Agenda item 7(a)

Report by the Secretariat on Decision XXXIII/4: Enhancing the global and regional atmospheric monitoring of substances controlled by the Montreal Protocol
Decision XXXIII/4: Enhancing the global and regional atmospheric monitoring of substances controlled by the Montreal Protocol

Requested the Ozone Secretariat, in consultation with relevant experts from the SAP, the TEAP and the ORM, to report to the parties on:

(a) Options for the regional monitoring of atmospheric concentrations of controlled substances and operationalization challenges

(b) Identification of suitable locations for possible high-frequency measurements and flask sampling for regions not, or not sufficiently, covered by existing atmospheric monitoring

(c) Options for means of establishing new monitoring capacity and related costs, taking into account existing monitoring infrastructure
Outline

- Background information
- Response to the provisions of decision XXXIII/4
- Update on the implementation of the European Union-funded pilot project:
  
  “Regional quantification of emissions of substances controlled under the Montreal Protocol”
  
  *developed in 2021 based on a white paper by experts in atmospheric monitoring of controlled substances presented to the 11th meeting of the ORM (parts I and II)*

- Suggested way forward
- Concluding remarks
Two different approaches are mainly used for emission estimates:

- The **global approach** uses averages of the stations in red and orange to calculate global emissions.
- The **regional approach** uses wind trajectories and observations at various stations to monitor a region (pictured in blue shading).

- Sum of current regional emissions DO NOT EQUAL the global estimate.
- The world is not sufficiently sampled - need coverage from more regions.
Emission Estimate Approach 1 (global)

- The global average of atmospheric levels is determined by:
  - Emissions
  - Losses in the atmosphere (*calculated by atmospheric models and laboratory measurements*)

- The change in the atmospheric concentrations, $\Delta \chi$, in a year is:
  $$\Delta \chi = \text{Emissions} - \text{Loss} \rightarrow \text{Emissions} = \Delta \chi + \text{Loss}$$
  where Loss depends on the substance’s lifetime

- The CFC-12 lifetime is 102 years, so if there were no emissions, CFC-12 atmospheric levels should decrease ~1% per year after complete cessation of emissions

*Emission estimates from Approach 1 are highly dependent on observations quality (accuracy & precision), the lifetime, and the ability to measure globally average values*
Global emissions can be estimated from long-lived CFCs (e.g., CFC-12) because they are well-mixed across the globe.

CFC-12 atmospheric levels were increasing into 1988.

Emissions were also increasing into 1988.

Note: **NH levels > SH levels** because most emissions occur in the NH. It takes 1-2 years to mix air from the NH to the SH.
Global emissions can be estimated from long-lived CFCs (e.g., CFC-12) because they are well-mixed across the globe.

The growth of CFC-12 began to decelerate after the signing.

Emissions dramatically decreased after 1988.

![Graph showing atmospheric levels and emissions of CFC-12](http://agage.mit.edu/)

Figure 1.3 (WMO/UNEP, 2022)
Global emissions can be estimated from long-lived CFCs (e.g., CFC-12) because they are well-mixed across the globe.

Atmospheric levels had stopped growing by the early 2000s.

Emissions had fallen to very low values early in this century.
Continued emission decreases have caused atmospheric levels of CFC-12 to decrease → the Protocol has worked!

Atmospheric levels have continued to decrease since the early 2000s

Emissions have also continued to decrease

Note: By 2010, **NH levels = SH levels** → low emissions in both hemispheres allows mixing across the tropics to equalize levels between the hemispheres. Levels are declining at about -1% per year, as per expectations with no emissions
Emission Estimates Approach 2 (regional)
Estimating emissions from regional observations (NOAA GML)

- Average flow is from the west to east on the US West Coast
- Trinidad Head is on the coast with no local emission sources of HFC-134a from the Pacific
- Winds from the west over inhabited regions pick up HFC-134a, causing enhancements, and revealing regional emissions sources between the clean ocean and inland stations

Figure courtesy of Steve Montzka
Local to regional to global monitoring

Monitoring from satellites: Not quite possible for most MP gases

Monitoring by aircraft: Possible for all MP gases but expensive and intermittent

Local emissions from local monitoring

Regional emissions from monitoring at a distance downstream

Global emissions from monitoring at pristine sites
Rapid action in roughly 5 years between first evidence to concrete action with clear results

- Global emissions of long-lived substances can be currently quantified with AGAGE and NOAA
- Need regional data for decision-making
Options for regional monitoring (1)

Where should we locate stations to optimally enable decision-making?

