National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Investigation of the air quality around the landfill Sint Maarten 2019

Measurements and results of the MOD field visit in January 2019

RIVM Report 2019-0056

P. Morgenstern et al.

National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

Investigation of the air quality around the landfill Sint Maarten 2019

Measurements and results of the MOD field visit in January 2019

RIVM Report 2019-0056

Colophon

DOI 10.21945/RIVM-2019-0056

P. Morgenstern (author), RIVM
E. van Putten (author), RIVM
A. Stolk (author), RIVM
L. van Leeuwen (author), RIVM

Contact:
Pepijn Morgenstern
CBRN response organisatie
Pepijn.Morgenstern@rivm.nl

This investigation was performed by order, and for the account of the Ministry of VROMI, within the framework of the Environmental Incident Service.

This is a publication of:
National Institute for Public Health and the Environment
P.O. Box 1 | 3720 BA Bilthoven
The Netherlands
www.rivm.nl/en

Synopsis

Investigation of the air quality around the landfill at Phillipsburg, Sint Maarten, 2019
Measurements and results of the MOD field visit in January 2019

At the beginning of 2019, the RIVM measured the air quality around the landfill at Philipsburg, Sint Maarten for two weeks. No or hardly any harmful substances were measured. During the measurement period there were no open fires at the landfill. As a result, the RIVM is unable to assess the potential health risks of substances released in the event of an open fire at the landfill. In order to do so, it is necessary to take measurements during an open fire. The local fire department could perform this task. RIVM can support the fire brigade with specialized equipment and knowledge.

The measurements were taken by the Environmental Incident Service (MOD) of the National Institute for Public Health and the Environment (RIVM) between 24th January and 6th February 2019. The measurements were taken at a distance of 500 to 2500 metres from the landfill. The RIVM did not perform any measurements at the landfill itself. The locations were chosen to provide a good insight into the possible exposure of the local population.

Measurements were taken to identify the following substances: particulate matter (PM10), inorganic gases, Volatile Organic Components (VOC), aldehydes, Polycyclic Aromatic Hydrocarbons (PAHs), dioxins and Polychlorinated Biphenyls (PCB). This is a broad "package" of substances that might be relevant in case of a fire. From the 206 samples taken, a representative selection of 90 samples was analyzed in special laboratories.

In some cases, the concentrations of aluminum and possibly of chromium measured were found to exceed the standards that apply if people were to breathe these substances continuously throughout their lives. However, the health effects of these exceedances are negligible. For PAHs, some samples exceeded the standards that would apply if these substances were ingested daily during a lifetime. This results in an almost negligible health risk. The odour nuisance that people experience can cause health problems such as nausea and headache.

Keywords: MOD, RIVM, air quality, waste, landfill, fire, Sint Maarten, odour, Irma

Publiekssamenvatting

Onderzoek naar de luchtkwaliteit rond de afvalberg, te Philipsburg, Sint Maarten, 2019

Metingen en resultaten van het MOD onderzoek januari 2019

Begin 2019 heeft het RIVM twee weken lang de luchtkwaliteit gemeten rond de stortplaats van Philipsburg, Sint Maarten. Er zijn niet of nauwelijks schadelijke stoffen gemeten. In de meetperiode waren er geen uitslaande branden op de vuilstort. Het RIVM kan dus niet beoordelen wat de mogelijke gezondheidsrisico's zijn van stoffen die vrijkomen bij uitslaande branden op de stortplaats. Om dat wel te kunnen doen, is het noodzakelijk om tijdens een brand te meten. Deze taak zou de lokale brandweer kunnen uitvoeren. Het RIVM kan de brandweer indien nodig ondersteunen met apparatuur en kennis.

De metingen zijn tussen 24 januari en 6 februari uitgevoerd door de Milieu Ongevallen Dienst (MOD) van het RIVM. Op afstanden van 500 tot 2500 meter van de stortplaats zijn op diverse plekken metingen gedaan. Op de afvalberg zelf is niet gemeten. De meetlocaties zijn zo gekozen dat ze een goed inzicht geven in de mogelijke blootstelling voor de lokale bevolking.

Er zijn metingen gedaan naar: fijn stof (PM10), anorganische gassen, Vluchtige Organische Componenten (VOC), aldehyden, Polycyclische Aromatische Koolwaterstoffen (PAK's), dioxinen en Polychloorbifenylen (PCB). Dit is een breed 'pakket' van stoffen waar bij een brand naar kan worden gekeken. Van de 206 genomen monsters is een representatieve selectie van 90 monsters geanalyseerd in speciale laboratoria.

In enkele gevallen overschrijden de gemeten concentraties aluminium en chroom de normen die gelden als mensen deze stoffen continu, hun leven lang inademen. Het gezondheidseffect van deze overschrijdingen is echter verwaarloosbaar. Voor PAK's overschrijden enkele monsters de normen die gelden als deze stoffen gedurende een heel leven via de mond zouden worden ingenomen. Dit levert een vrijwel verwaarloosbaar gezondheidsrisico op. De geurhinder die mensen ervaren kan gezondheidsklachten veroorzaken, zoals misselijkheid en hoofdpijn.

Kernwoorden: MOD, RIVM, luchtkwaliteit, afval, afvalberg, brand, Sint Maarten, geurhinder, Irma

Contents

1 Introduction

1.1 Background and context

The Environmental Incident Service (MOD) of the National Institute for Public Health and the Environment (RIVM) was commissioned to conduct research for the government of Sint Maarten. The request concerned support (in the form of technical assistance) in identifying the potential public health impact of fires at the landfill.

Regular outbreaks of fire at the Sint Maarten landfill generate dense clouds of smoke, a nuisance that affects a great many people. Apart from general known health concerns regarding smoke, there is no additional information available for this specific site. The government of Sint Maarten lacks the expertise to measure the possible impact this smoke might have for public health.

The Ministry of the Interior and Kingdom Relations has offered the government of Sint Maarten support, by requesting the RIVM's MOD to take measurements in order to assess the air quality around the landfill in relation to open fire on the landfill.

1.2 Aim / objectives

MOD's investigation was commissioned by Sint Maarten's Minister for Public Housing, Spatial Planning, Environment and Infrastructure (VROMI). Three questions were central to this investigation:

1. Which potentially hazardous substances released by the fire on Sint Maarten will MOD's measurement technology be able to identify?
2. What substances are currently being deposited there or have been deposited there in the past?
3. What potential public health risks do the identified substances pose?

1.3 Scope

The aim of our study was to measure hazardous materials in the air resulting from a fire. During our study, no fires broke out at the landfill. Therefore our research was limited to a 'no open fire scenario'. The research focused on gas and particulate matter in the area (downwind) where people potentially would be exposed. Sampling of crops has been considered, but there was no agricultural activity observed on the island (almost all food is imported), so that exposure route was considered irrelevant. Soil and water were not investigated.

Occasionally, the MOD took samples when odour was detected, presumably from the landfill. Occasionally, when there was activity involving excavators at the landfill, fumes from smouldering fires within the landfill were seen from a distance.

RIVM's MOD visited Sint Maarten from 21st January to 8th February 2019. Measurements were conducted between 24th January and 6th February 2019 (14 days).

2 Study design

2.1 Open fire versus smouldering fire

The purpose of this investigation was to carry out measurements of the potentially hazardous substances produced by an open fire at the landfill. This open fire did not occur. In the event of an open fire, massive amounts of black smoke would be expected. A lot of smoke presents good opportunities to measure the composition of the smoke and provides a picture of the 'worst case situation'. To study the potential effects that an open fire would have on public health, an actual fire is needed. Since there was no fire, these effects could not be studied.

In the absence of an open fire, measurements were taken in the surroundings of the landfill for 'no open fire conditions' over a period of 14 days. There was some marginal smoke produced by smouldering fires at the landfill and an odour presumably originating from the landfill was sometimes detected in the field. This might have had some influence on the measurements, but this is expected to be marginal.

2.2 Sampling, measurement, analysis, applied techniques

In this report, all three terms are used in a slightly different context. Measurement is the most general term and includes both measurements on-site (in the field) and the analysis conducted afterwards in a laboratory. Some measurements taken in the field, using field detection equipment, yield an immediate result: a component is detected or not. In general, the detection limit (lower limit of detection) of this type of equipment is high. This means that only high concentrations of a substance can be detected. Other measurements are done by sampling in the field in order to conduct an analysis in a laboratory afterwards. The detection limit of most analysis done is very low. This means low concentrations can be detected. In this study, RIVM has conducted specific measurements and analysis related to expected components in smoke. Samples were analysed by TNO Utrecht, RIKILT Wageningen, RPS Breda and RIVM's own laboratory at Bilthoven in the Netherlands. For personal protection of the RIVM team-members, also radiation detection equipment was used. No radiation was detected.

2.3 Measurement techniques and strategies

In Appendix 1, the instruments and techniques that are used in the field are described in greater detail. The measurement techniques basically consisted of the following categories:

1. Field detection that yields instantaneous (direct) information. For example, the multiRAE for inorganic gases.
2. Collecting gases for analyses. Examples are sample techniques such as canisters, 3M^{TM}-badges (Figure 1, a), aldehyde cartridges.
3. Collecting particulate matter in the air for analysis in a laboratory. There were four Leckel 'base stations' (Figure 1, b) where PM in the air was collected 24/7. KFG equipment (Figure *2*, a) was used for two hours of sampling at various locations.

4. A measurement-schedule was drafted to sample these various locations frequently. Field observations such as: ‘we smell an odour that seems to be related to the landfill’ were noted for all samples.
5. Collecting deposited (coarse) dust from smooth objects for a ‘historical perspective’ (Figure 1, c) and collecting coarse dust from petri dishes for a ‘two-week perspective’.

All the applied sampling and measurement techniques are described in more detail in Appendix 1.

Figure 1. 3M badge for passive sampling at location 1 (a), Leckel filter equipment at location D (b) and swiping dust for historical interpretation (c).

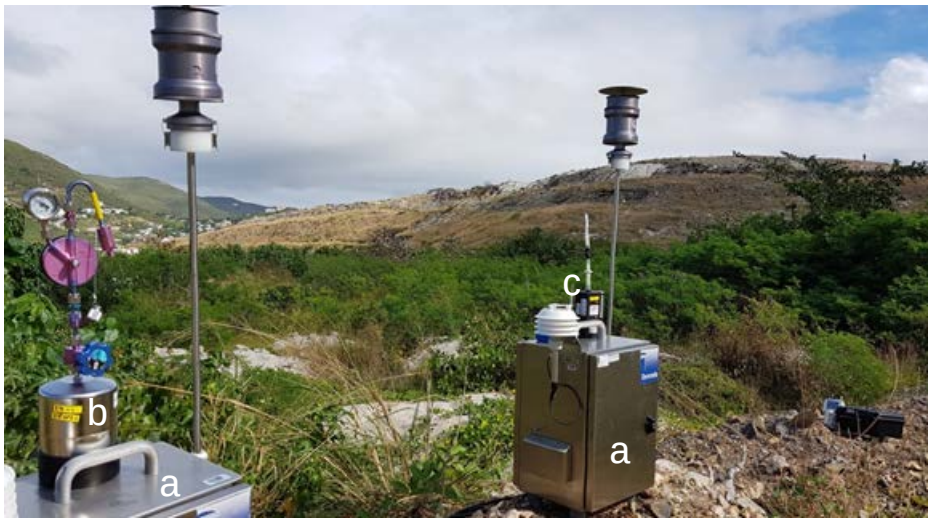


Figure 2. Two KFG dust samplers (a), canister (b) and pump with sorbent tube (c) at VROMI yard (location 4).

2.4 Sampling locations

Most sampling locations were chosen during the first two days of our stay. Some additional locations where added in the course of the field work. The selection of the sampling locations was based on the following principles:

For *downwind* measurement locations:

- With the prevailing wind direction (usually between south-east and north-east) in mind, measuring locations should be exposed to emissions from the landfill. However, local orography has a great influence on the airflow and local winds can deviate greatly from the direction of the prevailing wind. The smoke of past fires moved towards the sea via Fort William or via Little Bay. This was taken into account when measuring locations were selected. Figure 3 gives a general impression of local airflows under easterly (dominant) wind conditions.
- Relevant measuring locations should be located at sites where, in general, the local population might be exposed to emissions from the landfill.
- At measurement locations, the influence of disturbing local sources should be minimized as much as possible. In the area around the landfill, local traffic was expected to have the largest influence on the measurements. The selected measurement locations were chosen in such a way that the influence of the traffic emissions was assumed to be as minimal as possible.
- At measuring locations with continuous sampling equipment, a power supply is required. Also, the location should have no free public access.

Figure 3 *Local airflow under easterly wind conditions*

For *upwind* measuring locations:

- Upwind measurement locations are intended to determine the composition of the air before it is affected by emissions from the landfill. These locations may therefore not be affected by emissions from the landfill itself. Also, the influence of local emissions should be minimized.

Furthermore, the MOD had to take into account:

- Emissions from an asphalt plant on the north side of the landfill might influence the measurements. In order to make an estimation of these emissions possible, additional measurement locations were setup for this purpose. This turned out to be an irrelevant factor, since there was no activity at the asphalt plant during our measurement period.
- The wind speed during the day can differ from the wind speed at night (as shown in Figure 4).

