ZERO WASTE EUROPE

Hidden temperatures: emissions implications of temperatures in the post-combustion zone of waste incinerators

Case Study

February 2020 – ToxicoWatch

Introduction

Figure 1 Waste burning at the grid. Waste transported to furnace (photo K. Bouman, 10-12-2019 REC)

Waste-to-Energy incineration plants incorporate a number of methods for ensuring proper combustion and reducing emissions. The industry is guided by a set of environmental standards such as the Best Available Techniques (BAT) for Waste Incineration[1] to minimise the impact of their activities, including emission limits on unintentionally produced persistent organic pollutants.[2]

Recent studies by ToxicoWatch 'Hidden Emissions'[3] (2018) and 'Hidden Impacts of Waste Incineration Residues[4] (2019) reveal emissions of dioxin, furan and persistent organic pollutants far beyond the legally permitted emission limits.

These case studies are based on research on the most recent of 13 incineration plants in the Netherlands, a 'state of the art'[5] waste-to-energy (WTE) incineration plant, *Reststoffen Energie Centrale (REC),* in Harlingen, the Netherlands.

[1] Best Available Techniques (BAT) Reference Document for Waste Incineration: Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control). Available at: ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/best-available-techniques-bat-reference-document-waste-incineration-industrial-emissions

[2] The new formed substances are not produced intentionally, and are therefore called as unintentional persistent organic pollutants (UPOPs).

[3] Hidden emissions – A story from the Netherlands. Available at: zerowasteeurope.eu/wp-content/uploads/2018/11/NetherlandsCS-FNL.pdf

[4] The hidden impacts of incineration residues. Available at: zerowasteeurope.eu/wp-content/uploads/2019/11/zero_waste_europe_cs_the-hidden-impacts-of-incineration-residues_en.pdf

[5] When it was built in 2011, it was proudly announced by the Dutch Ministry of Economic Affairs as "a state of the art" installation, the best in Western Europe. Available at: zerowasteeurope.eu/2019/06/the-story-of-rec/

This third Case Study is based on work and research performed under the governmental working group 'Fase 2' [6] which had the objective to research the following questions:

- Is the incinerator complying with the required 2 second residence time above 850 °C in the post-combustion zone?
- What is the halogen content of waste?
- Is there a homogeneous state in temperature in the post-combustion zone?
- Is the polynomial to calculate the temperature in the post-combustion zone correct?
- Is the incinerator being tested under all conditions, even under the worst case scenario?
- Is the oxygen level at the post-combustion zone homogeneous?

Collectively, these questions help to gain a better understanding of the realities of controlling effective temperatures in the post-combustion zone of waste incinerators. Providing a clearer picture of waste incineration emissions.

The importance of temperatures in the post-combustion zone

Temperature is an important feature in the formation and destruction of molecules. A complete combustion breaks down all the molecules into basic elements, while an incomplete combustion produces pollutants like persistent organic pollutants (POPs) in the flue gases.[7] These newly formed substances are not produced intentionally, and are therefore called unintentional persistent organic pollutants (UPOPs).

Thermal treatment in the post-combustion zone is one of the measures put in place to minimise the emissions of POPs. Specifically, the EU Directive on Industrial Emissions[8] requires that the temperature of the flue gas in the post-combustion zone of a waste-to-energy plant has to be maintained to a temperature of at least 850 °C for two seconds:

"Waste incineration plants shall be designed, equipped, built and operated in such a way that the gas resulting from the incineration of waste is raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavourable conditions, ***to a temperature of at least 850 °C for at least two seconds****".*

[6] REC - Continu verbeteren door constructief samen te werken. Available at: www.omrin.nl/bij-mij-thuis/over-omrin/archief/rec-continu-verbeteren-door-constructief-samen-te-werken

[7] This processes occur during cooling down and also in cold spots in the post-combustion zone.

