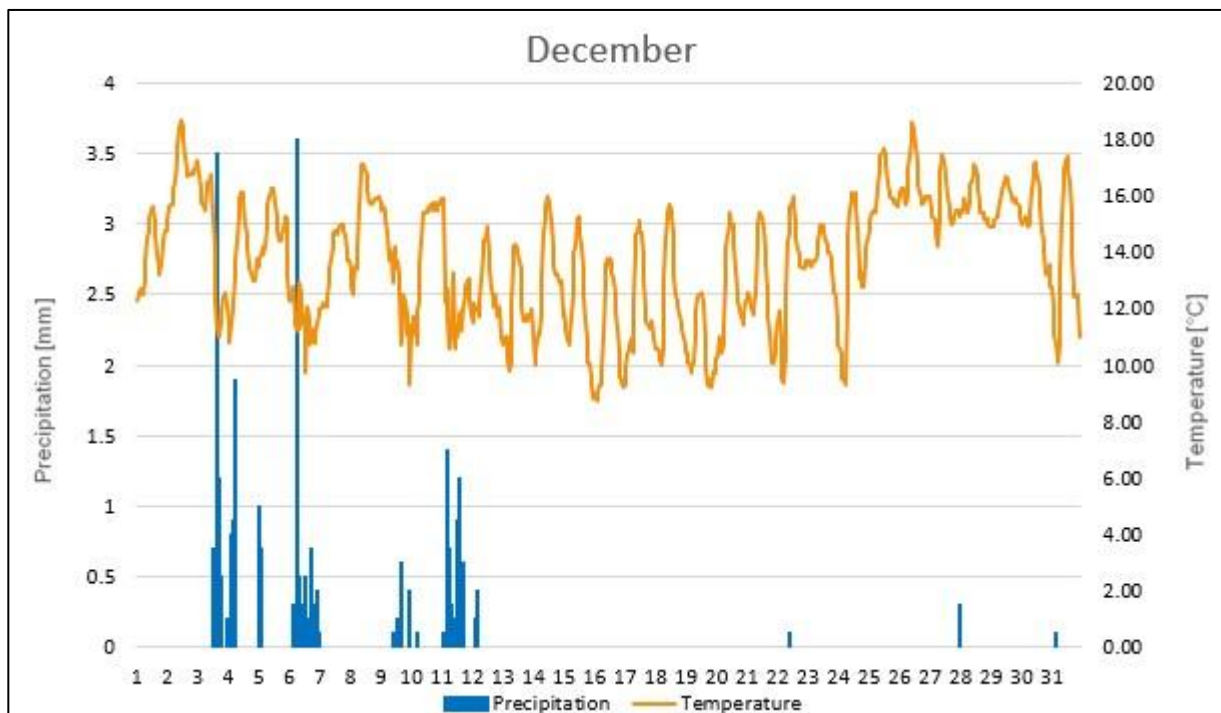
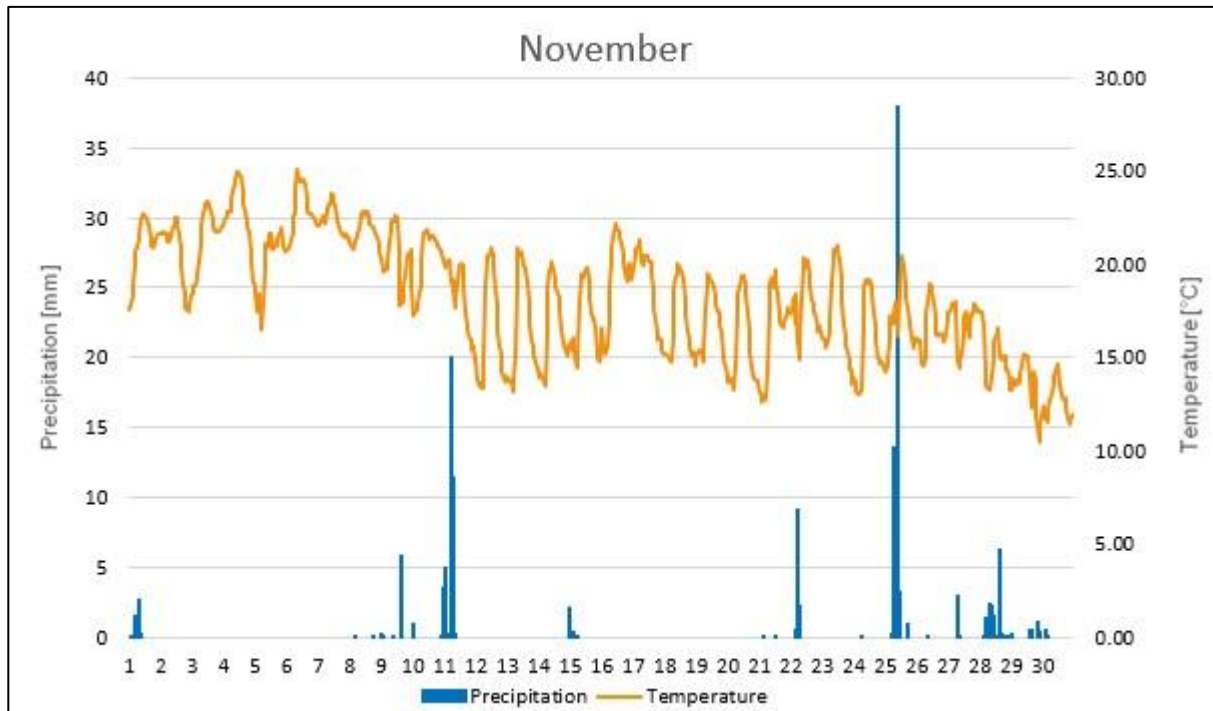












4.4.2 Anemometric regimes

As usual in meteorology studies, in the presented wind rose diagrams, has been indicated the angle or the direction of the wind (the direction in which the wind is coming), clockwise relative to the North.

For example, when indicated that the wind has angle of 90° (East), it is meant that it blows from East to West. Instead, into simulation scenarios and taking into account pollutant dispersion it's more effective to represent the wind vector (the direction in which the wind heads) rather than the direction of coming.

The general wind rose diagram, derived from the data of the whole year 2021, shows two predominant directions of the wind:

- The first, from Northwest to Southeast.
- The second one, almost in perpendicular direction than the first, from West-Southwest to East-Northeast.

The winds are oriented mainly into preferential directions that reflects the geographical and orographic settings of the area, as well the positioning of the major airport structures like the two main landing strips. The distance from the sea (6 km in almost all directions) does not allow the development of any significant phenomena of sea breeze or land breeze.

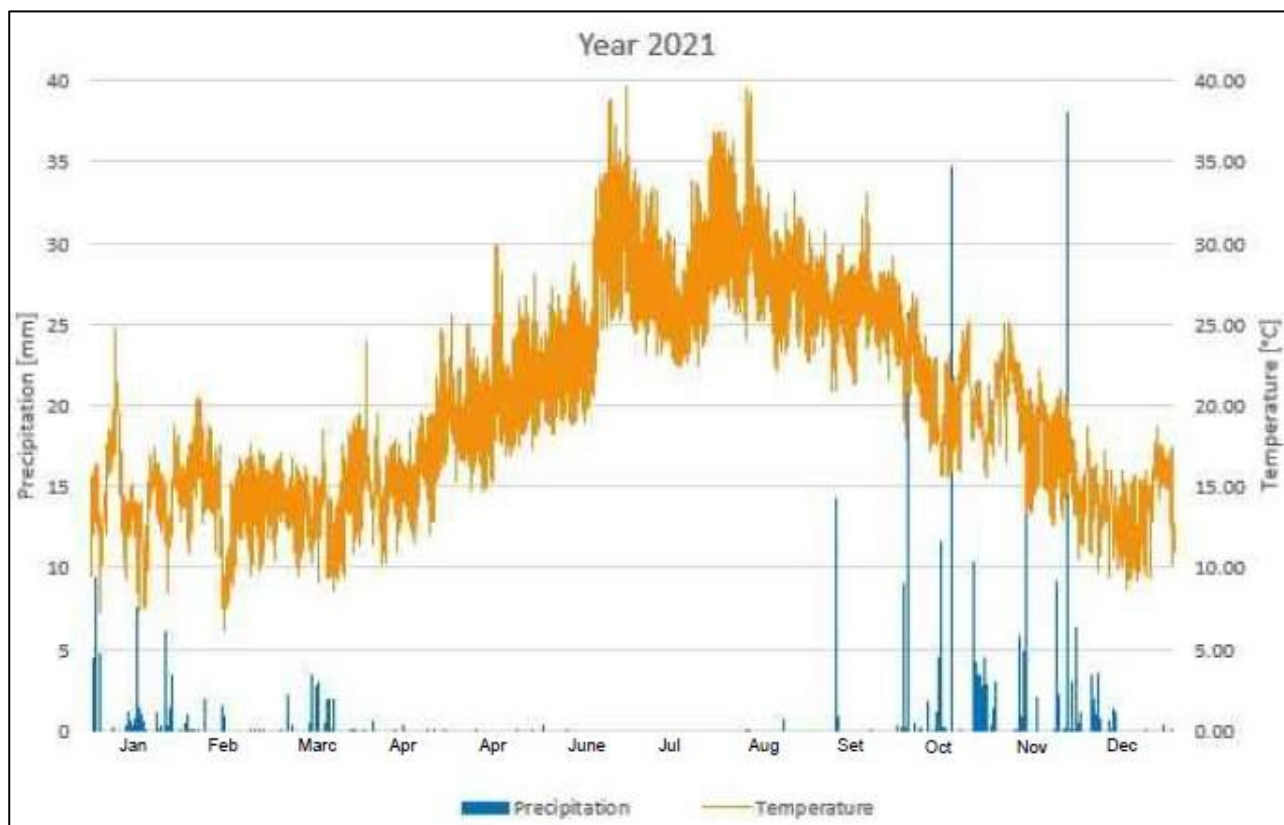
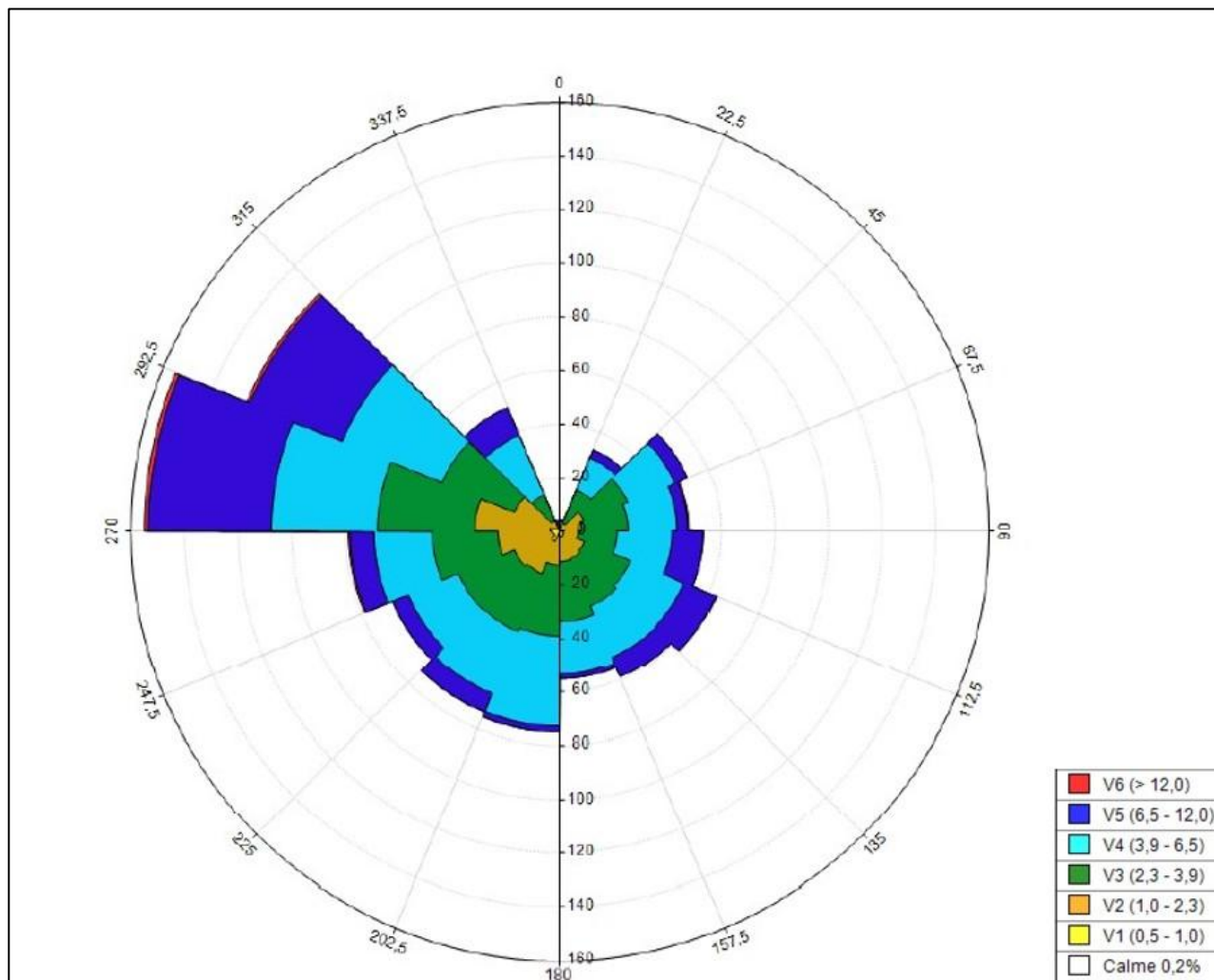


Figura 8 – Wind Year 2021 (8760 observation)



The seasonal wind rose-diagrams instead, highlights the following:

- Autumn and Winter wind directions resemble each other and are similar to the main trend for the entire year. The predominant direction is from Northwest to Southeast.
- Spring and Summer wind directions resemble each other too but are more often contributing the winds blowing from the other main direction (West-Southwest to East-Northeast).

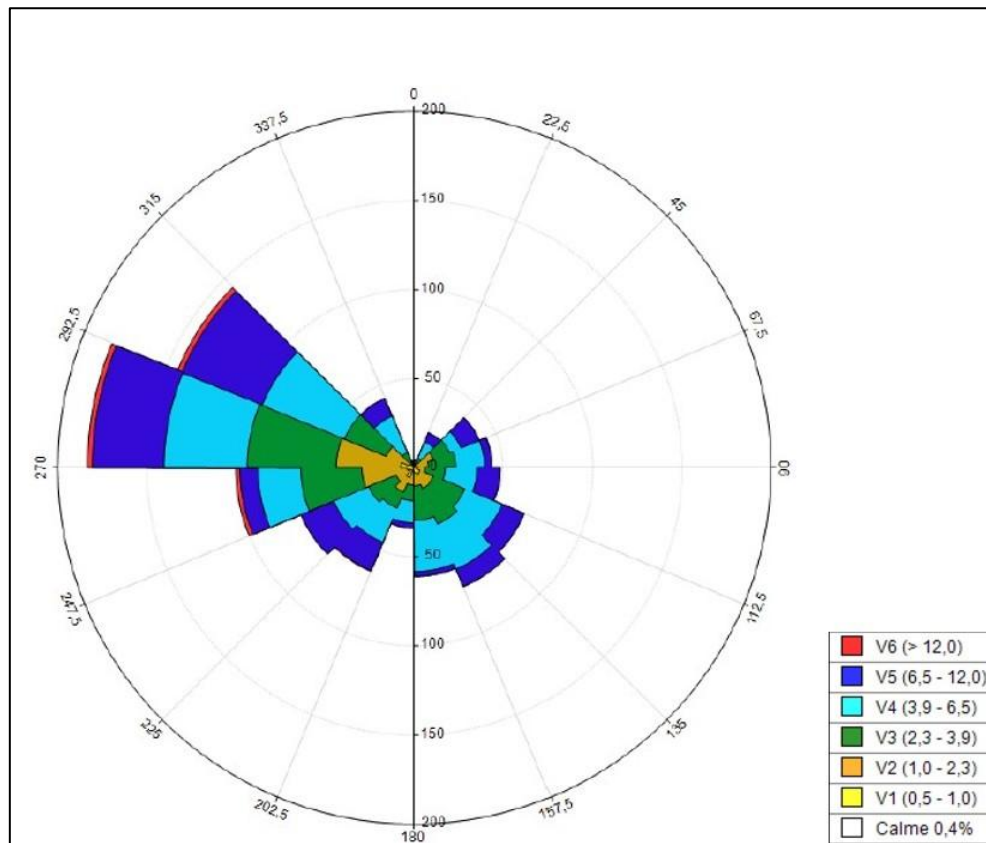


Figure 9. Seasonal wind rose-diagrams –Autumn–

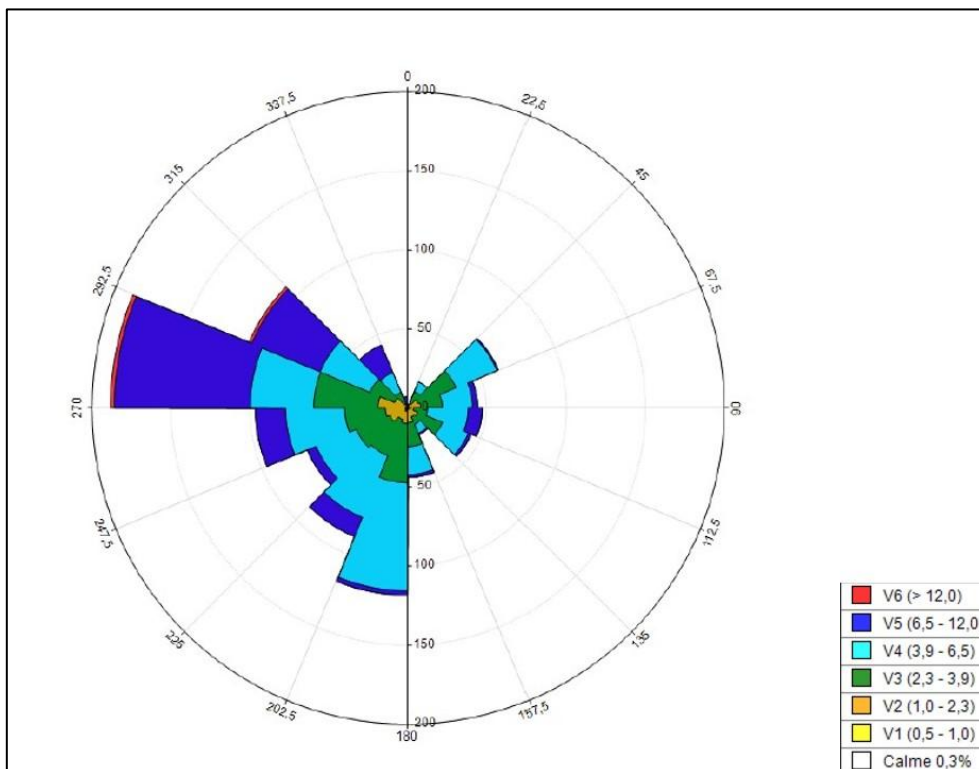


Figure 10 - Seasonal wind rose-diagrams Winter

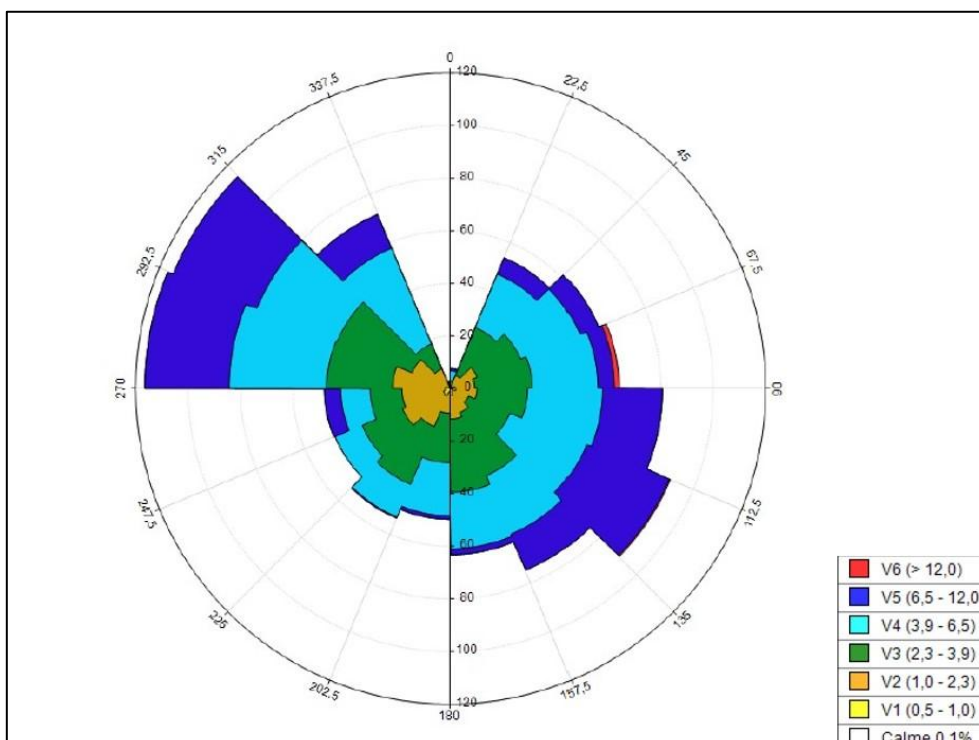


Figure 11 - Seasonal wind rose-diagrams Spring

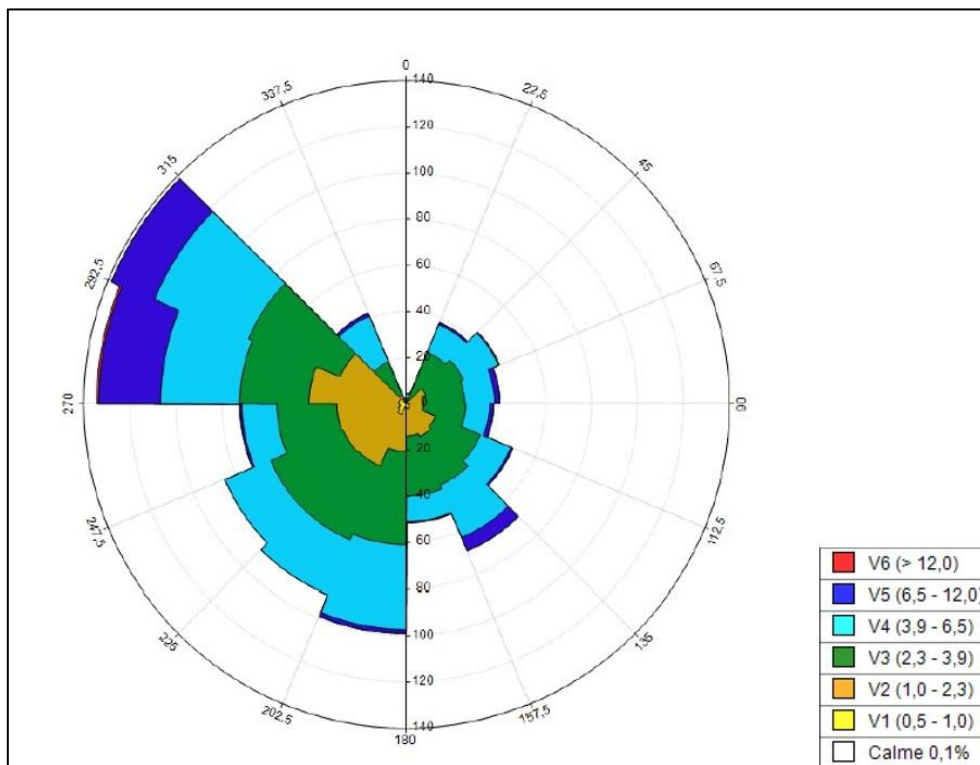


Figure 12 - Seasonal wind rose-diagrams Summer

The anemometric data files were created according to the format used by Aeronautica Militare (Joint Frequency Function) and compatible with the calculus module DIMULA.

