Mercury exposure in Dutch households supplied by gas

BACKGROUND

In the last decades mercury has been identified as a hazardous substance and the society has become conscious of its associated risks. As a result, regulation has been put in place to abolish or minimize the use of mercury in consumer products. In addition, intervention values for working (Treshold Limit Values, TLV) and living conditions have been established by the relevant authorities.

Natural gas can contain mercury. A substantial part of the mercury originally present in the gas is removed through processing the natural gas (removal of fluids). The efficiency of this process strongly depends on the method and conditions.

Monitoring programs executed by Gasunie Transport Services (GTS) and NAM have shown that there is a great variety in the mercury content of natural gas. Of those fields operated by NAM, the highest concentration of mercury in *unprocessed* gas is in the Groningen field. *Processed* Groningen gas is supplied to domestic users in The Netherlands and abroad.

The monitoring programs assessed the throughout the gas production and GTS transport chain. Until recently, mercury levels observed at GTS gas receiving stations were only a fraction of the mercury delivered at the entry points. This lead to the conclusion that mercury was absorbed in the GTS pipeline system. A KEMA study in 2012 showed that the mercury levels in gas in some of the exit points of the GTS transportation system had increased over time to values (up to 10 µg/ m^3). Higher values that could suggest that little to no adsorption takes place in that some pipelines, whereas significant reduction in mercury level is still measured over other parts of the pipeline system.

In 2013, GTS and NAM requested a *sample* test to be conducted by KEMA to determine the mercury concentration in gas that is supplied to domestic users (also referred to as households)[1]. The findings show that mercury is present at the gas entry points of households, with concentrations between 0,32 µg/m^3 and 0,75 µg/$m^{3,}$ with one outlier of 6,9 µg/m^3. This implies that consumers could be exposed to mercury by combustion of the gas which could affect the indoor air quality.

It is key for NAM and GTS to understand the relation between mercury in indoor air and mercury in the supplied gas to assess the risk of health exposure of Dutch households.

AIM

The purpose of this study is twofold:

1) Develop a model based on widely accepted parameters to assess the exposure of Dutch households to mercury in air through gas combustion.
2) Determine if current concentrations of mercury in natural gas can lead to exposure levels above the intervention values in air set by RIVM (Dutch national authority for Public Health and Environment).

[1] KEMA Rapport september 2013 'Inventarisatie kwikgehaltes bij eindverbruikers'

It will address the following aspects:

1. Current health exposure for different type of Dutch households
    a. Day average exposure µg/m^3 indoor air
    b. Peak exposure pattern in µg/m^3 indoor air
2. Maximum mercury content in gas based on RIVM life time exposure limit
    a. Average daily exposure equal to 0,05 µg/m^3
    b. Exposure to peaks > 0,05 µg/m^3

METHODOLOGY

The attached data sheet includes the following references to limits, key variables and assumptions.

Reference to RIVM mercury limit [2]

RIVM has defined lifetime exposure limit for mercury in indoor air at 0.05 µg/m^3. This is based on assessment of an average annual exposure for all groups, including children and pregnant women.

The same document advises a short duration (1 week) exposure limit of 10 µg/m^3 . This limit is not considered applicable for the daily exposure of mercury in air due to semi continuous gas consumption in households. This exposure limits relates to mercury spills through accidents (e.g. mercury spills through broken old mercury temperature meter, and is thus far higher than the life time exposure reference.

Key variables of exposure

- Sources of gas combustion affecting indoor air quality: 4-burner stove (cooking) and water boiler (heating water)
    - Please note that a water boiler (also referred to as water heater or geyser, in Dutch: geiser) refers to a water heating device that is placed in the cooking/living area which emits its combustion air to the indoor air. Different regulations apply for those houses build after the year 2012. Bouwbesluit 2012[3] dictates that water boilers need to have a combustion air removal channel connect to outside air, and thus becomes a closed system which does not emit to indoor air. However, this is only a requirement for newly build houses.
- Amount of gas consumption
- Duration in which the gas is released and combusted in the room (also referred to as the consumption pattern)
- Ventilation of the room where gas is consumed
- Mercury content of the supplied gas

The following variables are considered not significantly affecting the model or considered constant

- Sources of gas: Heating- a closed systems and thus the gas combustion does not affect the indoor air quality
- Number of people in a household
- Ventilation considered constant (not intermittent)

[2] RIVM (2011), GGD-richtlijn medische milieukunde, kwik in het binnenmilieu en gezondheid, RIVM rapport 609300021/2011