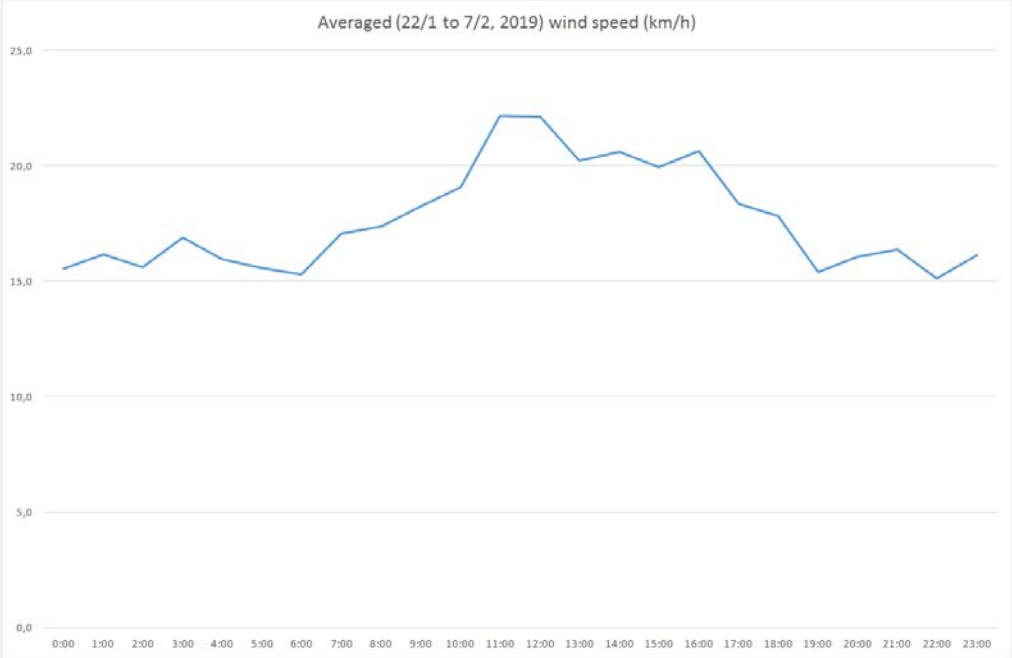


Figure 4 Averaged wind speed during the day for the period of 22th January to 7th February 2019.

In total, four monitoring locations (A-D) were chosen and fourteen other locations (1-14) were chosen for additional sampling. All locations are depicted in Figure 5 and a summarized description of the locations is given in Table 1.

Additional information on the locations and applied techniques is given in Appendix 1, Appendix 2 and Appendix 3.

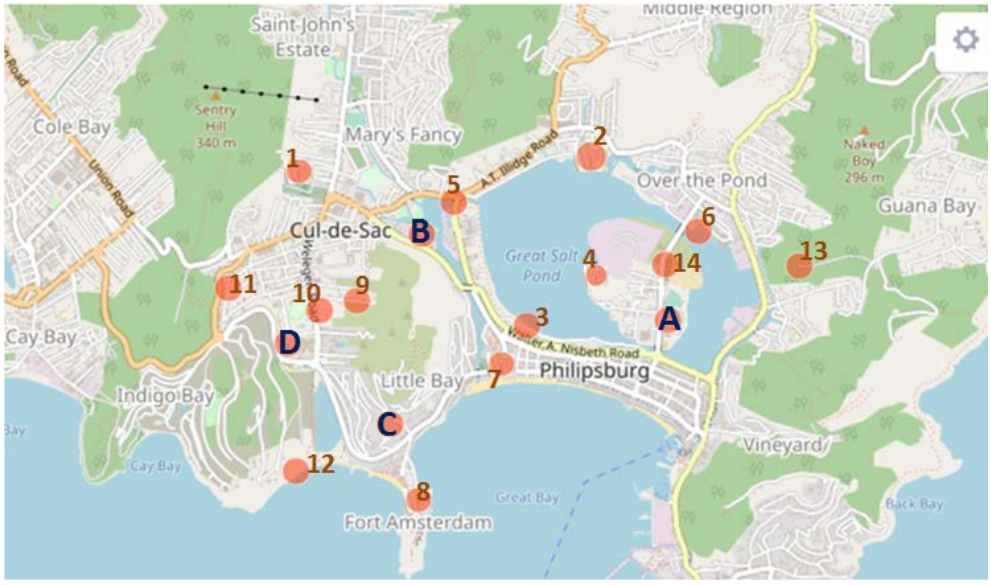


*Figure 5 Map of all sampling locations (●); **A-D** are fixed monitoring locations with Leckel 24/7 sampling equipment and **1-14** are historical and instantaneous locations using other techniques*

Table 1 Summarized description of locations and remarks

Code	Description	Continuous monitoring	Non-continuous monitoring
A	Festival terrain (upwind)	LE PA WI	KF CA SO AL
B	Miss Lalie	LE PA WI	CA SO AL
C	Belair	LE PA WI	CA SO AL
D	Fire department	LE PA WI	CA SO AL
1	Sugar Hill Drive	PA WI PE	KF CA SO AL
2	Asphalt plant – west side	PA WI PE	
3	W.A. Nisbeth road	PA PE WI	KF CA SO AL
4	VROMI yard	PA PE	KF CA SO
5	Roundabout near waste water treatment plant A.T. Illidge Road	PA	
6	Asphalt plant – east side	PA PE WI	
7	Graveyard (Kerkhofstraat)	PA PE WI	
8	Divi Hotel	PA (PE) WI	
9	Uphill east of Welgelegen Road	PA PE WI	
10	Welgelegen Road	PA PE WI	
11	Uphill west of Welgelegen Drive	PA PE WI	
12	Squirrel Drive	PA WI	
13	Viewpoint Bloomingdale (upwind)	PA	
14	Soualiga Road (Irma landfill)	PA	KF AL CA SO

Legend for Table 1

LE: Leckel air filter
KF: KFG air filter
CA: canister
SO: Sorbent tube
PA: Passive VOC (3M badge)
AL: Aldehyde sampling
PE: Petri dish Wipe
WI: Wiping of fixed objects

2.5 Health based guideline values to assess the risks of smoke

When accepting the assignment, RIVM assumed that substances could be measured in the smoke from an open fire during the investigation period. Smoke is a complex mixture of a large number of chemicals. Health complaints and health effects from exposure to smoke are caused by the combination of various chemicals and groups of chemicals that it contains. Currently, there is insufficient scientific literature available to derive health-based guideline values for exposure to smoke, as a complex mixture. Therefore, it is not possible to make a precise assessment of the health complaints or nuisance people experience at a given location caused by exposure to smoke.
But it is possible to estimate the potential health risks by comparing the measured concentrations of individual compounds that can be present in smoke (for example PM_{10}, PAHs, dioxins, heavy metals, volatile organic compounds (VOCs) and aldehydes) to health-based guideline values for the protection of public health.

These health-based guideline values are defined as the amount of a compound to which an individual can be exposed, on a daily basis, throughout their lifetime without incurring any significant health risk. They cover both oral and inhalation exposure (and, if necessary, dermal exposure), as well as classic toxic risks and carcinogenic risks.
The quality standards are generally expressed as a tolerable daily intake (TDI), an excess carcinogenic risk via intake (CR oral) – both of which cover exposure by oral ingestion – a tolerable concentration in air (TCA) or an excess carcinogenic risk via air (CR inhaled), both of which cover exposure by inhalation (Baars et al., 2001).

The health-based guideline values are based on existing toxicology reviews of such compounds, i.e. reviews conducted by national and international organizations such as RIVM, WHO, EU, US-EPA, IARC, ATSDR. These evaluations are carried out by national or international committees or by experts from home or abroad. They are generally considered to be critical and well-validated data sources.
The underlying dataset used for these reviews consists of the results of studies conducted into the effects of the compound in question in humans, a variety of toxicological endpoints investigated in animal experiments, plus information regarding the dose-effect relationship and regarding the mechanism (or mechanisms) of the toxic effect (or effects) observed. Full details of how these health-based guideline values were derived are given in the report by Baars et al. (2001).

For the purposes of the current investigation, RIVM compared the measured concentrations of particulate matter, PAHs, dioxins, heavy metals, VOCs and aldehydes with the available public health-based guideline values, as described above. Based on the outcomes of this comparison, information on the potential health risk due to exposure will be provided.

If no health-based guideline values were available, measured concentrations were compared to guideline values for workers. Though such values are derived for a specific group of people under specific

exposure conditions, a comparison can give an indication of potential health risks.

2.6 Relationship to study of the World Bank Group

EE&G Disaster Response, LLC (EE&G) has been retained by the World Bank to perform a preliminary screening of smoke from subsurface fires at the “debris and disposal sites” in Phillipsburg. In our study we refer to the same area as “landfill”. The work of EE&G / World Bank was done in support of the Hurricane Irma Restoration, Recovery and Resilience Program in Sint Maarten. Their field work was conducted on the 28th, 29th and 30th August 2018. The main differences between the research conducted by EE&G/the World Bank in August 2018 and the research conducted by MOD/RIVM in January/February 2019 are described in Table 2.

Table 2 Study conducted by EE&G for the World Bank in 2018 versus study conducted by RIVM for VROMI in 2019 near the landfill, Sint Maarten

EE&G / World Bank	**MOD / RIVM**
28th, 29th, 30th August 2018	24th January - 6th February 2019
Research related to the workers on or near the landfill	Research related to local residents of Philipsburg
Research conducted on the landfill	Research conducted in the town of Philipsburg in the surroundings of the landfill (500 metres – 2500 metres away from the landfill)
No open fire, only (occasional) smouldering fire within the landfill	No open fire, only (occasional) smouldering fire within the landfill
Sampling and measurement directly from the smoke plumes	Sampling and measurement of air in the surrounding area
Same analysis as MOD with exceptions: • $PM_{2.5}$ instead of PM_{10} • Also asbestos and ozone • No aldehydes Also, there is a slight difference in some of the elements analysed	Same analysis as EE&G with exceptions: • PM_{10} instead of $PM_{2.5}$ • No asbestos and ozone • Also aldehydes Also, there is a slight difference in some of the elements analysed
Results are compared to short-term and working conditions exposure levels	Results are compared to long-term and chronic exposure levels

2.7 Experiences in the Netherlands with landfill fires

The RIVM has over 30 years of experience in the Netherlands with different types of fire, including landfills and emissions. A summary of our knowledge has been included in Appendix 13.

3 Field work and results

3.1 Field observations

3.1.1 Open fire

During this time, the MOD visited Sint Maarten (21st January – 8th February 2019) and **no** open fires occurred. The two weeks following the MOD visit (8th February – 22th February), when a Leckel filter was continuously sampling three types of particulate matter in the air, also **no** open fires occurred.

3.1.2 Smouldering fires

On some occasions limited quantities of smoke from smouldering fire within the landfill were visually detected (see Figure *6*). However the focus of our investigation was not on the landfill itself (where this small amount of smoke can be detected best) but in the surrounded area (where it was impossible to see if smoke emerged on a small scale from the landfill). Since the amount of smoke from smouldering fires was so limited and this could only be seen near the landfill the presence or absence of smoke from smouldering fire did hardly play a role in our measurement strategy. However if smoke was detected on the landfill this was noted in the description of the samples of that day.

Figure 6 *Smoke holes (brown/black spots marked by a red arrow) from smouldering fires inside the landfill.*

3.1.3 Nuisance caused by odour

Nuisance caused by odour has been experienced by our team on several occasions during the field visits. This seems to be related primarily to the strength and precise path of the wind. The origin of the odour presumably was the landfill. If odour was detected in the field this was noted in the description of the samples.

3.2 Samples taken

The total number of samples taken with each technique are given in Table 3. In total, 206 samples were taken, 90 of which (44%) were analysed in the Netherlands (the selection of samples for analysis is explained in the next paragraph).

Table 3 Description of technique, number of locations

Technique	Locations	Number of samples collected	Number of samples analysed
Leckel air filter	4	52	15
KFG air filter	5	26	12
Canister	8	29	9
Sorbent tube	8	22	9
Passive VOC (3M badge)	18	18	18
Aldehyde sampling	7	11	8
Petri dish Swipe	10	20	13
Swiping of fixed objects	14	28	6
Total	**18**	**206**	**90**

Remark: the techniques are explained in 0.

After the MOD ended its investigation (22th February), a Leckel filter was left behind to take 24-hour samples for a period of two weeks. This Leckel was placed at a location near the sewage system. The idea was to have a last chance to take samples during an open fire. However, during these two weeks no fire occurred. The filters were not analysed (as it is expected the results would be similar to the samples taken earlier). Canisters were also left behind for the fire department to take air samples in the event of a fire (which occurred March 30th 2019).

3.3 Sample selection and analysis

A lot of samples were taken, but since there was no open fire during the measurement period, it was expected that the samples contain only very low amounts of chemicals, if any at all. Therefore a selection of samples was made. The sample selection included the variety in locations on different moments within the two week sampling period. All samples taken on days and/or locations when our field team detected either smoke from smouldering fire or odour presumably from the landfill, were included for analysis. The sample selection was deemed representative for the two weeks measurement period by the experts of the RIVM. Analysis was done in the Netherlands at RIVM, RPS, RIKILT and TNO. In total 90 samples out of 206 samples were analysed (see also Table 3).

3.4 Results

All the analysis results were processed. Many of the components investigated were not found in the samples. All results of the analysed samples that were above the detection and reporting limit are included in appendices Appendix 4 - Appendix 12. An interpretation of the results is made in the next chapter (Risk Assessment).

4 Risk assessment

4.1 Introduction

The results of the monitoring campaign are believed to be an indication for the long-term situation without an open fire. Substances that were measured were far below a health-based guideline value. In the sections below and in Appendix 4 – Appendix 12, a more elaborate assessment is provided.

4.2 Risk assessment measured concentrations in air

4.2.1 PM_{10}

With respect to Particulate Matter (PM_{10}), all measured concentrations at three out of four locations were below the EU annual average exposure limit of 40 µg/m^3. At the fourth location, this limit was exceeded twice during the monitoring campaign. On one of these occasions, the 24-hour exposure limit of 50 µg/m^3 was exceeded as well. The averaged exposures over the monitoring period indicate that the PM_{10} levels were well below the annual average exposure limit and does not present any concern. Whether exceeding the daily average exposure limit is a concern cannot be concluded with certainty. Exceeding this EU limit is permitted 35 times per year. Based on an extrapolation of the two-week monitoring campaign, the limit would be exceeded 26 times.