The climatological model use as raw data the so-called *Joint Frequency Function*. These “functions” are statistical aggregation of meteorological observation derived from historical data series.

Data are aggregated into seven tables that represents six classes of atmospheric stability A, B, C, D, E, F + G (Fog Class). Each table contain 18 rows and 6 columns of 1000-normalized data.

Columns represent the aggregation based on the wind intensity and velocity; rows represent the aggregation based on the direction in which the wind is coming.

Especially:

- the first 16 rows represent the 16 sectors of direction of the wind, starting from North and going clockwise (each sector has width of 22,5°);
- row 17 contains variable data, for which was possible to establish the intensity but not the direction of the wind;
- row 18 contains wind calm data, not measurable from the instruments.
- the first column contains just data from wind calm, every other wind episode has value set to 0.
- the velocity value written on every column represent the reference value of the velocity class used for the aggregation.
- In addition to the data on the wind condition, the “Joint Frequency Function” contains the following data too:
 - A table of occurrence frequencies of single classes normalized to 1000
 - Mean temperature of air and altitude of the meteorological station above the ground
 - The altitudes of thermal inversion typical for each stability class
 - A table normalized to 1000 with the occurrence frequency of the 14 classes of thermal inversion utilized only for Fog Class.
 - The wind velocity and the standard deviation, for use in calculations within the wind model.

metri di controllo | Sorgenti | Dati Meteor | Orografia e rugosità superficiale | Output

Strumento per la gestione delle Joint Frequency Function climatologiche

Nome del File : C:\Programmi\Maingroup Model Suite\WinDimula\vado figure\file ausiliari win dimula\Alb

Opzioni | **Classe A** | Classe B | Classe C | Classe D | Classe E | Classe F+G | Classe Nebbie | Altri Dati

Salva

Classi di Velocità

Frequenze Stabilità

Altezze di Inversione

Frequenze Inversione

Calme di Vento

Controlla

ENEL - A.M

Ordina

Chiudi

Direzione	Classi di velocità (m/s)					
	1.5	1.56	3.12	5.2	9.36	32
Settore 1	0	0.67	0	0	0	0
Settore 2	0	1.34	5.36	0	0	0
Settore 3	0	55.97	45.91	0	0	0
Settore 4	0	81.43	77.41	0	0	0
Settore 5	0	30.16	19.1	0	0	0
Settore 6	0	38.87	18.43	0	0	0
Settore 7	0	43.57	33.18	0	0	0
Settore 8	0	18.77	12.4	0	0	0
Settore 9	0	0.67	9.72	0	0	0
Settore 10	0	1.34	1.01	0	0	0
Settore 11	0	0	0	0	0	0
Settore 12	0	0	0	0	0	0
Settore 13	0	0	0	0	0	0
Settore 14	0	0	0	0	0	0
Settore 15	0	0.34	0	0	0	0
Settore 16	0	1.68	1.34	0	0	0
Variabili	0	0	2.68	0	0	0
Calma	498.66	0	0	0	0	0

Figure 13 Example of a JFF file table

4.5 DEFINITION OF THE EMISSION SOURCES

The main problem to estimate the emissions into the atmosphere is linked to the definition of emission source and to the chemical-physical characterization of the fumes. In the following, both geometrical characteristics of the chimney and chemical-physical characteristics of the fumes for the new Thermal Treatment Facility (MTTF).

4.5.1 Geometric characteristics of the emission chimney

- Geographical coordinates of the chimney: **449834 mE; 3977782 mN;**
- Altitude of the base: **58.20 from MSL;**
- Diameter: **2.50 m;**
- Height: **25 m.**

4.5.2 Characteristics of the emissions for each pollutant (MTTF)

The emission factors used are the provisional limit values in normal operating conditions based on “Tentative limit values under normal operating conditions based on BAT and IED” shown in the table 3 of the new EIA TORs dated 05/08/2024.

In detail for the parameter:

- Total dust, total volatile organic carbon (TVOC), hydrochloric acid, hydrofluoric acid, sulfur dioxide, nitrogen oxide and ammonia, used the Daily Average Value;
- Cadmium and Thallium and Total Metals and their compounds (As, Cr, Co, Cu, Mn, Pb, Sb, V and Ni) and Mercury, used the Average value over 30 min to 8 hours;

- Polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans (PCDD/F) + dioxin-like polychlorinated biphenyls (PCBs), used the Average value over 6 to 8 hours;
- Carbon monoxide, used the Daily Average Value.

Table 1 – Tentative limit values under normal operating conditions based on BAT and IED shown in the table 3 of the new EIA TORs

Pollutant	Limit of table 3 of EIA TORs	Unit
Total dust	5	mg/Nm ³
NO _x (expressed as NO ₂)	120	mg/Nm ³
NH ₃	10	mg/Nm ³
CO	50	mg/Nm ³
SO ₂	30	mg/Nm ³
HCl	6	mg/Nm ³
HF	1	mg/Nm ³
TVOC	10	mg/Nm ³
Hg	0.02	mg/Nm ³
PCDD/F+PCB dioxine	0.08	ng WHO-TEQ/Nm ³
Cd+Tl	0.02	mg/Nm ³
(Sb+As+Pb+Cr+Co+Cu+Mn+Ni+V)	0.03	mg/Nm ³

*Table Notes:

- Metals group are as follows:
 - Group 1: Cadmium (Cd) and Thallium (Tl);
 - Group 2: Mercury (Hg);
 - Group 3: Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni) and Vanadium (V).
- The emission limit value refers to the total concentration of dioxin and furans calculated using the concept of toxic equivalence (TEQ).

The gas conditions at the chimney top are estimated at:

	Unit	Line 1	Line 2
Normalised flue gas flow, wet at full load	Nm ³ /h @ 11%O ₂ dry gas	6860	6860
Anticipated temperature	°C	120-180	120-180
Anticipated O ₂ content	% dry gas	5 - 9	5-9
Actual flue gas flow, wet (@ 7% O ₂ dg and 150°C). Note 1	m ³ /h	7594	7594
Velocity at stack top, full load. Note 2	m/s	20	20
Velocity at stack top, minimum load (60%) Note 2	m/s	12	12

Notes:

1. The actual flue gas flow is re-calculated from the normalised using the actual temperature and oxygen content. Accordingly, the actual flue gas flow will vary depending on the actual data of the gasses.
2. The full load velocity at stack top is set in order to avoid stack noise. The EPC will adjust the flue dimensions to achieve correct velocity at the actual gas data of their specific design during the engineering phase. The full load velocity may be increased up to approximately 23 m/s if the part load velocity is too low to achieve sufficient dispersion.

The following abatement technologies are being considered:

Pollutant	Abatement technologies
Particulate matter (dust)	Cyclones, Electrostatic Precipitators (ESP) or Bag filters.
Oxides of nitrogen (NO _x)	SNCR, a sodium bicarbonate abatement system, activated carbon injection and bag filters.
Acid Gases (Sulphur dioxide & Halides (HCl & HF)	Dry sorbents (hydrated lime or possibly sodium bicarbonate) + Bag filter.
Heavy Metals	Activated Carbon Injection & Bag filters.
Dioxins & furans	Activated Carbon Injection & Bag filters + Combustion control and possibly flue gas recirculation.

4.6 OROGRAPHIC DATA AND SURFACE ROUGHNESS

The WinDimula calculation module provides for the insertion of the orographic data within the model for the study of the interference of the conformation of the territory with atmospheric diffusion.

The implementation of the orographic data in the model was made by producing an auxiliary calculation file (*.oro) which was produced on a rectangular mesh of the 50 * 50m pitch for a number of points equal to 36,000,000.

The file with the orographic data is a square matrix that contains the extrapolated altitude value on the intersection of all coordinates. To know the altitude values to be included in the file, a DTM (Digital Terrain Model) was produced starting from georeferenced topographic cartography.

The digital terrain model was produced by triangulating the inserted points, it is based on square areas with regular mesh integrated with a series of points quoted for the areas with more complex orography.

The DTM has the important characteristic of describing an irregular surface by means of a finite set of points with coordinates (X, Y, Z) in space. The original dimensioned points are generally spaced irregularly and according to the technique used for the measurements.

To obtain the model of soil for the present study, an exact interpolator IDW (Inverse Distance Weighting) was used as an interpolation algorithm, i.e. an interpolator capable of returning the exact value at each measuring instrumental point.

The three-dimensional model was developed not only for a useful representation of the territory but also for all derivation and analysis operations that can be carried out with it.

Nome del File: C:\Documents and Settings\GIANDOMENICO\Desktop\modello Malta\orografia\OR

Informazioni file Orografia

Numero di maglie (nx,ny): 120 120

Coordinate dell'origine (x0,y0): 446844 397493

Dimensioni singola maglia (dx,dy): 50 50

☐ Coordinate (i,j) e (x,y) ☐ Solo coordinate (i,j) ☒ Solo coordinate (x,y)

	446844	446894	446944	446994	447044	447094	447144	447194	447244	447294	447344	447394	447444	447494	447544	447594	447644	447694	447744	447794
3980943	62.35	60.73	57.53	54.92	53.37	52.09	52.66	55.37	56.35	53.28	51.21	50.3	54.76	55	55	53.36	50.08	47.96	44.79	41
3980993	64.78	62.43	59.97	58.37	57.27	55.06	55	57.27	59.79	56.96	53.84	53.11	55.18	56.62	55	54.53	50.52	49.63	45.15	42
3980843	65.44	64.92	63.41	62.69	60.7	59.83	59.08	59.53	62.46	59.08	56.33	55.12	57.5	57.5	56.38	54.67	52.45	49.94	46.03	44
3980793	68.82	68.69	67.37	67.29	64.86	62.74	63.55	62.37	62.93	61.42	59.36	57.62	57.5	57.5	57.5	54.99	52.81	50.04	48.08	47
3980743	68.78	71.04	70.21	70	68.6	67.74	67.15	65.08	65.16	65.1	62.61	60	59.97	59.84	57.52	55.26	53.97	52.45	50.21	49
3980693	67.39	73.57	73.47	72.54	72.46	71.4	70.13	67.52	67.52	67.5	63.05	62.52	61.72	60.47	60	57.7	56.67	54.91	53.85	52
3980643	64.16	75.52	78.47	76.56	75.68	74.97	74.05	70	70.03	69.97	65.12	65.27	64.21	63.39	62.1	61.5	60.07	58.63	58.02	56
3980593	60.13	74.89	82.42	82.71	81.22	78.62	77.61	75.05	74.04	72.34	66.29	68.03	68.34	67.77	68.65	67.11	65.4	64.93	62.7	60
3980543	62.23	77.14	86.97	87.44	85.08	82.48	82.35	80	76.94	73.58	67.72	70.36	74.9	74.77	75.29	74.66	73.04	70.9	67.54	65
3980493	64.74	78.64	89.64	90	89.27	87.32	85.38	80.08	79.15	72.56	70.81	74.89	81.03	80.68	80.33	80.57	79.92	76.68	75.02	70
3980443	67.54	85.13	93.5	92.79	92.54	91.74	89.92	87.09	81.98	72.64	75.48	82.02	85.29	85.78	85.64	85.3	84.72	82.15	79.99	74
3980393	74.86	83.39	97.38	97.26	97.85	97.46	94.63	91.5	83.4	73.2	79.07	86.46	90.63	92.26	92.17	91.3	89.66	85.19	82.17	75
3980343	91.21	100.92	102.62	104.78	105.94	104.2	99.85	94.99	86.81	76.38	82.36	92.25	98.42	99.03	97.93	97.42	96.53	91.88	89.3	82
3980293	100.99	103.79	104.97	107.46	109.62	107.6	104.49	97.69	88.6	81.74	82.69	94.81	102.21	102.17	100.91	100.35	99.81	97.08	92.48	87
3980243	105	106.38	107.73	109.9	111.83	110	105.79	102.18	94.33	81.65	87.28	97.4	104.97	106.03	105.81	104.9	103.56	100.93	97.97	95
3980193	107.5	108.07	110.15	112.41	114.13	113.49	109.84	105.99	98.21	82.69	92.27	103.06	108.89	111.21	110.67	109.95	107.52	105.23	102.5	100
3980143	110.02	110.7	112.48	114.8	115.5	115.02	112.48	108.81	102.76	87.29	100	105.69	112.46	113.28	112.04	112.5	112.27	110.14	107.44	105
3980093	112.06	112.5	112.6	116.15	117.5	117.46	115	110.32	107.24	100.81	109.35	109.99	114.77	115	115	115.43	116.45	115.33	112.56	112
3980043	112.55	112.5	113.89	116.21	120	119.44	115.98	112.7	110.11	109.36	112.35	112.69	116.93	117.63	118.27	119.85	119.73	119.7	117.43	115
3979993	112.5	112.5	113.07	117.94	119.51	119.82	117.45	114.98	113.27	113.33	114.79	116.95	119.96	121.52	120.59	120.52	121.95	122.49	120.9	118
3979943	115.05	114	115.91	116.3	119.23	118.85	117.5	117.5	115.37	116.7	117.54	119.95	121.19	124.83	126.2	127.42	125.98	125.08	124	121
3979893	116.86	121.76	118.82	120.17	120	117.57	117.5	117.5	117.55	119.73	120.57	122.2	124.23	127.31	127.77	129.92	128.4	127.44	125	122
3979843	122.5	122.5	123.27	122.11	118.72	117.97	118.04	117.7	120.03	122.2	122.78	124.92	127.36	128.43	130	130	130	130	127.1	125
3979793	124.77	124.28	125	124.56	124.3	123.82	121.01	120.36	122.19	124.43	125.13	127.6	130	130	131.62	132.5	132.5	131.34	129.91	125
3979743	125	125	125	125.76	125.07	127.32	127.5	127.24	126.44	127.15	127.92	130	132.5	132.5	132.5	132.5	132.5	132.5	132.5	128
3979693	125	125	125.97	126.81	126.85	127.56	129.91	129.21	127.5	129.41	130	132.42	133.94	134.82	134.6	132.53	132.4	132.5	132.46	129
3979643	125	125.68	127.16	125	125	127.58	130	126.1	126.47	130	131.97	132.5	135	135	134.19	131.1	131.01	130.86	128.83	125
3979593	125	126.55	125.21	124.03	122.58	128.28	129.83	128.67	127.29	128.2	130.49	132.86	135	134.57	129.94	127.05	125.27	121.5	117.59	111
3979543	122.84	123.65	121.43	122.2	122.5	125.36	126.89	123.42	122.56	124.03	125.68	129.65	132.39	129.2	121.68	111.82	106.29	104.73	99.03	92

Premere F1 sulle singole finestre per attivare la guida in linea

Salva Chiudi

02/03/2020 14.52

Figure 14. Examples of an orographic matrix used by the software

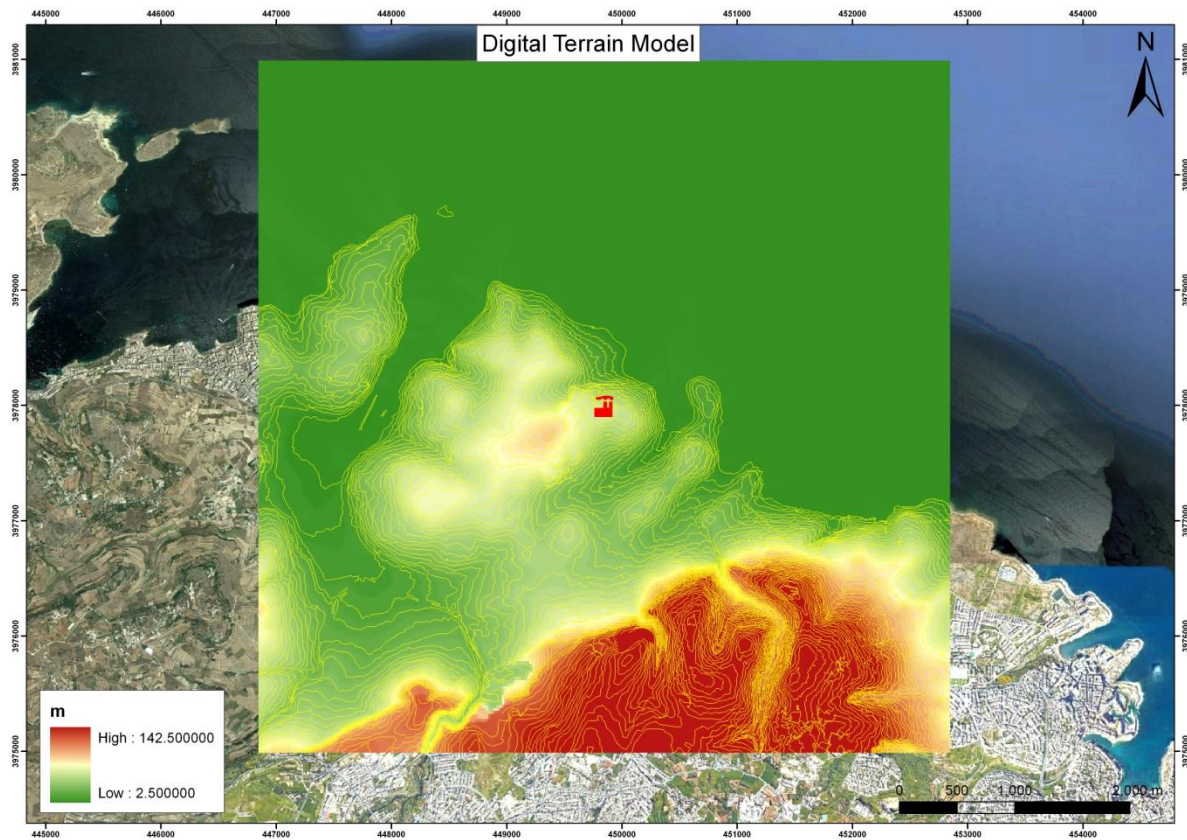


Figure 15. Extract of DTM with GIS software

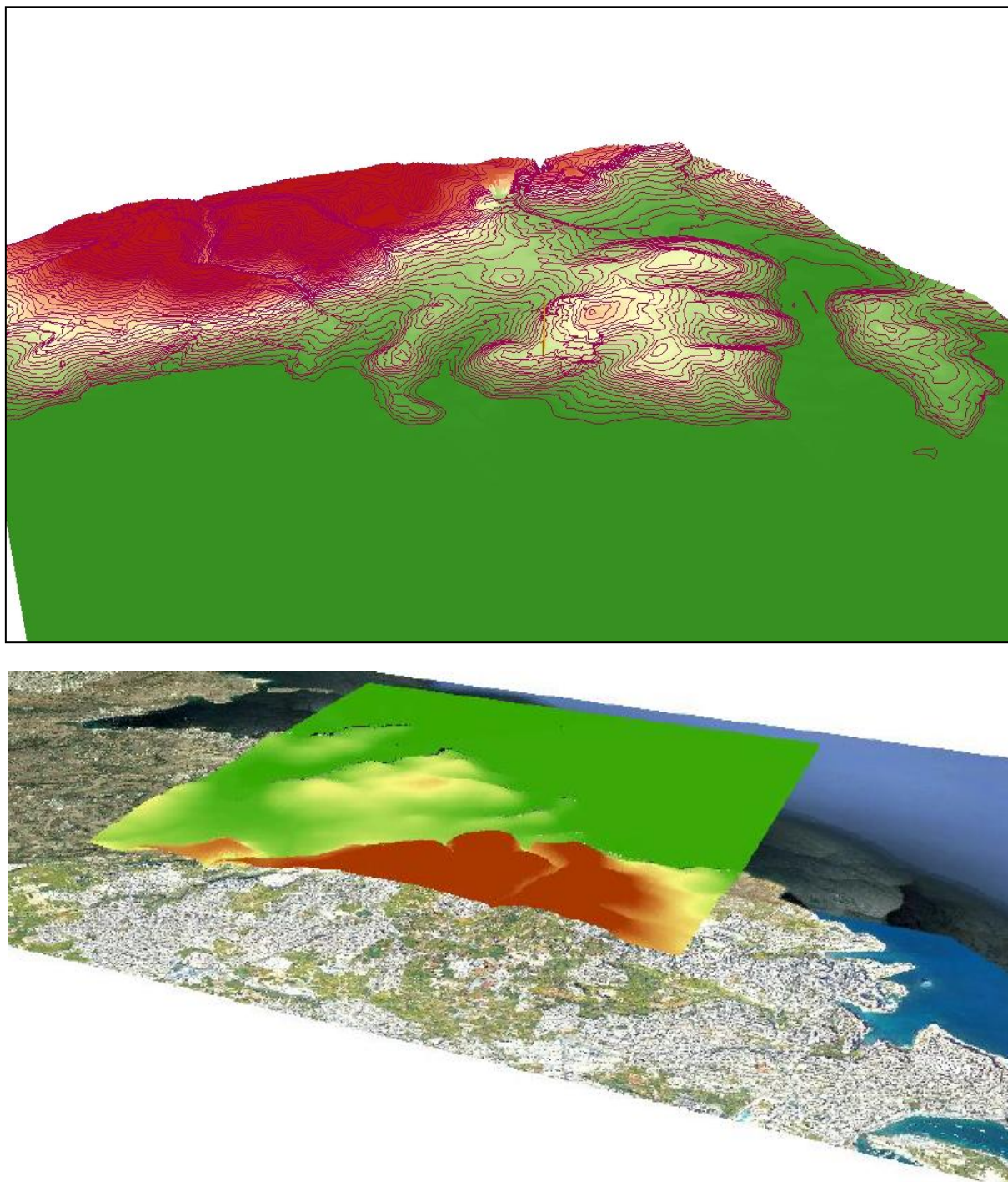


Figure 16. Extract of DTM with GIS software

4.7 EQUATIONS

4.7.1 Gaussian equation for the "Short Term" model

The Gaussian equation that expresses the concentration for high point sources with continuous emissions takes the following form:

$$C(x, y, z) = \frac{Q}{2\pi\mu\sigma(x)_y\sigma(x)_z} \exp\left[-\frac{y^2}{2\sigma(x)_y^2}\right] \cdot V \cdot D$$

Q: pollutant emission expressed as mass per unit of time

V: vertical term

D: decay term

$\sigma(x)_y, \sigma(x)_z$: lateral and vertical dispersion coefficients (m)

μ : wind speed at the altitude of the release (m / s)

x: leeward distance between the source and the receptor with respect to the wind direction

y: distance perpendicular to the wind direction between the plume axis and the receptor

z: altitude of the receptor relative to the ground

This equation is obtained on the basis of the following hypotheses:

- Stationary process
- Constant weather conditions
- Turbulent transport along the x axis negligible compared to advection transport
- Constant dispersion coefficients in y and z
- Constant emission
- Reflective ground

4.7.2 Gaussian equation for the "climatological" model

The climatological calculation uses the Gaussian formulation evaluated on the sectors of origin of the wind. In addition to the basic assumptions already described for the Short Term model, the following assumptions are made:

- the wind rose is divided into 16 sectors with a width of 22.5 °, the sectors are divided starting from the north in a clockwise direction;
- within each sector the concentration depends only on the radial distance between the source and the receptor (therefore there is no dependence on the distance perpendicular to the wind direction y);

In these hypotheses the equation used for climatological calculation is the following:

$$C(R, \Delta\vartheta, z) = \frac{Q}{\sqrt{2\pi} \cdot u \cdot R \cdot \sigma(R)_z \cdot \Delta\vartheta} \cdot V \cdot D \cdot S$$

Q: pollutant emission expressed as mass per unit of time

V: vertical term

D: decay term

R: source receptor radial distance in the calculation sector

$\Delta\theta$: size of the single sector

u: wind speed at altitude of release (m / s)

z: altitude of the receptor relative to the ground

S: smoothing function

$\sigma(R)_z$: source area

This equation represents the contribution to the concentration at a point R of a single point source. The total concentration value produced by a single source will be given by:

$$C_{tot} = \sum_{istab, idir, ivel} C(R, z) \cdot \frac{f(istab) \cdot f(istab, idir, ivel)}{10^6}$$

istab: sum on the stability classes (A, B, C, D, E, F + G, Mists)

idir: sum on the sectors of origin of the wind

ivel: sum on the speed classes

f (istab): frequency normalized to 1000 of occurrence of the istab-th stability class

f (istab, idir, ivel): normalized frequency at 1000 of the occurrence of the idir-th direction and the ivel-th speed class of the istab-th stability class

4.8 POSTPROCESSOR

The WinDimula calculation model incorporates the WDPstProc program, this is the post-processing module of the results calculated by the model.

