

Expert witness statement of Olaf Morgenstern on the role of methyl bromide as an ozone-depleting substance

INTRODUCTION

Qualifications and experience

1. My name is Olaf Morgenstern. I am a Programme Leader (Climate Variability and Change) at the Wellington campus of the National Institute of Water and Atmospheric Research (NIWA), where I have been employed since 2015. Previously, since 2008 I was based at the NIWA Lauder (Central Otago) site and was leading the Measuring and Modelling Atmospheric Composition programme. I was awarded a Diploma in Physics by the University of Freiburg (Germany) in 1993 and a PhD in Environmental Science by the Swiss Federal Institute of Technology (ETH) Zurich in 1998.
2. I have 23 years of professional experience in meteorology, atmospheric chemistry, and climate modelling. Prior to joining NIWA in 2008 I was based at the Department of Chemistry of the University of Cambridge (UK), where from 2003 onwards I was involved in the development of a novel formulation of atmospheric chemistry for use in a climate model. Before that I worked at the Max-Planck-Institute for Meteorology in Hamburg (Germany) and again in Cambridge on atmospheric chemistry and transport. During this time I acquired a thorough understanding of global atmospheric chemistry. I have been involved in the writing of the 2010, 2014, and 2018 World Meteorological Organization's Scientific Assessments of Ozone Assessments, in 2010 as a Lead Author and in 2014 and 2018 as an invited reviewer. Since 2015 I am serving as the Science Leader Earth System Modelling & Prediction for the Deep South National Science Challenge. I am a Lead Author of the 6th Assessment Report of the Intergovernmental Panel on Climate Change, due to be published in 2021.

Code of Conduct

3. I have read the Expert Witness Code of Conduct set out in the Environment Court Practice Note 2014 and I agree to comply with it. I confirm that the issues addressed in this statement of evidence are within my area of expertise, except where I state I am relying on the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from my expressed opinion.

SCOPE OF EVIDENCE

4. Methyl bromide (CH₃Br) is a pollutant which in trace amounts is ubiquitous in the lower atmosphere. It is partly anthropogenic in origin, and due to the presence of the bromine atom, engages in stratospheric ozone depletion. It is therefore controlled under the Montreal Protocol of 1987 which is an international agreement to protect the ozone layer by mandating a regulated phase-out of ozone-depleting substances. However, quarantine and pre-shipment (QPS) uses of CH₃Br have been exempt from the phase-out.
5. Below is an overview of the role of CH₃Br as an ozone depleting substance, involved, for example, in the re-occurrence of the Antarctic ozone hole every spring since the mid-1980s.

This document does not cover technical, health, local air-pollution, or legal aspects of CH₃Br usage.

SOURCES OF CH₃BR

6. Unless stated otherwise, data in the following are taken from the World Meteorological Organization’s Scientific Assessment of Ozone Depletion: 2018 (WMO, 2018), the latest in a quadrennial publication summarising the state of knowledge of ozone depletion. It uses data up to 2016.
7. The global-mean mole fraction of CH₃Br has decreased from approximately 7 parts per trillion by volume (pptv) in 2012 to ~6.8 in 2016 (Table 1), but showing a slight increase (after years of decrease) between 2015 and 2016. The two different measurement networks that document CH₃Br differ insignificantly (by up to 0.1 pptv) in their assessment. The most recent increase in CH₃Br is unambiguous but remains unexplained. In 2012, an estimated 84 Gg of CH₃Br was released into the atmosphere, with anthropogenic uses accounting for up to 20 Gg, including fumigation (QPS) of 7.4 Gg and fumigation (non-QPS) of 2.5 Gg. For comparison, in 1995-1998 fumigation (QPS) accounted for 8.1 Gg/year and fumigation (non-QPS) for 39.9 Gg/year. After this 94% reduction in non-QPS uses of CH₃Br, the QPS uses now globally outweigh the non-QPS uses (which are controlled by the Montreal Protocol; Figure 1). Natural sources comprising oceanic (32 Gg/year) and land vegetation production make up the remainder (Table 2, WMO, 2014).