4.2.2 PAHs, dioxins, PCBs and aldehydes

The measured concentrations of PAHs (polycyclic aromatic hydrocarbons), dioxins, dioxin-like PCBs (polychlorinated biphenyls) in PM_{10} and the concentration of aldehydes did not exceed the health-based guideline values. Therefore, exposure to the measured concentrations of these substances in the air is not expected to result in adverse health effects.

4.2.3 Elements

Elements, including heavy metals, measured in PM_{10} in the air revealed relatively high concentration results for some of the elements, whereas most other elements show low concentrations. The elements found in higher concentrations probably come from sea salt and sand being blown over the island. Of these elements, the levels of aluminium and chromium call for a deeper look. For aluminium, the (conservative) tolerable concentration in air (TCA) was exceeded by a factor of 8. However, it should be noted that the TCA has lingering uncertainties due to missing data. Hence, the TCA was reported to be very conservative. Furthermore, the measured values of aluminium showed the same concentration range as found as a background in the Netherlands and USA (ATSDR, 2008). In relation to the metal chromium (Cr), the oxidation state is relevant for the toxicity. It is unclear whether the chromium found is Cr(III) of Cr(VI)[1]. Cr(VI) is more toxic than Cr(III), but much less stable in the environment. For that reason (instability), it is assumed that most of the

[1] Additional chromium discrimination analysis that might have revealed if chromium VI was present could not be conducted, since the elemental analysis method was destructive for the samples.

chromium present in particulate matter in the air is Cr(III). The TCA for Cr(III) in air was not exceeded. In the unlikely case all chromium would be chromium (VI), the TCA would be exceeded in some samples collected during 2-hour sampling periods. However, in the 24 hour averaged Leckel samples, none of the TCA values for chromium were exceeded.

4.2.4 VOC

For the VOC, only for benzene was the chronic health-based guideline value exceeded by a factor of 2 in one sample taken near the landfill. Other samples (collected using a different sampling technique) at other locations indicated low concentrations of benzene, but not above the chronic health based guideline. For the other VOC, the available health-based guideline values were not exceeded. The fire department used canisters left behind by RIVM to sample in the event of a fire, which happened at 30th of March 2019. As Table 18 shows the results are higher than the results from the analysis carried out with the RIVM samples. However due to the lack of data of the exact measuring locations no further conclusions can be drawn based on these measurements.

4.3 Risk assessment measured concentrations in dust wipe samples

4.3.1 Dioxins and elements

The measured concentrations of dioxins and dioxin-like PCBs in dust wipe samples that could be contacted dermally or ingested via hand-to-mouth contact did not give indications that health-based guideline values would be exceeded. Therefore, exposure to these substances are not expected to result in adverse health effects.
Similarly, elements found in the dust wipe samples did not give any indications that health-based guideline values are being exceeded.
For chromium, the measured values exceed the value for Cr(VI) in the case that all measured chromium would be Cr(VI). However, it is more likely that a significant part of the measured chromium is the less toxic Cr(III), and that the health based guideline values are not exceeded. Again, it was noted that certain elements showed relatively high concentrations, which is probably due to sea salt and sand.

4.3.2 PAHs

For PAHs, the sum of the measured values expressed as benzo[a]pyrene equivalents was compared to the Virtually Safe Dose (VSD) of 0.005 µg/kg bw/day. The VSD is a chronic health-based guideline value that corresponds to a risk of an extra cancer case of one per million based on a lifetime exposure. At location ‘graveyard’, the benzo[a]pyrene equivalents amounted up to 0.009 µg/kg bw/day (highest value), which exceeds the VSD by a factor of 2. This may result in an extra risk of cancer (2 per million per lifetime exposure). Based on wind directions, as shown in Figure 3, higher levels of exposure were expected at this location and this is supported by findings of elements and dioxins at this location. PAHs may have other sources as well, such as traffic or combustion processes, and thus it is unknown whether the landfill is the primary source of the PAHs exposure. Also, the assumption has been made that the dust wipe samples are representative for the exposure potential of local residents. In any case, exposure to PAHs is undesirable, therefore RIVM advises preventing high emissions of PAHs (for example caused by

fires at the landfill) or avoiding contact with contaminated surfaces as much as possible.

4.3.3 Odour nuisance

An unpleasant odour has been detected by the RIVM in the field on several occasions, which seemed to originate from the landfill. In general, the perception of an odour can cause nuisance and even cause nausea, without being exposed to harmful amounts of a certain substance (RIVM 2009b).

5 Conclusions and recommendations

5.1 Conclusions

On the basis of these measurements, no conclusions can be drawn about the possible substances released in the event of an open fire. The following conclusions are based on the 'no open fire conditions' scenario:

- In the two weeks during which measurements were taken, only a few substances were found in low concentrations.
- For aluminium, some of the measured concentrations exceeded the health-based guideline value for chronic exposure.
- In the unlikely case all chromium would be Cr(VI), some of the measured concentrations exceeded the health-based guideline value for chronic exposure. However it is assumed that most chromium would be Cr(III) since that form is more stable in the environment. In that case, no health-based guideline values are exceeded.
- For PAHs, the concentrations found in dust wipe samples exceeded the health-based guideline value for lifelong daily intake. PAHs are emitted as a result of fires, but are also emitted through combustion gases of vehicles.
- Odour was detected by the field team. Odour nuisance can be a source of health complaints by the population.
- RIVM has detailed information about background concentrations for different components in the Netherlands, but no information on the background concentrations for Sint Maarten. This study provides an initial insight into these background conditions.

5.2 Recommendations

- The recommendation is to strive for the prevention of fire. This might reduce the amounts of elements, dioxins and PAHs in coarse dust. Alternatives to waste incineration in open burn pits are available.
- Measurements during an open fire are needed to indicate possible health risks for the population as a result of such an event. The local fire department could perform this task. RIVM can support the fire brigade with specialized equipment and education. An additional project could strengthen this collaboration.

Appendix 1 Sampling and measurement techniques

The instruments and techniques that were used in the field are described in Table 4. The content is explained below the table.

Table 4 Instruments, techniques, components, measurement period

Components measured / analysed	**Coarse dust**	**Particulate Matter 10 µm (PM_{10})**	**Particulate matter per fraction 0.3 | 0.5 | 1.0 | 2.5 | 5.0 | 10 µm**	**PAHs**	**Dioxin**	**Elements (including heavy metals)**	**VOC**	**Aldehydes**	**Hg**	**Radioactivity (β and Y)**	**Inorganic: CO |H_2S | SO_2 |HCN | CL2 | |PH_3 | NH_3 | NO | NO_2**	
Instrument / technique												**Measurement period**
Low Volume Sampler Filter, Sequential sampler (**Leckel** SEQ47/50)		x		x	x	x						24 hours / 7 days a week
Low Volume Sampler Filter, small filter device (**KFG**)		x		x	x	x						± 2 hours
Dust particle counter (**Lighthouse** 3016 IAQ)			x									Continuous / minute
Canister							x					± 2 hours
3M (3500 **badge**)							x					± 2 weeks
Activated charcoal tube (SKC226-01)							x					± 2 hours
Aldehyde cartridge (Waters DNPH)								x				± 2 hours
Wipe sample	x			x	x	x						Historical / ± 2 weeks
Gas screening for personal protection (MultiRAE)											x	Instantaneous / continuous

Components measured / analysed	**Coarse dust**	**Particulate Matter 10 µm (PM_{10})**	**Particulate matter per fraction 0.3 | 0.5 | 1.0 | 2.5 | 5.0 | 10 µm**	**PAHs**	**Dioxin**	**Elements (including heavy metals)**	**VOC**	**Aldehydes**	**Hg**	**Radioactivity (β and Y)**	**Inorganic: CO |H_2S | SO_2 | HCN | CL2 | PH_3 | NH_3 | NO | NO_2**	
Instrument / technique													**Measurement period**
Mercury vapour monitor (Lumex RA-915)									x				Instantaneous / continuous
IdentiFINDER for personal protection (FLIR R400)										x			Instantaneous / continuous
Niton-XL3t XRF						x							Instantaneous

Underlined and bold: as frequently used in this report

Explanation of the components measured / analysed:

- Coarse dust: coarse dust is released during fires and can be analysed for its components. Coarse dust includes both small and large particles. Coarse dust can be sampled by wiping a surface (the techniques are explained on the next page).
- Particulate matter: these particles are much smaller than coarse dust and are defined by their diameter. PM_{10} contains particles with a diameter smaller than 10µm. PM_{10} can be collected on a filter (both on the Leckel and the KFG filter equipment) and analysed for elements, PAHs and dioxins. The lighthouse particle counter was used to gain some insight into the differentiation of the diameters (no conclusive insights could be made however).
- Polycyclic aromatic hydrocarbons (PAHs): a group of organic compounds made up of two or more benzene rings. Always released during fires and considered to be suspected carcinogens. Coarse dust and PM_{10} samples were analysed for PAHs.
- Dioxin: a collective name for a group of organic compounds, some of which highly toxic, that can be formed when materials that contain chlorine, such as plastics, are burned. Coarse dust and PM_{10} samples were analysed for dioxin.
- Elements (including heavy metals): all types of elements can be released during a fire, depending on the material that is being burned. Some heavy metals, in particular, are considered highly toxic, such as lead and cadmium. Coarse dust and PM_{10} samples were analysed for elements.
- Volatile organic compounds (VOC): the collective name for a group of hydrocarbons that readily vaporize. For instance, the components of fuels and solvents. These substances are related to a number of different environmental problems, including climate change, smog (including summer smog), and acidification. Furthermore, some of these substances are known to have potentially harmful effects on human health. Air samples taken by canister, 3M-badge and charcoal-tube were analysed for VOC.
- Aldehydes: a collective name for a group of chemical compounds with a common structure. Many have a strong odour. Aldehydes are used in products such as glues, resins, perfumes and hairsprays. Aldehydes can be carcinogenic. Aldehydes are sampled on special DNPH cartridges.
- Hg (mercury), radioactivity and inorganics: these measurements were mostly done for personal protection / as a check.

Explanation of the instruments / techniques used:

- Leckel: we used this low-volume filter sampler to collect particulate matter with an aerodynamic diameter <10µm (PM_{10}) at four fixed ‘base locations’. Every day a new filter was sampled for 24 hours, seven days a week. Therefore the result gives good insight into the daily concentration of PM_{10}. The filters are analysed for PM_{10} concentration and the presence of PAHs, dioxin and elements (heavy metals). See Figure 7.
- KFG: we used this low-volume filter sampler to collect particulate matter with an aerodynamic diameter <10µm (PM_{10}) at various locations. The sampling time was around two hours per sample. We tried to gain extra insight through our sampling

strategy, e.g. by sampling at a short distance from the landfill and longer distances and at times and places where odour was detected. The filters are analysed for PM_{10} concentration and the presence of PAHs, dioxin and elements (heavy metals). See Figure 8.

- The lighthouse detector was used to measure particulate matter in the field in combination with both Leckel and KFG, but only for confirmative purposes. See Figure 9.
- Three sampling techniques were used with respect to Volatile Organic Compounds (VOC).
  - A canister is a metal vacuum sphere that can be filled with air during a determined period of time. We sampled for ±2 hours per sample.
  - The 3M™-badges work through vapor diffusion (a passive type of sampling) and our sampling period was ±2 weeks.
  - The charcoal tubes are filled with a sorbent (charcoal). Air is actively pumped through the tube for ±2 hours per sample.

  All (three) sampling techniques require analysis in a laboratory afterwards. See Figure 10.
- Aldehyde cartridges are specially designed to capture chemicals in the group of aldehydes (such as formaldehyde, acetone, etc.). Air is actively pumped through the cartridge for ±2 hours per sample. The samples are analysed in a laboratory afterwards. See Figure 11.
- Wipe sampling (Figure 12) of coarse dust was done primarily in three manners:
  - 'Historical' samples were taken by swiping coarse dust off a known surface (e.g. 25 cm^2) from smooth objects upon initial arrival at a location (for example, a stone at the graveyard). As can be imagined, this yields the dust deposited during a unknown timeframe.
  - 'Two weeks' samples are from exactly the same locations as the 'Historical samples' but wiped after two weeks.
  - 'Petri dish' samples are collected by placing petri dishes at chosen locations and wiping the petri dish after a period of ±14 days.
- Several techniques that are normally used for personal protection were applied during the field visits. The multiRAE sensors detect inorganic gases such as CO, H_2S, etc. If a fire were to occur, this equipment would collect information on inorganic compounds released as a result of the fire. Additionally, a mercury detector and equipment to detect radiation were also applied. Since nothing was detected using these techniques, no results are included in this report.
- A Niton handheld XRF was used in the field to obtain an initial estimate (semi-quantitative) of the heavy metals collected on filters. Since the analysis in the laboratory yields much more reliable and quantifiable results, no niton results are included in this report.