The program analyzes the output files (* .mbf -MaindBinaryFile-) produced by WinDimula and evaluates the concentrations relative to:

- average hourly concentrations
- average daily concentration over eight hours
- daily average concentration
- annual concentrations
- winter concentrations
- exceeding of threshold values for consecutive hours.

It is possible to use one of the predefined pollutants using the values provided by the Ministerial Decree or to enter a new type of pollutant specifying the limits and exceedances allowed. In addition to the results of the verification calculation, it is possible to display the time series of each receptor and the results calculated by WinDimula in each meteorological situation analyzed.

5 RESULTS OBTAINED FROM THE MODEL

The data obtained from the model consist of the outputs at average hourly concentrations on an annual basis at each point of the investigated area within a radius of influence equal to 6 km from the chimney.

From the hourly concentrations it was possible to evaluate the concentrations of each pollutant investigated in relation to each month, therefore, the behavior of the fallout for the entire year.

The data obtained were processed with the MMS RunAnalyzed which allows to perform various elaborations such as the calculation of statistical indices (such as averages and percentiles) on the specified time intervals, useful for comparison with the regulatory reference levels for each pollutant or for discriminating analysis in the various receptor points.

The interpolation results were exported in format (.GRD) inserted in a GIS software and reported on cartography using the QGIS program.

This representation is documented by the forecast emission maps shown in the Annexes 1.

By observing the diffusion maps, it was possible to draw further considerations relating to the dispersion of substances from the chimney and to deposition on the ground.

5.1 SPATIAL ELABORATIONS

A specific spatial processing of the data obtained from the model was carried out, in order to assess the probability of significant effects on the quality of the ambient air (including exceeding the environmental limit values) as well as on the deposition levels of particular components, due to the operation of a Waste to Energy plant. The analysis focused on an area of influence estimated within a radius of 6 km from the chimney.

The “Area of Influence – AOI” has been defined as the largest area around the plants obtained considering the areas where the contribution of the plant to the annual environmental levels of NO₂, PM₁₀ or PM_{2,5} is as follows:

PM 10 → 0.3 µg / m³

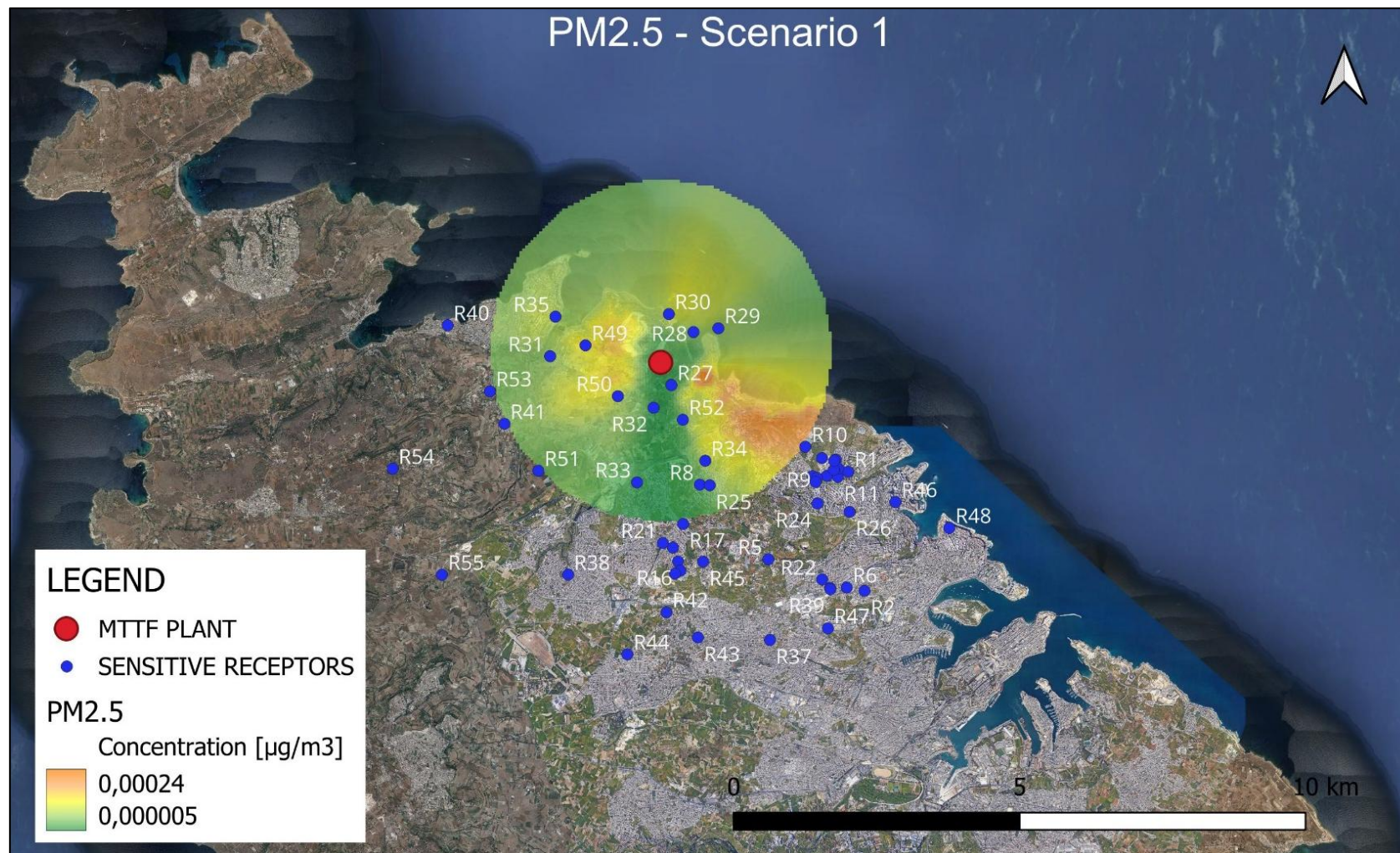
NO₂ → 0.3 µg / m³

PM_{2.5} → 0.19 µg / m³

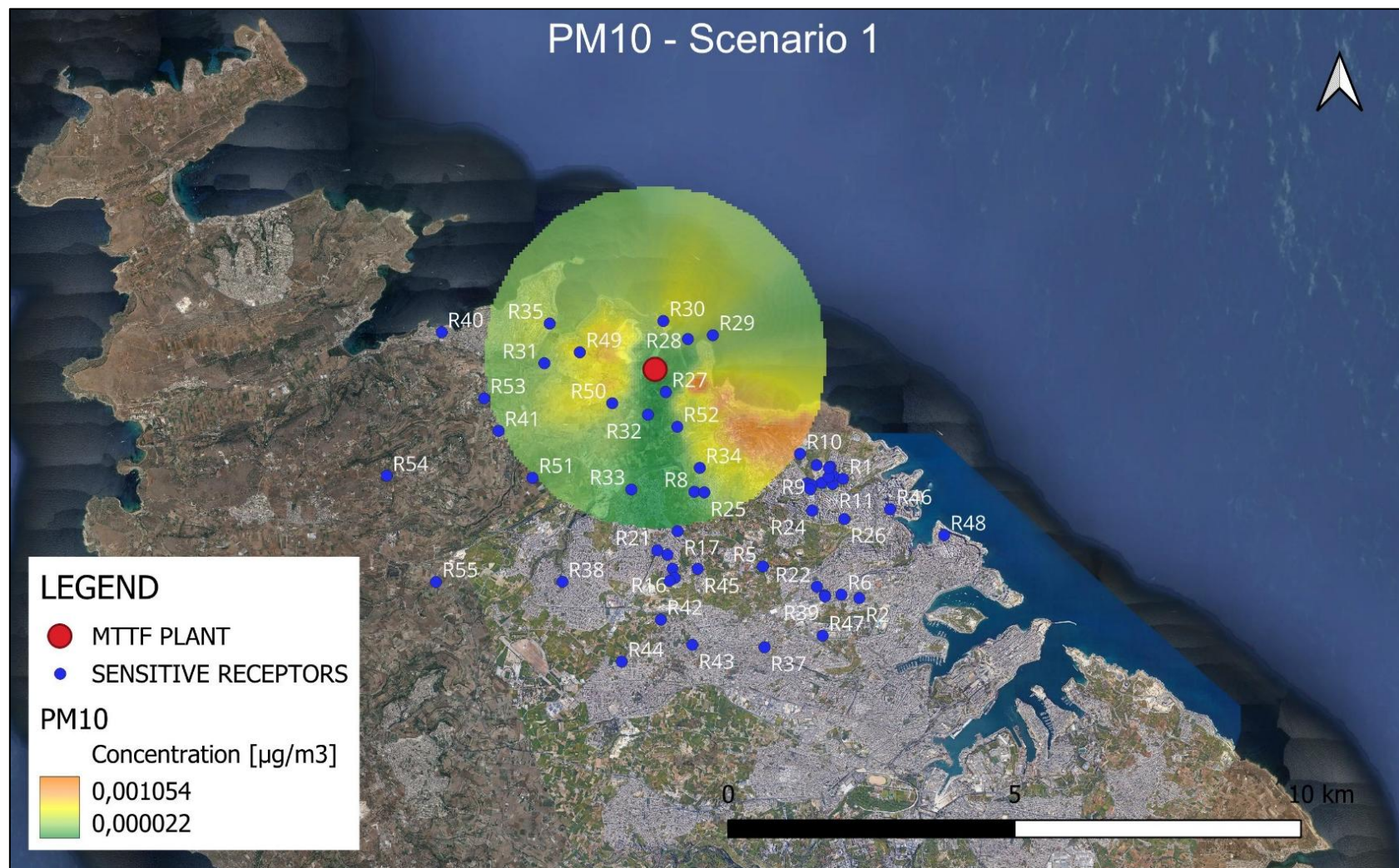
The models and the spatial analysis was developed with the aim of obtaining a spatial data resolution of 5 × 5 m².

The isoconcentration maps have been created in order to define in detail the areas in which the calculated concentrations expressed as µg/m³. A color gradient between orange and red was used to highlight areas with higher concentrations. All maps are listed in Annex 1.

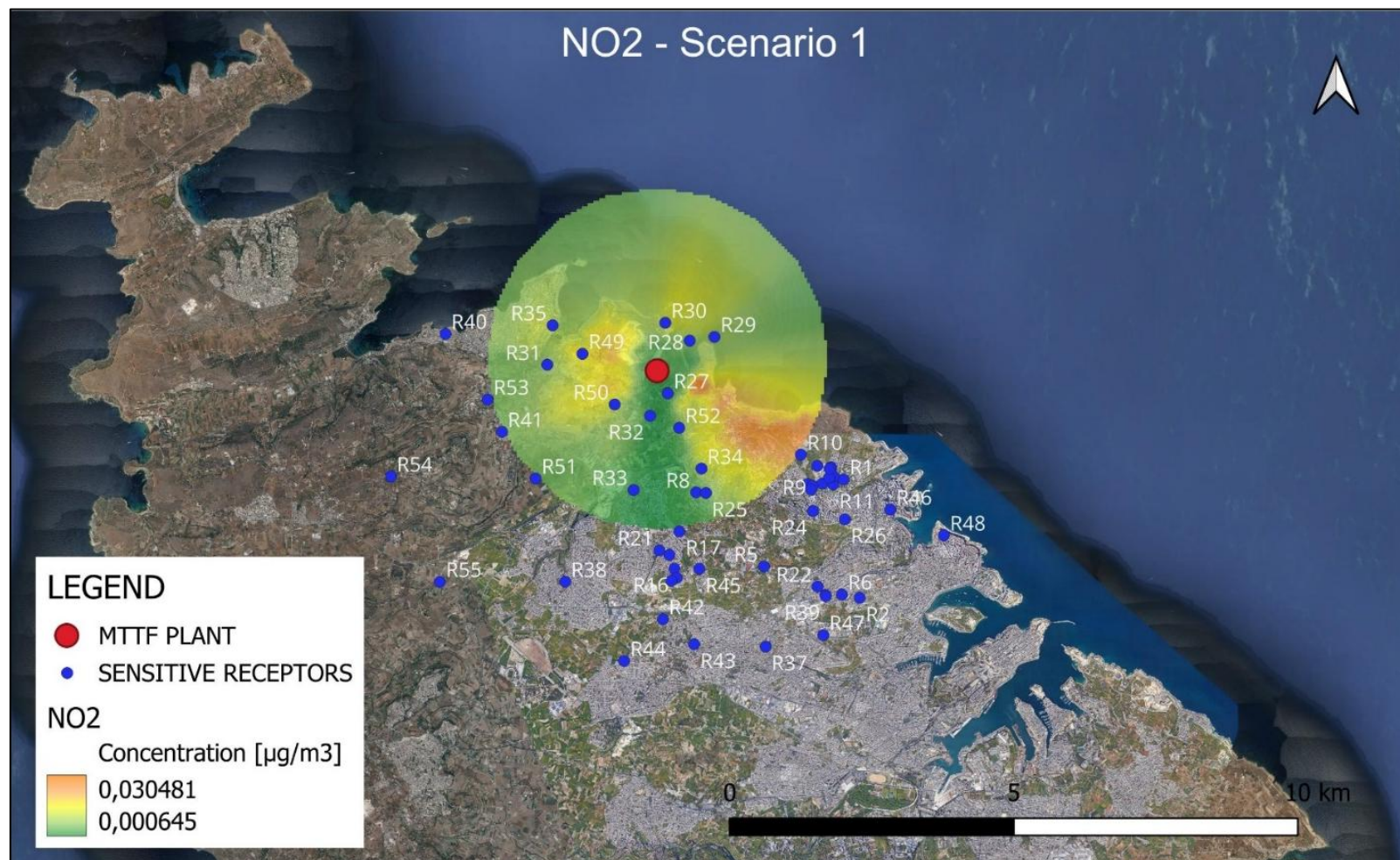
5.1.1 Isoconcentration maps PM_{2.5} – SCENARIO 1 (chimney height = 25 meter)



5.1.2 Isoconcentration maps PM10 – SCENARIO 1 (chimney height = 25 meter)



5.1.3 Isoconcentration maps NO₂– SCENARIO 1 (chimney height = 25 meter)



5.2 PERCENTILE EVALUATION

In accordance with the TOR's provisions, the 90.4th percentile of concentrations for PM10 and the 99.8th percentile of concentrations for NO2 were estimated.

With the aim of obtaining a comparable dataset, these statistical parameters have been calculated at the receptors for each parameter relation to a year (as shown in table 1 and table 2).

Part II of Schedule 7 to Regulation 29 of S.L. 549.59 sets the following (legally binding limit values):

- an annual limit value of 40 $\mu\text{g}/\text{m}^3$ for PM10, a daily limit value for PM10 of 50 $\mu\text{g}/\text{m}^3$ which cannot be exceeded on more than 35 calendar days (90.4% of the daily readings in a calendar year should be $< 50 \mu\text{g}/\text{m}^3$);
- an annual limit value of 40 $\mu\text{g}/\text{m}^3$ for NO2 and an hourly limit value of 200 $\mu\text{g}/\text{m}^3$, which cannot be exceeded more than 18 times per calendar year (99.8 % of the hourly readings in a calendar year should be $< 200 \mu\text{g}/\text{m}^3$).

AIR QUALITY ASSESSMENT

Development of a Waste to Energy Facility, to operate in conjunction with other waste management operations within the Maghtab Environmental Complex, Maghtab integration with a new Marsa Thermal Treatment Facility (MTTF)

Table 2. Maximum values of fallout to the receptors (PM10) for the Scenario 1 (chimney height 25 meter)

RECEPTORS		Distance from the chimney [km]	SCENARIO 1 (H=25 meters)	
			PM10	
			Avarege hourly value	Percentile 90.4 (PM10)
			Annual limit value [40 µg/m3]	Daily Limit Value [50 µg/m3]
R1	Verdala International School Pembroke	3,80 km	0.00044	0.00136
R2	Chiswick House School San Gwann	5,36 km	0.00018	0.00053
R3	St Catherine's High School Pembroke	3,31 km	0.00061	0.00182
R4	St Michael's School Pembroke	3,52 km	0.00060	0.00182
R5	St Michael's Foundation San Gwann	3,92 km	0.00013	0.00045
R6	St Francis School San Gwann	5,10 km	0.00017	0.00054
R7	St Clare Primary College Pembroke	3,50 km	0.00047	0.00147
R8	Karmnu Sant Primary School Gharghur	2,22 km	0.00014	0.00045
R9	Bice Mizzi Vassallo Primary School P	3,40 km	0.00058	0.00177
R10	St Clare Secondary Pembroke	2,93 km	0.00082	0.00261
R11	Sprachcaffe Language School Pembroke	3,69 km	0.00041	0.00124
R12	San Miguel Resource Centre Pembroke	3,28 km	0.00071	0.00222
R13	M.U.S.E.U.M Pembroke	3,62 km	0.00044	0.00130
R14	Risen Christ Church Pembroke	3,56 km	0.00043	0.00131
R15	National Sports School Pembroke	3,42 km	0.00055	0.00171
R16	Simblija Care Home Naxxar	3,49 km	0.00002	0.00007
R17	Golden Care Retirement Home Naxxar	2,85 km	0.00003	0.00012
R18	Primary School Naxxar	3,24 km	0.00002	0.00007
R19	MRC Middle School Naxxar	3,65 km	0.00002	0.00006
R20	Giovanni Curmi Higher Secondary Naxx	3,69 km	0.00002	0.00006
R21	Naxxar Parish Church Naxxar	3,16 km	0.00002	0.00006
R22	St Clare's Primary College San Gwann	4,72 km	0.00016	0.00049
R23	San Gwann Parish Church San Gwann	4,93 km	0.00016	0.00052
R24	Immaculate Mother of the Church Swie	3,69 km	0.00045	0.00140
R25	St Bartholomew Parish Church Gharghu	2,31 km	0.00021	0.00079
R26	Clubclass English School Swieqi	4,20 km	0.00029	0.00080
R27	Agricultural land Maghtab	0,43 km	0.00006	0.00023
R28	Żona fil-Ba'ar madwar G'awdex - MT000	0,79 km	0.00033	0.00117
R29	Żona fil-Ba'ar bejn il-Ponta ta' San	1,18 km	0.00031	0.00108
R30	L-G'adira s-Safra (MT0000008)	0,86 km	0.00042	0.00155
R31	Is-Salini (MT0000007)	1,94 km	0.00028	0.00107
R32	Triq ir-Ramla Maghtab Residential &	0,78 km	0.00004	0.00013
R33	Triq Jules Verne Naxxar Residential	2,13 km	0.00006	0.00016
R34	Triq Fidel Zarb G'arg'ur Residential	1,88 km	0.00033	0.00124
R35	Dawret il-Qawra Qawra Residential Ar	2,01 km	0.00037	0.00124
R36	Triq Napuljun Tagliaferro Pembroke R	3,48 km	0.00045	0.00142
R37	Triq M. Pulis Birkirkara Residential	5,21 km	0.00006	0.00022
R38	Constitution Road Mosta Residential	4,04 km	0.00007	0.00020
R39	Triq San Guzepp San Gwann Residentia	4,95 km	0.00016	0.00052
R40	Parish Street St Paul's Bay Resident	3,78 km	0.00019	0.00063
R41	Triq il-Maghsar Burmarrad Residentia	2,93 km	0.00025	0.00076
R42	Triq Preziosi Lija Residential Area	4,37 km	0.00002	0.00005
R43	Triq Balaguer Balzan Residential Are	4,85 km	0.00002	0.00009
R44	Triq Annabelle Preca Attard Resident	5,13 km	0.00002	0.00007
R45	Triq il-Harruba Iklin Residential Ar	3,56 km	0.00004	0.00013
R46	Triq L'Apap St Julian's Residential	4,78 km	0.00038	0.00112
R47	Mater Dei Hospital Msida	5,49 km	0.00013	0.00043
R48	Tower Road Sliema Residential Area	5,81 km	0.00035	0.00102
R49	Farm at Triq il-Katakombi Salina	1,35 km	0.00059	0.00223
R50	Farm at Sqaq Habel Zwejra Maghtab	0,95 km	0.00040	0.00147
R51	Farm and fields at Triq Burmarrad Bu	2,86 km	0.00018	0.00064
R52	Farms at Bahar ic-Caghaq	1,06 km	0.00016	0.00053
R53	Agricultural land at Triq il-Wardija	3,02 km	0.00020	0.00064
R54	Agricultural land at Triq is-Sagra Fa	5,03 km	0.00014	0.00043
R55	Agricultural land Triq Sir Temi Zamm	5,32 km	0.00011	0.00035

AIR QUALITY ASSESSMENT

Development of a Waste to Energy Facility, to operate in conjunction with other waste management operations within the Maghtab Environmental Complex, Maghtab integration with a new Marsa Thermal Treatment Facility (MTTF)

Table 3. Maximum values of fallout to the receptors (NO₂) for the Scenario 1 (chimney height 25 meter)