Table 1: CH₃Br abundances and trends in recent years (WMO, 2018, table ES-2).

	Mole fraction in 2012 (pptv)	Mole fraction in 2015	Mole fraction in 2016	Trend (pptv/year) 2015-2016	Trend (%/year)	Network
CH ₃ Br	7.06	6.66	6.8	0.14	2.1	AGAGE, in situ
	6.95	6.64	6.86	0.22	3.3	NOAA, flask

8. The important contribution of natural emissions means that there is a substantial natural, pre-industrial abundance of CH₃Br which (in the Intergovernmental Panel on Climate Change (IPCC) “historical” scenario; Meinshausen et al., 2011) is estimated at 5.8 pptv. This means that in 2012, the CH₃Br abundance was approximately 20% above its natural background.

Table 2: Estimated global sources and sinks of CH₃Br in 1995-1998, and in 2012 (Gg/year). From WMO (2014), Table 1-4.

Sources of CH ₃ Br (Gg/year)	1995-1998	2012
Leaded petrol	3 (0.6-6)	0-3
Fumigation (QPS)	8.1 (7.5-8.7)	7.4 (6.9-7.8)
Fumigation (non-QPS)	39.9 (28.2-55.9)	2.5 (1.7-3.5)
Indoor biofuel use	6 (3-9)	6 (3-9)
Open field burning	17 (7-27)	17 (7-27)
Ocean	32 (22-44)	32 (22-44)
Terrestrial plants	~17.4	~17.6
Sinks of CH₃Br (Gg/year)		
Reaction with OH	74 (63-83)	56 (48-63)

Loss to soil/land surface	40 (25-54)	30 (19-41)
Loss to ocean	43 (27-58)	33 (20-44)
Loss in stratosphere	5	4

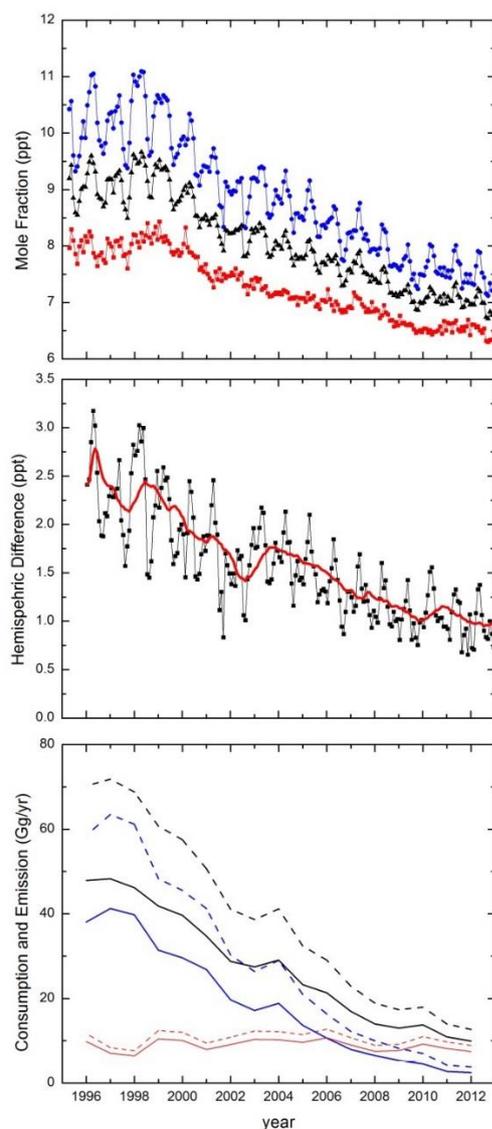
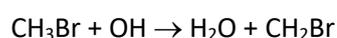


Figure 1: (top) Mean mole fraction of CH_3Br (blue: northern hemisphere; red: southern hemisphere; black: globe). Centre: Interhemispheric difference (caused by dominantly northern-hemisphere emissions). Bottom: Global consumption/emission of CH_3Br for fumigation. Red: QPS use. Blue: Non-QPS use. Black: total. Dashed: Consumption. Solid: emissions. (from WMO, 2014, figure 1-10).