Figure 7 Leckel 24/7 dust sampler at Belair (location C)

Figure 8 Leckel 24/7 dust sampler (a), KFG dust sampler (b), canister (c) and pump with sorbent tube (d) at the festival terrain (location A)

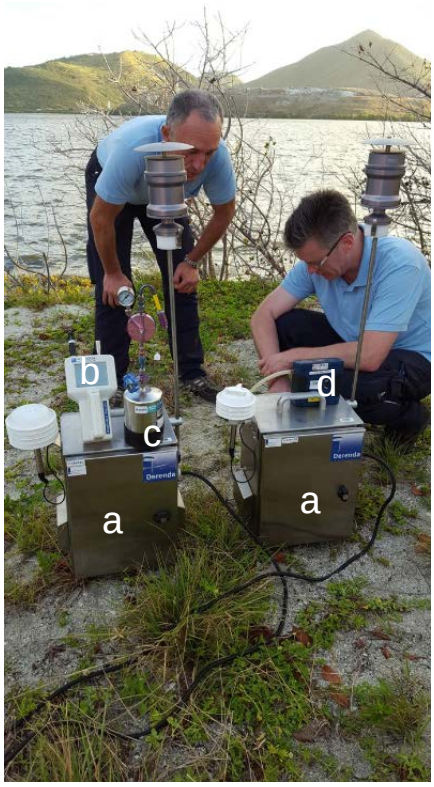


Figure 9 Two KFG dust samplers (a), a lighthouse dust detector (b) a canister (c) and pump with adsorption tube (d) at W.A. Nisbeth road (location 3)

Figure 10 *Pump (a) with charcoal tube, 3M™-badge (b) for passive sampling and metal canister with restrictor (c) for a sampling time of ± 2 hours at Belair (location C).*

Figure 11 Pumps with active carbon tube (a) and aldehyde cartridge (b)

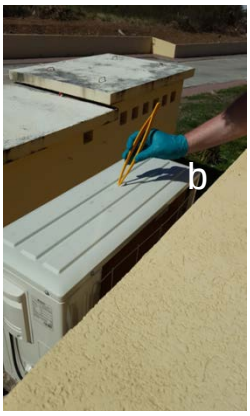


Figure 12 Dust sampling: wiping a Petri dish (a) and a 'historical wipe' (b).

Appendix 2 Location description and strategy

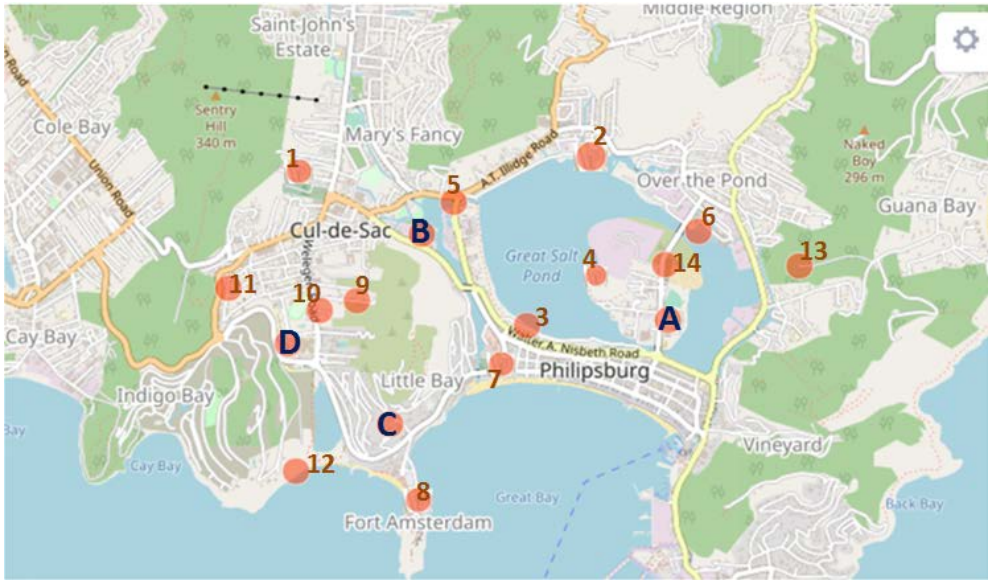


Figure 13 *Map of all sampling locations (●); **A-D** are fixed locations with Leckel 24/7 sampling equipment and **1-14** are locations with other techniques*

The locations can be classified into a few groups:

1. *Locations with continuous sampling of particulate matter (PM_{10}).*
   At these locations, daily samples of particulate are taken by the Leckel sampler. These samples can be used to determine the daily average PM_{10} concentration and can afterwards be analysed for the presence of heavy metals, polycyclic aromatic hydrocarbons (PAH) and dioxins.
   In addition to the Leckel sampler, these locations are also provided with a passive sampler. This sampler will indicate the average concentration of Volatile Organic Compounds (VOC) during the measurement campaign.
   At the start and at the end of the campaign, wipe samples were taken here.
   At regular intervals, mobile measurement equipment was used at these locations in order to monitor the emission from the landfill under smouldering conditions.
   Measurement locations in this group are: A-B-C-D, whereby location A is used for background measurements (marked * in Table 5).
2. *Measurement locations selected for additional measurements in the event a fire occurs.*
   In the event of a fire at these locations, mobile measurement equipment would be used for sampling the compounds released by the fire. When no fire occurs, measurements are taken at these locations at regular intervals in order to monitor the emission from the landfill under smouldering conditions. In addition, VOC sampler measurements and wipe samples are taken at these locations.Measurement locations in this group are: 1-3-4.

3. *Measurement locations used for information on the spatial distribution of released compounds*
   These locations were selected to get a more complete impression of the spatial distribution of compounds released by the landfill in addition to the measurements in groups 1 and 2.
   At these locations, only VOC sampler measurements and wipe samples are taken.
   Measurement locations in this group are: 7-8-9-10-11-12-13, such that 13 is used as background measurement without any traffic emissions (marked *). At this location, no wipe samples were taken.
4. *Locations for determining the influence of local emissions.*
   To produce estimates of the influence of local emission sources, some additional measurement locations were selected.
   Locations 2 and 6 were set up to monitor the contribution of emissions from the asphalt plant. Location 6 was to be used for background measurements here (marked * in Table 5).
   During the campaign, no activity was observed at the asphalt plant, so no mobile measurements were performed here during the campaign and therefore only VOC sampler measurements and wipe samples were taken at these locations.
   Location 5 was used as an indicator for local traffic emissions. Here only a passive VOC measurement was taken.
5. Location for monitoring smouldering emission
   In order to get an idea of the emissions from the smouldering landfill, location 14 was set up. At this location, a strong odour of smouldering material is almost always present. Measurements taken here can be used as a worst-case indicator for landfill emissions when no fire is present.

Table 5 Description of locations, sampling methods and remarks.

Code	Description	Remarks	classification	Continuous monitoring	Non-continuous monitoring
A	Festival terrain	Used for background measurements	1*	LE PA WI	KF CA SO AL
B	Miss Lalie	Situated on the rooftop in order to minimize influence of traffic emissions. Expected to be exposed to the highest concentration in the event of a fire when wind is from a SE-E direction.	1	LE PA WI	CA SO AL
C	Belair	Situated at a (unused) parking location of an apartment complex. Location is located on a hillside in order to minimize the influence of traffic emissions. Is expected to be exposed when wind is from a NE direction.	1	LE PA WI	CA SO AL
D	Fire department	Situated on a rooftop of the fire department. Is used to give an indication of ambient levels at a more remote location.	1	LE PA WI	CA SO AL
1	Sugar Hill Drive	In a residential area where the population is expected to be exposed to relatively high concentrations in the event of a fire with wind from a SE-E direction.	2	PA WI PE	KF CA SO AL
2	Asphalt plant – west side	Location originally meant to determine the contribution of the asphalt plant to the air quality. In hindsight, the asphalt plant was not active during the period of our study.	4	PA WI PE	
3	W.A. Nisbeth road	This site will be exposed to emissions from the landfill when winds are from a E-NE direction and, under these conditions, the highest concentrations are expected here. The site is not influenced by traffic emissions. Extensive sampling techniques were conducted at this site.	2	PA PE WI	KF CA SO AL
4	VROMI yard	Located at a storage location of VROMI. Location has shortest distance to the landfill and should give an indication of pollution levels in the centre of Philipsburg in the event of a fire with winds from a N-NE direction.	2	PA PE	KF CA SO
5	Roundabout near waste-water treatment plant A.T. Illidge Road	Located near a roundabout with a lot of traffic. Used as an indicator for local traffic emissions.	4	PA	
6	Asphalt plant – east side	Location was meant as a background location for the measurements at location 2.	4*	PA PE WI	

Code	Description	Remarks	classification	Continuous monitoring	Non-continuous monitoring
7	Graveyard (Kerkhofstraat)	Used to provide more spatial information in relation to the measurements at locations C, 3 and 4.	3	PA PE WI	
8	Divi Hotel	Used to provide more spatial information in relation to the measurements at locations C, 3 and 4.	3	PA (PE) WI	
9	Uphill east of Welgelegen Road	Is used to give an indication of ambient levels at a more remote location and should also give an indication of the spatial distribution along the slopes of the valley (together with locations 10 and 11). Contribution of traffic to the air quality is expected to be limited at this site.	3	PA PE WI	
10	Welgelegen road	Is used to give an indication of ambient levels at a more remote location and should also give an indication of the spatial distribution along the slopes of the valley (together with locations 9 and 11). Contribution of traffic to the air quality is expected to be limited at this site.	3	PA PE WI	
11	Uphill west of Welgelegen Drive	Is used to give an indication of ambient levels at a more remote location and should also give an indication of the spatial distribution along the slopes of the valley (together with locations 9 and 10). Contribution of traffic to the air quality is expected to be limited at this site.	3	PA PE WI	
12	Squirrel drive	Used to give more spatial information in relation to the measurements at locations C and D. Due to local orography, this location might be influenced by both most common local airflows (see Figure 1)	3	PA WI	
13	Viewpoint Bloomingdale (upwind)	Location used for visual observations of the landfill. Measurement should give an indication of background levels without any influence of traffic emissions.	3*	PA	
14	Soualiga Road (Irma landfill)	At this location, a strong odour of smouldering material is almost always present. Is used as a worst-case indicator of landfill emissions when no fire is present.	5	PA	KF CA SO AL

Legend for Table 1

LE: Leckel air filter,
KF: KFG air filter
CA: canister
SO: Sorbent tube
PA: Passive VOC (3M badge)
AL: Aldehyde sampling
PE: Petri dish Wipe
WI: Wiping of fixed objects
* considered as backgroun

Appendix 3 Geographic setting and photograph locations

Location A
Type of location: SE 0.56 km (from top of the landfill)
Location description: Festival terrain
Address: Festival Village
Coordinates: North 18.02791444449981 West 63.04373873118244
Situation map and picture:

Location B
Type of location: W 1.3 km (from top of the landfill)
Location description: Roof Miss Lalie Commercial Centre
Address: Bush Road
Coordinates: North 18.03297975624337 West 63.05906341007713
Situation map and picture:

Location C
Type of location: SW 1.8 km (from top of the landfill)
Location description: Garden overlooking Great Bay
Address: Spanish Fort Road
Coordinates: North 18.021837118302724 West 63.0610135969157
Situation map and picture:

Location D
Type of location: WSW 2.2 km (from top of the landfill)
Location description: Roof of the fire department
Address:
Coordinates: North 18.02658681137072 West 63.06737872106083
Situation map and picture:

Location 1 Sugar Hill Drive
Type of location: NNW 2.1 km (from top of the landfill)
Location description: Rural street with some local traffic. Few goats being herded
Address: Sugar Hill Drive
Coordinates: North 18.036295898189643 West 63.06614240223156
Situation map and picture:

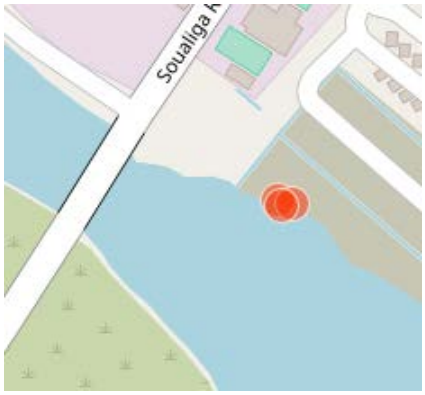
Location 2 Asphalt plant – west side
Type of location: N 0.67 km (from top of the landfill)
Location description: Sand, undeveloped land
Address: Dominica Road
Coordinates: North 18.037238736435395 West 63.04820523397282
Situation map and picture:

Location 3 W.A. Nisbeth Road
Type of location: WSW 0.71 km (from top of the landfill)
Location description: border of the salt lake
Address: W.A. Nisbeth Road
Coordinates: North 18.02770713583985 West 63.05257451456032
Situation map and picture:

Location 4 VROMI yard
Type of location : SSW 0.22 km (from top of the landfill)
Location description : Storage of material and vehicles
Address : Soualiga Drive
Coordinates : North 18.029713008580195 West 63.04850896209758
Situation map and picture:

Location 5 Roundabout WTP
Type of location: WNW 1.1 km (from top of the landfill)
Location description: Roundabout near water treatment plant
Address: A.T. Illidge Road
Coordinates: North 18.03485334384367 West 63.057064501928004
Situation map and picture:

Location 6 Asphalt plant – east side
Type of location: ENE 0.60 km (from top of the landfill)
Location description: border of the salt lake
Address: Golden Lily Cactus Road
Coordinates: North 18.03318114050508 West 63.04185345455505
Situation map and picture:



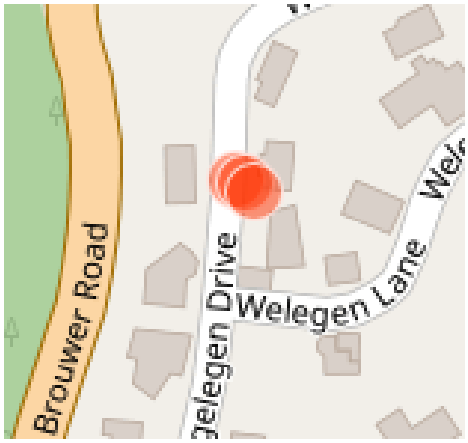
Location 7 Graveyard (Kerkhofstraat)
Type of location: SW 1.0 km (from top of the landfill)
Location description: Cemetery
Address: Kerkhofstraat
Coordinates: North 18.025181797615872 West 63.05362783522977
Situation map and picture:

Location 8 Divi Hotel
Type of location: SW 1.9 km (from top of the landfill)
Location description: garden near entrance resort
Address: Little Bay Road
Coordinates: North 18.01998525129316 West 63.05992769403065
Situation map and picture:

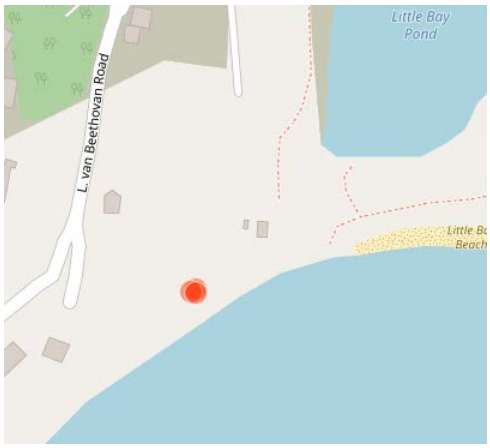
Location 9 Uphill east of Welgelegen Road
Type of location: W 1.7km (from top of the landfill)
Location description: Hillside, urban
Address: Chameleon Drive
Coordinates: North 18.029129318210288 West 63.063107383411
Situation map and picture:

Location 10 Welgelegen Road (Valley fire dept)
Type of location: W 2.0 km (from top of the landfill)
Location description: roadside
Address: Bison Drive
Coordinates: North 18.029129318210288 West 63.063107383411
Situation map and picture:

Location 11 Welgelegen Drive (West of fire dept)
Type location: W 2.6 km (from top of the landfill)
Location description: Urban
Address: Welgelegen Drive
Coordinates: North 18.02770713583985 West 63.05257451456032
Situation map and picture:

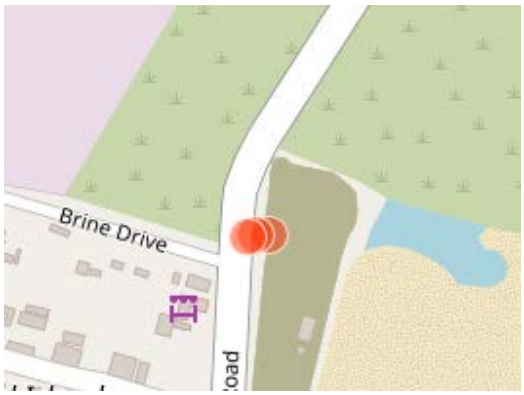


Location 12 Squirrel Drive (Little Bay)
Type of location: SW 2.5 km (from top of the landfill)
Location description: Beach Little Bay
Address: Squirrel Drive
Coordinates: North 18.01907568368899 West 63.06686803829631
Situation map and picture:



Location 13 Viewpoint Bloomingdale
Type of location: W 1.2 km (from top of the landfill)
Location description: Viewpoint upwind
Address: Nameless parallel road, north of Guana Bay Road
Coordinates: North 18.031169172965505 West 63.0356433116587
Situation map and picture:

Location 14 Soualiga Road (Irma landfill)
Type of location: W 0.3 km (from top of the landfill)
Location description: Road
Address: Soualige Road
Coordinates: North 18.03118884460733 West 63.043964926364794
Situation map and picture:



Appendix 4 Particulate matter (PM_{10}) in air

Table 6 – daily average concentration for particulate matter (PM_{10}) in the air at the four monitoring (24/7) locations (A – D) in µg/m³.

	Festival terrain (A)	**Miss Lalie (B)**	**Belair (C)**	**Fire department (D)**
Date	µg/m³	µg/m³	µg/m³	µg/m³
24-1-2019	10	not monitored	11	12
25-1-2019	13	not monitored	16	42
26-1-2019	15	not monitored	15	17
27-1-2019	11	not monitored	14	15
28-1-2019	12	17	13	14
29-1-2019	8	13	9	55
30-1-2019	9	10	10	10
31-1-2019	10	13	12	12
1-2-2019	10	13	12	11
2-2-2019	11	12	11	9
3-2-2019	6	7	6	6
4-2-2019	9	11	10	10
5-2-2019	9	14	9	24
6-2-2019	9	14	10	14
7-2-2019	n.a.	9	10	12
average over period	**10**	**12**	**11**	**18**

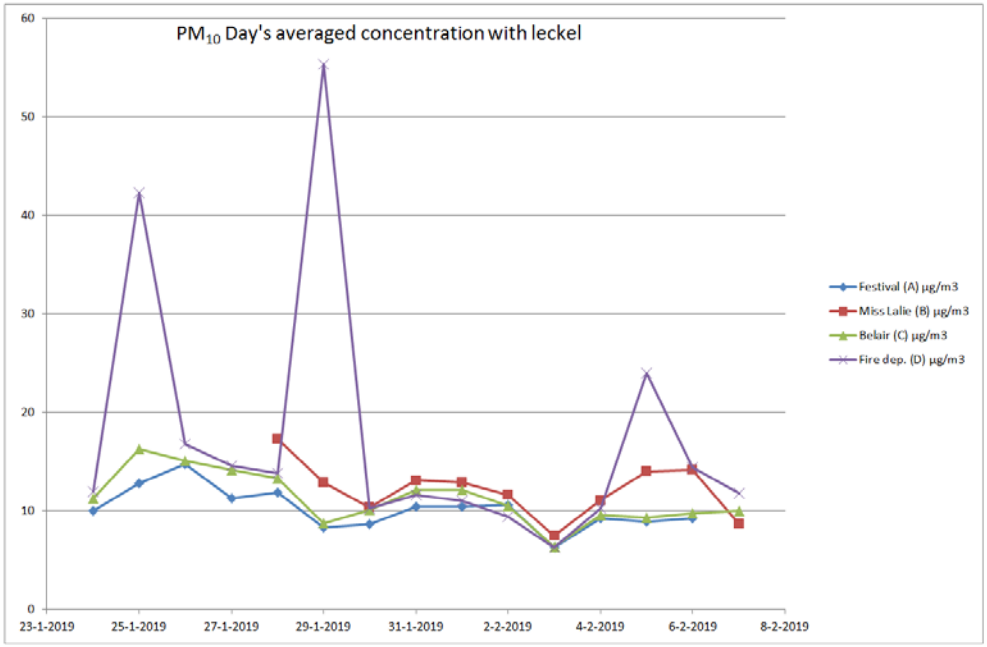


Figure 14 Chart of daily average concentration for particulate matter (PM_{10})

Figure 16 and Table 4 show that concentrations of particulate matter (PM_{10}) vary from day to day for all four locations following a similar pattern. Only at location D (fire department) were three peaks identified.

The European Union (EU) has set the annual average exposure limit for PM_{10} at 40 µg/m^3 and a 24-hour average exposure limit at 50 µg/m^3, which may be exceeded only 35 times a year (reference: rvs.rivm.nl).

All concentrations measured at locations A, B and C are below the EU annual average exposure limit of 40 µg/m^3. At location D (fire department), the annual average exposure limit is exceeded twice, one time of which exceeds the 24-hour average exposure limit of 50 µg/m^3. Note that the calculated daily average over the two-week period remains well below the annual average exposure limit.

Appendix 5 Elements in PM_{10} in the air

Table 7 Elements (including heavy metals) above the detection limit and reporting limit in PM_{10} in the air ($\mu g/m^3$).

Sample code	SXMF005	SXMF007	SXMF019	SXMF031	SXMF053	SXMF098	SXMF101	SXMF090	SXMF080	SXMF085	SXMF083	SXMF125	SXMF077		
Element	Festival terrain (A)	Festival terrain (A)	Miss Lalie (B)	Belair (C)	Fire department (D)	Festival terrain (A)	Festival terrain (A)	Irma Landfill (15)	VROMI yard (4)	VROMI yard (4)	W.A. Nisbeth road (3)	W.A. Nisbeth road (3)	Sugar Hill Drive (1)	TCA (µg/m3)	Source
Al	0.02	0.02	0.05	0.04	0.03	**0.10**	**0.09**	**0.34**	**0.22**	**0.42**	**0.16**	**0.20**	**0.24**	0.05	RIVM, 1993
B	0.00	0.00	0.00	0.00	<	0.07	0.04	0.03	0.11	0.07	0.03	0.04	0.07	Sea salt/sand	
Ca	0.27	0.22	0.55	0.43	0.35	1.03	0.65	3.37	1.53	4.48	1.32	10.01	1.79	Sea salt/sand	
Cr	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02	0.02	0.02	0.02	0.03	0.02	Cr (III): 60 Cr (VI): 0.0025	RIVM, 2001
Cu	0.00	<	0.00	0.00	0.00	<	<	<	<	<	<	0.03	<	1.00	RIVM, 2001
Fe	< DL	<	0.08	0.07	0.06	<	0.23	0.64	<	0.72	0.63	0.67	<	Not available	
K	0.12	0.07	0.10	0.10	0.08	<	0.13	<	0.26	<	<	0.26	0.27	Sea salt/sand	
Mg	0.30	0.23	0.32	0.32	0.28	0.25	0.44	0.72	0.45	0.75	0.55	0.80	0.69	Sea salt/sand	
Mn	<	<	0.00	<	<	<	<	<	<	<	<	<	<	0.15	WHO, 2000
Na	2.57	2.17	2.37	2.38	2.17	5.31	4.01	7.71	6.50	7.84	7.50	8.63	8.33	Sea salt/sand	
Sb	<	<	0.00	0.00	0.00	<	<	<	<	<	<	<	<	3.20	RIVM, 1992
Si	0.28	0.23	0.33	0.39	0.31	2.28	1.07	3.22	2.90	4.05	2.83	4.12	3.83	Sea salt/sand	
Sn	<	<	<	<	<	<	<	0.04	<	<	<	<	<	TWA 8-h: 2	SER
Sr	0.00	0.00	0.00	0.00	0.00	<	<	0.01	<	0.01	<	0.13	<	Not available	
Ti	0.00	<	0.00	0.00	0.00	<	0.00	0.01	<	0.02	<	<	0.01	Not available	
Zn	0.02	0.05	0.02	<	<	<	<	<	<	<	<	<	<	Not available	

Al = aluminium, B=Boron, Ca=Calcium, Cr=Chromium, Cu=Copper, Fe=Iron, K=Potassium, Mg=Magnesium, Mn=Manganese, Na=Natrium, Sb=Antimony, Si=Silicon, Sr=Strontium, Ti=Titanium, Zn=Zinc, <=below the analysis and / or reporting level

Leckel 24-hr sampling

KFG approximately 2-hr sampling

Samples of particulate matter present in the air have been collected using two techniques: 24-hr samples with Leckel filter equipment at the four monitoring locations (A-D) and 2-hr sampling with KFG equipment at various locations (A and 1-15). KFG sampling was performed for two hours, while Leckel sampling was done for 24 hours; so when there are peaks in the emission you can 'catch' these peaks with KFG while, with Leckel sampling, the peak is averaged over the day. Moreover, the KFG sampling was targeted as they, for example, were performed at moments when odour was detected or when it was anticipated that landfill emission could be detected.
In a selection of the samples (see Section 3.3), quantitative analysis of the elements was conducted in the Netherlands by TNO.

Based on the results of the analyses, the following can be concluded:

- The measured concentrations of boron, calcium, potassium, magnesium, sodium and silicon probably originate from sea salt and sand as these are known sources for these elements.
- Aluminium concentrations exceed the Tolerable Concentration in Air (TCA) of 0.05 µg/m^3 in the eight KFG samples, the highest measured concentration was 0.42 µg/m^3. However, the authors who derived this TCA in 1993 stated that "exposure data are missing and the proposed toxicological limit value is rather conservative". The critical toxic effect on which this TCA based is unknown. In a more recent evaluation aimed at deriving an Occupational Exposure Limit (OEL) for aluminium and aluminium compounds, the Dutch Health Council (Gezondheidsraad 2010) derived a value of 50 µg/m^3 for aluminium chlorohydrate (equivalent to 15 µg Al/m^3) based on increased frequency of local inflammation in airways in a study in rats (seen at ≥0,25 mg/m^3). However, because it is uncertain which form of aluminium (soluble or insoluble) was responsible for the critical toxic effect, the Dutch Health Council did not extrapolate this value to other aluminium compounds.
  Though the value of 15 µg Al/m^3 cannot be used for the general public exposure to unknown forms of aluminium, it does suggest that the 1993 TCA is likely to be overly conservative. As to possible systemic effects (in internal organs/tissues) by aluminium an oral tolerable daily intake of 0.3 mg Al/kg bw/day has been proposed (EU SCHEER 2017). Taking into account a low absorption of 0.3% in the GI-tract this value is associated with a body dose of 0.9 µg/kg bw/day. Exposure to the highest measured concentration would lead to maximal exposure of 0,12 µg/kg bw/day (based on inhalation of 20 m^3 per day and a body weight of 70 kg). This exposure is below the limit of 0.9 µg/kg bw/dag. This indicates the absence of a systemic health risk at the maximum concentration measured of 0.42 µg/m^3. Overall the conclusion for aluminium is that an actual health risk is unlikely.
- In relation to the metal chromium (Cr), the oxidation state is relevant for the toxicity. It is unclear whether the chromium found is Cr(III) of Cr(VI), of which the latter is the most toxic, yet much less stable in the environment. For that reason (instability), it is assumed that most of the chromium present in particulate matter in the air is mainly Cr(III). The TCA for Cr(III) in air was not exceeded.

- The measured concentrations of copper and tin (Sn) do not exceed the available guideline values of 1 µg/m^3 (TCA) and 2 mg/m^3 (occupational value, TWA 8-h), respectively.
- For zinc, there is no TCA available. However, occupational safety limits in the United States range from 1 to 5 mg/m3 for an 8-hour time weighted average for a 40-hour workweek for zinc substances. (ATSDR, 2005).
- For iron (Fe), strontium (Sr) or titanium (Ti), no tolerable concentration in air was available.
- Manganese (Mn) and Antimony (Sb) were measured at very low concentrations, either below the detection limit or in the range of nanogram per cubic metre.

Appendix 6 Elements in coarse dust

Table 8 Elements (including heavy metals) in dust wipe samples (µg/m²).