RECEPTORS		Distance from the chimney(km)	SCENARIO 1 (H=25 meters)	
			NO ₂	
			Avarege hourly value Annual limit value [40 µg/m ³]	Percentile 99.8 (NO ₂) Hourly Limit Value [200 µg/m ³]
R1	Verdala International School Pembroke	3,80 km	0.01240	0.15000
R2	Chiswick House School San Gwann	5,36 km	0.00488	0.09020
R3	St Catherine's High School Pembroke	3,31 km	0.01700	0.21100
R4	St Michael's School Pembroke	3,52 km	0.01680	0.19500
R5	St Michael's Foundation San Gwann	3,92 km	0.00375	0.12100
R6	St Francis School San Gwann	5,10 km	0.00468	0.09200
R7	St Clare Primary College Pembroke	3,50 km	0.01310	0.16600
R8	Karmnu Sant Primary School Gharghur	2,22 km	0.00414	0.35400
R9	Bice Mizzi Vassallo Primary School P	3,40 km	0.01630	0.20500
R10	St Clare Secondary Pembroke	2,93 km	0.02320	0.24100
R11	Sprachcaffe Language School Pembroke	3,69 km	0.01160	0.15500
R12	San Miguel Resource Centre Pembroke	3,28 km	0.02000	0.20800
R13	M.U.S.E.U.M Pembroke	3,62 km	0.01230	0.15900
R14	Risen Christ Church Pembroke	3,56 km	0.01210	0.16100
R15	National Sports School Pembroke	3,42 km	0.01560	0.20400
R16	Simbija Care Home Naxxar	3,49 km	0.00066	0.05250
R17	Golden Care Retirement Home Naxxar	2,85 km	0.00090	0.07360
R18	Primary School Naxxar	3,24 km	0.00067	0.05510
R19	MRC Middle School Naxxar	3,65 km	0.00065	0.05090
R20	Giovanni Curmi Higher Secondary Naxx	3,69 km	0.00063	0.05050
R21	Naxxar Parish Church Naxxar	3,16 km	0.00060	0.05270
R22	St Clare's Primary College San Gwann	4,72 km	0.00454	0.09600
R23	San Gwann Parish Church San Gwann	4,93 km	0.00456	0.09380
R24	Immaculate Mother of the Church Swie	3,69 km	0.01260	0.19500
R25	St Bartholomew Parish Church Gharghu	2,31 km	0.00614	0.35100
R26	Clubclass English School Swieqi	4,20 km	0.00819	0.12200
R27	Agricultural land Mag'tab	0,43 km	0.00172	0.12600
R28	ona fil-Ba'ar madwar G'awdex - MT000	0,79 km	0.00956	0.56700
R29	ona fil-Ba'ar bejn il-Ponta ta' San	1,18 km	0.00911	0.53300
R30	L-G'adira s-Safra (MT0000008)	0,86 km	0.01220	0.67900
R31	Is-Salini (MT0000007)	1,94 km	0.00813	0.34500
R32	Triq ir-Ramla Mag'tab Residential &	0,78 km	0.00111	0.07400
R33	Triq Jules Verne Naxxar Residential	2,13 km	0.00160	0.23300
R34	Triq Fidel Zarb G'arg'ur Residential	1,88 km	0.00966	0.43200
R35	Dawret il-Qawra Qawra Residential Ar	2,01 km	0.01070	0.35100
R36	Triq Napuljun Tagliaferro Pembroke R	3,48 km	0.01260	0.16600
R37	Triq M. Pulis Birkirkara Residential	5,21 km	0.00173	0.08510
R38	Constitution Road Mosta Residential	4,04 km	0.00207	0.10800
R39	Triq San Guzepp San Gwann Residentia	4,95 km	0.00454	0.09350
R40	Parish Street St Paul's Bay Resident	3,78 km	0.00538	0.13800
R41	Triq il-Magh'sar Burmarrad Residentia	2,93 km	0.00722	0.20900
R42	Triq Preziosi Lija Residential Area	4,37 km	0.00050	0.04440
R43	Triq Balaguer Balzan Residential Are	4,85 km	0.00064	0.06170
R44	Triq Annabelle Preca Attard Resident	5,13 km	0.00049	0.04110
R45	Triq il-Harruba Iklin Residential Ar	3,56 km	0.00104	0.10300
R46	Triq L'Apap St Julian's Residential	4,78 km	0.01050	0.10900
R47	Mater Dei Hospital Msida	5,49 km	0.00357	0.08670
R48	Tower Road Sliema Residential Area	5,81 km	0.00961	0.09380
R49	Farm at Triq il-Katakombi Salina	1,35 km	0.01720	0.59400
R50	Farm at Sqaq Habel Zwejra Maghtab	0,95 km	0.01170	0.77700
R51	Farm and fields at Triq Burmarrad Bu	2,86 km	0.00515	0.20600
R52	Farms at Bahar ic-Caghaq	1,06 km	0.00462	0.44100
R53	Agricultural land at Triq il-Wardija	3,02 km	0.00581	0.19000
R54	Agricultural land at Triq is-Sagra Fa	5,03 km	0.00399	0.09240
R55	Agricultural land Triq Sir Temi Zamm	5,32 km	0.00292	0.08690

5.3 DEPOSITION RATE EVALUATION

The dispersion model was used to define and calculate the areas in which the mass deposition rates on an annual daily basis are higher.

The results obtained were then compared with the limits indicated in the EIA TOR's and shown below in the table.

Table 4. Limit of pollutant (ref. TOR's Table 4 dated 08/05/2024)

Pollutant	Limit
Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F)	4 pg WHO-TE/m ² · day (bulk deposition)
Cadmium (Cd)	2 µg/m ² · day (bulk deposition)
Arsenic (As)	4 µg/m ² · day (bulk deposition)
Mercury (Hg)	1 µg/m ² · day (bulk deposition)
Nickel (Ni)	15 µg/m ² · day (bulk deposition)
Lead (Pb)	100 µg/m ² · day (bulk deposition)
Thallium (Tl)	2 µg/m ² · day (bulk deposition)

Corine land cover was used for the definition of the type of soil cover, this allowed to define the site-specific parameters for the calculation of the depositions.

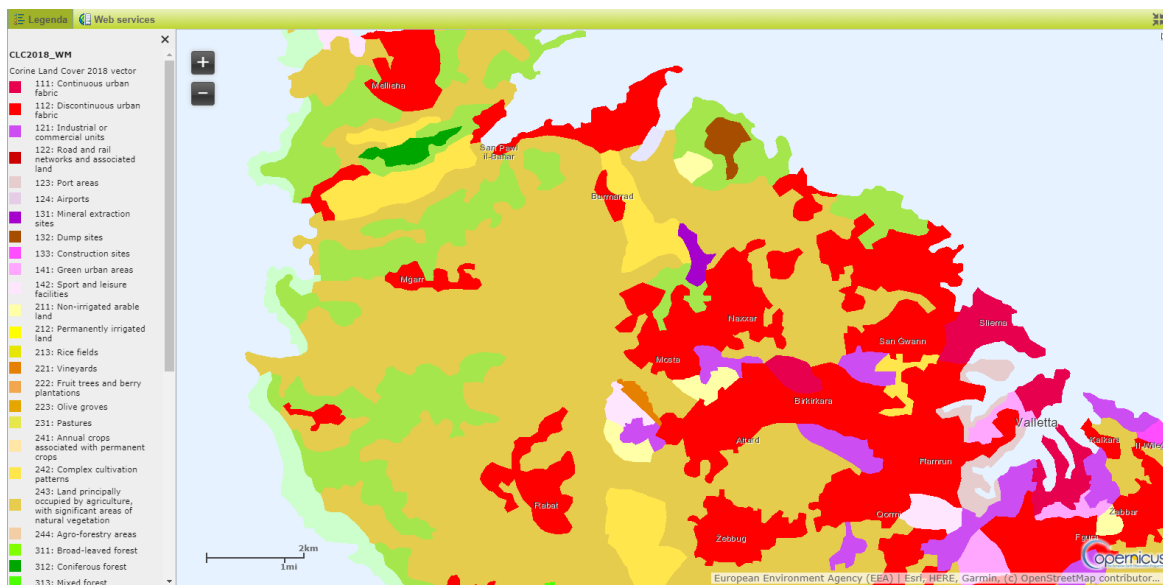


Figure 17. Extract of Corine Land Cover utilized in to modellization

The results obtained are listed below with the individual conservative assessments:

1) Metals Group 1

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.019 $\mu\text{g}/\text{m}^2\text{-day}$, a much lower value than:

- the **deposition limit imposed for Cadmium equal to 2 $\mu\text{g}/\text{m}^2\text{-day}$** ;
- the **deposition limit imposed for Thallium equal to 2 $\mu\text{g}/\text{m}^2\text{-day}$** ;

This result is conservative because it will be the total of Cd and Tl concentrations –metal of group 1-).

2) Metals Group 2

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.013 $\mu\text{g}/\text{m}^2\text{-day}$, a much lower value than:

- the **deposition limit imposed for mercury equal to 1 $\mu\text{g}/\text{m}^2\text{-day}$** .

3) Metals Group 3

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.092 $\mu\text{g}/\text{m}^2\text{-day}$ (scenario 1), a much lower value than:

- the **deposition limit imposed for Arsenic equal to 4 $\mu\text{g}/\text{m}^2\text{-day}$** ;
- the **deposition limit imposed for Nickel equal to 15 $\mu\text{g}/\text{m}^2\text{-day}$** ;
- the **deposition limit imposed for Nickel equal to 100 $\mu\text{g}/\text{m}^2\text{-day}$** .

This result is (conservative result because it will be the total of Sb-As-Pb-Cr-Co-Cu-Mn-Ni-V concentrations –metal of group 3-).

4) Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F) + dioxin – like polychlorinated biphenyls (PCBs)

From the model results it emerges that the maximum daily concentrations (calculated as the sum of hourly deposits for a single day) are equal to 0.064 pg WHO-TE/m²-day (scenario 1), a much lower value than:

- **deposition limit imposed for Polychlorinated dibenzo-p-dioxins/ polychlorinated dibenzofurans (PCDD/F) equal to 4 pg WHO-TE/m²-day.**

Table 5 - Comparison of the table limits in table 4 of EIA TORs with the maximum concentrations on calculation Domain

POLLUTANT	Limit table n°4 of TOR 08/05/2024	Mass deposition rates on annual daily basis - MAXIMUM CONCENTRATION ON CALCULATION DOMAIN	Distance from the chimney [km]
CHIMNEY HEIGHT=25 m			
Cd [µg/m ² *d]	2	0.0186	2,45
Tl [µg/m ² *d]	2	0.0186	2,45
Hg [µg/m ² *d]	1	0.0130	0,21
Ni [µg/m ² *d]	15	0.0920	2,45
As [µg/m ² *d]	4	0.0920	2,45
Pb [µg/m ² *d]	100	0.0920	2,45
PCDD/F + PCB [pgWHO-TE/m ² *d]	4	0.0644	2,45

Table 6 - Comparison of the table limits in table 4 of EIA TORs with the maximum concentrations on calculation Receptors

POLLUTANT	Limit table n°4 of TOR 08/05/2024	Mass deposition rates on annual daily basis - MAXIMUM CONCENTRATION ON CALCULATION RECEPTORS	Distance from the chimney [km]
SCENARIO 1 (CHIMNEY HEIGHT=25 m)			
Cd [µg/m ² *d]	2	0.0161	2,93
Tl [µg/m ² *d]	2	0.0161	2,93
Hg [µg/m ² *d]	1	0.0017	1,18
Ni [µg/m ² *d]	15	0.0786	2,93
As [µg/m ² *d]	4	0.0786	2,93
Pb [µg/m ² *d]	100	0.0786	2,93
PCDD/F + PCB [pgWHO-TE/m ² *d]	4	0.0543	2,93

5.4 COMPARISON THE RESULT OBTAINED OF MODEL

The following table shows the maximum concentration values of the pollutants calculated on the calculation domain and on the Receptors to be compared with the limit to be respected and which refer to 3% of the limit values or plate values established in directive 2008/50/ec on quality environmental air and cleaner air for living in Europe (table n°2 of EIA TORs).

The results obtained from the air dispersion model show lower values than the limits set in the table 2 of EIA TORs dates 08/05/2024.

Table 7 - Comparison of the table limits in table 2 of EIA TORs with the maximum concentrations on calculation Domain

MAXIMUM CONCENTRATION ON CALCULATION DOMAIN		CHIMNEY HEIGHT=25 m	Limit Table 2 of TOR 08/05/2024
Average mass deposition rates Metals Group 1 [ng/m ³]	Value	0.00568	< Cd --> 0.15 ng/m ³
	distance of chimney	0,78 km	
Average mass deposition rates Metals Group 2 [ng/m ³]	Value	0.00565	< Hg --> 1.5 ng/m ³
	distance of chimney	0,78 km	
Average mass deposition rates Metals Group 3 [ng/m ³]	Value	0.0087	< Pb --> 15 ng/m ³
			< As --> 0.18 ng/m ³
			< Ni --> 0.60 ng/m ³
	distance of chimney	0,78 km	< Cr --> 0.50 ng/m ³
Average mass deposition rates Metals Group 3 [pg/m ³]	Value	8,7	< Cr (IV) --> 51 pg/m ³
	distance of chimney	0,78 km	
Deposizione media PCDD/F+PCB [fg WHO-TE/m ³]	Value	0.02258	< 70 fg WHO-TE/m ³
	distance of chimney	0,78 km	
Average Hourly value of PM10 [µg/m ³]	Value	0.00105	< 1.2 µg/m ³
	distance of chimney	0,78 km	
Average Hourly value of PM2.5 [µg/m ³]	Value	0.00024	< 0.6 µg/m ³
	distance of chimney	0,78 km	
Average Hourly value of NO2 [µg/m ³]	Value	0.03048	< 1.2 µg/m ³
	distance of chimney	0,78 km	

Table 8 - Comparison of the table limits in table 2 of EIA TORs with the maximum concentrations on calculation Receptors

MAXIMUM CONCENTRATION ON CALCULATION RECEPTORS		CHIMNEY HEIGHT=25 m	Limit Table n°2 of TOR 08/05/2024
Average mass deposition rates Metals Group 1 [ng/m ³]	Value	0.00434890	< Cd --> 0.15 ng/m ³
	Receptor	R10 - distance of chimney 2,93 km	
Average mass deposition rates Metals Group 2 [ng/m ³]	Value	0.00431150	< Hg --> 1.5 ng/m ³
	Receptor	R10 - distance of chimney 2,93 km	
Average mass deposition rates Metals Group 3 [ng/m ³]	Value	0.00675320	< Pb --> 15 ng/m ³
			< As --> 0.18 ng/m ³
			< Ni --> 0.60 ng/m ³
	Receptor	R10 - distance of chimney 2,93 km	< Cr --> 0.50 ng/m ³
Average mass deposition rates Metals Group 3 [pg/m ³]	Value	6,75	< Cr (IV) --> 51 pg/m ³
	Receptor	R10 - distance of chimney 2,93 km	
Average mass deposition rates PCDD/F+PCB [fg WHO-TE/m ³]	Value	0.017	< 70 fg WHO-TE/m ³
	Receptor	R10 - distance of chimney 2,93 km	
Average Hourly value of PM10 [µg/m ³]	Value	0.000821656	< 1.2 µg/m ³
	Receptor	R10 - distance of chimney 2,93 km	
Average Hourly value of PM2.5 [µg/m ³]	Value	0.000183242	< 0.6 µg/m ³
	Receptor	R10 - distance of chimney 2,93 km	
Average Hourly value of NO2 [µg/m ³]	Value	0.0232	< 1.2 µg/m ³
	Receptor	R10 - distance of chimney 2,93 km	

6 EVALUTATIONS AND RECOMMENDATIONS

The purpose of the work has been to use dispersion modelling suites, in order to assess for the likelihood of significant effects on ambient air quality as well as on the deposition levels of particular components, due to the operation of Magħtab Thermal Treatment Facility (MTTF).

The analysis focused on the area of influence of the plant and includes sensitive receptors in this area. For deposition levels, sensitive receptors include all agricultural areas within this area.

The same suite of dispersion modeling was used, in order to assess for the likelihood of significant effect on ambient air quality (including exceedances of the ambient limit values in SL549.59) as well as on the deposition levels of particular components, due to the operation of the new plant MTTF.

Previously this study was developed the air dispersion model considering three different scenarios: heights of the chimney of 25 meter (scenario 1), heights of the chimney of 30 meter (scenario 2), heights of the chimney of 35 meter (scenario 3).

The results of the previous study did not highlight significant variations in the impacts on air quality for the three different scenarios, so ultimately the designers decided to consider the optimal height of the chimney that of Scenario 1 (H=25 meters) with the shortest chimney causing the least significant impacts on air quality.

For this reason, the analysis was developed considering the scenario 1 (heights of the chimney of 25 meter).

The emission factors used is the provisional limit values in normal operating conditions based on BAT and IED in table 3 of the EIA TOR dated 05/08/2024.

The utilized model has been capable of predicating the dispersion and deposition of pollutants under variable meteorological conditions ranging from the most favorable to the least favorable. The modelling suite permitted the annual calculation of the required parameters.

The spatial resolution obtained by the model has been $5 \times 5 \text{ m}^2$, to enable the identification of impacts at sensitive receptors.

The results obtained with the application of the model, in compliance with the orographic data, meteorological data and the emission of pollutants from the chimney, made it possible to arrive at the following final considerations.

1. **The area of influence - AOI**, area around the plant in which the contribution of the plant to the annual ambient levels of NO_2 , PM_{10} or $\text{PM}_{2.5}$ is $0.3 \mu\text{g}/\text{m}^3$ for NO_2 or $0.3 \mu\text{g}/\text{m}^3$ for PM_{10} or $0.19 \mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$, whichever results in the largest AOI. If the area of the AOI is $< 11.3 \text{ km}^2$ then the AOI shall be assumed to be a circle of radius 6 km center on the chimney.
 - a. **NO_2** , the simulated concentrations are lower than $0.3 \mu\text{g}/\text{m}^3$ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.68 km (scenario 1);
 - b. **PM_{10}** , the simulated concentrations are lower than $0.3 \mu\text{g}/\text{m}^3$ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.68 km (scenario 1);
 - c. **$\text{PM}_{2.5}$** , the simulated concentrations are lower than $0.19 \mu\text{g}/\text{m}^3$ on entire calculation domain and receptors. The maximum concentrations have been estimated in a radius centered on chimney equal to about 0.68 km (scenario 1).

2. In accordance with the TOR's provisions, the **90.4th percentile of concentrations for PM10** and the **99.8th percentile of concentrations for NO2** were estimated. With the aim of obtaining a comparable dataset, these statistical parameters have been calculated at the receptors for each parameter relation to a year.

From the model results it emerges that all concentration values are below the regulatory limits.

7 CALIBRATION

The second phase of the study a 9 week monitoring was conducted to establish the baseline values of PM₁₀ (*Skypost*) and 8 week monitoring was conducted to establish the baseline values of NO₂ (*Passam*), the results obtained from the monitoring are reported in this chapter.

It was used a *significance criteria tool* to determine the significance of the impact at all sensitive receptors and at any point within the investigated area.

In the period between November 30, 2020 through February 14, 2021, an air quality monitoring campaign was conducted to assess PM₁₀ concentrations. The monitoring was in a single sampling point with at the point “MAGHTAB COMPLEX - GHALLIES AND TA ZWEJRA LANDFILLS AREA” at the following geographical coordinates 35°56'24.85"N 14°26'29.99"E.

The following instrumentation was used for sampling - Sequential Station for dust sampling (SKYPOST PMHV), BRAVO X-R 230 VAC, Sampler head PM10, Silicone tubes, Glass Fiber Filters-.

The method used for Sampling and determination of PM 10 was EN 12341:2014. In the period between November 30, 2020 through January 25, 2021, an air quality monitoring campaign was conducted to assess NO₂ concentrations. The monitoring was in a single sampling point at the following geographical coordinates 35°56'16.78"N 14°26'58.14"E.



Figure 18. Identification of the monitoring point.

Passive-type samplers represent a sampling system for monitoring air quality, using the physical process of diffusion to sample pollutants. Such samplers to measure nitrogen dioxide are based on the principle of diffusion of NO₂ on absorbent triethanolamine. One type of sampler is the "Passam" derived from the Palmes tube design, it is designed for two different sampling durations:

- Long-term (one week);
- Short-term (8-48 hours).

The Passam long-term sampler has a slightly conical shape with a diffusion path length of 73.5 mm and an inner diameter of 9.82 mm while the short-term sampler has a shorter diffusion path length of 20 mm and a larger diffusion

diameter of 23 mm. The latter is applicable for daily measurements therefore to monitor air quality standards or personal air concentrations in exposure studies.



Figure 19. Passive-Type samplers "Passam"

7.1 RESULTS OF PM₁₀

The analytical results obtained in the nine weeks of PM₁₀ monitoring are shown below.

- Evaluated the data recorded of the stations Maltese "Air Quality" and in particular the two different Station types, Gharb (Rural background) and Msida (Traffic);
- where the data is present, comparison of the PM₁₀ and PM_{2.5} levels in Gharb to the levels in Msida

it is possible to conclude that the PM₁₀ concentrations of monitoring on 08 December 2020, 08 and 10 January 2021 and 08 February 2021 were influenced by "Sahara Dust" and consequently are excluded by the purposes of this work.