[3] Ministerie van Binnenlandse zaken en Koninkrijk relaties (2012) Bouwbesluit 2012; Toelichting toevoer van verbrandingslucht en afvoer van rookgas.
http://www.google.nl/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&ved=0CCoQFjAA&url=http%3A%2F%2Fwww.rijksoverheid.nl%2Fbestanden%2Fdocumenten-en-publicaties%2Fbrochures%2F2012%2F06%2F11%2Finfoblad-toevoer-van-verbrandingslucht-en-afvoer-van-rookgas-bouwbesluit-2012%2Finfoblad-toevoer-van-verbrandingslucht-en-afvoer-van-rookgas-bouwbesluit-2012.pdf&ei=UJpCUpX7FInX0QXRvYGAAQ&usg=AFQjCNGolsShjaEopYAUA8DIDfkcWFRf1g&bvm=bv.53077864,d.d2k

Assumptions

Ventilation

Ventilations strongly depends on the housing conditions; including presence of windows, degree of insulation, or presence of mechanical ventilation. Therefore, the model represents the variations in ventilation circumstances by means of three scenarios; high ventilation, mid ventilation, low ventilation.

Scenarios	Ventilation [turnovers/hr]	Comment
High ventilation	8	Maximum possible ventilation for household use
Mid ventilation	5	
Low ventilation	2	Minimum ventilation on the basis van bouwbesluit 2003, 2012[4]

This study has chosen three ventilation scenarios based on turnovers per hour. This range of minimum to maximum is to show the sensitivity of the mercury concentration relative to the ventilation circumstances for different types of houses.

The minimum of ventilation of 2 turnovers per hour used in this study is based on Woningbouw voorschriften from 2003 and 2012. Houses build before 2003 could either have slightly more ventilation (poor insulation in older houses) or less (houses which have been well insulated but no mechanical ventilation).

The table below shows that the ventilation factor used in this study, is very similar to the NEN1087 (bouwbesluit) regulation. For the worst case condition scenario (small space) the ventilation factor is a chosen slightly more conservative.

NEN1087 (bouwbesluit):

Ruimte	Ventilatie	Average exposure (µg/m^3)	1hr exposure		20 min exposure (3x/dag)	
			Max. Hg conc. (µg/m^3)	Time Hg conc. > 0.05 µg/m^3	Max. Hg conc. (µg/m^3)	Time Hg conc. > 0.05 µg/m^3
30 m^3	75 m^3/hr	0.016	0.30	100 min	0.18	49 min
60 m^3	100 m^3/hr	0.013	0.20	104 min	0.11	40 min
120 m^3	150 m^3/hr	0.0097	0.12	86 min	0.058	11 min

NAM aannames:

Ruimte	Ventilatie	Average exposure (µg/m^3)	1hr exposure		20 min exposure (3x/dag)	
			Max. Hg conc. (µg/m^3)	Time Hg conc. > 0.05 µg/m^3	Max. Hg conc. (µg/m^3)	Time Hg conc. > 0.05 µg/m^3
30 m^3	60 m^3/hr	0.020	0.35	116 min	0.20	59 min
60 m^3	120 m^3/hr	0.011	0.18	91 min	0.10	34 min
120 m^3	240 m^3/hr	0.0072	0.090	60 min	0.052	2 min

A ventilation of 2 turnovers/hour represents poor ventilation Meaning that the total volumetric content of the room is replaced twice within the hour with clean air. In the model it is assumed that with the replacement of air no mercury remains behind. However, a certain amount of mercury in air, also referred to as a background value, is accounted for.

[4] BOUWBESLUIT 2003 and 2012

Gas consumption

For the gas consumption for cooking the 65 m^3/year is used as established by ENECO[5],[8]. This number is similar to industry information from ATAG-Pelgrim (personal communication, July 2013). ATAG-Pelgrim states that a general 4-burner stove uses a maximum of 2 m^3/hr. Preparing a dinner will take about 20 minutes with a capacity of 25% of the stove. This results in a gas consumption of 60 m^3/year, and thus similar to Eneco number of 65 m^3/year.

Gas consumption for cooking and water boiler is defined by Eneco at 440 m^3/year, which means a gas consumption for water boiler is 375 m^3/year. According to information from ATAG-Pelgrim (personal communication), a general water boiler uses 1.3 m^3/hour. To achieve a gas consumption of 375 m^3/year the water boiler must be used for 1 hour each day. This is considered realistic. In all scenarios average gas consumption reference of Eneco of 440 m^3/year will be used.

Gas consumption for heating the house are considered to have no impact on indoor air quality since the flue gasses are discharged via exhaust pipes. It is assumed that the gas consumption for cooking and water boiling are independent from the size of the house.

Gas consumption pattern

The exposure of individuals depends both on how much gas is used in this model assumed constant 440 m^3/day and the pattern of use (continuous, once a day or several moments during the day). All three patterns are considered and in our view the worst case scenario depicted in the graphs below.

