

# Ozone Treatment of Extract Air from a Restaurant Kitchen with Heat Recovery

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## Abstract

*Ozone generation equipment was installed to reduce the cost of cleaning the fat out of the extract ducting system in a fast-food restaurant. The reduced fat content would also help to protect the air handling unit, which comprised recovery of heat from the extract air. However, there is a health respect for ozone, which is a highly reactive irritant. Chemical reactions may also lead to the production of nitrogen dioxide, aldehydes and other volatile organic compounds.*

*Concentrations of the compounds mentioned were measured both by passive and active sampling. Measurements were made outdoors and indoors as well as in the supply, extract and exhaust air streams.*

*With ozone generation the ozone concentration in the extract and exhaust air was higher than 450 µg/m<sup>3</sup>. However, no increase of the ozone concentration in the supply or indoor air was observed. There were no observations of any formaldehyde generation. Neither were there any signs of nitrogen dioxide generation influencing the supply or indoor air, although the exhaust air concentration was higher than the extract air concentration.*

*The measurement results point to incomplete chemical reactions still occurring in the exhaust air. This indicates that the length of ducting available and the air speed did not leave enough time to complete the chemical reactions to break down the different contaminants. However, in this situation with a coil heat exchanger this is of no significance, but if a rotary heat exchanger was to be used, the design must allow enough reaction time at maximum flow.*

**Keywords – ozone generation; extract air; chemical reactions; heat-recovery; air quality**

## 1. Introduction

There is a health respect for ozone, not only for the positive aspects of this powerful purifying chemical agent, but also the all too often difficult to predict and unforeseen consequences of using ozone. The chemical reactions which leads to cleaner ducting and reduced maintenance costs can also lead

to the production of a variety of compounds [1, 2], including nitrogen oxides and aldehydes (for example formaldehyde). There is also a risk of an excess of ozone, which even in low concentrations is associated with negative health implications [3].

As mentioned, one motivation of using ozone generators in exhaust air systems is to eliminate or at least drastically reduce the need of cleaning the ductwork from fat. Another motivation is to enable the use of efficient heat recovery; the ozone generation is claimed to prevent the heat exchanger from becoming clogged by fat. Ozone generation systems dedicated for this purpose are commercially available.

This paper presents results from a project intended to study a selection of air contaminants that may be generated when ozone is released in the extract air from a restaurant kitchen.

## 2. Materials and Methods

### Measurement Location

Measurements were carried out in a fast-food restaurant where an ozone generator (corona discharge glass cell) had been installed in the extract air from the frying griddle in the kitchen. The ozone generating capacity was 10 000 mg/h and the extract air flow rate was 4.2 m<sup>3</sup>/s. The ventilation system was in continuous operation during the entire sampling periods.

The premises are ventilated with mechanical supply and extract air and the air handling unit is equipped with heat recovery by coil heat exchangers. Figure 1 shows a sketch of the air handling and ventilation system. The locations where air samples were taken for subsequent analysis are also indicated in the figure.

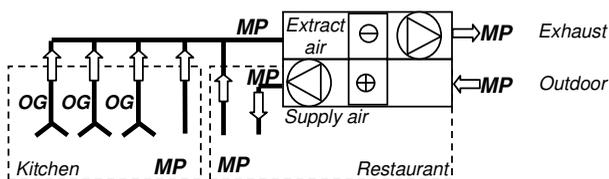


Fig. 1 Sketch of the air handling and ventilation system with points of air sampling marked (MP), and points of ozone generation marked (OG)

Through contact with equipment suppliers from Swegon and Interzon, and the advice of the SP Swedish National Technical Research Institute (SP), a measuring strategy was devised.

### Measurement Methods

The concept was to conduct two separate sets of measurements under the heating season, using the measuring points indicated in Figure 1. The two sets of measurements comprised the methods summarized below:

1. Passive sampling over a period of 2-3 weeks where absorptive samplers were installed and continuously exposed to the environment over the measurement period. By this sampling the concentrations of ozone, nitrogen dioxide and a variety of volatile organic compounds (VOC) were determined as average values over extended periods.
2. Active samplers, where the air was pumped through the absorptive material over a short period of time (approximately 80 minutes). By this sampling the concentrations of a variety of VOCs and formaldehyde were determined as short-term values.