[8] Directive on Industrial EMissions. Available at: eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0075

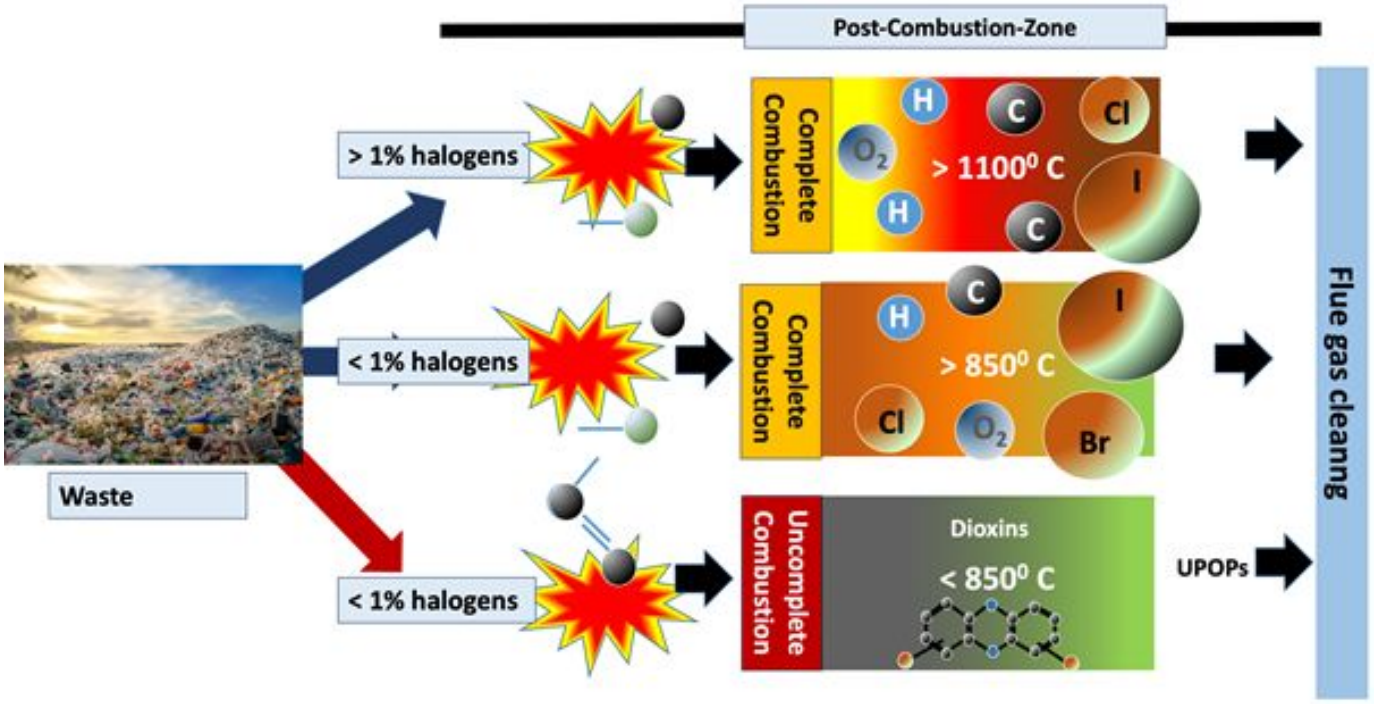

Figure 2: Complete and incomplete combustion (ToxicoWatch)

However, in the presence of halogenated[9] content of organic substances (such as chlorine) above 1% of the waste content, the Directive on Industrial Emissions requires that a higher temperature of 1100°C should be applied in the post-combustion zone:

"If hazardous waste with a content of more than 1 % of halogenated organic substances, expressed as chlorine, is incinerated or co-incinerated, the temperature required to comply with the first and second subparagraphs shall be at least 1100°C".

A high degree of accuracy in measuring and controlling the aforementioned temperature is therefore required to prevent the formation of POPs. In almost the totality of WTE plants this measurement process is carried out by using practical industrial thermometers.

[9] The halogens are a group in the periodic table consisting of five chemically related elements: fluorine, chlorine, bromine, iodine, and astatine.

Consistency in measuring the halogen content of waste

One of the concerns of ToxicoWatch has been the determination of the halogen content[10] of the waste content. Halogens are a group of elements such as chlorine found in everyday products such as plastics and electronics which are a significant part of our daily household waste. As stated above, the Directive on Industrial Emissions requires the halogen content to be lower than 1% in the waste content, otherwise higher temperatures are required in the post-combustion zone:

"If hazardous waste with a content of more than 1 % of halogenated organic substances, expressed as chlorine, is incinerated or co-incinerated, the temperature required to comply with the first and second subparagraphs shall be at least 1100 °C".