Mercury concentration in gas

For the purpose of this exercise a value of 20 µg/m^3 is used for mercury in gas delivered to end consumers.

Background value

A certain amount of mercury is constantly present in air. RIVM considers the background value of mercury in air in the Netherlands to be 3 ng/m^3 [6].

Homogenous diversion of mercury in air

In this study it is assumed that indoor air quality, and the thus the mercury concentration, is homogenous in air due to ventilation and air circulation.

Situations described in model: Type of household and scenarios

Concentration of mercury indoor air will be modelled by using three types of housing (A, B,C) which represent the different circumstances of accommodation.

Type of	Definition	Volume	Total gas	Gas consumption

[5] ENECO (2011) Gas consumption for cooking and using a water boiler: http://thuis.eneco.nl/~/media/eol/pdf/tarieven-2011/tarieven-variabel-onbepaalde-tijd/gas-per-1-januari-2011

[6] RIVM (2011), GGD-richtlijn medische milieukunde, kwik in het binnenmilieu en gezondheid, RIVM rapport 609300021/2011

household		of space [m^3]	consumption[7] [m^3/yr]	for cooking and heating water[8 9] [m^3/yr]
House A	Small shared student kitchen	30	900	440
House B	Family house with large kitchen	60	1590	440
House C	Detached house	120	2220	440

For each type of house, three ventilation scenarios will be calculated to represent a wide range of housing conditions (old, new, insulated, not-insulated).

Scenarios	Ventilation [turnovers/hr]	Comment
High ventilation	8	Maximum possible ventilation for household use
Mid ventilation	5	
Low ventilation	2	Minimum ventilation on the basis van bouwbesluit[10]

[7] Nuon (2013) Gas consumption domestic households: http://www.nuon.nl/energie-besparen/e-manager/gemiddeld-energieverbruik.jsp

[8] ENECO (2011) Gas consumption for cooking and using a water boiler: http://thuis.eneco.nl/~/media/eol/pdf/tarieven-2011/tarieven-variabel-onbepaalde-tijd/gas-per-1-januari-2011

[9] Personal Communication 5.1.2.e (July 2013) with ATAG-Pelgrim

[10] BOUWBESLUIT 2003 en 2012

PART 1 RESULTS – Current health exposure households

A. Average exposure

The concentrations µg/m3 below show the exposure of Dutch households for three different types of housing, and accounting for three ventilation scenarios. All of the values are below the 0,05 µg/ m^3 limit of RIVM. With the highest exposure value being 0,020 µg/m^3.

	High ventilation [µg/m³]	Mid ventilation [µg/m³]	Low ventilation [µg/m³]
House A	0.0072	0.0097	0.020
House B	0.0051	0.0064	0.011
House C	0.0040	0.0047	0.0072

B. Peak exposure in worst case scenario

The aim of this section of the analysis is to test whether one could measure concentrations values above 0,05 µg/ m^3 if a short (e.g. 15 min) test on indoor air quality would be conducted. The RIVM advises the GGD, the Municipal Health authority in the Netherlands (GGD, Gemeentelijke gezondheids dienst) on indoor air quality. If the GGD finds indoor air quality containing > 0,05 µg/ m^3 of mercury, they are advised by the GGD to check the emission sources of mercury in that particular home.