- Suitable location
- Observing System Simulation Experiments (OSSEs)
- Idea of emission regions
- Expertise
- Sophisticated analytical instruments
- Tower
- Air-conditioned room
What does it take to meaningfully estimate regional emissions? A few more specific issues:

- Ability to measure VERY minute concentrations of parts per trillion (to visualize: Ability to detect less than 1 part in 1,000 billion)
- Precision AND accuracy- accuracy directly translates to estimated emission amounts
- Instrumentation and costs: Lower initial costs if an established analytical facility can analyze flask samples. This provides indications of the suitability of the location and some estimates of emissions. Better and more accurate estimates require high-frequency sampling. However, the cost and level of expertise needed are higher.
Identification of suitable locations

Two needs for station location: Site selection using OSSEs and emission estimates

- Need to overlap potential emission regions with sites capable of “sensing” these emissions
- Well situated stations less than about 2000 km from the source regions would be ideal

Shading represents areas where emissions can be reliably estimated on regional scales
### Weekly sampling (USD):
- Initial cost ~15 K (flask + valves + and pump + shipping cases + …)
- Shipping and analysis ~25K

### Daily sampling (USD):
- Initial cost ~70K
- Shipping and analysis ~90K

### Plus, infrastructure and personnel

### OSSEs and modelling capability ~150K USD
- + Start up* costs + Personnel cost**

* Air intake tower, AC, reliable electric power, data connectivity, access for personnel and supplies, and building space (for high frequency or protected space for flask samples)

** Depends on location

### One-time instrumentation and ancillary equipment
- ~400K USD

### Operating costs:
- ~150K - 350K USD

### Plus, infrastructure and highly-skilled personnel
EU-funded pilot project: Regional quantification of emissions of substances controlled under the Montreal Protocol

Three phases

1. Identification of suitable locations and countries for flask measurements and high-frequency in-situ stations

2. Implementation of flask sampling measurement programmes in one or two developing countries

3. Development and implementation of a collaboration plan for continuing observations, calibrations, data sharing and modelling

- Current focus on the Northern Hemisphere where the uses and manufacture of controlled substances the highest
- Establish connections with relevant networks and research institutions

https://ozone.unep.org/eu-funded-project-regional-quantification-emissions-substances-controlled-under-montreal-protocol
Evaluated potential sites for Montreal Protocol gas monitoring, Prof. Ronald Prinn and Dr. Jianxiong Sheng (MIT, Cambridge, USA) as funded by NASA

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The EU pilot project has funded observations in collaboration with the Univ. of Bristol (Dr. Anita Ganesan) and the University of Dhaka (Prof. Abdus Salam) in Bangladesh at Bhola Island.
EU Pilot Project: An update

- 5 cases (60 samples) collected between 13 Feb – 4 Jun 2023 and another 3 cases (36 samples) are to arrive in Bristol in the end of June
- Major work carried out to identify calibration, sampling, or other instrumental effects that could result in inaccuracies
- Approximately 40 MP gases are measured, including ODSs and HFCs, as well as several important non-MP GHGs like SF₆ and CF₄
- 4-5 chemicals have potential calibration, sampling, or other issues that will be addressed further with arrival of an up-to-date calibration standard
**EU Pilot Project: An update (4)**

- Bhola Island Station is in operation and fills a much-needed gap in the South Asia region.
- Bhola data mainly reflects the higher levels of NH emissions versus the SH.
- Limited data excursions from the red northern hemisphere baseline suggests there are no local (<10 km) major HCFC-22 sources.
- Variations in the observations are likely due to meteorological variations.
- Calibration and validation of Bhola data is an ongoing process.
- High-frequency observations and multiple year operation would provide improved science yields.

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**HCFC-22**

![HCFC-22 concentrations graph](image)

- **Trinidad Head (Calif., USA)**
- **Bhola Island (Bangladesh)**
- **Cape Grim (Australia)**

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**University of BRISTOL**
Suggested way forward in atmospheric monitoring of controlled substances

- Complete the pilot project at Bhola Island to prove the feasibility of concept
- Expand regional monitoring sites
- Install high-frequency measurements at suitable stations
- Continue providing necessary information to the parties to the Montreal Protocol

Needs

- Assistance from parties to identify suitable sites with availability of expertise, willingness and desire to share data transparently within a reasonable time frame
- Additional resources to hasten measurement availability and provide reliable data for decision-making
Concluding remarks (1)

- Global emissions are well estimated with current “baseline” stations (emissions estimate approach 1) for long-lived substances.
- The difference between NH and SH helps identify hemispheric differences in emissions.
- Combination of meteorology and accurate measurements enables estimate emissions over a region (emissions estimate approach 2).
- With sufficient stations using approach 2, the sum of emissions from approach 2 should match the total emissions from approach 1. However, current coverage is insufficient.
- Major gaps for approach 2: South America, Central America, most of Africa, the Middle East, Eastern Europe, South Asia, and the maritime continent (approximately comprised of Indonesia, Philippines, New Guinea, Malay Peninsula).
- A few OSSEs performed to find locations to fill regional gaps.
Concluding remarks (2)

- Locations must be carefully chosen. Start with flask measurements in collaboration with an established analytical facility.

- Need for suitable stations away from polluted areas (not too far to avoid complete plume mixing), with a tower, air-conditioned building, electric power, IT connectivity, personnel and supplies.

- Careful observations and calibration are critical! The sensitivity of observations must less than 1.0 part per trillion. The smallest contaminations or deviations in techniques can ruin the data.

- Flask observations at Bhola Island in Bangladesh have begun using funds from the EU pilot project. Preliminary data shows promise. We will know more in about a year.

- Assistance from parties to identify suitable sites is important as well as additional resources to hasten measurement availability.
Thank you for your attention