Both sets of air samples were analyzed by SP and The Swedish Environmental Research Institute (IVL), using the methods summarized below:

The VOCs were sampled on Tenax adsorbent and subsequently analyzed by gas chromatography using a flame ionization detector, and mass spectrometry (GC/MS/FID).

Formaldehyde was sampled using DNF-adsorbents; UMEX 100 – SKC samplers in the case of passive sampling, and Waters SepPak Exposure samplers in the case of active sampling. The samples were analyzed by high-performance liquid chromatography (HPLC).

Nitrogen dioxide and ozone were sampled on IVL adsorbents which were analyzed by the corresponding IVL method.

The operational status of the ventilation system was logged via the control and surveillance system of the buildings. These data comprise airflow rates and temperature levels.

### **3. Results and Discussion**

#### **Results from Passive Sampling**

Figure 2 summarizes the ozone concentrations determined by passive sampling over a 17-day period with the ozone treatment active. The results show that the indoor ozone concentration was low, both in the restaurant and in the kitchen. The concentrations measured indoors were slightly over  $20 \mu\text{g}/\text{m}^3$ . These values are substantially lower than the Swedish Environmental Quality Norm for good outdoor air quality. This norm originates from the European directive on ambient air quality [4]. For ozone this norm is  $120 \mu\text{g}/\text{m}^3$ , expressed as an 8-hour average value. The World Health Organization [3] recommends sharpening the guideline value for ozone to  $100 \mu\text{g}/\text{m}^3$ . During sunny spring-days the ozone concentration in urban locations may exceed  $100 \mu\text{g}/\text{m}^3$ . The measured indoor concentrations, in the studied restaurant, are found at substantially lower levels. Furthermore, the ozone concentration indoors was about 50% of that outdoors, which is as expected. No reference data for restaurants have been found, but data

reported from office buildings show indoor concentrations in the interval 20-80% of those measured outdoors [5].

Figure 2 also shows that the ozone concentrations were about the same outdoors and in the supply air. Thus, the ozone found indoors was mainly supplied from outdoors, despite the extremely high concentration observed in the extract air due to the ozone treatment.

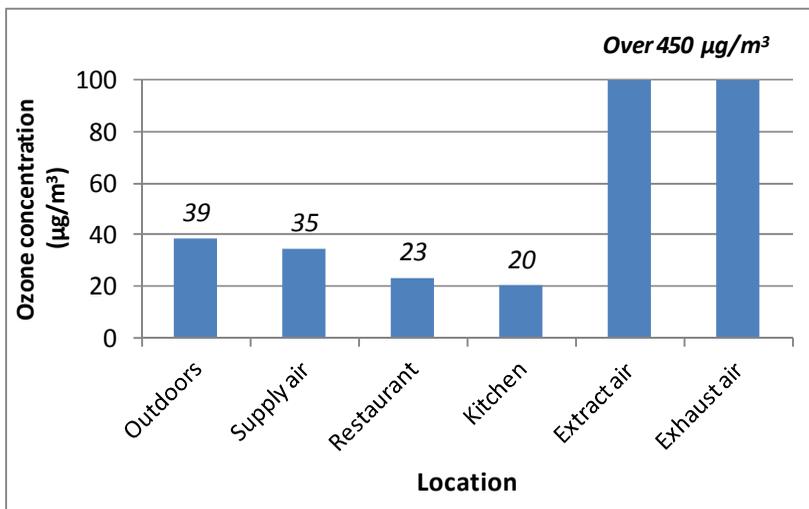


Fig. 2 Ozone concentrations measured by passive sampling over a 17-day period in January and February 2010.