Date	Concentration $\mu\text{g}/\text{m}^3$	Note
30/11/2020	35,54557	
01/12/2020	34,00583	

AIR QUALITY ASSESSMENT

Development of a Waste to Energy Facility, to operate in conjunction with other waste management operations within the Maghtab Environmental Complex, Maghtab integration with a new Marsa Thermal Treatment Facility (MTTF)

Date	Concentration $\mu\text{g}/\text{m}^3$	Note
02/12/2020	25,20966	
03/12/2020	15,14551	
04/12/2020	22,93721	
05/12/2020	31,01656	
06/12/2020	9,070117	
07/12/2020	34,82106	
08/12/2020	126,2198	Influenced by "Sahara Dust"
09/12/2020	25,66575	
10/12/2020	19,04426	
11/12/2020	8,070928	
12/12/2020	6,076344	
13/12/2020	19,04725	
14/12/2020	27,56596	
15/12/2020	41,48911	
16/12/2020	36,91152	
17/12/2020	17,05182	
18/12/2020	16,9589	
19/12/2020	15,23422	
20/12/2020	11,33528	
21/12/2020	10,3402	
22/12/2020	18,77318	
05/01/2021	33,01264	
06/01/2021	38,44424	
07/01/2021	69,00376	
08/01/2021	103,9381	Influenced by "Sahara Dust"
09/01/2021	49,95808	
10/01/2021	124,6392	Influenced by "Sahara Dust"
11/01/2021	24,84758	
12/01/2021	13,78766	
13/01/2021	20,67771	
14/01/2021	22,49389	
15/01/2021	23,21344	
16/01/2021	13,1352	
17/01/2021	15,3269	
18/01/2021	33,65013	
19/01/2021	13,05926	
20/01/2021	18,77318	
21/01/2021	16,32493	
22/01/2021	12,33407	
23/01/2021	19,76408	
24/01/2021	18,94121	
25/01/2021	19,58838	
26/01/2021	15,22225	

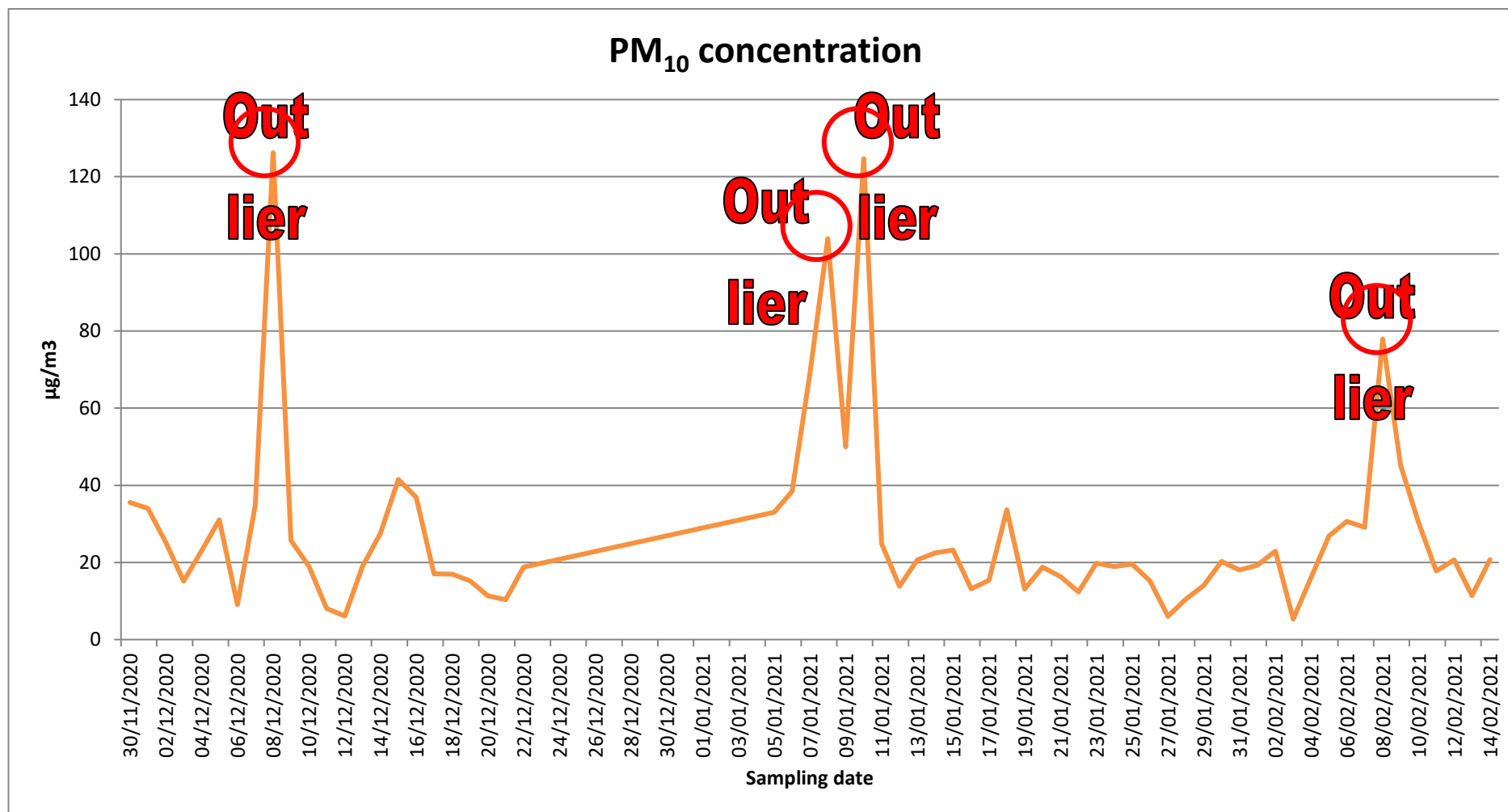
AIR QUALITY ASSESSMENT

Development of a Waste to Energy Facility, to operate in conjunction with other waste management operations within the Magtab Environmental Complex, Magtab integration with a new Marsa Thermal Treatment Facility (MTTF)

Date	Concentration $\mu\text{g}/\text{m}^3$	Note
27/01/2021	6,020831	
28/01/2021	10,47726	
29/01/2021	14,04767	
30/01/2021	20,22319	
31/01/2021	18,04859	
01/02/2021	19,2151	
02/02/2021	22,92883	
03/02/2021	5,301926	
05/02/2021	26,82652	
06/02/2021	30,63299	
07/02/2021	29,10899	
08/02/2021	77,91027	Influenced by "Sahara Dust"
09/02/2021	45,21028	
10/02/2021	30,4748	
11/02/2021	17,77557	
12/02/2021	20,67609	
13/02/2021	11,42596	
14/02/2021	20,75051	

7.1.1 Statistical parameters

Statistical parameters					
Average	90,4° percentile	Min	Max	Dev.ST	Median
22,407	36,136	5,302	69,004	11,677	19,588



7.1.2 Significance Criteria PM₁₀

It was used a significance criteria tool to determine the significance of the impact at all sensitive receptors and at any point within the investigated area.

To determine the impact, the tool used considers:

- The annual limit value ($\mu\text{g}/\text{m}^3$)
- The baseline concentration ($\mu\text{g}/\text{m}^3$) - The baseline concentration value considered was the average daily value
- The change ($\mu\text{g}/\text{m}^3$) - the worst case scenario was considered for the determination of the exchange rate.

Table 9 - Impact Criteria Tool for PM₁₀

Change in the annual PM ₁₀ dAA levels due to scheme					
CAA for PM ₁₀		dAA $\leq 0,4$ $\mu\text{g}/\text{m}^3$	$0,8 \mu\text{g}/\text{m}^3 \leq$ dAA $\leq 2,0$ $\mu\text{g}/\text{m}^3$	$2,4 \mu\text{g}/\text{m}^3 \leq$ dAA $\leq 4,0$ $\mu\text{g}/\text{m}^3$	dAA $> 4 \mu\text{g}/\text{m}^3$
	CAA $\geq 44 \mu\text{g}/\text{m}^3$	Moderate	Major	Major	Major
	$43,6 \mu\text{g}/\text{m}^3 \leq$ CAA $\leq$ $41,2 \mu\text{g}/\text{m}^3$	Moderate	Moderate	Major	Major
	$40,8 \mu\text{g}/\text{m}^3 \leq$ CAA $\leq$ $38 \mu\text{g}/\text{m}^3$	Minor	Moderate	Moderate	Major
	$37,6 \mu\text{g}/\text{m}^3 \leq$ CAA $\leq$ $30,4 \mu\text{g}/\text{m}^3$	Not significant	Minor	Moderate	Moderate
	CAA $\leq 30 \mu\text{g}/\text{m}^3$	Not significant	Not significant	Minor	Moderate

For the calculation of the CAA of PM₁₀, that is the corrected annual average, the following formula has been proposed

$$CAA = \frac{p_{y+1}^{x \text{ weeks}}}{p_y^{x \text{ weeks}}} \times P_y^{52 \text{ weeks}}$$

Where:

CAA is the corrected annual average;

- $P_{y+1}^{x\ weeks}$ is the concentration of NO₂ or PM₁₀ measured by the consultants throughout the 6 (9) week (baseline) monitoring period;
- $P_y^{x\ weeks}$ is the concentration of NO₂ or PM₁₀ measured throughout the same 6 (9) week monitoring period of the preceding year at a comparable ERA fixed station;
- $P_y^{52\ weeks}$ is the annual average of NO₂ or PM₁₀ measured at the comparable ERA fixed station.

The annualization factor for PM10 considered is 1.14 (based on the Zejtun 2019 data).

Considering a baseline value equal to 22.41 µg/m³, the annualization factor 1.14 the result of the CAA calculation is equal to 25.54.

7.2 RESULTS OF NO₂

The analytical results obtained in the eight weeks of NO₂ monitoring are shown below.

Test Report Air Pollution Measurement

NO2

Nitrogen dioxide measurement by means of passive sampler

customer information

customer: AIS Technology Ltd

customer ID: MAI

contact person: Sacha DUNLOP

project: Air Quality Study -

reference: for Waste-to-Energy Project

passive samplers

date received: 02.02.2021

type: tube (Palms)

pollutant: NO2

limit of detection: 0.75 ug/m3 (14 days)

sampling rate: 0.734 [ml/min]

protective filter: yes

analysis

method: SP01 photometer, Salzmann

analyte: NO2

date: 03.02.2021

place: passam ag

test report

created on: 04.02.2021

created by: K. Bodei

checked on: 05.02.2021

checked by: S. Huber

file name: MAI012001

pages: 1

note: applies to the sample as received; results below the detection limit are indicated with "<" and the associated value; this method is accredited to ISO 17025 measurement uncertainty <25%; concentration calculated assuming: T = 20°C; p = 1013 hPa; further information at www.passam.ch

measuring site	passive sampler		measuring period				measurement				result		comment on the analysis
	label	lot no.	date	time	date	time	exp. time [h]	blank [ABS]	sample dilution	value [ABS]	m. analyte/ sampler [ug]	C	
35.937995, 14.449484, A1	MAI 1	180919	30/11/2020	10.00	28/12/2020	10.00	672,0	0,005	1	0,005	< 0.01	< 0.3	specs not met: shelf life;
35.937995, 14.449484, A2	2	180919	30/11/2020	10.00	28/12/2020	10.00	672,0	0,005	1	0,117	0.25	8,4	specs not met: shelf life;
35.937995, 14.449484, B1	9	180919	28/12/2020	10.00	25/01/2021	07.30	669,5	0,005	1	0,103	0.22	7,4	specs not met: shelf life;
35.937995, 14.449484, B2	7	180919	28/12/2020	10.00	25/01/2021	07.30	669,5	0,005	1	0,213	0.46	15,7	specs not met: shelf life;

passam ag

air quality monitoring

ISO ACCREDITED
LABORATORY
SERVING THE WORLD

Outlier

7.2.1 Statistical parameters

Statistical parameters					
Average	99,8° percentile	Min	Max	Dev.ST	Median
10,49	15,648	7,40	15,70	4,52	8,41

7.2.2 Significance Criteria NO₂

It was used a significance criteria tool to determine the significance of the impact at all sensitive receptors and at any point within the investigated area.

To determine the impact, the tool used considers:

- The annual limit value ($\mu\text{g}/\text{m}^3$)
- The baseline concentration ($\mu\text{g}/\text{m}^3$) - The baseline concentration value considered was the average daily value
- The change ($\mu\text{g}/\text{m}^3$) - the worstcase scenario was considered for the determination of the exchange rate.

Table 10 - Impact Criteria Tool for NO₂

Change in the annual NO ₂ dAA levels due to scheme					
CAA for NO ₂		dAA $\leq 0,4$ $\mu\text{g}/\text{m}^3$	$0,8 \mu\text{g}/\text{m}^3 \leq$ dAA $\leq 2,0$ $\mu\text{g}/\text{m}^3$	$2,4 \mu\text{g}/\text{m}^3 \leq$ dAA $\leq 4,0$ $\mu\text{g}/\text{m}^3$	dAA $> 4 \mu\text{g}/\text{m}^3$
	CAA $\geq 44 \mu\text{g}/\text{m}^3$	Moderate	Major	Major	Major
	$43,6 \mu\text{g}/\text{m}^3 \leq$ CAA $\leq$ $41,2 \mu\text{g}/\text{m}^3$	Moderate	Moderate	Major	Major
	$40,8 \mu\text{g}/\text{m}^3 \leq$ CAA $\leq$ $38 \mu\text{g}/\text{m}^3$	Minor	Moderate	Moderate	Major
	$37,6 \mu\text{g}/\text{m}^3 \leq$ CAA $\leq$ $30,4 \mu\text{g}/\text{m}^3$	Not significant	Minor	Moderate	Moderate
	CAA $\leq 30 \mu\text{g}/\text{m}^3$	Not significant	Not significant	Minor	Moderate

The annualization factor for NO₂ considered is 1 (based on SWQ9 DT 2020 data).

Considering a baseline value equal to $10.49 \mu\text{g}/\text{m}^3$, the annualization factor 1 the result of the CAA calculation is equal to 10.49.

7.3 COMPLIANCE WITH THE 90.4TH PERCENTILE CRITERION FOR PM₁₀.

In accordance with the TOR's provisions, the baseline of the 90.4th percentile of the daily for PM₁₀ was calculated.

The following equation $PCT = (1.46 \times CAA) - 0.03$ was used;

Where CAA (in $\mu\text{g}/\text{m}^3$) is the average of the 9week monitoring period and corrected to an annual average using a factor, PCT is the 90.4th percentile of the daily PM₁₀ averages in $\mu\text{g}/\text{m}^3$.

$$PCT = (1.46 \times 25.54) - 0.03 = 37.26 \mu\text{g}/\text{m}^3$$

To assess compliance with the 90.4th percentile criterion for PM₁₀ the following scheme was used.

Table 11 - Impact Criteria Tool for 90.4th percentile (PCT) for PM₁₀

		Change in the PCT (dPCT) due to scheme ($\mu\text{g}/\text{m}^3$)			
PCT		$dAA \leq 0,5 \mu\text{g}/\text{m}^3$	$1.0 \mu\text{g}/\text{m}^3 \leq dAA \leq 2,5 \mu\text{g}/\text{m}^3$	$3.0 \mu\text{g}/\text{m}^3 \leq dAA \leq 5,0 \mu\text{g}/\text{m}^3$	$dAA > 5,0 \mu\text{g}/\text{m}^3$
	$PCT \geq 50 \mu\text{g}/\text{m}^3$	Moderate	Major	Major	Major
	$54,5 \mu\text{g}/\text{m}^3 \leq PCT \leq 51,5 \mu\text{g}/\text{m}^3$	Moderate	Moderate	Major	Major
	$41,5 \mu\text{g}/\text{m}^3 \leq PCT \leq 47,5 \mu\text{g}/\text{m}^3$	Minor	Moderate	Moderate	Major
	$47 \mu\text{g}/\text{m}^3 \leq PCT \leq 38 \mu\text{g}/\text{m}^3$	Not significant	Minor	Moderate	Moderate
	$CAA \leq 37,5 \mu\text{g}/\text{m}^3$	Not significant	Not significant	Minor	Moderate

7.3.1 Sensitive receptors

A geostatistical analysis was carried out to study the interference between the estimated concentrations of PM₁₀, NO₂ and PCT and all the sensitive receptors identified within the 6 km area around the waste incinerator.

55 sensitive receptors have been identified, for each the geographical coordinates, the location and the linear distance of the incinerator are reported.

The table below shows the information of each receptor.

Receptor No.	Name	Coordinates	Distance
R1	Verdala International School, Pembroke	35°55'33.67"N 14°28'49.07"E	3,80 km
R2	Chiswick House School, San Gwann	35°54'26.02"N 14°29'0.87"E	5,36 km
R3	St Catherine's High School, Pembroke	35°55'30.98"N 14°28'24.17"E	3,31 km
R4	St Michael's School, Pembroke	35°55'31.24"N 14°28'34.19"E	3,52 km
R5	St Michael's Foundation, San Gwann	35°54'43.73"N 14°27'53.62"E	3,92 km
R6	St Francis School, San Gwann	35°54'27.88"N 14°28'48.44"E	5,10 km
R7	St Clare Primary College, Pembroke	35°55'40.57"N 14°28'40.21"E	3,50 km
R8	Karmnu Sant Primary School, Gharghur	35°55'25.82"N 14°27'5.60"E	2,22 km
R9	Bice Mizzi Vassallo Primary School, Pembroke	35°55'29.92"N 14°28'27.30"E	3,40 km
R10	St Clare Secondary, Pembroke	35°55'47.69"N 14°28'19.09"E	2,93 km
R11	Sprachcaffe Language School, Pembroke	35°55'30.60"N 14°28'41.83"E	3,69 km
R12	San Miguel Resource Centre, Pembroke	35°55'41.26"N 14°28'30.65"E	3,28 km
R13	M.U.S.E.U.M Pembroke	35°55'35.46"N 14°28'42.10"E	3,62 km
R14	Risen Christ Church, Pembroke	35°55'34.72"N 14°28'39.08"	3,56 km
R15	National Sports School, Pembroke	35°55'27.69"N 14°28'26.35"E	3,42 km
R16	Simblija Care Home, Naxxar	35°54'42.13"N 14°26'50.75"E	3,49 km
R17	Golden Care Retirement Home, Naxxar	35°55'3.49"N 14°26'54.07"E	2,85 km
R18	Primary School, Naxxar	35°54'50.02"N 14°26'47.09"E	3,24 km

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Receptor No.	Name	Coordinates	Distance
R19	MRC Middle School, Naxxar	35°54'37.01"N 14°26'52.35"E	3,65 km
R20	Giovanni Curmi Higher Secondary, Naxxar	35°54'35.28"N 14°26'48.54"E	3,69 km
R21	Naxxar Parish Church, Naxxar	35°54'52.52"N 14°26'39.98"E	3,16 km
R22	St Clare's Primary College, San Gwann	35°54'32.44"N 14°28'31.27"E	4,72 km
R23	San Gwann Parish Church, San Gwann	35°54'27.65"N 14°28'36.81"E	4,93 km
R24	Immaculate Mother of the Church, Swieqi	35°55'15.51"N 14°28'27.78"E	3,69 km
R25	St Bartholomew Parish Church, Gharghur	35°55'25.49"N 14°27'12.52"E	2,31 km
R26	Clubclass English School, Swieqi	35°55'10.80"N 14°28'50.10"E	4,20 km
R27	Agricultural land, Magħtab	35°56'22.21"N 14°26'45.34"E	0,43 km
R28	Żona fil-Baħar madwar Għawdex - MT0000112	35°56'52.41"N 14°27'0.53"E	0,79 km
R29	Żona fil-Baħar bejn Il-Ponta ta' San Dimitri (Għawdex) u Il-Qaliet (MT0000105)	35°56'54.63"N 14°27'17.86"E	1,18 km
R30	L-Għadira s-Safra (MT0000008)	35°57'2.52"N 14°26'43.28"E	0,86 km
R31	Is-Salini (MT0000007)	35°56'38.19"N 14°25'20.58"E	1,94 km
R32	Triq ir-Ramla, Magħtab Residential & Industrial Area	35°56'9.33"N 14°26'32.99"E	0,78 km
R33	Triq Jules Verne, Naxxar Residential Area	35°55'26.90"N 14°26'21.72"E	2,13 km
R34	Triq Fidel Zarb, Gharghur Residential Area	35°55'39.42"N 14°27'9.29"E	1,88 km
R35	Dawret il-Qawra, Qawra Residential Area	35°57'0.72"N 14°25'24.15"E	2,01 km
R36	Triq Napuljun Tagliaferro, Pembroke Residential Area	35°55'39.77"N 14°28'39.18"E	3,48 km
R37	Triq M. Pulis, Birkirkara Residential Area	35°53'57.91"N 14°27'55.10"E	5,21 km
R38	Constitution Road, Mosta Residential Area	35°54'34.35"N 14°25'34.08"E	4,04 km
R39	Triq San Guzepp, San Gwann Residential Area	35°54'26.90"N 14°28'37.06"E	4,95 km
R40	Parish Street, St Paul's Bay Residential Area	35°56'55.42"N 14°24'8.97"E	3,78 km
R41	Triq il-Magħsar, Burmarrad Residential Area	35°55'59.70"N 14°24'49.00"E	2,93 km
R42	Triq Preziosi, Lija Residential Area	35°54'13.20"N 14°26'42.79"E	4,37 km
R43	Triq Balaguer, Balzan Residential Area	35°53'59.04"N 14°27'4.81"E	4,85 km
R44	Triq Annabelle Preca, Attard Residential Area	35°53'49.31"N 14°26'15.74"E	5,13 km

Receptor No.	Name	Coordinates	Distance
R45	Triq il-Harruba, Iklin Residential Area	35°54'42.16"N 14°27'8.16"E	3,56 km
R46	Triq L.Apap, St Julian's Residential Area	35°55'16.57"N 14°29'22.03"E	4,78 km
R47	Mater Dei Hospital, Msida	35°54'4.63"N 14°28'35.51"E	5,49 km
R48	Tower Road, Sliema Residential Area	35°55'1.99"N 14°29'59.81"E	5,81 km
R49	Farm at Triq il-Katakombi, Salina	35°56'44.52"N 14°25'45.23"E	1,35 km
R50	Farm at Sqaq Habel Zwejra, Maghtab	35°56'15.73"N 14°26'8.07"E	0,95 km
R51	Farm and fields at Triq Burmarrad, Burmarrad	35°55'33.18"N 14°25'12.83"E	2,86 km
R52	Farms at Bahar ic-Caghaq	35°56'2.57"N 14°26'53.43"E	1,06 km
R53	Agricultural land at Triq il-Wardija, Wardija	35°56'18.06"N 14°24'38.77"E	3,02 km
R54	Agricultural land at Triq is-Sagra Familja, Bidnija	35°55'33.91"N 14°23'31.26"E	5,03 km
R55	Agricultural land, Triq Sir Temi Zammit, Mosta	35°54'33.82"N 14°24'6.01"E	5,32 km

The thematic maps shown in the following figures describe the spatial distribution of the sensitive receptors with respect to the survey area and the relationships between each receptor and the calculated concentrations of PM₁₀, NO₂ and PCT.

A summary table was also drawn up where the concentration value calculated by the model and integrated with the values obtained from monitoring was reported. A color scale was used to emphasize the most disturbed sensitive receptors, the color scale varies from green (lower concentrations) to red (higher concentrations).