In principle, to determine the halogen content, a chemical analysis of waste should be done on the waste input (feedstock). However, there is no legal requirement for how often this analysis should be conducted and on which halogens it should focus - **which is a clear loophole in the legislation**.

In the case of the REC incinerator, only two samples of waste were analysed on the halogen content, one in 2011 and one in 2017 on special request of ToxicoWatch. This represents less than 0,000000003% of a total of 2,800,000tonnes of waste incinerated. Raising questions about the lack of control on what is incinerated at the REC incinerator. Notably, the last analysis in 2017 found 0,9% of chlorine, just 0.1% under the limit of hazardous waste. However, other halogens such as bromine were not analysed as it's currently not required by law.

Lack of transparency in monitoring the post-combustion zone temperatures

The lack of transparency from the REC plant in communicating about the actual post-combustion temperatures has been one of the many difficulties in conducting this research.

Although the Directive on Industrial Emissions requires a verification of temperatures in the post-combustion zone within 6 months of premier operation, the REC management did not provide any evidence that this was actually done. Also, prior to initial operation of the incinerators, temperature investigations should have been done under the normal and licensed worst-case conditions to ensure they can meet the temperature requirements for environmentally sound incineration.

In 2014, a Harlinger journalist Jeroen Pietersma was invited to visit the REC plant. In the control room, he observed the temperatures lower than required by the law (See Figure 3). According to the journalist, the manager of the plant explained that this lower temperature was "*a result of combusting wet waste, sewage sludge*".[11] After the publication of these results in the media, a representative of the province of Friesland

[10] The halogens are a group in the periodic table consisting of five chemically related elements: fluorine, chlorine, bromine, iodine, and astatine. Halogens are found in every day (disposable) consumption products, which is a significant part of daily household waste.
[11] The information is available at ToxicoWatch upon request.

justified the temperature with the excuse that the pyrometers measuring the temperatures were simply too dirty to measure real temperatures.[12]

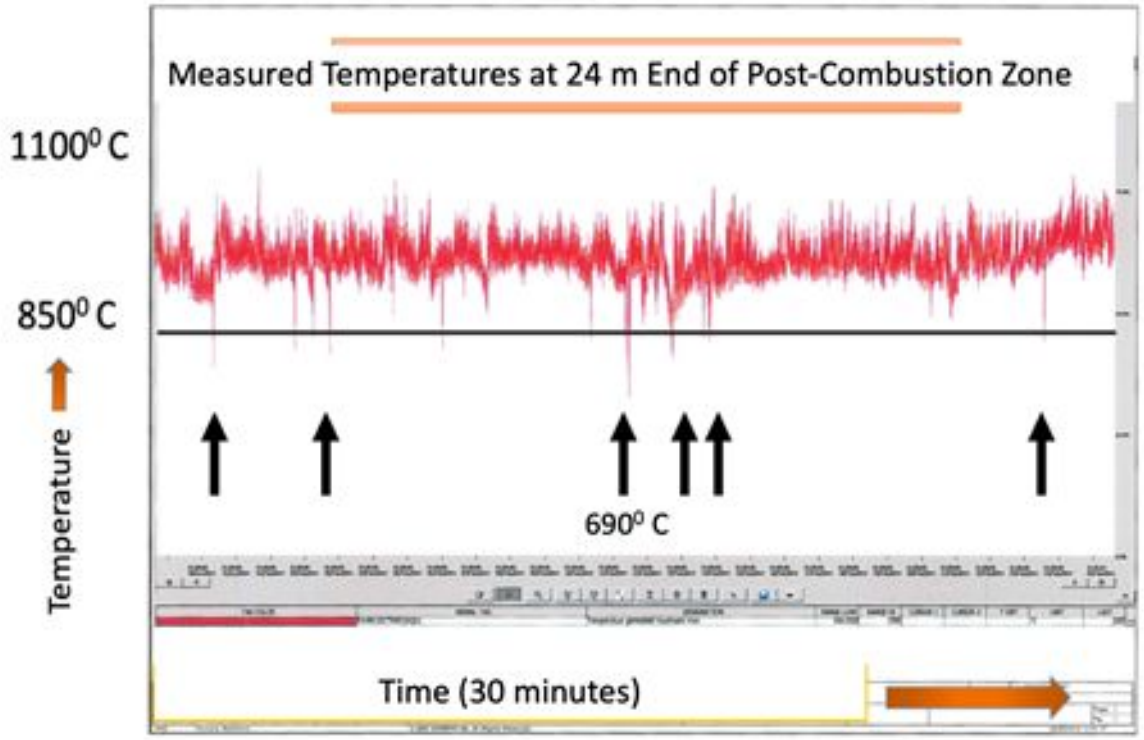

Figure 3: Temperature graph at 24m measurement plane post-combustion zone (HC 22-08-2014, data sheet REC)