Figure 3 shows the nitrogen dioxide concentrations measured by passive sampling during the same 17-day period, with ozone treatment. Similar to the case with ozone, it is clear that the nitrogen dioxide concentration indoors was comparatively low - below 30 µg/m<sup>3</sup> in the supply air, kitchen and restaurant. The Swedish environmental quality norm for nitrogen dioxide is 40µg/m<sup>3</sup> expressed as annual average value, 60 µg/m<sup>3</sup> expressed as 24-h average and 90 µg/m<sup>3</sup> expressed as 1-h average value. The concentrations measured indoors are all below these normative values.

The results show that the main source of nitrogen dioxide is to be found outdoors. The concentration measured in the exhaust air is higher than that measured in the room air and in the extract air, which is hard to explain. This suggests that the ozone in the extract air oxidized nitrogen monoxide to nitrogen dioxide. This reaction would have started at the point of ozone generation and then proceeded through the entire extract-exhaust ductwork, also on the exhaust air side of the air handling unit.

The nitrogen dioxide concentration indoors was 60-70 % of the concentration outdoors, which is a plausible relation. As ozone, nitrogen

dioxide is a highly reactive compound which usually shows strong sink effects; it has a strong tendency of reacting with other compounds, in the air as well as on the surfaces of the interior of the duct, the air handling unit and indoors.

The fact that the supply air concentration was substantially lower than the outdoor concentration may indicate that nitrogen dioxide reacted, for example, on the surfaces of the heat exchanger. It is not necessarily the only explanation to the concentration reduction.

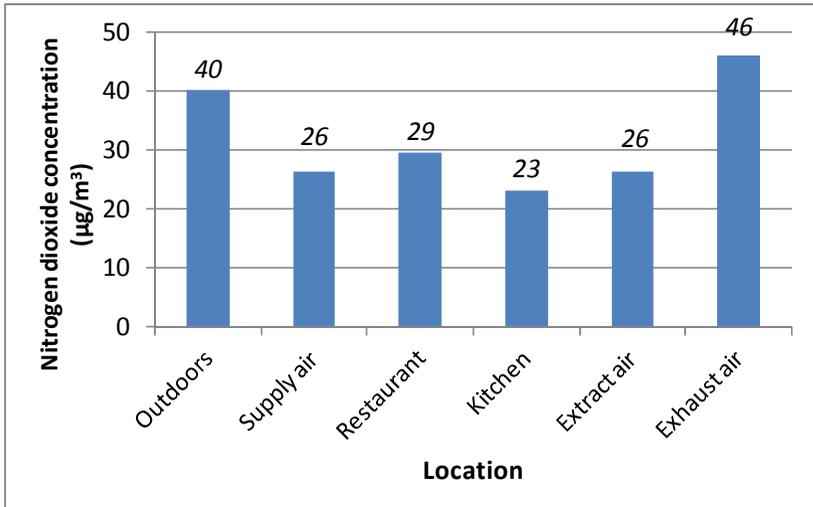


Fig. 3 Nitrogen dioxide concentrations measured by passive sampling during 17 days in January-February, 2010.

Figure 4 shows a summary of the total VOC concentration measured by passive sampling simultaneously with the sampling of ozone and nitrogen dioxide. The concentrations in the extract air and the exhaust air were about ten times the concentrations observed in the other locations. The reason may be that organic compounds were released at the frying griddle in the kitchen. The explanation may also be related to the very high ozone concentration in the extract air. The ozone decomposes fat from the frying, which may contribute to the content of organic vapors in the air.

The concentrations of VOCs in the outdoor air, supply air and indoor air were all of the same magnitude; about 10% of that in the extract air.

The VOC concentration in the supply air was about twice as high compared to the outdoor concentration. The explanation is not related to any mass transfer over the heat recovery unit, since this is of the coil type, without any air leakage between the extract and supply sides. Neither is the explanation related to "back draft" of room air into the supply air system –

since the fans were in continuous operation. However, it is not realistic that the supply air VOC concentration was about the same as the indoor concentration. With a supply concentration of  $100 \mu\text{g}/\text{m}^3$  the indoor concentration would have been higher than  $100 \mu\text{g}/\text{m}^3$  due to internal VOC emissions, e.g. from building products, furniture etc. Thus, it appears as if the measured supply air VOC concentration is higher than the real concentration. The observation is based on one set of measurements only, which is too little to allow for any conclusions in this respect.