SINKS OF CH_3Br

- In common with practically all volatile organic carbon compounds, the biggest sink of CH_3Br is reaction with the hydroxyl radical:



- CH_2Br is short-lived and releases Br into inorganic forms such as HBr and HOBr, which then get removed in rain or deposited to the surface. This process removed around 56 Gg of

CH₃Br in 2012. Other sinks involve deposition to soil (30 Gg) and to the sea (33 Gg). Only around 4 Gg are lost in the stratosphere. This means that CH₃Br is controlled by tropospheric and surface removal, implying a short overall lifetime (compared for example to chlorofluorocarbons, CFCs) of about 0.8 years. Changes in emissions are therefore quickly reflected in the atmospheric abundance of CH₃Br.

ROLE OF CH₃BR IN STRATOSPHERIC OZONE CHEMISTRY

11. As indicated above, only a minor fraction of CH₃Br ever makes it into the stratosphere. A further fraction is oxidised in the troposphere but the oxidation products are lofted into the stratosphere. The total abundance of bromine in the stratosphere in 2010 was approximately 20 pptv. Approximately 7 pptv of this is due to CH₃Br; the remainder is due to halons (industrial organic bromine compounds that are also controlled by the Montreal Protocol) and “very short-lived substances” (VSLs), i.e. natural bromine compounds of mostly oceanic origin such as dibromomethane (CH₂Br₂; Figure 2).

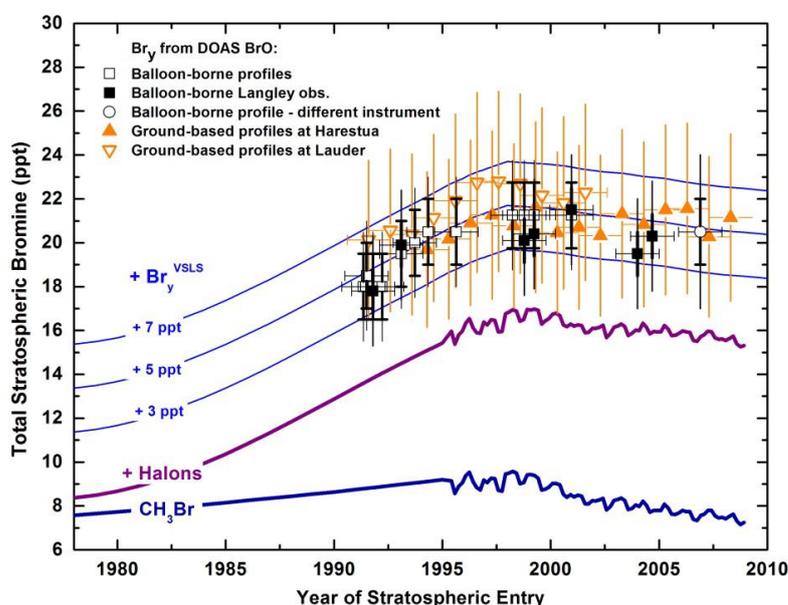
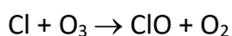
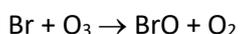
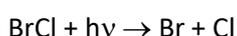
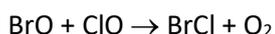
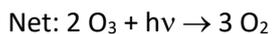


Figure 2: Origin of stratospheric bromine: Dark blue: CH₃Br. Violet: halons. Light blue: very short lived bromine compounds of mostly of natural, oceanic origin. Symbols: Measurements of total bromine.