The publication of low temperatures in the post-combustion zone raises questions about whether the plant meets the legally required temperature levels. This is particularly worrying as the research has shown that even small changes in temperature can result in large changes in concentrations of UPOPs in the flue gas.[13]

Discrepancies in determining the extent of the post-combustion zone

One of the key issues in measuring the combustion temperatures is the determination of the starting point of the post-combustion chamber. The original documents of the constructor of the facility set the starting point at 18m. At 18m (the so called first measurement plane) is where a homogeneous mixing of air and temperatures can be verified as required.

[12] Idem.
[13] See for example, De-novo formation of dioxins and furans and the memory effect in waste incineration flue gases. Available at: www.researchgate.net/publication/5282846_De-novo_formation_of_dioxins_and_furans_and_the_memory_effect_in_waste_incineration_flue_gases

Nevertheless, the REC plant, took the secondary air inlet at 14m as the starting point of the post-combustion zone. This is just a few meters from the auxiliary burners (See Figure 4) that supply heat during shutdowns and start-ups.

Combustions is a dynamic process and transient conditions occur regularly, making homogeneous temperatures relevant for POP destruction. Efficient mixing of gases can be monitored at level of 18m. However, no agreement could be achieved between the REC management and the governmental working group on the starting point of the post-combustion zone.

Misplacement of thermometers

A high degree of accuracy in measuring and controlling the temperatures in the post-combustions zone is required to prevent the formation of POPs.
The Directive on Industrial Emissions requires that the measurements should be done near the inner wall of the combustion chamber.

*"**In waste incineration plants, the temperatures set out in the first and third subparagraphs shall be measured near the inner wall of the combustion chamber.** The competent authority may authorise the measurements at another representative point of the combustion chamber[14]".*

Best practice, for example, as noted in the English review of Best Available Techniques[15] (BAT) recommends placing the thermometers at the inside wall of the post-combustion chamber to accurately measure the temperatures. This means that the temperature measurements should be conducted at the height of 18m and 24m (See Figure 4).

[14] Article 50 (2) of the Directive on Industrial Emissions. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0075

[15] In an English review of Best Available Techniques (BAT) it is recommended to place thermometers at the wall of the post-combustion zone. Available at: Review of BAT for New Waste Incineration Issues, R&D Technical Report P4-100/TR Part 2 Validation of Combustion Conditions, D Scott & A Collings