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SCENARIO 1													
Receptor No.	Distance	Baseline PM10 (CAA)	PM10	Change PM10 (dAA)	Impact ¹	Baseline NO ₂ (CAA)	NO ₂	Change NO ₂ (dAA)	Impact ¹	Baseline PCT	PCT	Change PCT (dPCT)	Impact ¹
		µg/m ³	µg/m ³	µg/m ³		µg/m ³	µg/m ³	µg/m ³			µg/m ³	µg/m ³	
R1	3,80 km	25.54	25.54	0.00044	N/S	10.49	10.50	0.0124	N/S	37.26	37.26	0.0010	N/S
R2	5,36 km		25.54	0.00018	N/S		10.49	0.0049	N/S		37.26	0.0007	N/S
R3	3,31 km		25.54	0.00061	N/S		10.51	0.0170	N/S		37.26	0.0013	N/S
R4	3,52 km		25.54	0.00060	N/S		10.51	0.0168	N/S		37.26	0.0013	N/S
R5	3,92 km		25.54	0.00013	N/S		10.49	0.0038	N/S		37.26	0.0006	N/S
R6	5,10 km		25.54	0.00017	N/S		10.49	0.0047	N/S		37.26	0.0006	N/S
R7	3,50 km		25.54	0.00047	N/S		10.50	0.0131	N/S		37.26	0.0011	N/S
R8	2,22 km		25.54	0.00014	N/S		10.49	0.0041	N/S		37.26	0.0006	N/S
R9	3,40 km		25.54	0.00058	N/S		10.51	0.0163	N/S		37.26	0.0012	N/S
R10	2,93 km		25.54	0.00082	N/S		10.51	0.0232	N/S		37.26	0.0016	N/S
R11	3,69 km		25.54	0.00041	N/S		10.50	0.0116	N/S		37.26	0.0010	N/S
R12	3,28 km		25.54	0.00071	N/S		10.51	0.0200	N/S		37.26	0.0014	N/S
R13	3,62 km		25.54	0.00044	N/S		10.50	0.0123	N/S		37.26	0.0010	N/S
R14	3,56 km		25.54	0.00043	N/S		10.50	0.0121	N/S		37.26	0.0010	N/S
R15	3,42 km		25.54	0.00055	N/S		10.51	0.0156	N/S		37.26	0.0012	N/S
R16	3,49 km		25.54	0.00002	N/S		10.49	0.0007	N/S		37.26	0.0004	N/S

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R17	2,85 km	25.54	0.00003	N/S	10.49	0.0009	N/S	37.26	0.0004	N/S
R18	3,24 km	25.54	0.00002	N/S	10.49	0.0007	N/S	37.26	0.0004	N/S
R19	3,65 km	25.54	0.00002	N/S	10.49	0.0006	N/S	37.26	0.0004	N/S
R20	3,69 km	25.54	0.00002	N/S	10.49	0.0006	N/S	37.26	0.0004	N/S
R21	3,16 km	25.54	0.00002	N/S	10.49	0.0006	N/S	37.26	0.0004	N/S
R22	4,72 km	25.54	0.00016	N/S	10.49	0.0045	N/S	37.26	0.0006	N/S
R23	4,93 km	25.54	0.00016	N/S	10.49	0.0046	N/S	37.26	0.0006	N/S
R24	3,69 km	25.54	0.00045	N/S	10.50	0.0126	N/S	37.26	0.0011	N/S
R25	2,31 km	25.54	0.00021	N/S	10.50	0.0061	N/S	37.26	0.0007	N/S
R26	4,20 km	25.54	0.00029	N/S	10.50	0.0082	N/S	37.26	0.0008	N/S
R27	0,43 km	25.54	0.00006	N/S	10.49	0.0017	N/S	37.26	0.0005	N/S
R28	0,79 km	25.54	0.00033	N/S	10.50	0.0096	N/S	37.26	0.0009	N/S
R29	1,18 km	25.54	0.00031	N/S	10.50	0.0091	N/S	37.26	0.0009	N/S
R30	0,86 km	25.54	0.00042	N/S	10.50	0.0122	N/S	37.26	0.0010	N/S
R31	1,94 km	25.54	0.00028	N/S	10.50	0.0081	N/S	37.26	0.0008	N/S
R32	0,78 km	25.54	0.00004	N/S	10.49	0.0011	N/S	37.26	0.0005	N/S
R33	2,13 km	25.54	0.00006	N/S	10.49	0.0016	N/S	37.26	0.0005	N/S
R34	1,88 km	25.54	0.00033	N/S	10.50	0.0097	N/S	37.26	0.0009	N/S
R35	2,01 km	25.54	0.00037	N/S	10.50	0.0107	N/S	37.26	0.0009	N/S
R36	3,48 km	25.54	0.00045	N/S	10.50	0.0126	N/S	37.26	0.0011	N/S

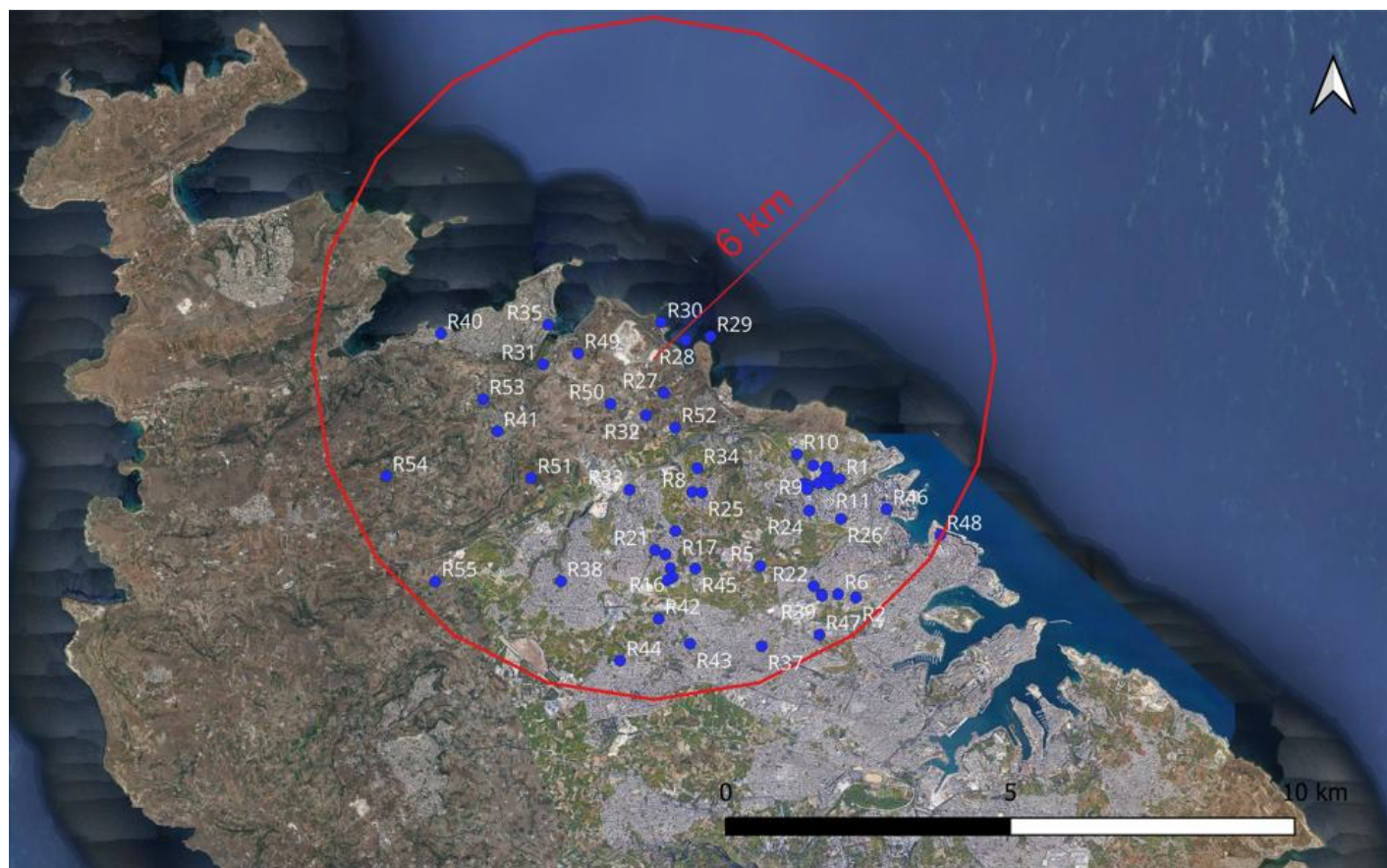
AIR QUALITY ASSESSMENT

Development of a Waste to Energy Facility, to operate in conjunction with other waste management operations within the Magtab Environmental Complex, Magtab integration with a new Marsa Thermal Treatment Facility (MTTF)

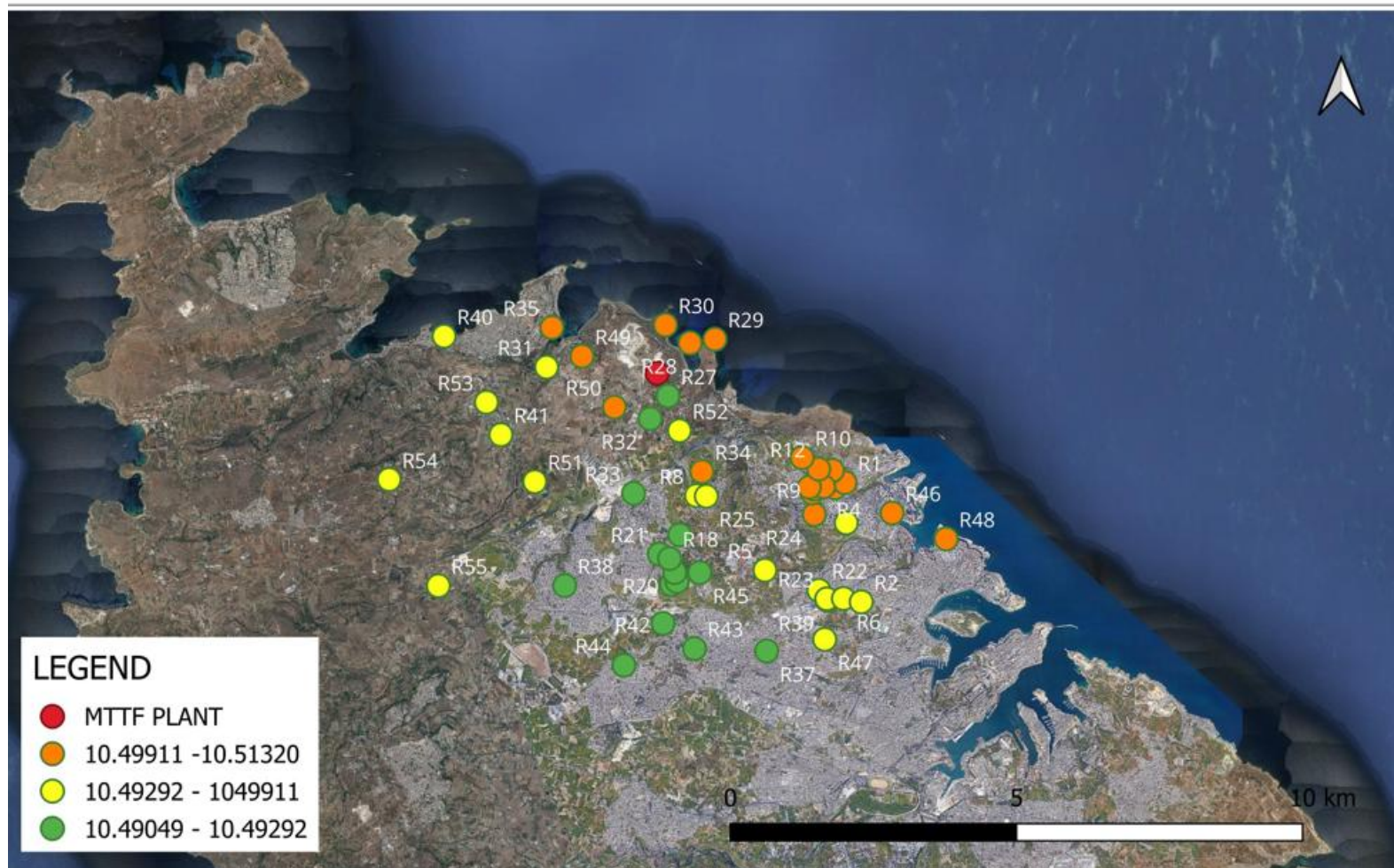
R37	5,21 km	25.54	0.00006	N/S	10.49	0.0017	N/S	37.26	0.0005	N/S
R38	4,04 km	25.54	0.00007	N/S	10.49	0.0021	N/S	37.26	0.0005	N/S
R39	4,95 km	25.54	0.00016	N/S	10.49	0.0045	N/S	37.26	0.0006	N/S
R40	3,78 km	25.54	0.00019	N/S	10.50	0.0054	N/S	37.26	0.0007	N/S
R41	2,93 km	25.54	0.00025	N/S	10.50	0.0072	N/S	37.26	0.0008	N/S
R42	4,37 km	25.54	0.00002	N/S	10.49	0.0005	N/S	37.26	0.0004	N/S
R43	4,85 km	25.54	0.00002	N/S	10.49	0.0006	N/S	37.26	0.0004	N/S
R44	5,13 km	25.54	0.00002	N/S	10.49	0.0005	N/S	37.26	0.0004	N/S
R45	3,56 km	25.54	0.00004	N/S	10.49	0.0010	N/S	37.26	0.0005	N/S
R46	4,78 km	25.54	0.00038	N/S	10.50	0.0105	N/S	37.26	0.0010	N/S
R47	5,49 km	25.54	0.00013	N/S	10.49	0.0036	N/S	37.26	0.0006	N/S
R48	5,81 km	25.54	0.00035	N/S	10.50	0.0096	N/S	37.26	0.0009	N/S
R49	1,35 km	25.54	0.00059	N/S	10.51	0.0172	N/S	37.26	0.0013	N/S
R50	0,95 km	25.54	0.00040	N/S	10.50	0.0117	N/S	37.26	0.0010	N/S
R51	2,86 km	25.54	0.00018	N/S	10.50	0.0052	N/S	37.26	0.0007	N/S
R52	1,06 km	25.54	0.00016	N/S	10.49	0.0046	N/S	37.26	0.0006	N/S
R53	3,02 km	25.54	0.00020	N/S	10.50	0.0058	N/S	37.26	0.0007	N/S
R54	5,03 km	25.54	0.00014	N/S	10.49	0.0040	N/S	37.26	0.0006	N/S
R55	5,32 km	25.54	0.00011	N/S	10.49	0.0029	N/S	37.26	0.0006	N/S

¹ Not Significant (N/S), Minor (MI), Moderate (MO), Major (MA)

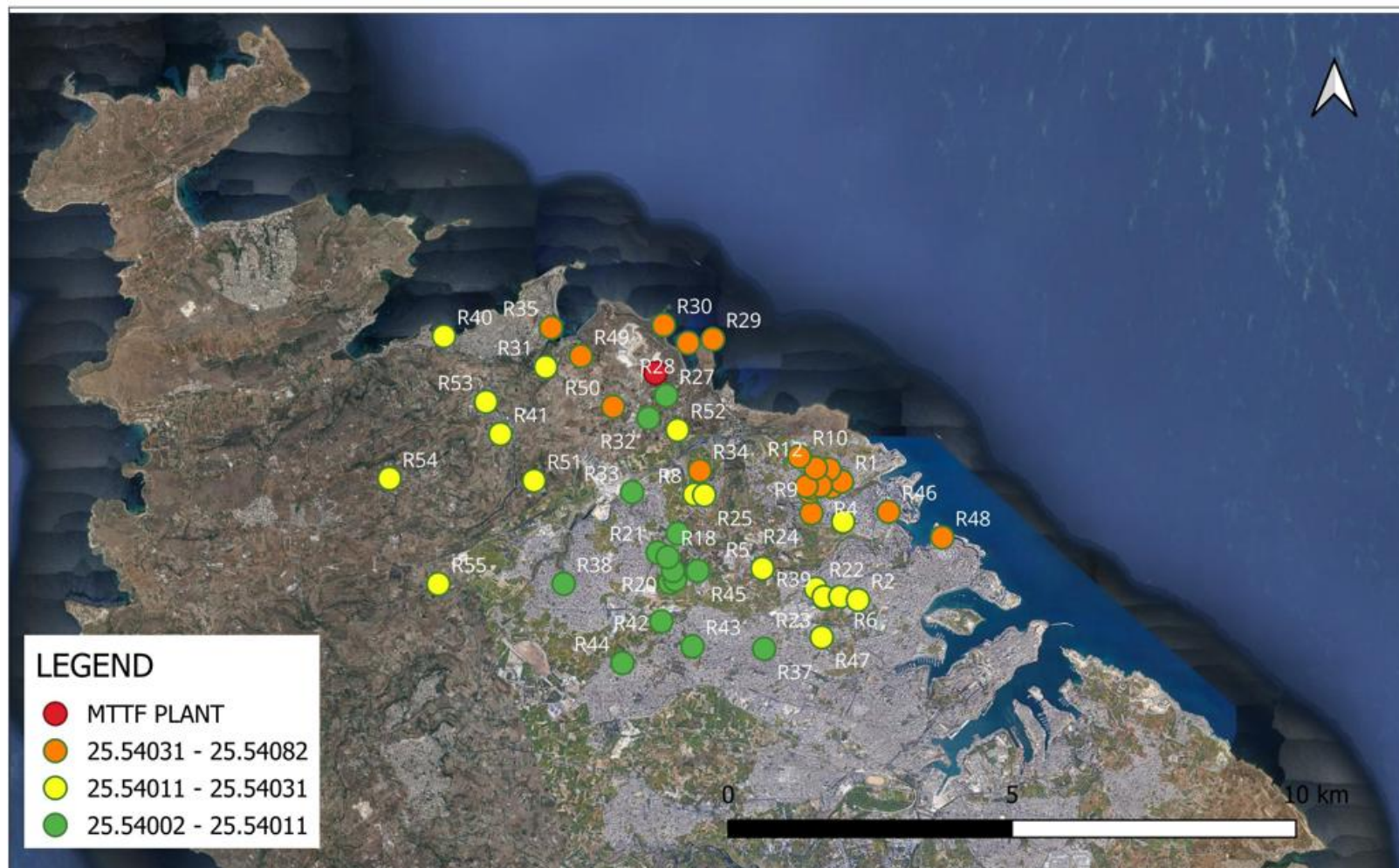
SENSITIVE RECEPTORS



NO₂ - SCENARIO 1



PM10 - SCENARIO 1



Summary of Impact table

Impact type and source			Impact receptor		Effect & Scale							Probability of impact occurring / Unavoidable / Likelihood	Overall impacts significance	Proposed mitigation measures	Residual impacts significance	Others requirements
Impact type	Specific intervention leading to impact	Project phase (construction/ operation/	Receptor type	Sensitivity & resilience toward impact	Direct/ Indirect/ Cumulative	Beneficial/ Adverse	Severity	Physical/ geographic extent of impact	Short- / Medium- / Long-term	Temporary (indicate duration)/ Permanent	Reversible (indicate ease of reversibility)/					
Emissions from stack	hazardous waste incineration plant	Construction	Residential areas, Agricultural land and disturbed ground Natura2000 Sites of Community Importance (SCI) Natura2000 Special Protection Area (SPA) Natura2000 SPA and SCI Tree Protected Areas	Not Significant	Direct	Adverse	Low	Immediate surroundings	Long-term	Temporary combustion phases	Reversible with some difficulty	Remote	Minor	Monitoring of the pollutants levels around the Scheme to ensure that they are within limits, and periodic monitoring and maintenance of the abatement technologies	Minor	N/A

7.3.2 Cumulative Impact

Reference to Section 4.5 - "Other environmental effects" of the EIA Specifications, the cumulative impacts of the project were assessed with those of other existing and/or approved projects and other waste management plants identified within the Waste Management Plan Waste (2021 -2030). This will take into account existing environmental problems, areas of particular environmental importance that may be affected and the use of natural resources. Specifically, the cumulative impact was assessed between the Marsa Thermal Treatment Facility built (MTTF) plant project with the Maghtab Waste to Energy Facility (WtE).

The results obtained show that the cumulative impact of the project and the Waste to Energy facility can be considered NOT SIGNIFICANT.

The overlap of the emissions from two production plants (WtE and MTFF) does not show a substantial variation in the fallout calculated at the sensitive receptors identified in the investigated areas, compared to what was obtained only from the MTTF (show in table 12).

The results obtained show that the construction of the MTTF plant adjacent to the WtE plant, not produce a significant worsening of the atmospheric impact on the identified receptors.

The AOI is determined by whichever parameter results in the largest AOI. However, if the area defined in this way is less than 11.3 km², then the AOI is assumed to be a circle of radius 6 km centered on the chimney. The results obtained show for NO₂ and PM₁₀ concentrations higher than 0.3 µg/m³ occurred up to a distance of approximately 1.35 km from the chimney in a north-east and north-west direction, specifically at the R27 - R28 - R29 - R30 - R49 - R50 - R52 receptors, but the value is significantly lower than the 40.0 µg/m³ limit (ALV), thus contributing to a negligible adverse impact.

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CUMULATIVE IMPACT													
Receptor No.	Distance	Baseline PM10 (CAA)	PM10	Change PM10 (dAA) MTTF+WtE	Impact ¹	Baseline NO ₂ (CAA)	NO ₂	Change NO ₂ (dAA) MTTF+WtE	Impact ¹	Baseline PCT	PCT	Change PCT (dPCT) (µg/m ³)	Impact ¹
		µg/m ³	µg/m ³	µg/m ³		µg/m ³	µg/m ³	µg/m ³			µg/m ³	µg/m ³	
R1	3,80 km	25.54	25.6604	0.120442	N/S	10.49	10.6224	0.1324	N/S	37.26	37.4342	0.1742	N/S
R2	5,36 km		25.6402	0.100175	N/S		10.5949	0.1049	N/S		37.4047	0.1447	N/S
R3	3,31 km		25.6706	0.130606	N/S		10.6370	0.1470	N/S		37.4491	0.1891	N/S
R4	3,52 km		25.6606	0.120598	N/S		10.6268	0.1368	N/S		37.4345	0.1745	N/S
R5	3,92 km		25.6401	0.100131	N/S		10.5938	0.1038	N/S		37.4046	0.1446	N/S
R6	5,10 km		25.6402	0.100168	N/S		10.5947	0.1047	N/S		37.4046	0.1446	N/S
R7	3,50 km		25.6705	0.130466	N/S		10.6331	0.1431	N/S		37.4489	0.1889	N/S
R8	2,22 km		25.6801	0.140143	N/S		10.6341	0.1441	N/S		37.4630	0.2030	N/S
R9	3,40 km		25.6706	0.130581	N/S		10.6363	0.1463	N/S		37.4490	0.1890	N/S
R10	2,93 km		25.7008	0.160822	N/S		10.6732	0.1832	N/S		37.4932	0.2332	N/S
R11	3,69 km		25.6704	0.130413	N/S		10.6316	0.1416	N/S		37.4488	0.1888	N/S
R12	3,28 km		25.6807	0.140711	N/S		10.6500	0.1600	N/S		37.4638	0.2038	N/S
R13	3,62 km		25.6704	0.130438	N/S		10.6323	0.1423	N/S		37.4488	0.1888	N/S
R14	3,56 km		25.6704	0.130430	N/S		10.6321	0.1421	N/S		37.4488	0.1888	N/S
R15	3,42 km		25.6706	0.130555	N/S		10.6356	0.1456	N/S		37.4490	0.1890	N/S

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R16	3,49 km	25.6000	0.060023	N/S	10.5507	0.0607	N/S	37.3460	0.0860	N/S
R17	2,85 km	25.6100	0.070031	N/S	10.5609	0.0709	N/S	37.3606	0.1006	N/S
R18	3,24 km	25.5900	0.050023	N/S	10.5407	0.0507	N/S	37.3314	0.0714	N/S
R19	3,65 km	25.6000	0.060022	N/S	10.5506	0.0606	N/S	37.3460	0.0860	N/S
R20	3,69 km	25.6000	0.060021	N/S	10.5506	0.0606	N/S	37.3460	0.0860	N/S
R21	3,16 km	25.5800	0.040020	N/S	10.5306	0.0406	N/S	37.3168	0.0568	N/S
R22	4,72 km	25.6402	0.100162	N/S	10.5945	0.1045	N/S	37.4046	0.1446	N/S
R23	4,93 km	25.6402	0.100163	N/S	10.5946	0.1046	N/S	37.4046	0.1446	N/S
R24	3,69 km	25.6504	0.110448	N/S	10.6126	0.1226	N/S	37.4197	0.1597	N/S
R25	2,31 km	25.6802	0.140213	N/S	10.6361	0.1461	N/S	37.4631	0.2031	N/S
R26	4,20 km	25.6403	0.100293	N/S	10.5982	0.1082	N/S	37.4048	0.1448	N/S
R27	0,43 km	26.0101	0.470059	N/S	11.2117	0.7217	N/S	37.9447	0.6847	N/S
R28	0,79 km	25.8903	0.350330	N/S	11.0396	0.5496	N/S	37.7699	0.5099	N/S
R29	1,18 km	25.8603	0.320314	N/S	10.9991	0.5091	N/S	37.7261	0.4661	N/S
R30	0,86 km	25.8904	0.350423	N/S	11.0422	0.5522	N/S	37.7700	0.5100	N/S
R31	1,94 km	25.7803	0.240281	N/S	10.7381	0.2481	N/S	37.6092	0.3492	N/S
R32	0,78 km	25.6800	0.140038	N/S	10.6311	0.1411	N/S	37.4629	0.2029	N/S
R33	2,13 km	25.5901	0.050056	N/S	10.5416	0.0516	N/S	37.3315	0.0715	N/S
R34	1,88 km	25.7303	0.190334	N/S	10.6897	0.1997	N/S	37.5363	0.2763	N/S
R35	2,01 km	25.7904	0.250370	N/S	10.7507	0.2607	N/S	37.6239	0.3639	N/S

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Development of a Waste to Energy Facility, to operate in conjunction with other waste management operations within the Magtab Environmental Complex, Magtab integration with a new Marsa Thermal Treatment Facility (MTTF)

R36	3,48 km	25.6704	0.130449	N/S	10.6326	0.1426	N/S	37.4489	0.1889	N/S
R37	5,21 km	25.6401	0.100061	N/S	10.5917	0.1017	N/S	37.4045	0.1445	N/S
R38	4,04 km	25.6201	0.080074	N/S	10.5721	0.0821	N/S	37.3753	0.1153	N/S
R39	4,95 km	25.6402	0.100162	N/S	10.5945	0.1045	N/S	37.4046	0.1446	N/S
R40	3,78 km	25.6802	0.140189	N/S	10.6354	0.1454	N/S	37.4631	0.2031	N/S
R41	2,93 km	25.6703	0.130253	N/S	10.6272	0.1372	N/S	37.4486	0.1886	N/S
R42	4,37 km	25.5900	0.050017	N/S	10.5405	0.0505	N/S	37.3314	0.0714	N/S
R43	4,85 km	25.6200	0.080022	N/S	10.5706	0.0806	N/S	37.3752	0.1152	N/S
R44	5,13 km	25.5800	0.040017	N/S	10.5305	0.0405	N/S	37.3168	0.0568	N/S
R45	3,56 km	25.6300	0.090036	N/S	10.5810	0.0910	N/S	37.3899	0.1299	N/S
R46	4,78 km	25.6504	0.110380	N/S	10.6105	0.1205	N/S	37.4196	0.1596	N/S
R47	5,49 km	25.6401	0.100127	N/S	10.5936	0.1036	N/S	37.4046	0.1446	N/S
R48	5,81 km	25.6403	0.100350	N/S	10.5996	0.1096	N/S	37.4049	0.1449	N/S
R49	1,35 km	25.8506	0.310593	N/S	10.9872	0.4972	N/S	37.7119	0.4519	N/S
R50	0,95 km	25.9004	0.360405	N/S	11.0617	0.5717	N/S	37.7846	0.5246	N/S
R51	2,86 km	25.6502	0.110181	N/S	10.6052	0.1152	N/S	37.4193	0.1593	N/S
R52	1,06 km	25.8502	0.310159	N/S	10.9746	0.4846	N/S	37.7112	0.4512	N/S
R53	3,02 km	25.6702	0.130203	N/S	10.6258	0.1358	N/S	37.4485	0.1885	N/S
R54	5,03 km	25.6301	0.090144	N/S	10.5840	0.0940	N/S	37.3900	0.1300	N/S
R55	5,32 km	25.6101	0.070106	N/S	10.5629	0.0729	N/S	37.3608	0.1008	N/S

¹ Not Significant (N/S), Minor (MI), Moderate (MO), Major (MA)

8 EMISSIONS IN TONS

The annual emission loads in tonnes have been estimated assuming that the incinerator complies with the daily limit values in Table 3 of EIA TOR (Appendix 4B, January 2019). The limit Values in Table 3 are expressed as dry gas at 273.15 K, 101.3 kPa, and 11% oxygen.