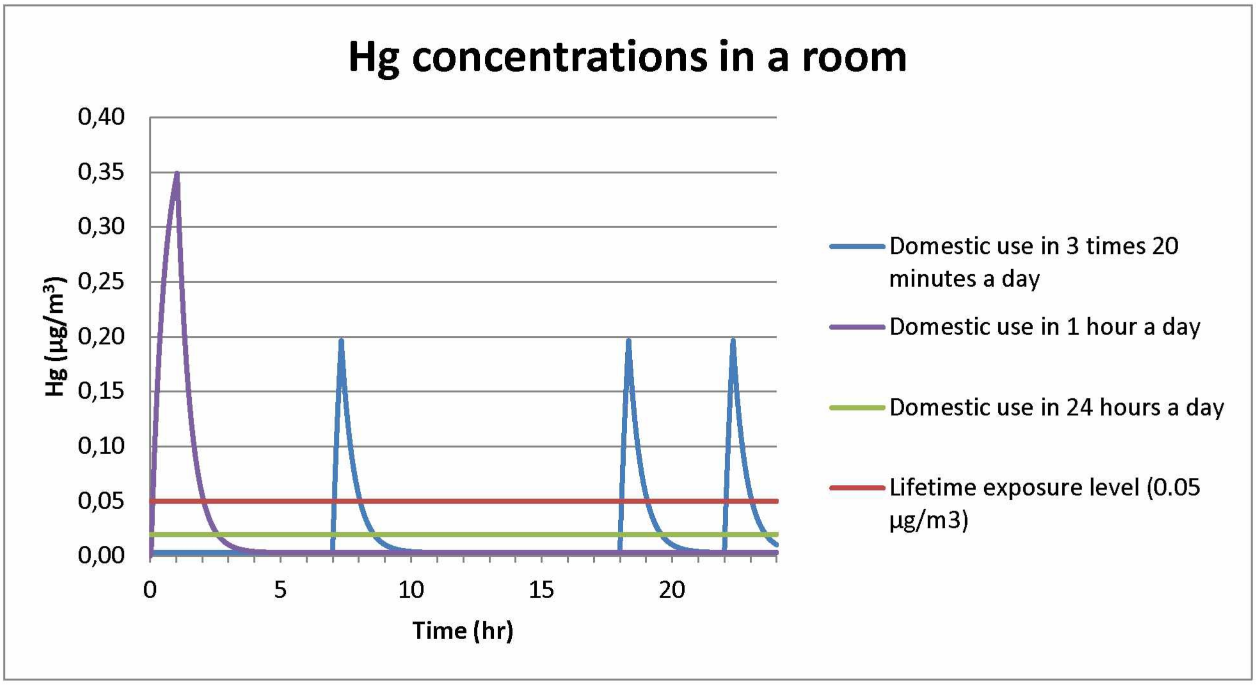
PLEASE NOTE that the RIVM does not regard a exposure > 0,05 µg/m^3 Life time exposure limit as harmful, as long as the average lifetime exposure remains < 0,05 µg/m^3

Whether and how many peaks of mercury concentrations in indoor air occur depends on the gas consumption pattern. For this assessment it is relevant to analyse the 'worst case' scenario; meaning a room of 30 m^3 with a ventilation of 2 turnovers/hr.

When the daily gas consumption is used in only one hour the mercury concentration in the room will become 0.35 µg/m^3. Due to refreshing of the air, the mercury level decreases when the gas consumption stops. The mercury level is 2 hours above 0.05 µg/m^3.

It is more realistic to assume that the gas is used in 3 times 20 minutes (at 7:00 am, 6:00 pm and 10:00 pm). In that case the mercury concentration in the room will become 3 times 0.20 µg/m^3 and stays 3 times 1 hour above 0.05 µg/m^3.

The results for the different gas consumption patterns and the consequent exposure mercury exposure are shown in graph 1.



Graph 1: Mercury concentration in a room of 30 m³ for different gas consumption patterns

The above stated results indicate that – despite the daily average exposure being below the recommended 0,05 µg/m^3 limit of RIVM - one could measure mercury concentrations above 0,05 µg/m^3. This would only occur if a test is conducted for a short period of time (< 3 hours).

PART 2 RESULTS – Maximum mercury concentration in gas based on RIVM

A. Maximum mercury concentration in gas for to prevent life time exposure limit exposure of 0.05 μg/m^3 mercury in indoor air

When 440 m^3/year is consumed constantly the mercury concentration in the room will be 0.020 μg/m^3. If one were to reach the lifetime exposure limit of 0.05 μg/m^3 - using 440 m^3/yr of gas - the mercury concentration in supplied gas would be equal to 56 μg/m^3.

B. Maximum mercury concentration in to prevent any measurable peak above 00,05 μg/m^3 in indoor air

To prevent the presence of mercury peaks > 0,05 μg/m3 in indoor air, the following concentrations of mercury in Groningen gas apply.

	High ventilation [μg/m³]		Mid ventilation [μg/m³]		Low ventilation [μg/m³]	
	1 hour	20 min	1 hour	20 min	1 hour	20 min
House A	9.34	10.0	5.88	7.19	2.7	4.80
House B	18.6	20.0	11.7	14.3	5.41	9.59
House C	37.3	40.1	23.5	28.7	10.8	19.2

CONCLUSION

Based on the outcome of the model, one can conclude that the mercury concentrations in gas for domestic use, as shown in the 2013 KEMA test, will not (including worst case conditions) exceed the RIVM life time exposure value of 0,05 μg/m^3.

The highest concentration measured during the KEMA sampling program was 6,9 μg/m^3 mercury in gas which would lead to an approximate peak exposure of 0,07 μg/m^3 in indoor air during 3 hours a day based on the scenario that the gas is burned in 3 period of 20 minutes during the day. Based on this model a poorly ventilated small house, which is supplied gas with containing a mercury concentration of 20 μg/m^3, would on a daily average still stay below the intervention value of 0,05 μg/m^3. The peak concentrations would, however, exceed this value with a factor 4.