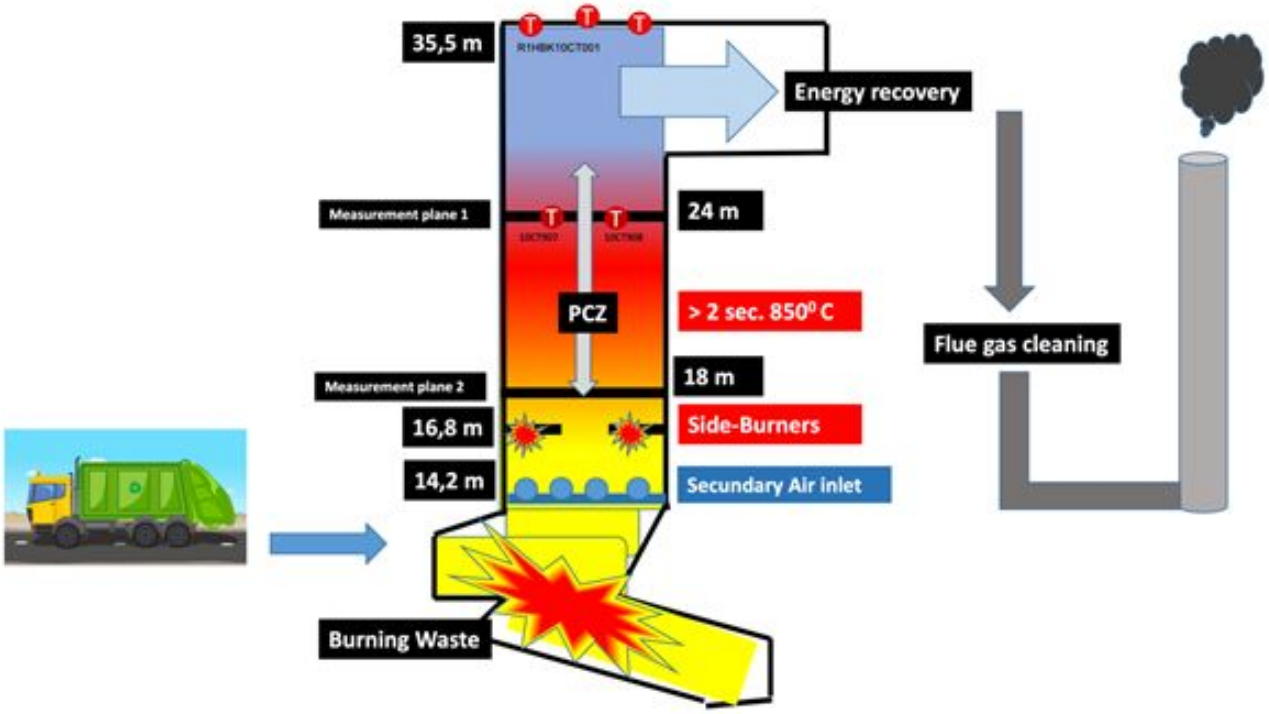

Figure 4: Post-combustion zone

Contrary to these guidelines, the REC incinerator is doing measurement by using pyrometers located at the top of the roof (35,5 m) and adding a figure (so called polynomial) to calculate the temperature in the post-combustion zone. The research shows that the REC is calculating the temperatures at the height of 14,2meters,[16] 4 meters lower than the starting point of the post-combustion chamber.[17] This is the level where the secondary air inlet (14,2m) and the auxiliary burners[18] (16,8m) are situated and meant to maintain the temperature above 850°C. Therefore, these measurements cannot be representative of the homogeneous temperature in the post-combustion zone.

This inaccurate method to determine the starting point of the post-combustion zone could be the result of lacking clear guidelines in the Dutch legislation as regards to the temperature measurements.[19] However, it could also be a problem with enforcement.

In addition, the polynomial or applied addition number was found by the research to be too high (70°C higher).[20] Therefore, the polynomial has to be lowered by 70°C. The REC explained that refractory changing (changing of the stones and tiles) is causing the difference in calculated temperatures. However, no change of refractories has taken place, and even if this could have influenced the temperatures, the polynomial is still questionable as the measurements, as shown below, were incomplete and not performed under the worst case scenarios.

[16] Measurement report REC, Harlingen, Netherlands, 21.08.2017, TÜV Report No.: 936/21239402/A Cologne, 21.08.2017
[17] This is a difference of 3,6m and with a temperature gradient of 22,9°C per meter a difference of 83°C exists between these two locations
[18] The auxiliary burners activate automatically to prevent that the temperature of the combustion gas falls below 850 or 1,100 °C whatever the case may be.
[19] Also, the revised European BAT does not specify how the measurements should be done.
[20] IDEM

Incomplete temperature measurements

According to TÜV[21] research of the REC plant, the temperatures in the post-combustion zone should be measured on two cross-section measurement planes at 18m and 24m (see Figure 5). For representative sampling 18 measure points should be taken in a cross-section measurement plane. These measurements of 18 points in one plane each need to be done at 6 different time frames within 4 hours.[22] This means a total of 216 measurements. However, according to the report by TÜV, 96 measurements from the total of 216 were not performed due to technical obstructions (see figure 5) resulting in an impaired verification of the 2 seconds residence time of the flue gases above 850°C.

Despite the impaired measurements, the data indicates the existence of cold spots in the post combustion zone, at the level of 30,5m. This strongly indicates the impaired destruction of POPs.