Finally, it can be concluded that the measured indoor VOC concentrations are not remarkably high. For example, according to a recent indoor environment investigation (BETSI, see [www.boverket.se](http://www.boverket.se)), the total VOC concentration in residential buildings typically may be found at about  $230 \mu\text{g}/\text{m}^3$ .

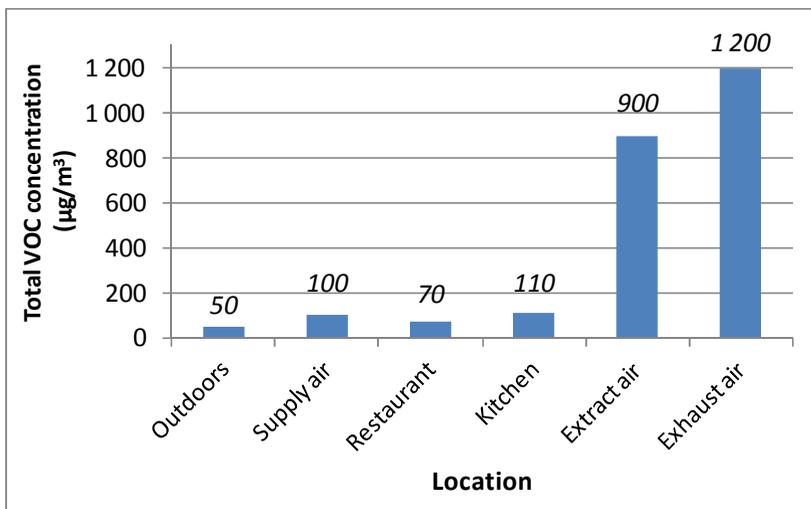


Fig. 4 Total VOC concentrations measured by passive sampling during 17 days in January-February 2010.

### Results from Active Sampling

Figure 5 summarizes the results from active sampling of VOCs during two consecutive 80-minute periods. First, samples were taken with ozone treatment in operation. Immediately after that, samples were taken without ozone treatment. The total restaurant sales were also recorded during the two periods. The sales can be assumed to reflect the intensity of the cooking that took place in the restaurant kitchen. Thus, it is assumed that the sales to some extent reflect the intensity of the generation of cooking fumes and fat.

The sampling comprised two slightly different procedures. One set of samplers were equipped with grease filters to prevent clogging of the

samplers with fat. Another set of samplers were not equipped with any grease filters. The samplers with grease filters showed somewhat lower concentrations than the ones without. However, the relation between the cases with and without ozone treatment is about the same, regardless of whether grease filters were used or not.

One interpretation of the data presented in Figure 5 is that the total VOC concentration increased with increasing sales. However, there is a possibility that the increase of the VOC concentration was induced by the ozone generation itself. It is unfortunate that the sales happened to be higher during the period with ozone generation. This complicates the interpretation and it is not possible to determine which of the explanations is the correct one, or if the truth is a combination of the two.

Figure 6 shows the formaldehyde concentrations that were measured by active sampling, simultaneously with the VOC sampling. The concentrations were about the same, both with and without ozone treatment. This can be interpreted as if neither the cooking nor the ozone treatment generated any formaldehyde. The measured concentrations can be regarded as very low; they are of the same magnitude as typically observed in the outdoor air. Thus, there are no indications of any indoor formaldehyde generation. For comparison it can be mentioned that a normal or typical exposure level in residential buildings is 20-25 $\mu\text{g}/\text{m}^3$  – about ten times higher than the values measured in the present investigation.

