Simmering Sauces! Elevated Formaldehyde Concentrations from Gas Stove Burners

Dustin Poppendieck[1], Mengyan Gong[2]

[1]National Institute of Standards and Technology, Gaithersburg, MD, 20899 USA
[*]*Corresponding email: dustin.poppendieck@nist.gov*

SUMMARY
Formaldehyde is listed as a human carcinogen, and can be formed as a primary by-product during combustion processes. Past studies have not detected elevated formaldehyde concentrations from gas stoves, perhaps due to the time averaging nature of previous sampling campaigns or because the burners were operated at a high setting.[1] In this research we used a real-time formaldehyde monitor to show that simmering of a gas burner can increase indoor formaldehyde concentrations above the California Office of Environmental Health Hazard Assessment (OEHHA) Acute Reference Exposure Level (REL). When one or more burner simmered and the kitchen hood exhaust was off average ambient kitchen formaldehyde concentrations increased 60 μg m^{-3} to 100 μg m^{-3} above pre-simmering levels. Concentrations varied with time and location in the kitchen during burner operation. Peaks concentrations were up to 830 μg m^{-3} above pre-simmering, and didn't necessarily occur in front of stove.

KEYWORDS
Cooking, Natural Gas, Combustion, Formaldehyde, Source, Peak Concentrations

1 INTRODUCTION
Formaldehyde is listed as a human carcinogen by the International Agency for Research on Cancer (IARC)[1]. The California Office of Environmental Health Hazard Assessment (OEHHA) Acute Reference Exposure Level (REL) for formaldehyde is 55 μg m^{-3} and Chronic REL is 9 μg m^{-3}.[2] Mullen et. al.[3] surveyed 344 kitchens and found time-averaged (five days to ten days) geometric mean formaldehyde was 14.9 ppb (18.6 μg m^{-3}). However, there is no known literature investigating acute formaldehyde exposure scenarios during cooking, largely due to reliance on time-averaged sampling techniques.

Figure 1: Gas stove burner simmering (on lowest setting).

This effort investigated potential formaldehyde (CH_2O) emission during operation of natural gas burners on stoves and in ovens. Formaldehyde is a major intermediate in the combustion of methane, resulting from the reaction of the methyl radical and oxygen radical; however, formaldehyde usually reaches only trace levels since typically it is consumed as quickly as it is formed. But when simmering on a burner, the flame reaction zone impinges upon the metal burner, conductively cooling the flame. At lower flame temperatures, formaldehyde and nitrogen dioxide (NO_2) emissions are higher (nitrogen oxide (NO) is favoured at higher flame temperatures). Hence, the lower simmering flame temperature may result in a higher NO_2/NO ratio and higher formaldehyde generation rate (as compared to a burner operating on full output). The question raised in this work is whether a simmering burner leads to short term formaldehyde kitchen concentrations at levels of interest (above the OEHHA Acute REL).

2 METHODS
Emissions from a natural gas stove were measured in the National Institute of Standards and Technology (NIST) manufactured test house facility. To minimize mixing throughout the house and isolate the kitchen area, the forced-air distribution system (used during heating and cooling) was off during the experiments. As a result, the temperature and relative humidity

were not controlled during the experiments. A small mixing fan was used in the kitchen during injection of the tracer gas. Whole house air change rates were measured using a sulphur hexafluoride (SF_6) tracer system, including a tracer sample in the kitchen. The whole house air change rates during the experimental period ranged from 0.19 h^{-1} to 0.38 h^{-1}, while the decay rates in the kitchen ranged from 0.35 h^{-1} to 0.46 h^{-1}.

A real-time formaldehyde monitor using absorption spectroscopy sampled air at five breathing height (1.4 m) locations in the 45 m^3 kitchen test volume. One sampling point was located 0.33 m in front of stove. The remaining sampling points were distributed throughout the room, 1.3 m to 3.4 m from the flame. A scanning mobility particle sizer (SMPS) connected to a condensation particle counter (CPC) was used to classify and count particles from 2.5 nm to 64 nm. The highest particle number concentrations were typically at 2.5 nm. The particle monitor was located 1.1 m from the flame at a height of 1.6 m. Temperature and relative humidity were recorded at the same location. NO_2 and NO were measured using a chemiluminescent analyzer.

3 RESULTS AND DISCUSSION

Background formaldehyde concentrations ranged from 25 μg m^{-3} to 61 μg m^{-3} prior to stove ignition. The experiments demonstrated (Table 1) that one burner set at "high" produces formaldehyde lower than the OEHHA chronic REL (9 μg m^{-3}), while simmering one or four gas burners (burner at "lo") without local exhaust ventilation can elevate the formaldehyde concentrations above the OEHHA acute REL (55 μg m^{-3}). Operation of vent fan can reduce the increase in formaldehyde concentration, but the increase is still statistically significant (student t-test).

Table 1. Summary of Experimental Results

Experimental Conditions	HCHO Conc. Increase (Mean ± SD, μg m^{-3})[8]	Peak HCHO Increase (μg m^{-3})	NO_2/NO Ratio[1]	Peak Particle Concentration (#/cm^3, 2.5 nm)	Temp. (Mean ± SD, °C)	Relative Humidity (Mean ± SD, %)
1 burner at "lo"[2]	72 ± 18	120	25	53 549	29.4 ± 0.1	32.5 ± 0.1
1 burner at "lo" w/ frying pan[2,3]	100 ± 26	260	25	NR[9]	26.1 ± 1.7	20.8 ± 4.3
1 burner at "lo" w/ vent fan[2, 4]	26 ± 7.8	59	25	10 925	24.7 ± 0.4	23.0 ± 0.7
4 burners at "lo"[5]	60 ± 35	830	9.3	224 843	27.6 ± 0.0	33.3 ± 0.0
1 burner at "high"[6]	5.0 ± 8.2	51	0.3	576 178	28.9 ± 1.3	34.2 ± 1.7
oven[7]	22 ± 14	380	NR[9]	NR[9]	26.2 ± 0.0	22.6 ± 0.3

[1]Ratios from separate experiments with same experimental conditions, determined 15 min after burner ignited.
[2]"lo" setting on 5,000 BTU burner.
[3]25 cm diameter frying pan was filled with roughly 350 mL water.
[4]Vent fan on lowest setting at 180 m^3 h^{-1}.
[5]"lo" setting on 5,000 BTU, "lo" setting on two 9,500 BTU burners, "lo" setting on a 12,000 BTU burner
[6]"high" setting on 12,000 BTU burner
[7]Oven was set at 77°C.
[8]Concentrations averaged from 60 to 120 minutes after burner ignition four first four experiments. Concentration averaged for fifteen minutes after burner ignition for last two experiments due to decay after ignition.
[9]Not recorded.

This research highlights a transient formaldehyde source when simmering food on gas stoves. This exposure could be significant if local exhaust vent fans are not used or available.

4 REFERNCES:

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