Overview

- **Working from atmospheric observations, the paper from Montzka et al in Nature derived that an additional 13,000 ± 5,000 tonnes/year of CFC-11 has been released into the atmosphere from 2014 to 2016.**
- **The reasons that CFC-11 is being emitted into the atmosphere, and its potential sources, are not known. Additional scientific investigations might better identify potential sources, and other information useful for a comprehensive technical analysis of this issue.**
- **TEAP is coordinating with SAP and has started to investigate potential sources of the CFC-11 emissions. At this point, there are some facts we can share with parties as background to the technical scenarios which we will need to consider further.**
- CFC-11 (trichlorofluoromethane, $CFCl_3$) was used primarily as a foam-blowing agent (for flexible and polyurethane insulating foams), as a refrigerant (for centrifugal chillers used in large commercial buildings), and in a range of other smaller or less common uses, including asthma inhalers (as a solvent in the manufacturing process), tobacco expansion, and as a solvent/carrier for fire extinguishing agents. There are alternative chemicals or products available as replacements for CFC-11.
- According to an AFEAS paper[1], CFC-11 production peaked in the 1980s between 350,000 and 400,000 tonnes per year. This is consistent with the Montzka et al paper, which states that peak emissions in the late 1980s were about 350 gigagrams (or 350,000 tonnes) per year.
- Under the Montreal Protocol, production of CFC-11 in developed countries was phased out in 1996; production of CFC-11 in developing countries was phased out in 2010. Exceptions were made for small amounts of CFC-11 production for essential uses (i.e. asthma inhalers), as authorised by the Protocol.
- Production of CFC-11 for non-feedstock and feedstock[2] uses is required to be reported to UNEP under Article 7. Production of CFC-11 to supply essential uses was less than 400 tonnes every year since 2010 and ceased altogether after 2014. No feedstock uses of CFC-11 are reported from parties or known.
- CFC-11 is produced from HF and carbon tetrachloride in the liquid phase in the presence of an antimony catalyst. A mix of CFC-11 and CFC-12 is produced, with the proportion of CFC-12 and CFC-11 controlled by varying the operating conditions. 100% CFC-12 is achieved relatively easily; 100% CFC-11 is more difficult to achieve but not impossible in well-operated facilities. An operating range of 30:70, either way, can be comfortably achieved. In well-operated facilities, emissions from production processes are low (average 0.5%).
- TEAP has been aware that CFC-11 was advertised on at least one internet trading website for sale and distribution in various markets for foam blowing. TEAP is unaware whether these listings for sale were legitimate offers and/or whether any purchases were made.

Additional detail about potential sources:

- Montzka et al noted that "The increase in emission of CFC-11 appears unrelated to past production; this suggest unreported new production…" The possible applications related to these emissions are the subject of speculation.

---

1 https://unfccc.int/files/methods/other_methodological_issues/interactions_with_ozone_layer/application/pdf/cfc1100.pdfAFEAS reporting did not include sources from A5 countries. AFEAS reporting did not include sources from A5