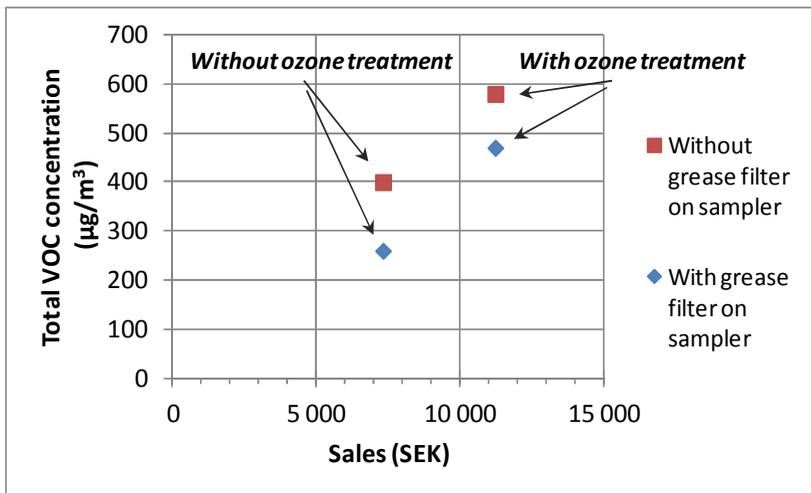


Fig. 5 Total concentration of VOCs in extract air measured by active sampling during 80 minutes in the middle of the day, 24 February 2010. One set of samplers were equipped with grease filters, the other was not.

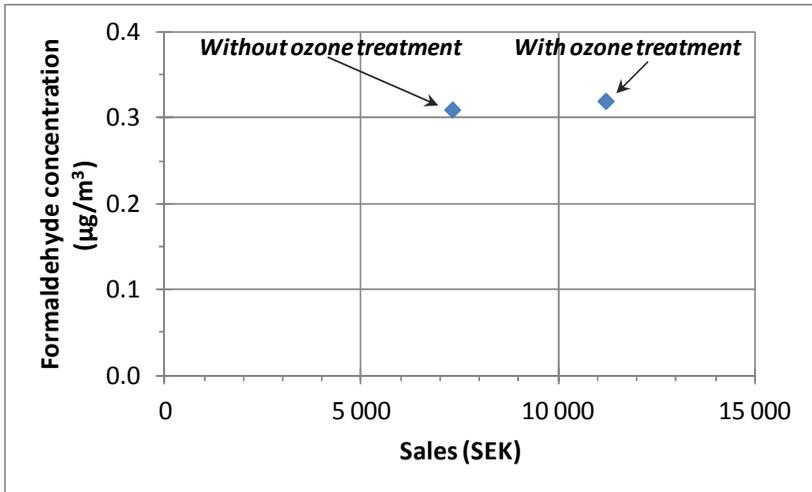


Fig. 6 Concentration of formaldehyde in extract air measured by active sampling during 80 minutes in the middle of the day, 24 February 2010. The samplers were equipped with ozone filters.

#### 4. Conclusions

The levels of ozone in the extract and exhaust air flows were higher than possibly could be accurately measured by the ozone samplers over the period of time. In these locations the level of ozone was clearly underestimated.

There were no signs in this case of any formaldehyde generation.

VOC levels increased between the two measuring points in the extract path of the air handling unit. This, together with the high ozone concentrations, points to incomplete chemical reactions still occurring and developing in the air.

If one is to use ozone generators to clean the extract air, then one can see the length of ducting available and the air speed in this renovated restaurant does not leave enough time to fully complete all the chemical reactions to break down the different contaminants. However in this situation with a coil heat exchanger this is of no significance, but if a rotary heat exchanger was to be used, the design must allow enough reaction time at maximum flow.

The ozone concentration in the extract and exhaust air was remarkably high. I may be hypothesized that gaskets in the air handling unit and other rubber materials will deteriorate when exposed to such high ozone concentrations over long periods of time. This may mean that materials in the extract-exhaust air system will age more rapidly than normal.

## **5. Acknowledgment**

Valuable suggestions from Lars Rosell, SP Technical Research Institute of Sweden, and Associate Professor Sarka Langer, IVL – The Swedish Environmental Research Institute, are acknowledged.

## **6. References**

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