Sample	STN27	STN46	STM1928	STN44	STN31	STN34	STN40	STN41	STN52			
description (code)	Sugar Hill Drive (1)	Graveyard (7)	Graveyard (7)	**Graveyard (7)**	Sugar Hill Drive (1)	Up wind Asphalt plant (6)	VROMI yard (4)	W. A. Nisbeth Road (3)	Down wind Asphalt plant (2)	**Intake per exposure occasion [µg/kg bw/event] for STN44**	TDI [µg/kg lg/day]	Source
Al	3030	1226	3503	**13477**	10772	3458	11223	2893	14379	**456**	1000 (TWI)a	EFSA, 2008
As	2	2	5	**34**	8	66	18	15	9	**1.14**	3 (0.5BMDL)	JECFA, 2011
B	6	11	11	184	141	212	95	273	157	Sea salt/sand		
Ba	27	13	25	**152**	82	30	84	31	65	**5.13**	200	ATSDR, 2007
Ca	17352	3592	17352	585425	35371	53405	66931	292363	247277	Sea salt/sand		
Cd	1	0	2	**2**	13	1	1	3	3	**0.08**	2.5 (TWI)	EFSA, 2009
Ce	5	<	4	**13**	<	<	<	<	8	**0.45**	Not available	
Co	3	2	4	**13**	9	6	13	5	16	**0.44**	1.4	RIVM, 2001
Cr	6	6	10	**60**	21	19	32	22	96	**2.02**	Cr (III): 300 Cr (VI): 0.1	EFSA, 2014
Cu	19	27	57	**149**	108	32	367	68	63	**5.05**	83	EFSA, 2006
Fe	3822	2702	6702	**23394**	13475	5360	21591	4909	13926	**792**	800	JECFA, 1983
K	363	189	509	17489	32819	10726	10275	87824	10246	Sea salt/sand		
Mg	1119	744	2034	18356	7535	7535	11593	17004	13397	Sea salt/sand		
Mn	61	28	88	**445**	286	114	366	127	290	**15**	30	RIVM, 2006
Mo	<	3	<	<	<	<	<	5	7	**0.10**	9	Vyskocil & Viau, 1999
Na	<	1120	1120	22994	10370	42832	10821	60867	56358	Sea salt/sand		
Ni	3	3	6	**21**	11	9	22	11	71	**0.70**	10	RIVM, 2006
P	201	<	328	**2786**	4761	2565	3788	7028	<	**94**	70000	EFSA, 2006

Sample	STN27	STN46	STM1928	STN44	STN31	STN34	STN40	STN41	STN52			
description (code)	Sugar Hill Drive (1)	Graveyard (7)	Graveyard (7)	**Graveyard (7)**	Sugar Hill Drive (1)	Up wind Asphalt plant (6)	VROMI yard (4)	W. A. Nisbeth Road (3)	Down wind Asphalt plant (2)	**Intake per exposure occasion [µg/kg bw/event] for STN44**	TDI [µg/kg lg/day]	Source
Pb	9	5	21	**71**	19	8	51	9	6	**2.41**	0.5 (BMDL)	EFSA, 2010
Sb	1	1	3	**8**	3	<	30	3	2	**0.26**	6	RIVM, 2009
Si	416	1194	1866	3299	4124	3056	2804	3285	10233	Sea salt/sand		
Sr	37	40	178	**8113**	248	703	582	4193	2295	**275**	600	RIVM, 2006
Ti	154	28	191	**384**	214	104	357	30	882	**13**	Not availaible	
V	6	5	14	**63**	40	17	67	18	52	**2.12**	2	RIVM, 2009
Y	2	0	2	**9**	3	1	5	3	6	**0.31**	Not available	
Zn	35	19	238	**754**	430	9	278	180	404	**26**	360	EFSA, 2006

Al = aluminium, As=Arsenic, B=Boron, Ba=Barium, Ca=Calcium, Cd=Cadmium, Ce=Cesium, Co=Cobalt, Cr=Chromium, Cu=Copper, Fe=Iron, K=Potassium, Mg=Magnesium, Mn=Manganese, Mo=Molybdenum, Na=Natrium, Ni=Nickel, P=Phosphorus, Sb=Antimony, Si=Silicon, Sr=Strontium, Ti=Titanium, V=Vanadium, Y=Yttrium, Zn=Zinc, <=below the analysis and / or reporting level

Elements (including heavy metals)_in dust wipe samples are analysed according to the same methodology as the measurements for particulate matter present in air. However, human exposure to dust on surfaces is different from the exposure to dust in the air. The exposure route for particulate matter in air is via the lungs, while the most relevant exposure route to dust on the ground is dermal and hand-to-mouth contact.

It was noted that the concentration of the 'historical' samples yield lower concentrations than the 'petri dish' samples for the location Sugar Hill Drive. At the graveyard location, the historical sample lay between the two other samples at the graveyard location.

In general, the highest concentrations were measured in the sample obtained at the graveyard (sample no. STN 44, in bold in Table 9). As a reasonable worst-case scenario, the exposure of toddlers to elements,

(including) heavy metals, was calculated based on this sample, following the draft MOD guideline.

Standard assumptions for calculating hand-to-mouth exposure:

- Skin-soil adherence: 0.35 mg/cm2 (child, recreation)2
- Hand surface from a 4.5 year-old child: 389 cm2
- Bodyweight (4.5 year-old child): 16.3 kg
- Amount of dust per m2: 500 mg/m2
- Uptake from metals from dust to hands: 50% (50% hand-mouth contact, worst-case)

Variables:

- Concentration in dust wipe sample: [C] in µg/m^2

Calculation of exposure:

- Exposure to dust per event: 0.35 x 389=138 mg dust
- Concentration per mg dust: C/500 µg/mg
- Exposure of child per event: 138 x C/500 µg
- Uptake fraction: 0.5
- Exposure per kg of bodyweight: 138 x C/500/16.3*0.5 µg/kg bw/event

The calculated values were compared to chronic health-based guideline values.

In relation to public health, the following can be stated:

- Most concentrations are low
- The elements boron, calcium, potassium, magnesium, sodium and silicon probably have their origin in sea salt and sand.
- In relation to the metal chromium (Cr), the oxidation state is relevant for the toxicity. It is unclear whether the chromium found is Cr(III) of Cr(VI), of which the latter is the most toxic, yet much less stable in the environment. For that reason (instability), it is assumed that most of the chromium present is mainly Cr(III).
- For all elements, where a chronic health-based guideline value for oral exposure was available, this was not exceeded.
- For the elements of caesium, titanium and yttrium, no health-based guideline values were available.

[2] http://www.mass.gov/eea/docs/dep/cleanup/laws/dermadhe.pdf

Appendix 7 PAHs in PM_{10} in the air

Table 10 Polycyclic Aromatic Hydrocarbons (PAHs) above analytical and reporting threshold (pg/m^3).

Sample number	SXMF006	SXMF008	SXMF016	SXMF017	SXMF038	SXMF046	SXMF051	SXMF076	SXMF079	SXMF082	SXMF084	SXMF087	SXMF089	SXMF124
	Festival terrain (A)	Festival terrain (A)	Miss Lalie (B)	Miss Lalie (B)	Belair (C)	Fire department (D)	Fire department (D)	Sugar Hill Drive (1)	VROMI yard (4)	W.A. Nisbeth Road (3)	VROMI yard (4)	Festival terrain (A)	Irma landfill (14)	W.A. Nisbeth Road (3)
Benzo[a]anthracene	<	<	1.3	<	1.0	<	0.8	<	<	<	<	<	<	<
Chrysene	0.6	0.7	1.7	2.8	1.4	1.2	1.0	6.4	6.5	5.3	10.3	6.1	9.6	7.5
Benzo[b]fluoranthene	5.3	4.9	46.4	19.6	21.5	10.6	12.2	46.9	52.0	52.4	108.2	38.1	152.6	58.3
Benzo[k]fluoranthene	<	<	0.3	<	0.3	0.1	0.1	<	<	<	<	<	1.1	0.8
Benzo[j]fluoranthene	<	<	1.8	0.5	1.0	0.4	0.5	<	<	<	3.5	<	4.6	<
ieno[123cd]pyrene	0.2	<	3.0	0.4	1.0	0.4	0.6	<	1.6	5.0	2.9	<	4.0	2.0
Dibenzo[ah]anthracene	<	<	62.0	<	<	<	<	<	<	<	<	<	<	<
Benzo[ghi]perylene	0.0	0.0	0.4	0.1	0.3	0.1	0.1	0.4	0.5	0.9	0.8	0.2	1.5	0.5
Total Bap-equivalent	6.2	5.6	116.9	23.5	26.5	12.9	15.4	53.7	60.6	63.6	125.6	44.4	173.4	69.1

Leckel 24-hr sampling

KFG approximately 2-hr sampling

Chemical analysis of PAHs in particulate matter found in air samples has been performed by RIKILT. The EU target value for air for PAHs of 1 ng/m3, as Benzo(a)pyrene (BaP), was not exceeded.

In 2018, RIVM derived a new health-based guideline value for exposure to PAHs via oral exposure (RIVM, 2018), the excess lung cancer risk. This value is lower than de EU-target value. The excess lung cancer risk per µg/m^3 -year is 0.00042 for the general population for the EFSA 8-PAH (a different selection than the 16 EPA PAHs: benzo[a]pyrene, chrysene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[ghi]perylene, dibenz[ah]anthracene, indeno[1,2,3-cd]pyrene). This value was not exceeded.

Appendix 8 PAHs in coarse dust

Table 11 *Polycyclic Aromatic Hydrocarbons (PAHs) in coarse dust wipe samples (µg/m²).*

Sample number	STN08	STN26	STN45	STM1927	STN30	STN33	STN39	**STN43**	STN17	STN07	**STN43**	
Location	W. A. Nisbeth Road (3)	Sugar Hill Drive (1)	Graveyard (7)	Graveyard (7)	Sugar Hill Drive (1)	Asphalt plant - upwind (6)	VROMI yard (4)	**Graveyard (7)**	Asphalt plant - downwind (2)	W. A. Nisbeth Road (3)	**BaP equivalents**	Exposure per occasion [µg/kg lg/occasion]
Benzo[c]fluorene	0.01	<	<	<	<	<	<	**0.01**	<	<	**0.17**	0.0030
Benzo[a]anthracene	0.03	<	0.00	0.00	0.05	0.01	0.04	**0.07**	0.01	<	**0.01**	0.0002
Cyclopenta[cd]pyrene	<	<	<	<	<	<	<	**0.02**	<	<	**0.01**	0.0002
Chrysene	0.06	0.01	0.01	0.01	0.19	0.02	0.09	**0.16**	0.03	0.02	**0.02**	0.0003
5-Methylchrysene	<	<	<	<	<	<	<	**<**	<	<	**<**	-
Benzo[b]fluoranthene	0.05	0.00	0.01	0.01	0.13	0.02	0.05	**0.12**	0.03	0.02	**0.10**	0.0017
Benzo[k]fluoranthene	0.02	<	0.00	0.00	0.06	0.01	0.02	**0.05**	0.01	<	**0.00**	0.0000
Benzo[j]fluoranthene	0.02	<	0.00	0.00	0.05	0.01	0.02	**0.05**	0.01	0.01	**0.01**	0.0002
Benzo[a]pyrene	0.02	<	0.01	0.00	0.04	0.02	0.02	**0.07**	0.01	<	**0.07**	0.0012
ieno[123cd]pyrene	0.02	<	0.01	0.00	0.04	0.02	0.02	**0.06**	0.01	<	**0.00**	0.0001
Dibenzo[ah]anthracene	0.01	<	<	<	0.01	<	<	**0.01**	<	<	**0.12**	0.0020
Benzo[ghi]perylene	0.05	0.00	0.03	0.01	0.08	0.08	0.04	**0.20**	0.04	0.01	**0.00**	0.0000
Dibenzo[a,l]pyrene	<	<	<	<	<	<	<	**<**	<	<	**<**	-
Dibenzo[a,e]pyrene	<	<	<	<	<	<	<	**0.01**	<	<	**0.01**	0.0001
Dibenzo[a,i]pyrene	<	<	<	<	<	<	<	**<**	<	<	**<**	-
Dibenzo[a,h]pyrene	<	<	<	<	<	<	<	**<**	<	<	**<**	-
Som PAK4 (lb)	0.15	0.01	0.03	0.03	0.41	0.07	0.20	**0.42**	0.09	0.04		**0.0090**
Som PAK16 (ub)	0.53	0.06	0.10	0.08	0.73	0.30	0.38	**0.90**	0.27	0.26		

'Historical'
petri dish
2 weeks

For PAHs, human exposure to swipe dust is different from the exposure to air. The exposure route for particulate matter in the air is via the lungs, while the most relevant exposure route to dust on the ground is dermal contact and hand-to-mouth contact.

It was noted that some of the ‘historical’ samples yield lower concentrations than the ‘petri dish’ samples.

In general, the highest concentrations were measured in the sample obtained at the graveyard (sample no. STN 44, in bold in Table 12). As a reasonable worst-case scenario, the exposure of toddlers to elements, (including) heavy metals, was calculated based on this sample. For this calculation, the measured concentrations for the individual USEPA 16 PAHs are converted to benzo[a]pyrene equivalents and compared to a chronic health-based guideline value.

Standard assumptions for calculating hand-mouth exposure:

- Skin-soil adherence: 0.35 mg/cm^2 (child, recreation)[3]
- Hand surface from a 4.5 year-old child: 389 cm^2
- Bodyweight (4.5 year-old child): 16.3 kg
- Amount of dust per m^2: 500 mg/m^2
- Uptake of metals from dust to hands: 100% (worst-case)

Variables:

- Concentration in swipe dust: [C] in µg BaP-equivalents/m^2

Calculation of exposure:

- Exposure to dust per event: 0.35 x 389=138 mg dust
- Concentration per mg dust: C/500 µg/mg
- Exposure of child per event: 138 x C/500 µg
- Exposure per kg of bodyweight: 138 x C/500/16.3 µg/kg bw/event

The sum of the calculated BaP equivalents was compared to the Virtually Safe Dose of 0.005 µg/kg bw/day, which is a health-based guideline value corresponding to the risk of extra cancer cases of one per million per lifetime exposure. Since the sum of benzo[a]pyrene equivalents exposure per occasion is 0.009 µg/kg bw/day, the Virtually Safe Dose is exceeded by an approximate factor of 2. This may result in an additional risk of cancer cases (2 per million per lifetime exposure).