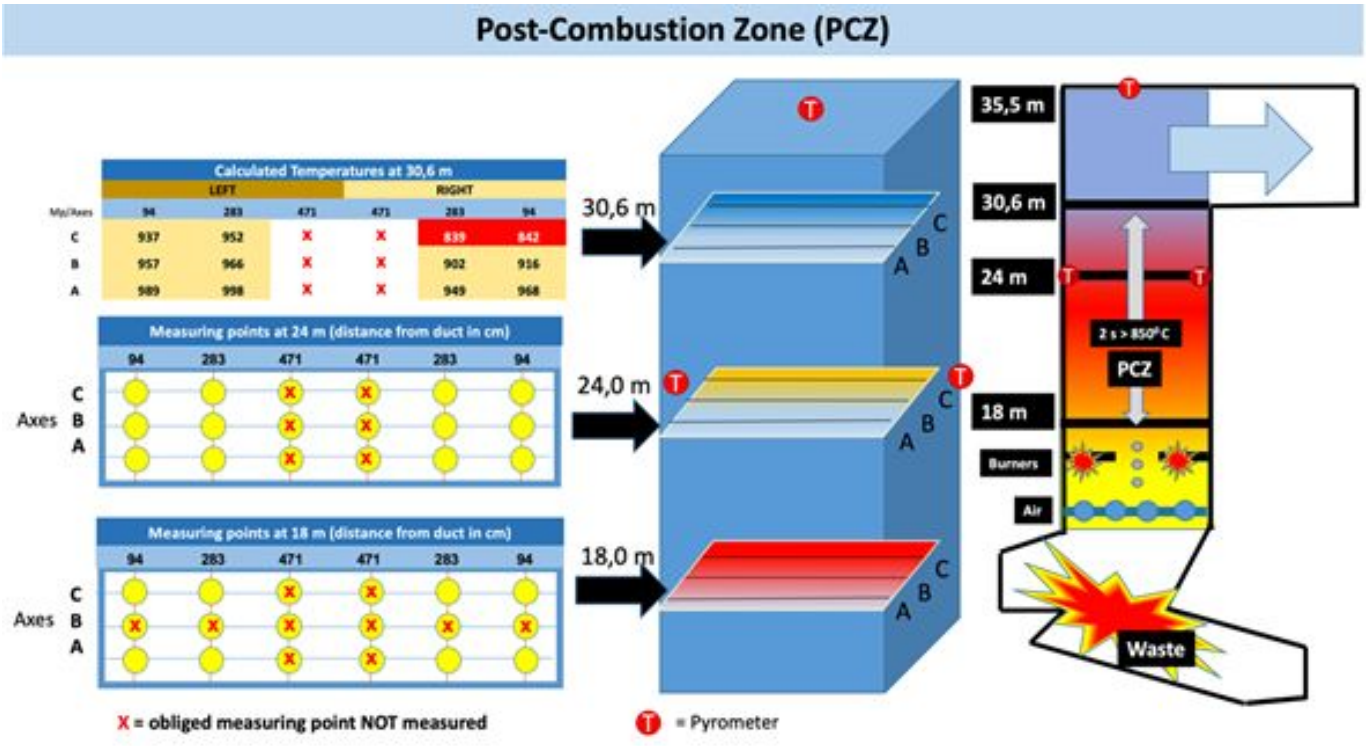

Figure 5: Post-combustion zone and temperature measurements

[21] Measurement report REC, Harlingen, Netherlands, 21.08.2017, TÜV Report No.: 936/21239402/A Cologne, 21.08.2017
[22] IDEM

Challenges with homogeneity in oxygen levels

Complete combustion needs optimal mixing with oxygen. The Directive on Industrial Emissions requires sufficient oxygen levels of 6% in the post-combustion zone with a maximum of a 50% deviation at each measuring point. Figure 6 shows deviations in full and part load conditions of the oxygen levels at REC. Blue circles show deviations of oxygen exceeding 50% deviation limits. It can be concluded that the oxygen levels are far from homogenous, indicating that the optimum mixing of gases is not being reached and not complying the Directive on Industrial Emissions.