12. Once in the stratosphere, CH₃Br is oxidized or photolysed to free the bromine atom. This then engages in ozone depletion. This occurs in several chemical cycles. Most of them also involve chlorine and enhance the effect of chlorine activation on polar stratospheric clouds, for example:





13. For every revolution of this cycle, two ozone molecules are lost. This process requires sunlight and proceeds faster under elevated active chlorine conditions; both occur during the ozone hole season in polar spring, but bromine also destroys ozone away from the poles. Hence the presence of bromine enhances the effect of chlorine-catalyzed ozone depletion; bromine itself acts as a catalyst. There are variants of this cycle that involve different intermediates (such as the chlorine peroxy-radical, ClO_2) that also result in ozone depletion.
14. Chlorine and bromine are sometimes combined into a measure called “equivalent effective stratospheric chlorine” (EESC) which is the amount of chlorine alone that would have the same effect on ozone as the actual abundances of chlorine and bromine combined. For this purpose, bromine is converted into an equivalent amount of chlorine that would have the same impact on global ozone. This involves multiplying the bromine volume mixing ratio by a factor of 60 to turn it into an equivalent chlorine amount (Newman et al., 2011). WMO (2014) estimates that in the year 2011 7 pptv of bromine in the stratosphere were due to CH_3Br (Figure 2). This converts into a chlorine equivalent of 420 pptv (Cl). Total EESC in the polar stratosphere is presently approximately 3900 pptv (Figure 3), meaning CH_3Br contributes approximately 11% to global polar EESC.

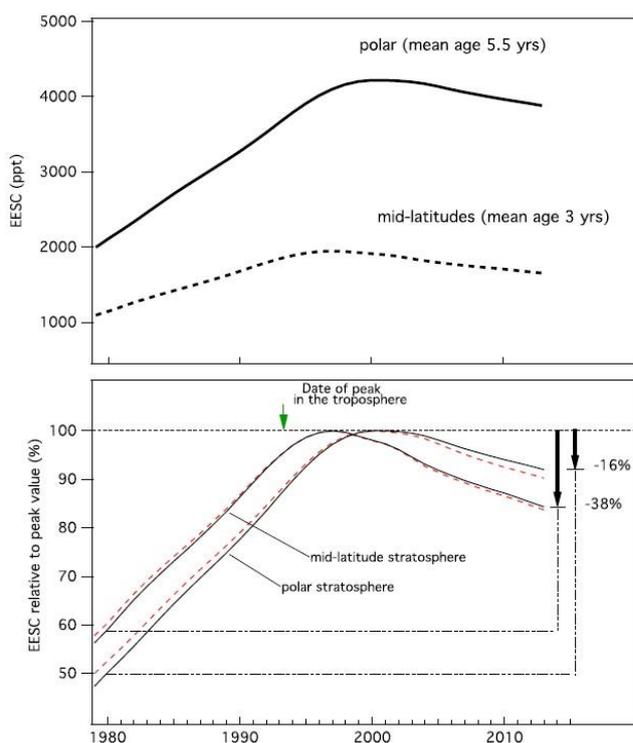


Figure 3: EESC in the polar and mid-latitude stratosphere. By 2012 mid-latitude and polar EESC had decreased by 38 and 16%, respectively, relative to the peak abundance. The extrapolated polar EESC for 2015 is approximately 3900 pptv (WMO, 2014, figure 1-22).

SCALE OF NEW ZEALAND'S CH_3Br EMISSIONS

15. In 2018 (the last year for which data is available), the total industrial consumption of CH_3Br in New Zealand was approximately 664t, with a general upward trend since the year 2000

when around 125t were used. This marks a substantial increase on 2017 (586t). Most of New Zealand's usage is for fumigation of logs destined for export (MfE, 2017; UNEP, 2020) with a minor share used on imports. Between 2012 and 2018, in every year the consumption has been above 500t, making New Zealand as a country the 5th largest consumer worldwide after the USA (2660t), China (1228t), Vietnam (908t), and Australia (682t; all numbers are for 2018) (UNEP, 2020). On a per-capita basis, New Zealand remains by far worldwide the largest consumer of methyl bromide.

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