In 2018, RIVM derived a new health-based guideline value for exposure to PAHs via oral exposure (RIVM, 2018). This value is lower than the VSD; 0.0007 µg/kg bw/day for the EFSA 8-PAH (a different selection than the 16 EPA PAHs: benzo[a]pyrene, chrysene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[ghi]perylene, dibenz[ah]anthracene, indeno[1,2,3-cd]pyrene). The exposure per kg of bodyweight for these PAKs was calculated according to the method described above and resulted in an exposure of 0.0012 µg/kg bw/day. This value is exceeded by less than a factor of 2.

[3] http://www.mass.gov/eea/docs/dep/cleanup/laws/dermadhe.pdf

Appendix 9 Dioxins in PM_{10} in air

Table 13 Dioxins and dioxin-like PCBs in air (upper bound values in pg/m^3).

		WHO2005-PCDD/F-TEQ (ub)	WHO2005-PCDD/F-PCB-TEQ (ub)
Festival terrain (A) 24hr	29-jan	0.00	0.00
Festival terrain (A) 24hr	31-jan	0.00	0.00
Miss Lalie (B) 24hr	29-jan	0.04	0.04
Miss Lalie (B) 24hr	28-jan	0.02	0.02
Belair (C) 24hr	31-jan	0.00	0.00
Fire department (D) 24hr	24-jan	0.00	0.00
Fire department (D) 24hr	29-jan	0.00	0.00
Festival terrain (A) +/- 2hr	30-jan	0.20	0.22
Sugar Hill Drive (1) +/- 2hr	24-jan	0.16	0.18
W.A. Nisbeth Road (3) +/- 2hr	30-jan	0.21	0.22
W.A. Nisbeth Road (3) +/- 2hr	5-feb	0.17	0.18
VROMI yard (4) +/- 2hr	28-jan	0.17	0.18
VROMI yard (4) +/- 2hr	31-jan	0.27	0.28
Irma landfill (14) +/- 2hr	31-jan	0.58	0.60

Leckel 24-hr sample

KFG approximately 2-hr sample

The chemical analysis of dioxins and Polychlorinated Biphenyls (PCBs) in particulate matter in air samples were performed by RIKILT. The results have been compared to the allowable total weekly intake (TWI) of 2 pg TEQ (TCDD-equivalent) per kilogram of bodyweight (EFSA, 2018).

Assuming an average breathing volume of 1 m^3 per hour and an average bodyweight of 60 kilograms, the TWI of 2 pg TEQ/kg bw/week is not exceed if concentration TEQ/m^3 stays below 0.71 pg/m^3 (see calculation below):

Total breathing volume per week:

- 1 m^3 x 24 hours x 7 days = 168 m^3 per week
- TWI: 2 pg TEQ/kg bw x 60 kg = 120 pg TEQ/week
- 120 pg TEQ/week / 168 m^3/week = 0.71 pg/m^3

All measured values are well below this value.

Appendix 10 Dioxins in coarse dust

Table 14 Dioxins and dioxin-like PCBs in coarse dust wipe samples (upper bound values in pg/m^2).

	WHO2005-PCDD/F-TEQ (ub)	WHO2005-PCDD/F-PCB-TEQ (ub)
Sugar Hill Drive (1)	3	3
W. A. Nisbeth Road (3)	45	48
Graveyard (7)	1	1
Sugar Hill Drive (1)	30	31
Asphalt plant - downwind (2)	34	36
W. A. Nisbeth Road (3)	50	52
VROMI yard (4)	74	83
Asphalt plant - upwind (6)	31	32
Graveyard (7)	57	60

Historical' sample

Petri dish sample

Chemical analysis of dioxins and Polychlorinated Biphenyls (PCBs) in particulate matter in dust were performed by RIKILT.

The sample locations that are most relevant for this type of exposure are considered to be Sugar Hill Drive (urban setting) and the graveyard (in the middle of the village). However as in order to cover the worst-case measurements, calculations were performed with the highest measured concentration (VROMI yard).

The results were compared to the allowed total weekly intake (TWI) of 2 pg TEQ (TCDD-equivalent) per kilogram of bodyweight (EFSA, 2018).

Standard assumptions for calculating hand-mouth exposure:

- Skin-soil adherence: 0.35 mg/cm^2 (child, recreation)[4]
- Hand surface from a 4.5 year-old child: 389 cm^2
- Bodyweight (4.5 year-old child): 16.3 kg
- Amount of dust per m^2: 500 mg/m^2
- Uptake from metals from dust to hands: 100% (worst-case)

Variables:

- Concentration in swipe dust: [C] in pg TEQ/m^2

Calculation of exposure:

- Exposure to dust per event: 0.35 x 389=138 mg dust

[4] http://www.mass.gov/eea/docs/dep/cleanup/laws/dermadhe.pdf

- Concentration per mg dust: C/500 pg/mg
- Exposure of child per event: 138 x C/500 pg
- Exposure per kg of bodyweight: 138 x C/500/16.3 pg/kg bw/event

The measured concentration at the VROMI Yard of 83 pg TEQ/m^2 resulted in a calculated exposure of 1.41 pg/kg bw. This value does not exceed the TWI.

Appendix 11 Volatile Organic Compounds in the air

Different type of sampling techniques (canisters, charcoal-tubes, 3M badges) were used for the measurement of Volatile Organic Compounds (VOC) in the air. Different types of analysis and methods were conducted on these samples. In the end, a selection (11 in total) of the canister samples were analysed, as were a selection of the charcoal-tubes (10 in total) and all the 3M batches (18 in total). All results (above detection / reporting limit) are presented in the tables above. In most samples, no VOC were found at all. Only samples / substances with concentrations above the lower limit of detection are included (e.g. no substances were found in charcoal tubes, so no results are included in this report).

Table 15 Quantitative VOC results for canisters (TO15) in µg/m³

		Miss Lalie (B)	Belair (C)	Fire department (D)	Sugar Hill Drive (1)	VROMI yard (4)	Irma landfill (14)	Health-based guideline value		Source
	CAS	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³		
toluene	108-88-3	<10	<10	<10	<10	20	11	400	TCA	RIVM, 2001
p,m-xylene	106-42-3	<10	<10	n.d.	<10	<10	11	210000	TWA 8-h	SER
1,2,4-trimethyl-benzene	95-63-6	<10	<10	<10	<10	<10	10	100000	TWA 8-h	SER
tetrachloroethene	127-18-4	n.d.	n.d.	<10	<10	n.d.	10	250	TCA	RIVM, 2001
carbon disulfide	75-15-0	11	**105**	18	10	<10	23	26.3 15000	Indi-cative TCA TWA 8-h	RIVM, 2008 SER
2-hexanone	591-78-6	13	<10	<10	<10	<10	n.d.	**Not avail-able**		
n-heptane	142-82-5	n.d.	n.d.	<10	52	n.d.	n.d.	1200000	TWA 8-h	SER

Remark: these results are quantitative because the results can be compared to a 'standard' with known concentrations for these substances. Only components above the detection and reporting limit are presented, for example: the analysis also included benzene, but all measured concentrations were lower than the amount encountered in the blanc sample and were below or near the reporting limit. Therefore, benzene is not included in the table.

Table 16 ***Indicative*** *VOC results for canisters (AMDIS library)*

		VROMI Yard (4)	Irma landfill (14)	Belair (C)	festival terrain	Health-based guideline value		Source
		29-jan	1-feb	31-jan	31-jan			
	CAS	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3		
methanol	67-56-1	286	<50	<50	<50	816	Indicative TCA	RIVM, 2005
1-butanol	71-36-3	<50	59	79	130	Not available		

Remark: these results are indicative because the results cannot be compared to a 'standard' with known concentrations for these substances, so a theoretical calculation has to be made which results in an indicative concentration.

Table 17 Quantitative VOC results for 3M-badges

	STM1919	**Health-based guideline value**		**Source**
	Irma landfill (14)			
Component	**µg/m^3**			
2-methylbutane	10	18000000	TWA 8-h	SER
m/p-Xylene	24	210000	TWA 8-h	SER
Toluene	30	400	TCA	RIVM, 2001
Benzene	16	5	TCA	EU, 1998
		700	TWA 8-h	SER

One canister sample from the location at the landfill (14) contained several VOC. Several canisters (different locations) contained carbon disulphide (the highest concentration was found at Belair, location C). Only one 3M-badge contained several VOC (location 14). In the charcoal tubes no VOC were detected.

These results were compared with health-based guideline values for chronic exposure; only for benzene was the TCA exceeded at the landfill. However, the concentrations measured in canisters at other locations indicated low concentrations of benzene.
For two substances, 2-hexanone and 1-butanol, no health-based guideline values for long-term exposure were available.

Canister sampling by the fire department during a fire on 30th March 2019.

Three canisters were left behind at the fire station for air sampling. On 30th March three samples were taken during a fire on the 'new dump' at 14:00. Two canisters were placed on Soualiga Road (± 500 meters from the fire) and one was placed on the 'new dump' (<500 meter from the fire). However, the exact location for the three individual canisters is unknown. Besides that one canister was not filled with air and could not be analyzed. The results are presented in Table 18: the concentrations are higher than the concentrations in the samples taken by RIVM.

For acute incidents with a duration of less than 24 hours acute emergency guideline values are used, where for incidents with a prolonged duration sub-chronic or chronic health based guideline values are used.

Since detailed information on the exact sampling locations and the duration and intensity of the fire were not available RIVM is unable to determine which values should be used in order to assess the potential health risks. Therefor no conclusions can be drawn based on these measurements.

Table 18 Quantitative VOC results, above detection and reporting limit of 10 µg/m^3 , for canisters (TO15) in the two samples taken by the fire department on 30 March (µg/m^3)

		Code: Can4016	Code: Can4024
Substance	CAS	Exact sample location unknown	Exact sample location unknown
benzene	71-43-2	157	422
toluene	108-88-3	82	189
ethylbenzene	100-41-4	50	109
p,m-xylene	106-42-3	97	210
o-xylene	95-47-6	23	26
styrene	100-42-5	46	152
4-ethyltoluene	622-96-8	12	13
1,3,5-trimethylbenzene	108-67-8	13	14
1,2,4-trimethylbenzene	95-63-6	47	52
naphthalene	91-20-3	39	99
chloromethane	74-87-3	162	523
bromomethane	74-83-9	<10	24
tribromomethane	75-25-2	12	<10
1,2,4-trichlorobenzene	120-82-1	276	18
ethanol	64-17-5	343	285
acetone	67-64-1	81	142
carbon disulfide	75-15-0	64	50
2-butanone	78-93-3	13	28
methyl methacrylate	80-62-6	<10	16
2-hexanone	591-78-6	179	14
propene	115-07-1	220	533
1,3-butadiene	106-99-0	17	46
n-heptane	142-82-5	<10	16

Appendix 12 Aldehydes in air

Aldehyde sampling was done with special cartridges and analysis was conducted for eight different compounds belonging to the group of aldehydes (including formaldehyde, acetaldehyde, acetone, etc.). Only positive results are included in this report. In this case, only acetone was found.

Table 19 Aldehydes found in µg/m3.

	Acetone µg/m^3
Festival terrain (A)	20.9
Sugar Hill Drive (1)	8.5
Fire department (D)	4.7
Belair (C)	7.5
Miss Lalie (B)	8.0
Festival terrain (A)	3.3
Festival terrain (A)	2.8
Irma landfill (14)	4.4

No TCA is available for acetone. However, a time-weight average concentration for occupational exposure (1210000 µg/m^3, source:SER) is available. The measured values are well below this health-based guideline value for workers.

Appendix 13 Experience with landfill fires in the Netherlands

The following is a summary of what is known about the emissions of landfill fires, based on over 30 years of experience in the Netherlands and known literature (author: Marcel Broekman).

Introduction
Based on discussions held between the RIVM field team and the various parties involved, such as VROMI, BZK, the fire brigade and EE&G (2018), it appears that the precise composition of the landfill is unknown. It is suspected that the landfill consists of various discarded goods, parts and materials, such as:

a. Plastics (including polyvinyl chloride PVC),
b. Rubber (car tyres)
c. Metals
d. Glass and ceramic materials
e. Building materials (concrete, bricks, clay, sand, etc.)
f. Wood (including treated wood)
g. Paper and cardboard
h. Textiles (natural and synthetic materials)
i. Mineral oil (lubricating oil, diesel, fuel oil, hydraulic oil)
j. Vegetable / organic materials (Vegetable fruit and garden waste, frying fats, oil etc)
k. Chemical waste (acids, alkalis, cleaning agents, batteries, paint residues, pesticides, etc.)

In the event of a large landfill fire from the materials discarded above, typical combustion products such as water vapour (H_2O), carbon monoxide (CO), carbon dioxide (CO_2), carbon dust / black carbon, particulate matter (PM) and polycyclic aromatic hydrocarbons (PAHS) are always released. In addition, substances are released that are specific to the materials involved in the fire and that depend on the combustion conditions, such as source temperature and oxygen supply. For example, heavy metals (in the presence of electrical appliances, etc.) and dioxins (in the presence of chlorine-containing plastics such as PVC). In addition to the fuel, both the temperature and the amount of oxygen supply determine the substances that are released. Moreover, the firefighting methods used can also influence the nature and amount of the substances formed.