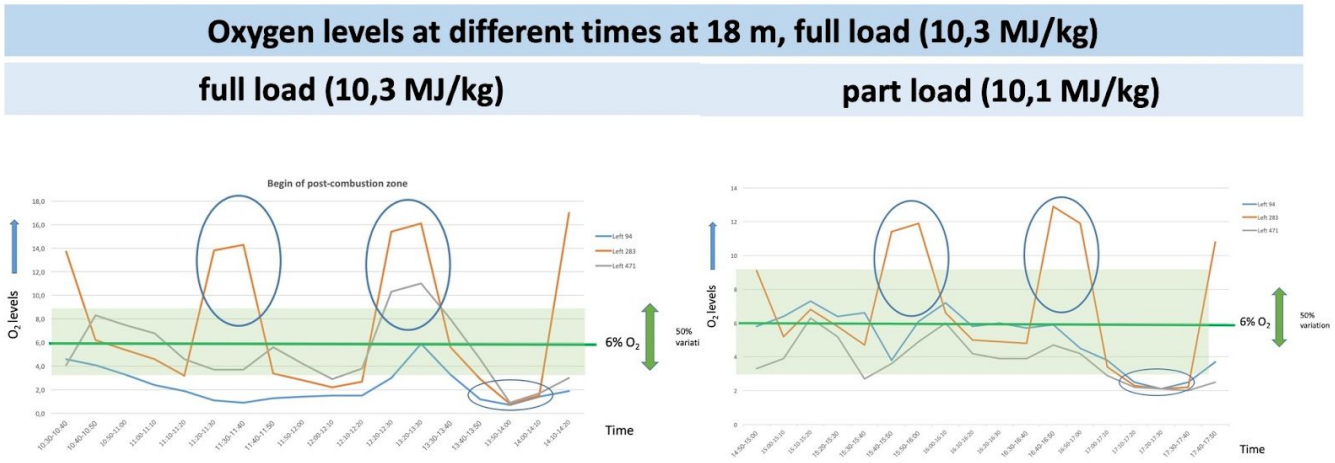

Figure 6: Oxygen measurements. green deviation limits, green line: 6% O_2 level

How the calorific value of waste has further implications related to temperature

The Directive on Industrial Emissions prescribes that waste incinerators must be tested under the most unfavourable conditions. This means, firstly, testing the plant at full and part load, and secondly, testing combustions with different calorific waste. Figure 7 shows the design load of the REC incinerator. According to the recommendations of the working group, the caloric value of waste must have a value between 9 and 15 MJ/kg. The lowest calorific value, the REC incinerator can combust, therefore, is a waste with a value of 9 MJ/kg.[23] Although the REC incinerator regularly burns waste of a low calorific value (sewage sludge), research on the calorific value of waste was performed only on waste with a calorific value of 10.3MJ/kg full load and 10.3 MJ/kg part load, which are normal operating conditions. This suggests that the waste input to the REC incinerator is not being fully appreciated, and the implications of these results are being overlooked. Similarly to the determination of the starting point of the post-combustion zone, no verification of waste combustion under the most unfavourable conditions could be achieved to check whether the incinerator still meets the legally

[23] Measurement report REC, Harlingen, Netherlands, 21.08.2017, TÜV Report No.: 936/21239402/A Cologne, 21.08.2017

required minimum temperature when incineration low calorific waste, sewage sludge.