2 Feedstock uses refer to the use of ODS as chemical building blocks for the commercial synthesis of other chemicals.

- CFC-11 produced as a by-product in other chemical manufacturing pathways is unlikely for technical reasons. This includes the production on HCFC-22, where maximum CFC-11 production could be 0.1%. Under normal operating conditions, CFC-11 production as a by-product of HCFC-22 production is negligible.
- CFC-11 used as a blowing agent in rigid polyurethane foams has largely been replaced by HCFC-141b. Even when rigid polyurethane foam is produced in an enclosed space (as in appliances or moulds), the foaming process results in some emissions of the foam-blowing agent (3-5%). Assuming an available supply of CFC-11, for the most emissive type of rigid polyurethane foam application (i.e., spray foam), with an emission rate of 15% during installation, a supply (or production) of approximately 90,000 tonnes per year of CFC-11 would be required to generate CFC-11 emissions of 13,000 tonnes per year.
- CFC-11 was used as a blowing agent for flexible foam, especially slabstock, with very high emission rates (up to 100%). Dichloromethane (and other alternatives) replaced CFC-11 in flexible foams, and is readily available at low cost.
- There were several very serious fires in East Asia about 8 years ago, where a concern arose about sufficient fire retardant used in cyclopentane blown foams used in building insulation. Standards were upgraded and there was a period of time when very little plastic insulation was allowed in construction.
- More recently, there have been a number of new patents published in the past 2 years related to CFC-11. It is not yet known in which jurisdictions these patents have been filed and whether or not any of these products have been commercialized.
- Past production made its way into global banks in foams and chillers, which are actually emitting CFC-11. Any remaining chemical stockpiles are also gradually leaking CFC-11. These gradual releases have continued before and after 2012.
- Total global inventory or bank of CFC-11 in chillers is estimated to be about 3-4,000 tonnes maximum.
- Most of the known bank of CFC-11 (estimated total: 1,420,000 tonnes in 2008) is projected to be in insulating foams, particularly closed-cell polyurethane that was used in cladding panels for buildings and appliances like refrigerators.
- Any additional production of CFC-11 will result in an increased volume of CFC-11 in banks and/or emissions.
- There are some emissions from the foam bank throughout the useful life and during the disposal process. Emissions from the bank are expected to gradually reduce over time based on the amount of foam blowing agent remaining in the foam.
- During the foam dismantling and disposal process, there are additional emissions from foams generally. A sudden increase in emissions from foam banks would require sudden destruction of closed foam cells with no abatement of this release. For context, 13,000 tonnes/year emissions would require the destruction of approximately two million tonnes of foam, which is the equivalent of one third of the entire global annual production of PU Rigid Foam (2017) including all blowing agents.
- CFC-11 emissions can result from recovery and recycling of the metal and plastic contents of insulating foam panels, where the CFC-11 blowing agent is allowed to be released. As an indication of magnitude for comparison purposes, disposal of 13 million US large-sized refrigerators would be required to release 13,000 tonnes CFC-11, every year since 2013. Double to quadruple this number would be needed to release this amount of CFC-11 if smaller refrigerators, such as those used in Asia

and Europe, were disposed. The largest market for domestic refrigerators in Asia is China, with a reported estimated disposal rate of the order of 1.5 million refrigerators per year.

- At the end of life, foams are sent to landfill sites generally where CFC-11 would slowly emit over time (0.5% per year) excluding any amount that might be bioremediated (chemical breakdown of CFC-11 by bacteria) in the landfill. There is the potential for bioremediation of up to 94% of the blowing agent (i.e., CFC-11) that reaches a landfill. Foam bank emissions after destruction of buildings or appliances are likely to occur over time from a landfill.
- For the observed trends to be related to the foams bank (leakage and/or disposal), there would need to have been an acceleration of the pre-existing trend after 2012.
- TEAP is not aware if there are new or unusual emissive uses of CFC-11 that started or accelerated after 2012. There are a number of possible practical uses for CFC-11, e.g. as a foam-blowing agent, a refrigerant, or as a quick evaporating solvent.

Additional information needed

- TEAP will need the help of parties and institutions of the Montreal Protocol with data to which TEAP does not have access.

- From parties and institutions related to the Montreal Protocol (e.g. Multi-lateral Fund Secretariat and MLF implementing agencies) that may have access to this information and may wish to share their annual information, which may or may not have been previously reported, with the Ozone Secretariat, to provide to TEAP for the period 2010 onwards (or earlier if available):
  - An inventory showing what production processes CTC produced as feedstock and in what quantities, might help track any undetected CFC-11 production.
  - Any data on inventory of any remaining produced CFC-11 and CFC-12 stockpiles or inventory (i.e., bulk chemical inventory not in foam or refrigerant banks).
  - Any data on existing foam and refrigerant banks
  - Any information related to the production of rigid and flexible polyurethane foams, extruded polystyrene, and chillers to determine growth patterns of these products.
  - Any information about patents related to CFC-11 and CFC-12 within their countries especially regarding recent patents and their commercialization
  - Any local requirements related to foam flammability
  - Any information related to CFCs or CFC containing foams or equipment that might be imported into their party for destruction
  - Any information related to illegal sales of CFC-11 or CFC-12
  - Information on trends in the quantities of HFC-23 emissions, associated with the production of HCFC-22 (swing plants used to produce HCFC-22 can also be used to produce CFC-11).
  - Information from parties on any national enforcement or compliance information investigating illegal production or use of CTC, CFC-11 and CFC-12