Table 9 – Daily Limit Value of Table 3 of EIA TORs January 2019

POLLUTANTS	LIMIT VALUE 1 [mg/Nm3]	LIMIT VALUE 2 [mg/Nm3]	LIMIT VALUE 3[mg/Nm3]
Dust	1	5	10
SO2	1	40	50
NOX	30	100	200
TOC	1	10	-
NH3	1	10	-

The annual mission loads in tonnes (shown in Table 10) have been estimated multiplying the values in table 3 with the mass flow of 4,34 Nmc/s.

Table 10 – The annual mission loads in tonnes estimated multiplying the values in table 3 with the mass flow

POLLUTANTS	LIMIT VALUE 1 [TON/year]	LIMIT VALUE 2 [TON/year]	LIMIT VALUE 3[TON/year]
Dust	0.000038	0.00019	0.00038
SO2	0.000038	0.00152	0.00190
NOX	0.001141	0.00380	0.00761
TOC	0.000038	0.00038	-
NH3	0.000038	0.00038	-

The EIA TOR of 08/05/2024 also specifies to estimate the annual emission loads in tonnes based on the daily emission contribution foreseen by the TTF for dust, SO₂, NO_x, TVOC and NH₃. The annual emission loads in tonnes were estimated on the basis of the daily emission contribution foreseen by the TTF for dust (PM_{2.5} and PM₁₀), SO₂, NO_x, TVOC and NH₃ (shown table 11). The maximum concentration values present in the calculation domain were considered and subsequently multiplied by the mass flow rate.

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Table 12 - The annual mission loads in Tonnes estimated on TTF's domain

POLLUTANTS	LIMIT VALUE 1 [TON/year]
PM2.5	0.0000000091
PM10	0.0000000401
SO2	0.0000003220
NO _x	0.0000012879
TOC	0.0000001073
NH3	0.0000001073

9 CONCLUSIONS

A 9 week air quality monitoring campaign was developed which made it possible to know the average daily concentrations of PM₁₀ and a 8 week air quality monitoring campaign was developed which made it possible to know the average daily concentrations of NO₂.

The values obtained from the 6 (9) week (baseline) monitoring period were annualized using a corrective factor provided by ERA: for PM10 was consider is 1.14 (based on the Zejtun 2019 data), for NO2 was consider is 1 (based on SWQ9 DT 2020 data).

The concentration values obtained formed the basis for evaluating the possible interferences between the sensitive receptors identified in the survey area and the repercussions due to the new Magħtab Thermal Treatment Facility.

Taking into account the orographic, meteorological data and polluting emissions from the chimney, the model gave the following results:

- The first iteration of the model established that the emission threshold NO₂ concentration levels (0.3 µg/m³); PM₁₀ (0.3µg/m³) and PM_{2.50} (0.19µg/m³) did not exceed a surface area of 11.3 km², in particular, concentrations higher than 0.3 µg/m³ for NO₂ and PM_{2.5} and 0.19 µg/m³ for PM₁₀ have never been verified. The maximum concentrations found at a distance of 0.68 km from the chimney are shown in the following table. Consequently, as per Terms of Reference Appendix 4, the area of influence (AOI) was set to a circle of radius 6 km centered on the chimney;

POLLUTANTS	REFERENT LIMITS	DEFINITION AREA OF INFLUENCE - AOI - MAXIMUM CONCENTRATION ON CALCULATION DOMAIN	
		SCENARIO 1 (CHIMNEY HEIGHT=25 m)	Distance (km)
PM10 [µg/m ³]	0.3	0.00105	0.68
PM2.5 [µg/m ³]	0.19	0.00024	0.68
NO2 [µg/m ³]	0.3	0.0305	0.68

- After a 9-week PM₁₀ monitoring period, the annual reference average PM₁₀ (CAA) was found to be 25.54 µg/m³, a value significantly lower than 40.0 µg/m³ limit (ALV), therefore contributing to a Not Significant impact.

All 55 sensitive receptors that were evaluated resulted in Not Significant impacts; After a baseline NO₂ monitoring period of 8 weeks, the baseline annual average NO₂ (CAA) was found to be 10.49 µg/m³, a value significantly lower than the 40.0 µg/m³ limit (ALV), therefore contributing to a negligible negative impact. All 55 sensitive receptors that were evaluated gave rise to Not Significant impacts.

The annual average of the 90.4th percentile PM₁₀ (PCT) was 37.26 µg/m³, a value significantly lower than 50.0 µg/m³ limit (ALV), thus contributing to a non-significant impact. All 55 sensitive receptors that were evaluated resulted in Not significant impacts.

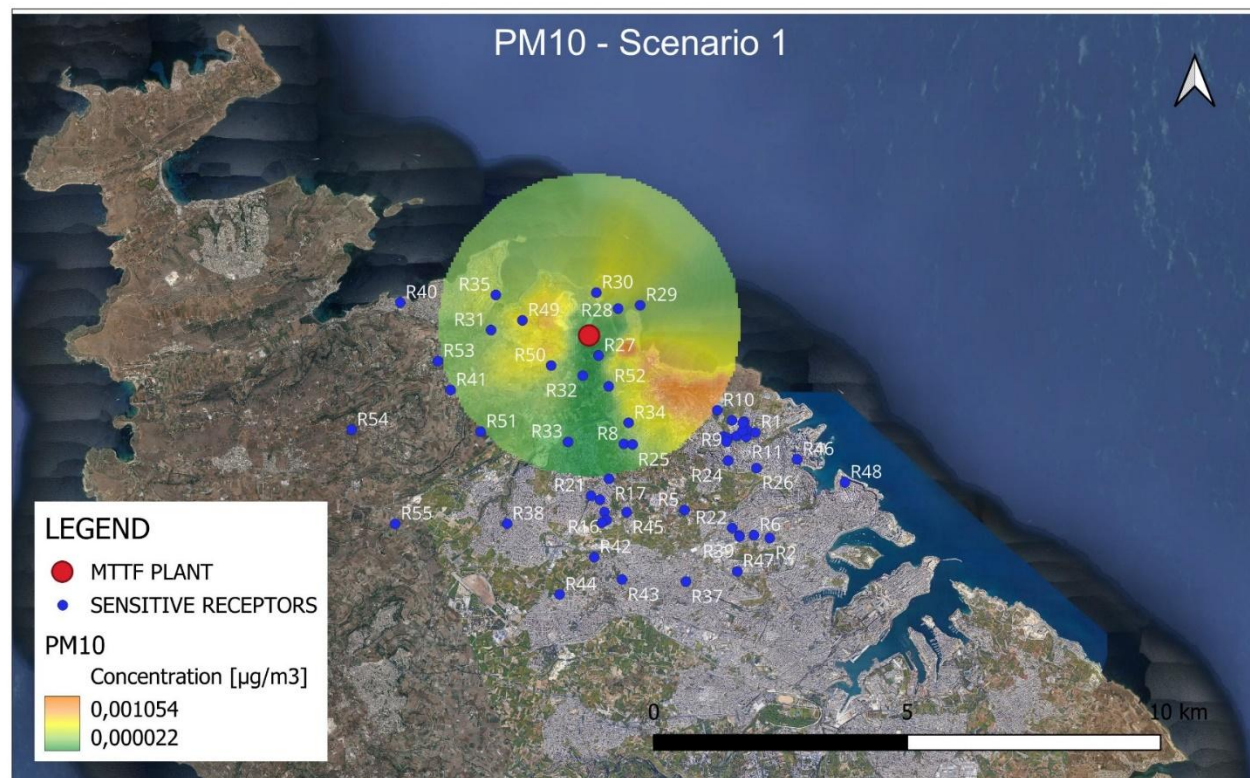
The fallout model processing carried out considering the 25 meter stack height scenario shows that there are no significant variations in the impacts on air quality.

Menfi, Italy 05/07/2023

ANNEX 1

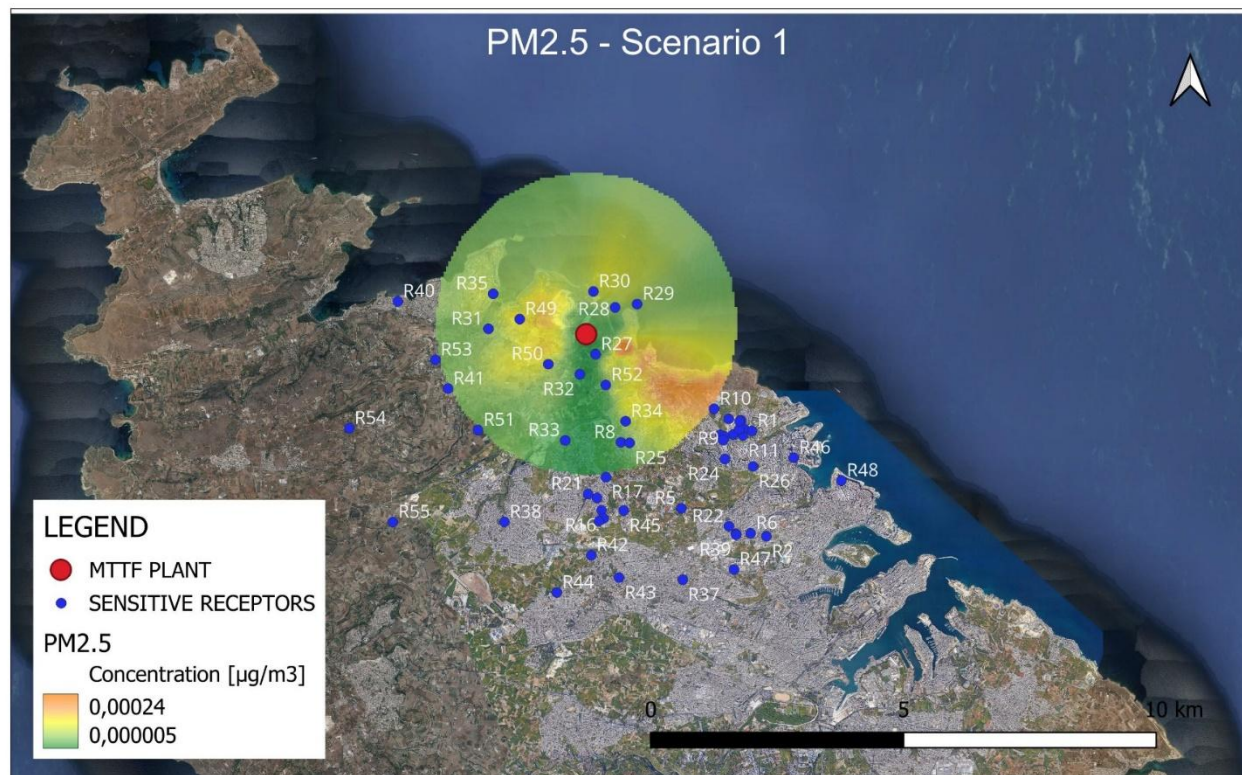
AIR QUALITY ASSESSMENT

Development of a Waste to Energy Facility, to operate in conjunction with other waste management operations within the Maghtab Environmental Complex, Maghtab integration with a new Marsa Thermal Treatment Facility (MTTF)