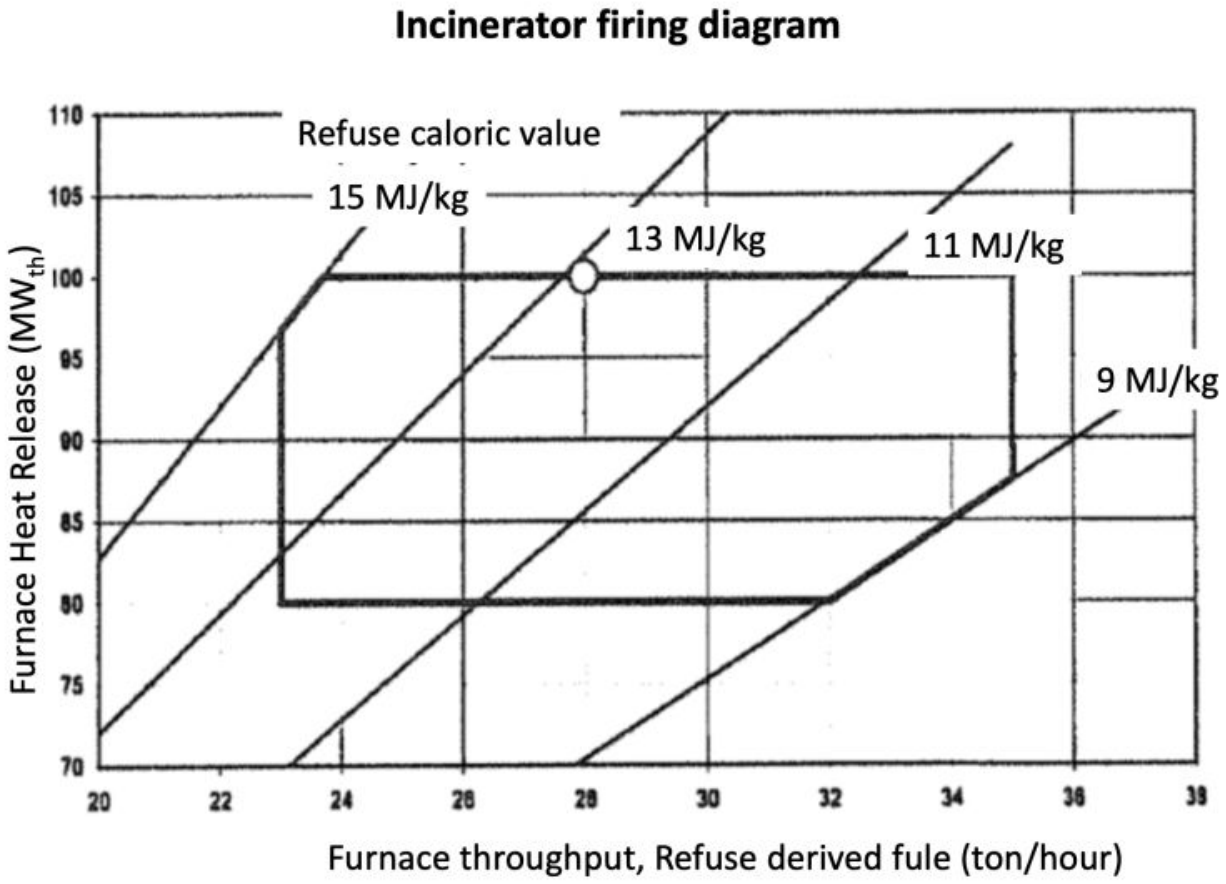

Figure 7: Design Load Case or Firing diagram of the incinerator REC (data REC)

Conclusions and recommendations

The research undertaken as part of the government working group 'Fase 2' indicates that the so-called 'state of the art' REC incinerator does not comply with the 2 seconds residence time above 850°C requirement needed to prevent the emissions of POPs.

The research also reveals high fluctuations of temperature and oxygen differences in the post-combustion zone, as well the existence of cold spots, strongly indicating that the destruction of POPs is impaired.

Moreover, the research further indicates a lack of waste input analysis for the hazardous content (halogen) that could have significant implications on the formation of POPs if the correct temperature is not applied.

Finally, this study has revealed serious shortcomings and legal loopholes in the control of temperatures in waste incineration.

In order to reduce emissions of UPOPs in the environment, a more stringent enforcement of the Directive on Industrial Emissions is recommendable to prevent the formation of unintentional persistent organic pollutants, such as dioxins, and to ensure that waste incinerators apply the best available techniques (BAT) and best environmental practices (BEP).

All incinerators should demonstrate that they comply with the requirement of the 2 seconds residence time of the flue gases above 850°C in a homogenous column of temperatures and oxygen measured with representative sampling even under the most unfavourable conditions.

The results of the REC incinerator case raise important questions for future policy-making concerning the safety of waste incineration, a practice that puts public health and the environment at stake while exacerbating climate change. Europe now has the opportunity to support more sustainable alternatives, while investing in reducing waste in the first place. It's clear that waste incineration is not able to meet the requirement to eliminate POPs, on the contrary, more POPs are produced in the process of burning waste.

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Zero Waste Europe is the European network of communities, local leaders, businesses, experts, and change agents working towards the same vision: phasing out waste from our society. We empower communities to redesign their relationship with resources, to adopt smarter lifestyles and sustainable consumption patterns, and to think circular. *zerowasteeurope.eu*

The ToxicoWatch foundation is a Non-Governmental Organization dedicated to creating a safer and healthier world by advancing the science of toxicology and raising awareness about toxic hazards. *toxicowatch.org*

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