The less complete a fire is, due to a lower source temperature and/or a reduced oxygen supply, the greater the risk of the formation of hazardous substances. This is especially the case during the smouldering phase of a fire.
The emitted substances in the smoke can also undergo changes due to their interaction with UV radiation and the reactivity of the substances present in the smoke or in the outside air. Under the influence of the prevailing meteorological conditions, air distribution and deposition on the soil then takes place. Gaseous substances will not deposit. The air concentration of these substances will dilute as a function of time, height and distance in relation to the seat of fire.

The dust-bound chemical components will eventually settle on the surface in the downwind area of the seat of the fire. Fragments and coarse dust will come closest to the source of fire. The particulate matter can be deposited at a wide range of different distances depending on the aerodynamic diameter. Ultra-fine dust (diameter <0.1 µm) will behave almost identically as gaseous substances. Particulate matter is indicated by the diameter of the largest particle in the fraction. For example, PM_{10} is particulate matter with a diameter of less than 10 µm. A distinction can also be made in the state of aggregation, namely solid.
As previously explained, the chemical composition of the coarse, fine and ultra-dust in the flue gases largely depends on the composition of the landfill and the combustion conditions during the fire and/or smouldering phase. A summary of the nature of burning materials and potentially released substances is given in Table 20.

Table 20 Hazardous substances released in the event of a fire with combustible materials

Materials	**Emitted substances**
Plastics	-aliphatic hydrocarbons (alkanes, olefins) -aromatic hydrocarbons (BETX, styrene, isobutylene, etc.) -aldehydes and ketones (formaldehyde) -alcohols, (alkyl) phenols and esters -furans -alkane carboxylic acids (formic acid, acetic acid)
Chlorinated plastics (PVC)	-hydrochloric acid -phosgene -vinyl chloride -chlorinated aliphatic and aromatic hydrocarbons -Chlorinated dioxins and furans
Nitrogen-containing plastics (PUR; ABS; nylon)	-nitrogen oxides -ammonia -blue acid -nitriles (benzonitrile) -amines -isocyanates -urea -Nitro-PAK
Fluorinated plastics (PTFE)	-hydrogen fluoride -carbonyl fluoride
Sulfur-containing plastics (PPS), polysulfone polyether sulfone	-sulfur dioxide and sulfuric acid -hydrogen sulfide and other sulfides (e.g. mercaptans) -sulfur trioxide carbon disulfide (rotten egg smell)
Additives Fire retardants, UV stabilizers, plasticizers, colour pigments	-hydrogen bromide bromobiphenyls and brominated dioxins and furans bromobisphenol-A -metal oxides (chromium, antimony, lead)
Rubber	-BETX and other alkylbenzenes

Materials	Emitted substances
(car tyres)	-aliphatic hydrocarbons (methane and other alkenes, alkynes) phenols -furans -aldehydes (including mainly benzaldehyde) alcohols and esters hydrochloric acid and hydrocyanic acid isocyanates fine dust -dioxins
Oil	-aliphatic and aromatic hydrocarbon (benzene) aldehydes -sulfur dioxide and nitrogen oxides fine dust
Wood/paper	-aliphatic and aromatic hydrocarbons (benzene, toluene) -phenol -aldehydes (formaldehyde and acetaldehyde) -sulfur dioxide and nitrogen oxides -ammonia, blue acid acetonitrile isocyanates fine dust -dioxins

As indicated, the landfill also contains non-combustible materials, including building materials, glass, ceramic materials and metals. The presence of these materials influences (indirectly) the burning temperature and the oxygen supply during the fire and/or smouldering phase of the landfill and thus also determines the nature and quantity of the emitted substances.

Effect distance (from released substances) in a fire
A RIVM study (Mennen and Belle, 2007) into the emissions of hazardous substances during large fires concluded, among other things, that in general, at distances from about 1 kilometre downwind of the seat of the fire, there are hardly any measurable quantities of hazardous substances in the air or the air. The study is based on scientific information collected from the literature and measurements of the MOD at around 50 fires. It should be noted, however, that there are exceptions to this rule of thumb: during some fires, hazardous substances are also detected at distances greater than 1 km as a result of the fire. This may, for example, be the result of a slight increase in plume because the fire has a relatively low temperature. This is certainly possible with burning waste.

Odour nuisance
Some substances are listed in the table that can cause odour nuisance at low air concentrations. This is particularly true for compounds such as hydrogen sulphide, carbon sulphide, isocyanates and mercaptans. In addition, formaldehyde, hydrocyanic acid gas, ammonia, cresols (methylphenols), formic acid and acetic acid might cause an odour-nuisance.

References

ATSDR (Agency for Toxic Substances and Disease Registry). 2005. Toxicological profile for Zinc. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry). 2007. Toxicological profile for barium and barium compounds, U.S. Department of health and Human Services, Public Health Service https://www.atsdr.cdc.gov/toxprofiles/tp24.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2008. Toxicological Profile for Aluminum. U.S. Department of Health and Human Services, Public Health Service. September. Available at http://www.atsdr.cdc.gov/toxprofiles/tp22.html
For the list of ATSDR minimal risk levels (MRLs), see http://www.atsdr.cdc.gov/mrls/index.html

Baars AJ, Theelen RMC, Janssen PJCM, Hesse JM, Van Apeldoorn ME, Meijerink MCM, Verdam L, Zeilmaker MJ. (2001). Re-evaluation of human-toxicological maximum permissible risk levels. RIVM report 711701025, National Institute for Public Health and the Environment, Bilthoven, the Netherlands. URL: https://www.rivm.nl/bibliotheek/rapporten/711701025.pdf

Beijk, R., D. Mooibroek, R. Hoogerbrugge (2008). Jaaroverzicht Luchtkwaliteit 2007. RIVM-rapport 680704005. RIVM, Bilthoven.

CBS, PBL, Wageningen UR (2013). Luchtverontreiniging tijdens de jaarwisseling, 1994-2017. www.compendiumvoordeleefomgeving.nl.

EU (1998), Position paper of the Council Directive on Ambient Air Quality Assessment and Management, Working Group on Benzene. http://ec.europa.eu/environment/air/pdf/ppbenzene.pdf

EFSA (2005) Opinion of the Scientific Committee on a request from EFSA related to A Harmonised Approach for Risk Assessment of Substances Which are both Genotoxic and Carcinogenic. The EFSA Journal (2005) 282, 1-31.

EFSA (2006) Tolerable upper intake levels for vitamins and minerals. Scientific Committee on Food - Scientific Panel on Dietetic Products, Nutrition and Allergies. February 2006. http://www.efsa.europa.eu/en/ndatopics/docs/ndatolerableuil.pdf

EFSA (2008) Safety of aluminium from dietary intake - Scientific Opinion of the Panel on Food Additives, Flavourings, Processing Aids and Food Contact Materials (AFC). The EFSA Journal (2008) 754, 1-34.

EFSA (2010) Scientific Opinion on Lead in Food - EFSA Panel on Contaminants in the Food Chain (CONTAM). EFSA Journal 2010; 8(4):1570. https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2010.1570

EFSA (2014) Scientific Opinion on the risks to public health related to the presence of chromium in food and drinking water. EFSA Panel on Contaminants in the Food Chain (CONTAM). EFSA Journal 2014;12(3):3595. http://www.efsa.europa.eu/en/efsajournal/doc/3595.pdf

EFSA (2018), Scientific Opinion on the Risk for animal and human health related to the presence of dioxins and dioxin-like PCBs in feed and food. EFSA Panel on Contaminants in the Food Chain (CONTAM). EFSA Journal 2018;16(11):5333. https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2018.5333

Environmental Engineering & Consulting (2018), Air Screening Results for Pond Island Municipal Waste Disposal Site and Temporary Debris Site International Advisory Support for Debris Management and Short-term Solid Waste Priorities for the Hurricane Irma Reconstruction, Recovery and Resilience Program on Sint Maarten. EE&G Project Number: 2018-4191, Miami, USA.

EU SCHEER (2017). Final opinion on tolerable intake of aluminium with regards to adapting the migration limits for aluminium in toys. https://ec.europa.eu/health/sites/health/files/scientific_committees/scheer/docs/scheer_o_009.pdf

Gezondheidsraad (2010) Aluminium and aluminium compounds - Health-based recommended occupational exposure limit. https://www.gezondheidsraad.nl/documenten/adviezen/2010/07/15/aluminium-en-aluminiumverbindingen-health-based-recommended-occupational-exposure-limit

JECFA (1983) Safety evaluation of certain contaminants in food. Prepared by the Twenty-second meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) https://apps.who.int/iris/bitstream/handle/10665/39165/WHO_TRS_696.pdf;jsessionid=C72CAFE492E44DC348C00051E652BA75?sequence=1

JECFA (2011) Safety evaluation of certain contaminants in food: Arsenic. Prepared by the Seventy-second meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) http://whqlibdoc.who.int/publications/2011/9789241660631_eng.pdf

Mennen, M.G. en N.J.C. van Belle (2007). Emissies van schadelijke stoffen bij branden. RIVM-rapport 609021051

OEHHA (2004) No significant risk levels (NSRLs) for the proposition 65 carcinogens benzo[b]fluoranthene, benzo[j]fluoranthene, chrysene, dibenzo[a,h]pyrene, dibenzo[a,i]pyrene, and 5-methylchrysene by the oral route, May 2004, Reproductive and Cancer Hazard Assessment Section Office of Environmental Health Hazard Assessment (OEHHA) California Environmental Protection Agency http://oehha.ca.gov/prop65/law/pdf_zip/062104clearcopy.pdf

OEHHA (2011) Public Health Goals for chemicals in drinking water - Hexavalent chromium (Cr VI), July 2011. http://oehha.ca.gov/water/phg/pdf/Cr6PHG072911.pdf

RIVM (1992) Exploratory report on Antimony and antimony compounds. RIVM rapport nr. 710401020.

RIVM (1993) Exploratory report on Aluminium and aluminium compounds. RIVM rapport nr. 710401022.

RIVM (2001) Herevaluatie van humaan-toxicologische maximum toelaatbare risico-waarden. RIVM rapport nr. 711701025. http://www.rivm.nl/bibliotheek/rapporten/711701025.pdf

RIVM (2005) Environmental Risk Limits for alcohols, glycols, and some other relatively soluble and/or volatile compounds; Integration of human and ecotoxicological risk. RIVM report 601501027/2005 https://www.rivm.nl/bibliotheek/rapporten/601501027.pdf

RIVM (2006) Chemicals in Toys - A general methodology for assessment of chemical safety of toys with a focus on elements. RIVM/SIR Revised Advisory Report 0010278A02. Revised Final Version, October 12, 2006

RIVM (2009) Re-evaluation of some human-toxicological Maximum Permissible Risk levels earlier evaluated in the period 1991-2001. RIVM-rapport nr. 711701092.

RIVM (2009b) Assessment of odor annoyance in chemical emergency management. RIVM Report 609200001/2009.

SCF (2003) Opinion of the Scientific Committee on Food on the Tolerable Upper Intake Level of Copper. SCF/CS/NUT/UPPLEV/57 Final, 27 March 2003

Social and Economic Council (SER), https://wetten.overheid.nl/BWBR0008587/2019-04-01/#BijlageXIII

US-EPA (2010) Development of a relative potency factor (RPF) approach for polycyclic aromatic hydrocarbon (PAHs) mixtures - In support of summary information on the Integrated Risk Information System (IRIS). Draft. http://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=194584

Vyskocil A and C Viau (1999) Assessment of molybdenum toxicity in humans. Journal of Applied Toxicology 19, Iss. 3, p.p. 185–192.

WHO (2000) Air Quality Guideline for manganese. Air Quality Guidelines - Second Edition. http://www.euro.who.int/__data/assets/pdf_file/0003/123078/AQG2ndEd_6_8Manganese.pdf

Abbreviations

<	Below detection limit or reporting limit
3M	3M-badges – 3M is a brand name
AL	Aldehyde cartridge
AMDIS	Library of GC/MS with database >300,000 compounds
ATSDR	Agency for Toxic Substances and Disease Registry
BaP	benzo(a)pyrene
BZK	Ministry of the Interior and Kingdom Relations of the Netherlands
CA	Canister
CR	Carcinogenic Risk
DL	Detection Limit
DNPH	Cartridge for aldehyde sampling
EE&G	EE&G Environmental Services, LLC (EE&G)
EU	European Union
GC/MS	Gas chromatography/Mass-spectrometer
IARC	International Agency for Research on Cancer
KF(G)	Klein Filter Gerate (small filter equipment)
lb	lower bound (all analysis results '< detection limit' are not included)
LE	Leckel (24/7 filter equipment)
m3	cubic metre
µg	microgram
MOD	Milieu Ongevallen Dienst (Environmental Incident Service) of the RIVM
MTR	Maximaal Toelaatbaar Risico (Dutch equivalent to the TCA)
PA	Passive VOC sampling by 3M-badge
PAHs	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorobifenyl
PE	Petri dish wipe sample
PM_{10}	Particulate Matter with diameter of 10 µm
PVC	Polyvinylchloride
TNO	Laboratory of the Netherlands Organisation for Applied Scientific Research
RIKILT	Laboratory of part of Wageningen University & Research
RPS	Laboratory of 'Rural Planning Services'
RIVM	Dutch National Institute for Public Health and the Environment
SO	Sorbent tube
TCA	Tolerable Concentration in Air
TEQ	TCDD-equivalents (TCDD is a specific dioxin)
TO15	Standard with approximately 60 volatile organic compounds for GC/MS analysis
TWA	Time Weighted Average
TWI	Tolerable Weekly Intake
ub	upper bound (all analysis results '< detection limit' are included)
US-EPA	United States Environmental Protection Agency
VOC	Volatile Organic Carbons
VROMI	Ministry of Public Housing, Spatial Planning, Environment and Infrastructure of Sint Maarten
VSD	Virtually Safe Dose
WHO	World Health Organization
WI	Wipe sample

RIVM
Committed to *health and sustainability* -