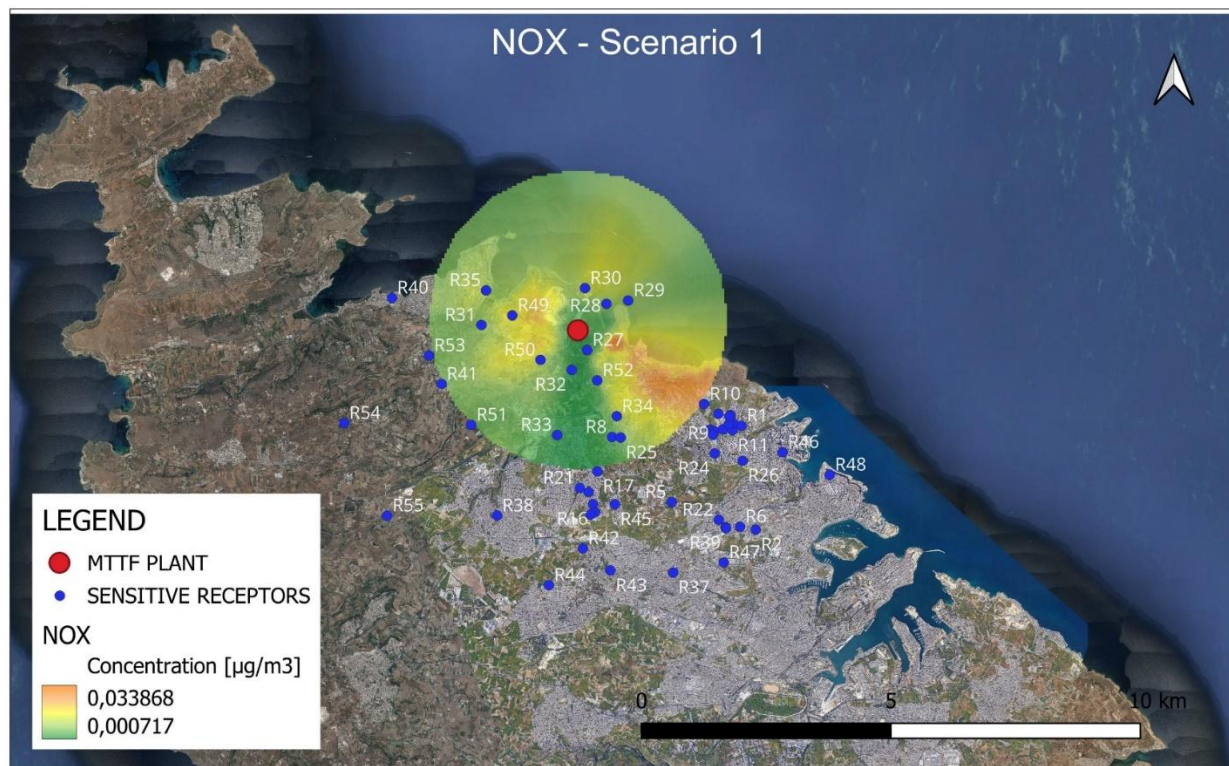
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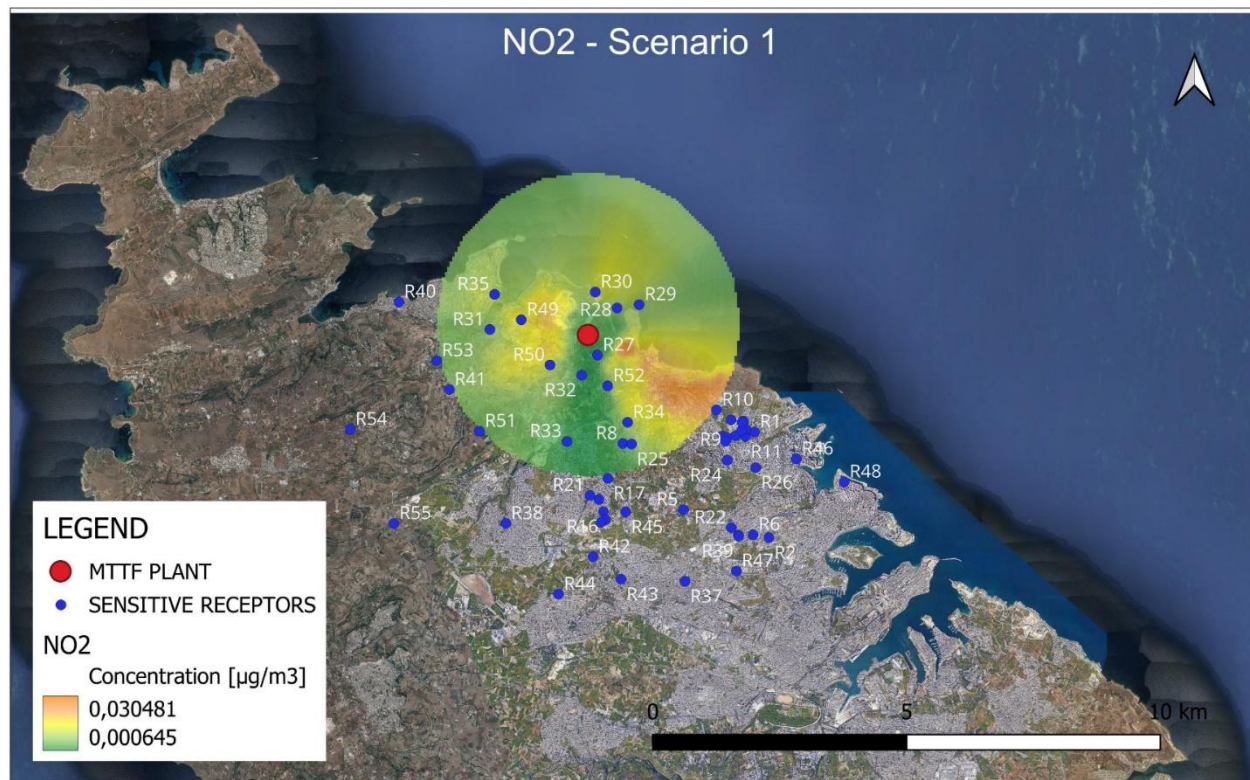
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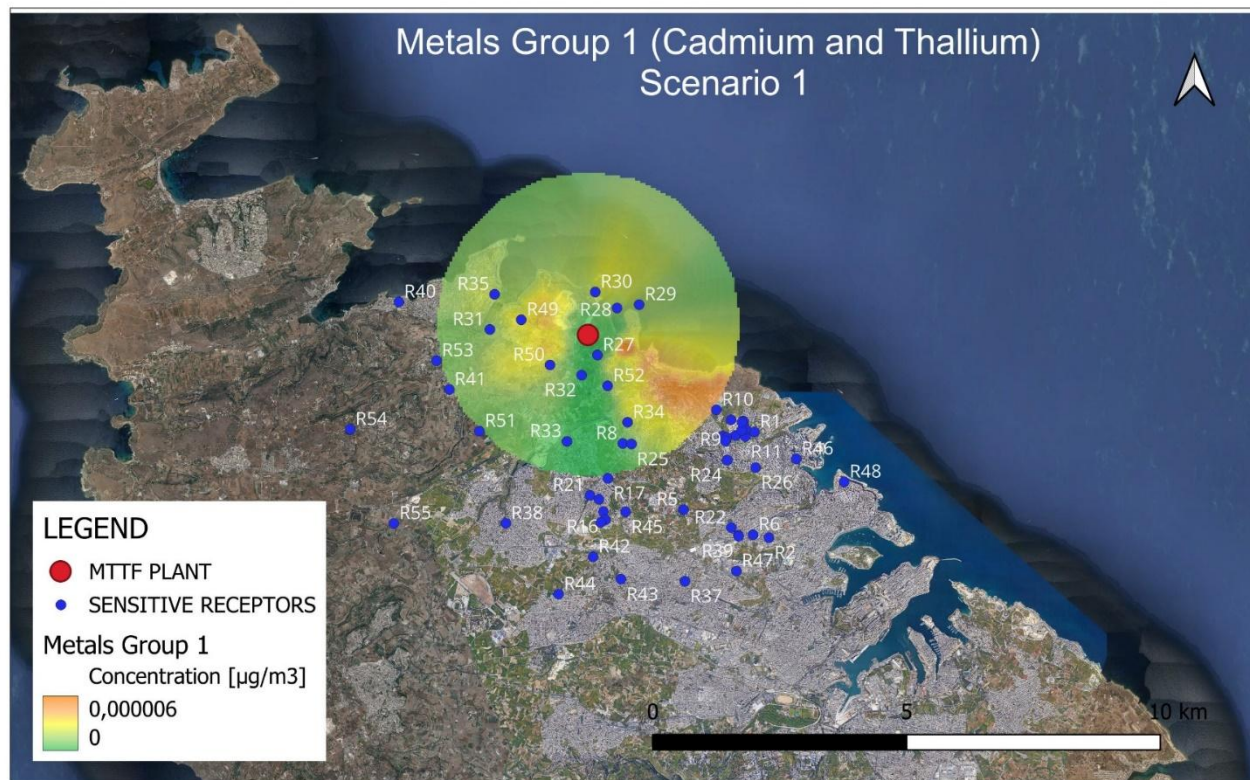
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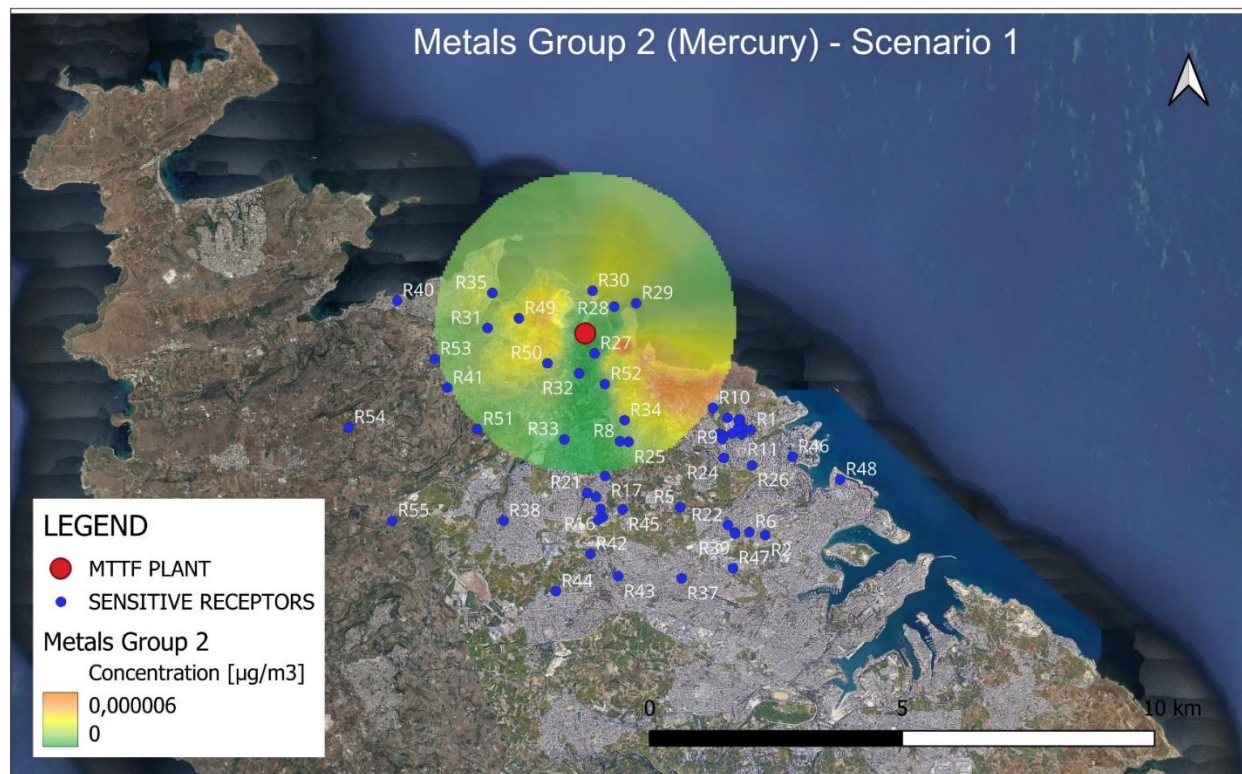
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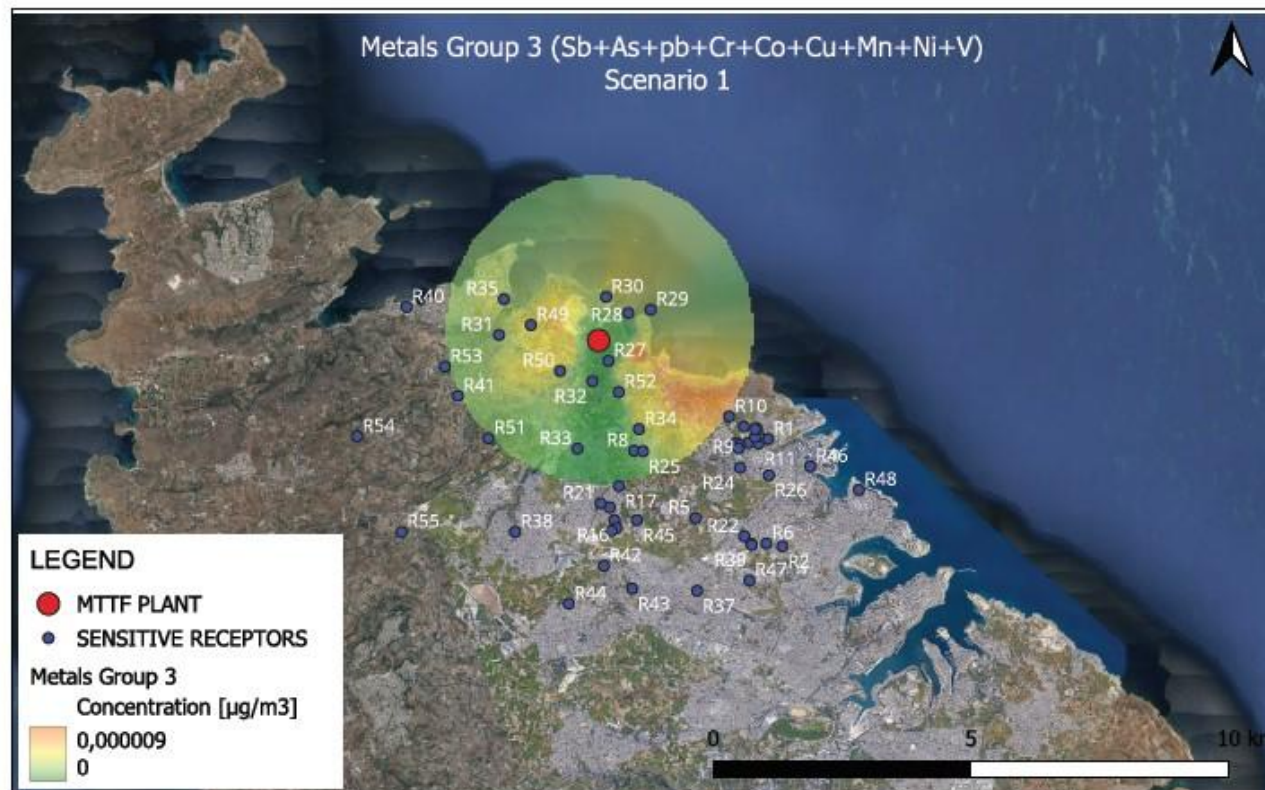
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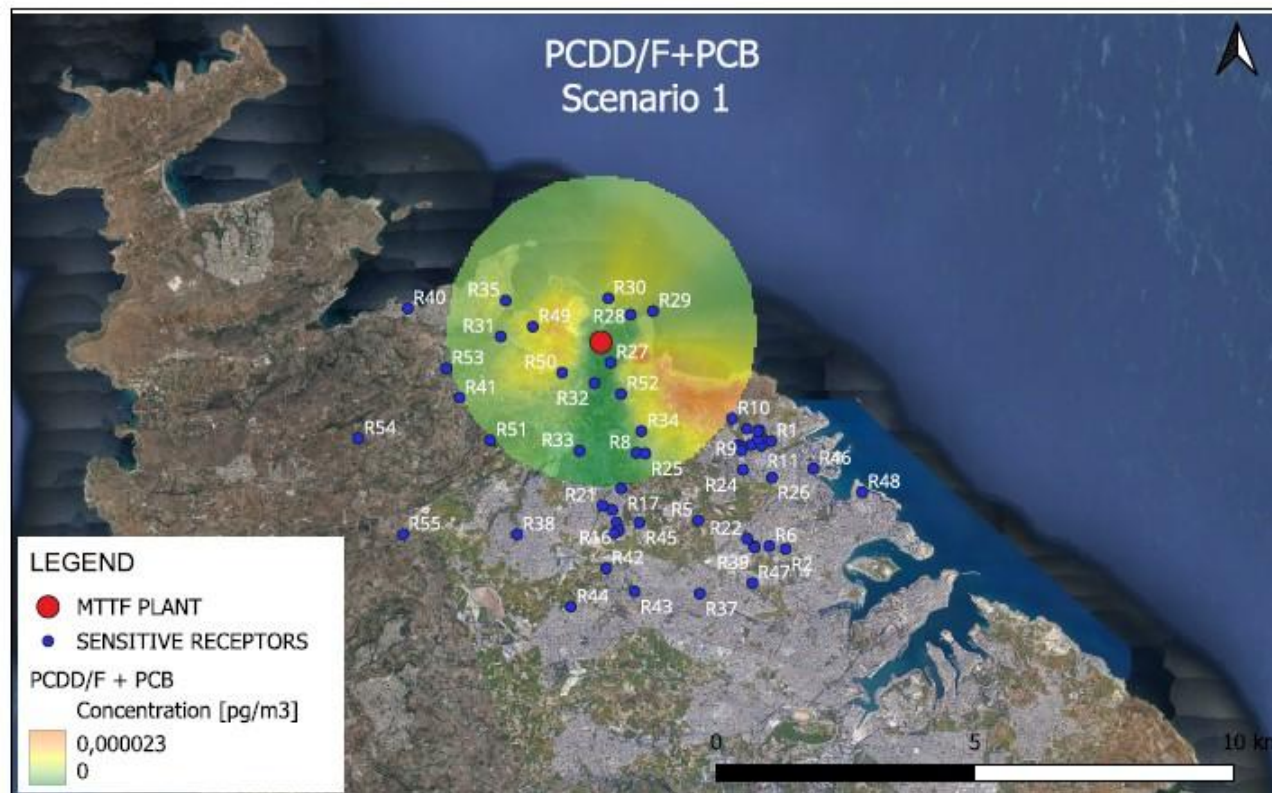
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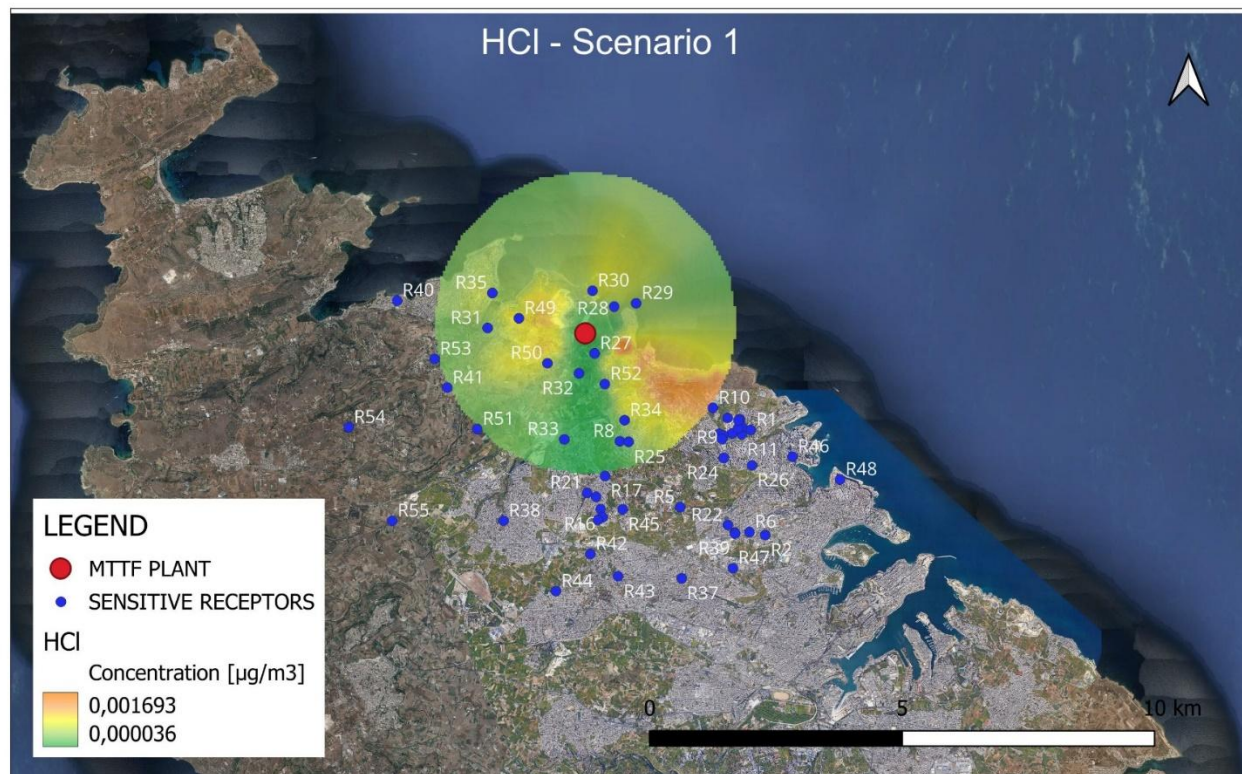
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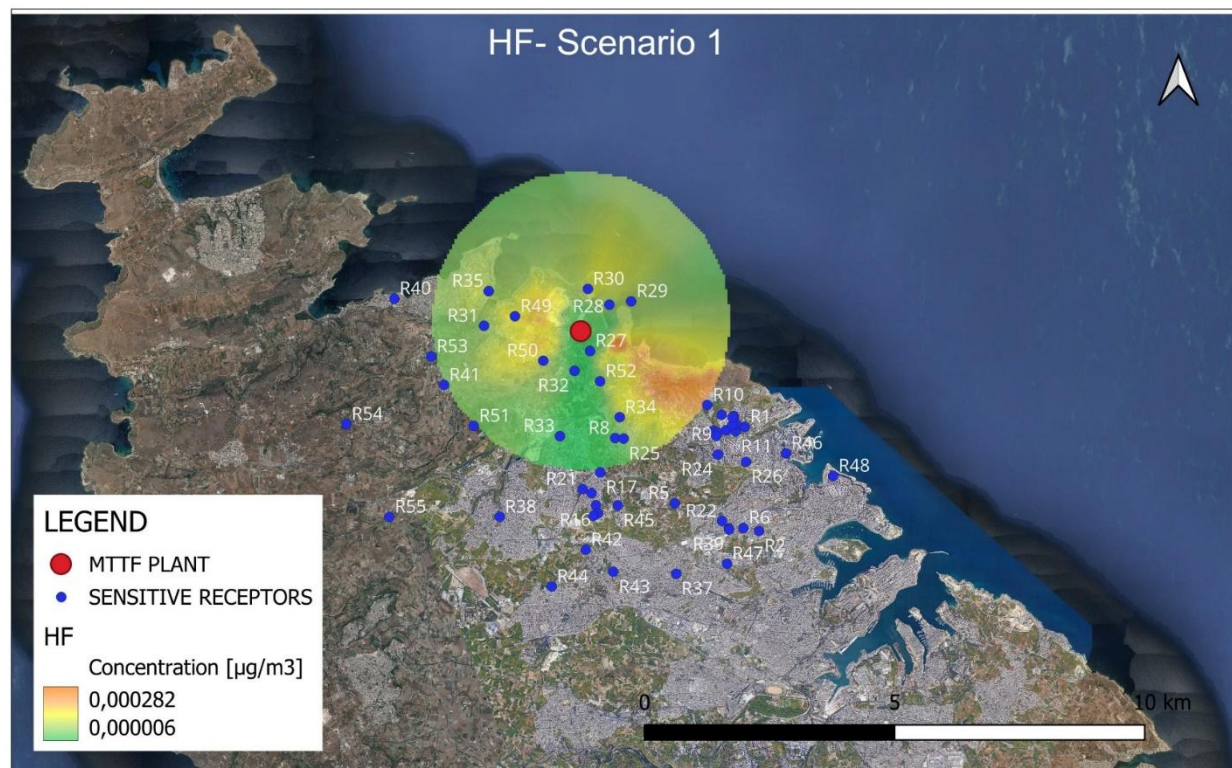
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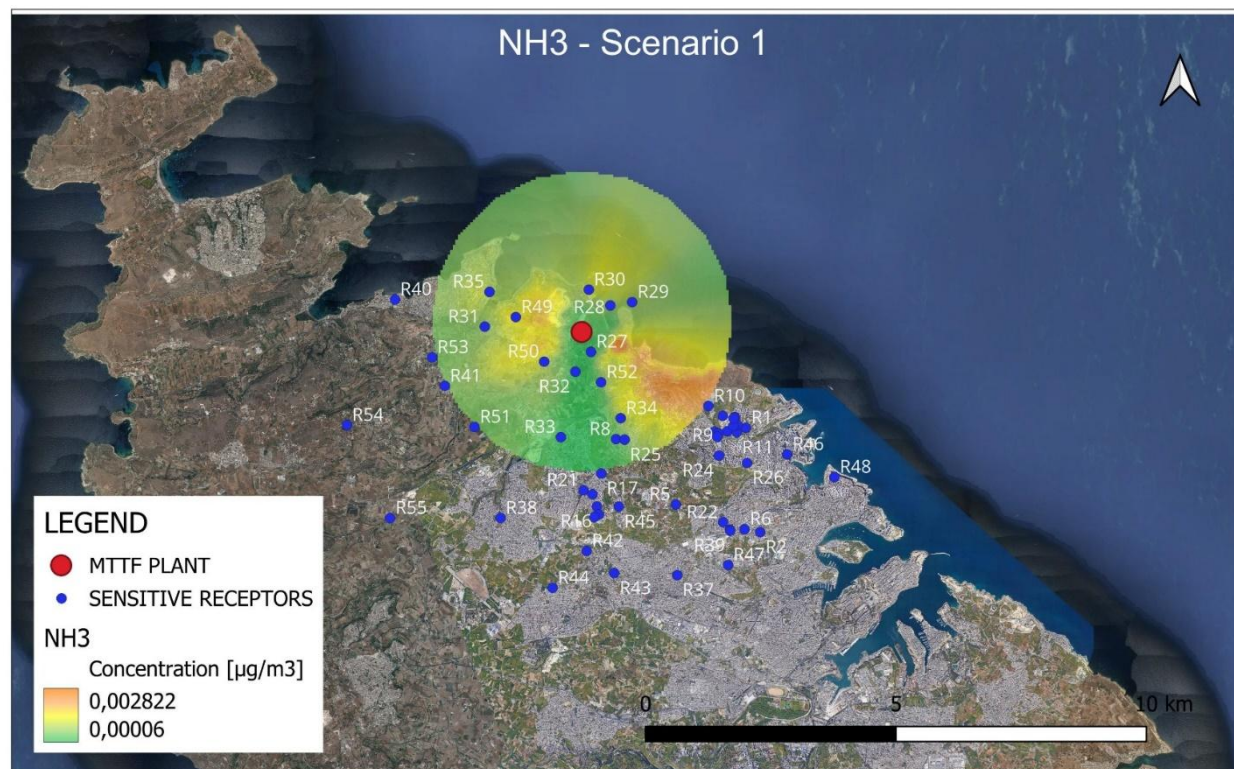
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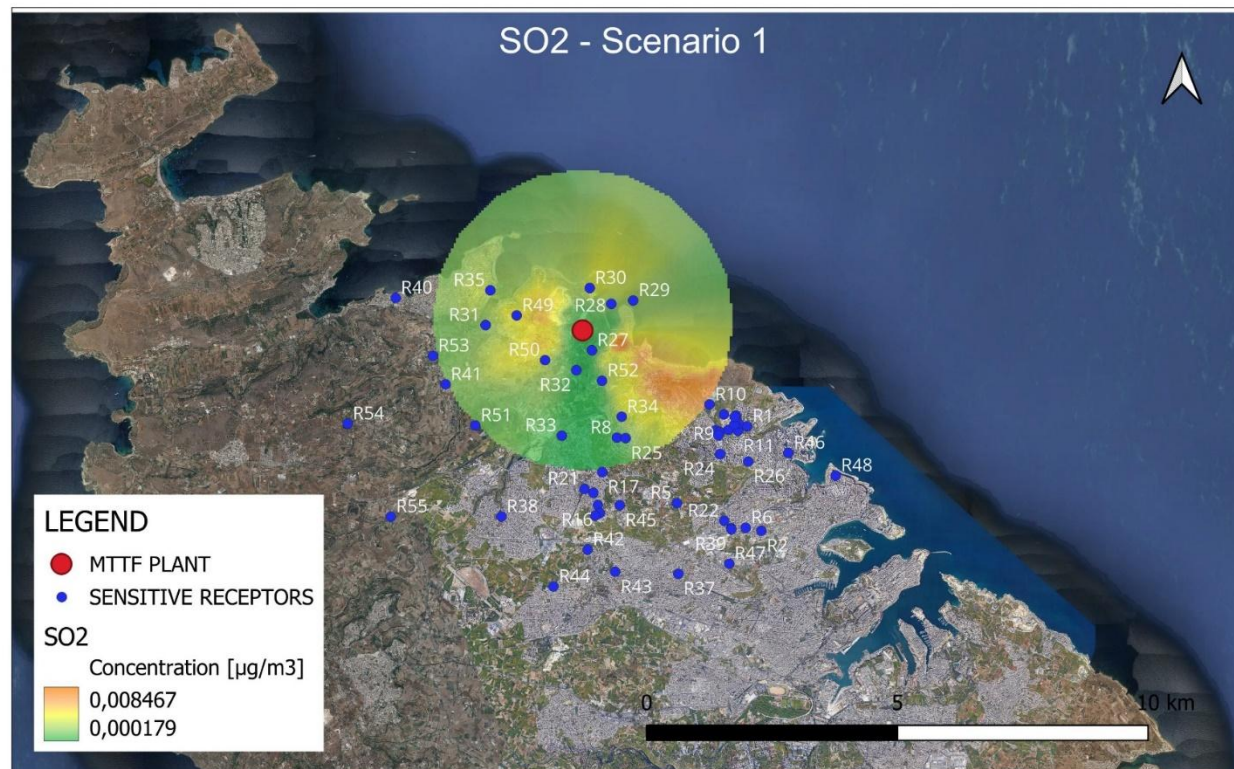
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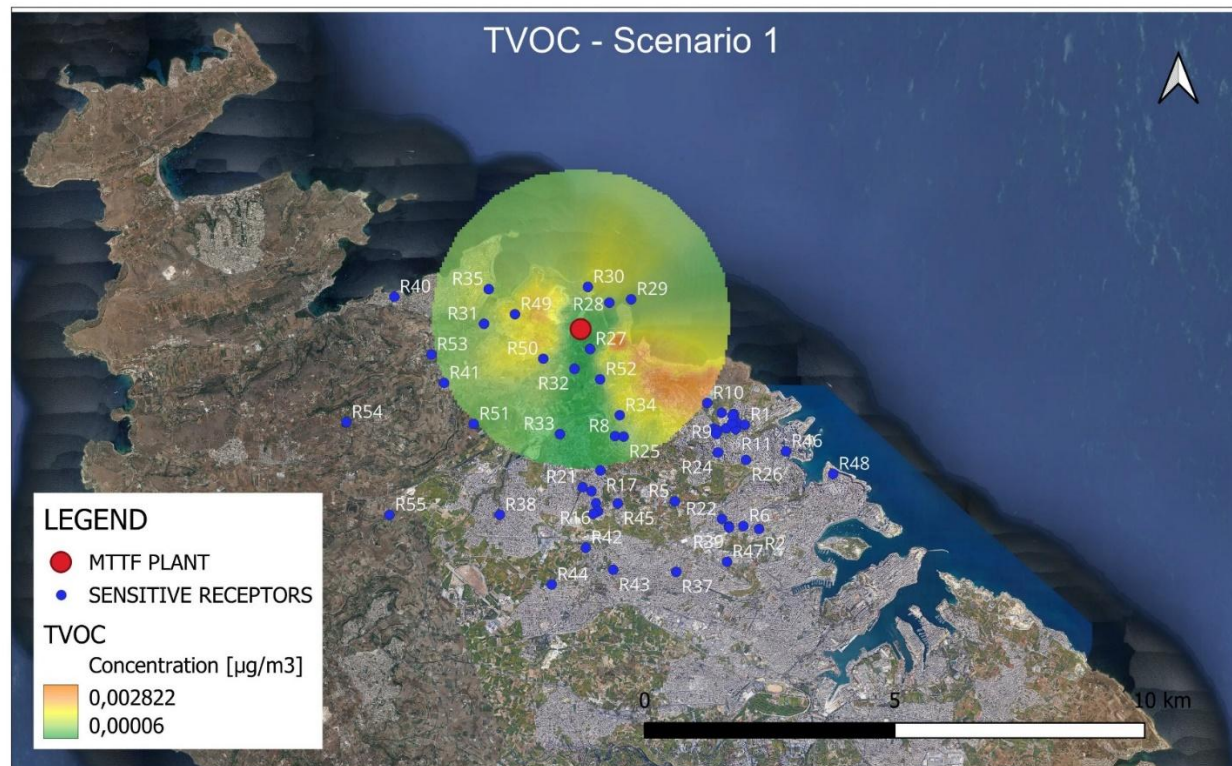
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